ON-BOARD DIAGNOSTICS

AJ27 Engine Management

Vehicle Coverage:

XJ Series 3.2L and 4.0L N/A 1999 to 2002 model year
XJ Series 4.0L S/C 2000 to 2002 model years
XK8 4.0L N/A 1999 to 2002 model years
XK8 4.0L S/C 2000 to 2002 model year

1 Contents

2 OBDII Systems

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

"Green States" are states in the Northeast that chose to adopt California emission regulations, starting in the 1998 model year. 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 Low Emissions Vehicle program (NLEV) requires compliance with California OBDII, including 0.020" evaporative system monitoring requirements. The NLEV program applies to passenger cars and light trucks up to 6,000 lbs. GVWR nationwide from 2001 model year through 2003 model year.

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

OBDII system implementation and operation is described in the remainder of this document.

3 AJ27 4.0L Engine Management System

The AJ27 power unit is available in 3.2L and 4.0L versions, and comprises:

- An eight-cylinder 90-degree 'V' configuration liquid cooled aluminum cylinder block incorporating 'Nikasil' plated cylinder bores.
- Pistons of open-ended skirt design, with two compression and one oil control ring.
- Two aluminum cylinder heads, each incorporating two camshafts.
- Four valves per cylinder.
- Aluminum valve lifters and top mounted shims.
- Variable valve timing of the intake camshafts (4.0L normally aspirated only).
- Camshaft covers manufactured from Vinylester.
- Aluminum timing cover, which accommodates the crankshaft front, oil seal.
- Single row primary and secondary chains drive the camshafts of each cylinder bank.
- An aluminum bed plate, incorporating iron main bearing supports, which accommodate the oil pump pick-up, diverter valve (if fitted) and oil filter.
- Main bearings are grooved in the upper positions and plain in the lower positions. They are manufactured from aluminum/tin material.
- A crankshaft with undercuts and rolled fillets for extra strength.
- Fracture-split connecting rods in sintered-forged steel.
- Brackets bolted to the front of the cylinder block are used to mount all accessories.
- A single, seven ribbed vee belt drives the front end accessories on all versions of the engine.
- A second, seven ribbed vee belt drives the supercharger.
- Automatic belt tensioners - one for the front end accessory drive and one for the supercharger where fitted. Each tensioner incorporates a belt wear indicator.
- An advanced engine management system incorporating electronic throttle control.
- The unit meets the requirements of the California Air Resources Board (CARB) OBDII USA legislation.

3.1 Engine Control Module

Engine management and exhaust emissions are controlled by the Engine Control Module (ECM), which has the following main functions:

- Fuel injection
- Idle Speed Control (ISC)
- Ignition
- Evaporative Emission (EVAP) loss system
- Engine cooling fans
- Climate control compressor clutch demand

The microprocessor within the ECM receives signals from various sensors and other control modules and uses a pre-determined program to compute engine management functions. Adaptive functions are incorporated in the ECM to cater for continuous adjustments to its computations to suit prevailing conditions. Because the system also controls emissions to suit all modes, neither carbon monoxide (CO) levels nor idle speed require service attention or adjustment, except if an error or component failure should occur.

OBD are controlled by the ECM with the continuous monitoring of incoming signals and the subsequent verification against what the module expects to 'see'. Should a signal be incorrect or missing, the ECM will substitute a fixed value to provide the 'limp home mode' and alert the driver of the problem.

Fixed values may be adopted for:

- Transmission Fluid Temperature (TFT)
- Mechanical guard position
- Throttle blade angle
- Camshaft Position (CMP)
- Intake Air Temperature (IAT)

Diagnostic Trouble Codes (DTC), including OBDII codes, are stored in the ECM memory and can be read by an appropriate retrieval tool.

Should either the ECM or Transmission Control Module (TCM) fail, ensure that the control housing cooling fan is operating correctly. Failure of the cooling fan must be rectified before renewing a control module and details of a fan failure should accompany a returned control module.

The ignition supply is the main power source for the ECM; an inertia fuel shut-off switch will disconnect this supply if the vehicle is subject to a violent deceleration, as in a collision. The ECM has separate ignition and battery supply inputs. The battery input maintains the ECM memory as long as the vehicle battery is connected.

3.2 Engine Management System Components

3.2.1 Electronic Throttle

The electronic throttle assembly, in response to signals from both the driver and the ECM, adjusts idle speed, sets the throttle valve to the position requested by the throttle pedal, speed and traction control, power limitation and catalyst warm-up.

3.2.2 Mass Airflow Sensor

The Mass Airflow (MAF) sensor assembly outputs an analogue voltage to the ECM. This sensor measures airflow into the engine intake system and is calibrated to measure kg/hour.

3.2.3 Intake Air Temperature Sensor

The Intake Air Temperature (IAT) sensor is located in the airflow sensor assembly and outputs an analogue voltage to the ECM. The ECM will substitute a default value equal to 50°C should this sensor fail.

3.2.4 Fuel Injectors

The eight fuel injectors are located in individual apertures in the intake manifold. The fuel rail is separate and supplies fuel to the top of each injector. Air injection is provided to the base of each injector to further improve fuel delivery and atomization. Air is provided by an air gallery that is an integral part of the intake manifold. The fuel injectors are electromagnetic solenoid valves controlled by the ECM. The electrical pulse time for the injector combined with the fuel pressure determines the volume of fuel injected to the manifold.

3.2.5 Fuel Delivery

The fuel pump provides fuel to the fuel rail where the circulating pressure is controlled by a pressure regulator valve; excess fuel is returned to the fuel tank. The pressure regulator valve is controlled by manifold depression so that fuel delivery pressure is maintained at approximately 300 kPa above manifold pressure.

3.2.6 Fuel Pump Relay

The ECM controls this component for normal engine running. The security system may disable this relay via communication with the ECM.

3.2.7 Fuel Level Sensor

The quantity of fuel in the fuel tank is measured by the fuel level sensor. This signal is used by the ECM as an input to certain diagnostics.

3.2.8 Evaporative Emission Canister Purge Valve

Excess vapor formed in the fuel tank is absorbed into the EVAP canister. While the engine is running, the fuel absorbed in the canister is gradually purged back into the engine. The rate of purging is governed by the operating conditions of the engine and vapor concentration level.

Operating conditions that affect the purge rate are:

- Speed and load
- Engine Coolant Temperature (ECT)
- Time elapsed from start up
- Closed loop fuelling

Determination of the vapor concentration is made by stepped opening of the EVAP canister purge valve and subsequent monitoring of the fuelling correction. This function is performed prior to purging, so that at the onset of purging, the EVAP canister purge valve can be set to the optimum position. Should the ECM be unable to determine the concentration before purging, a default value is employed, which is then modified whilst purging is in progress.

When the purging process is operational the ECM modifies the basic fuelling calculation to maintain the correct air fuel ratio. Purging is inhibited during fuel cut-off and stability/traction control intervention.

3.2.9 Engine Coolant Temperature Sensor

The sensor outputs a voltage to the ECM, which decreases as temperature increases.

3.2.10 Cooling Fans

In response to ECT and climate control system demand, the ECM will energize the cooling fans.

3.2.11 Climate Control Compressor

The ECM will allow the compressor clutch to be engaged if the ECT and load demand are normal. Should the driver require maximum engine power or if the ECT is high, the request will be denied.

3.2.12 Cranking Signal

The ECM reacts to a signal from the Body Processor Module (BPM) when the starter motor relay is energized. This signal is used to trigger starting, fuel and ignition strategies.

3.2.13 Engine Speed and Crankshaft Position Sensor

Engine speed and Crankshaft Position (CKP) are monitored by a sensor, which is mounted on the cylinder block (flywheel housing) in front of the crankshaft drive plate. It indicates rotational speed to the ECM, in the form of 35 pulses per crank revolution. Engine speed is used for synchronization of fuel and ignition systems, as well as other functions.

3.2.14 Camshaft Position Sensor

A CMP sensor is mounted at the rear of each cylinder head on the intake side and each provides four signals every 720 degrees of crankshaft rotation. The combination of signals from both sensors can indicate to the ECM when a particular piston is approaching top dead center on the compression stroke. Normally only the bank 1 sensor is used in conjunction with the engine speed and CKP sensor for normal fuelling and ignition functions.

On supercharged engines, only one sensor is used providing one signal every 720 degrees of crankshaft rotation. It is mounted at the rear of bank 1 cylinder head on the intake side. The signal, in conjunction with the signals from the CKP sensor, indicates to the ECM that the piston of cylinder 1 bank 1 is approaching top dead center on the compression stroke.

3.2.15 Variable Valve Timing

The valve timing (camshaft phasing) is infinitely variable within the maximum design limits of advance and retard. An actuating shuttle valve directs engine oil pressure to either side of the control piston within the Variable Valve Timing (VVT) unit to advance or retard the intake camshaft, as calculated and controlled by the ECM. Movement of the actuating shuttle valve is by a linear solenoid.

Closed loop sensing and control of each intake camshaft is provided by the ECM in response to signals from each CMP sensor.

3.2.16 Ignition

Ignition spark is produced by individual on-plug coil units. Each on-plug coil unit also comprises an amplifier module. The ECM controls each amplifier module, which in turn switches the coil primary to generate the high-tension voltage within the secondary winding.

3.2.17 Knock Sensors

These sensors use a piezo-electric sensing element to detect knock, which may occur under acceleration at critical conditions. Should detonation be present the ECM will retard the ignition timing of individual cylinders.

3.2.18 Exhaust Gas Recirculation Valve

The Exhaust Gas Recirculation (EGR) valve (where fitted) reduces nitrogen oxide emissions by re-circulating a portion of the exhaust gases back into the intake manifold.

3.2.19 Heated Oxygen Sensors

The Heated Oxygen Sensors (HO2S), one per bank, are situated upstream of the catalysts. Integral to the sensors are heaters (under ECM control) which allow the sensors to reach their operating temperature as soon as possible after engine start. A comparison between the level of oxygen in the exhaust gases to that in the atmosphere produces an output signal. This signal is used by the engine closed loop fuel strategy to make fuelling corrections and so control overall emission levels.

3.2.20 Oxygen Sensors

These sensors, one per bank, are situated downstream of the heated oxygen sensors. The comparison of upstream and downstream signals allows determination of catalyst conversion efficiency.

~~3.3~~Inputs and Outputs

Inputs and outputs are directed to and from the ECM through hard-wired connections and the Controller Area Network (CAN) and ISO 9141/2 (Serial Communication) data buses contained in the engine management harness.

JAGUAR

EM80

Pin	Circuit	Pin	Circuit	Pin	Circuit
001	EVAP canister purge valve activate	012	Electrical load inhibit	023	A/C control module electrical load request (heated windshield)
002	EVAP canister close valve activate	013		024	
003	Ground (power)	014	Charge air cooler pump relay activate	025	Compressor relay activate
004	Throttle motor power supply	015	ECT signal	026	
005	Throttle motor power supply	016	Speed control on status LED	027	ECM programming
006	Throttle motor power supply	017	Serial communications	028	Manifold Absolute Pressure (MAP) sensor signal
007	Throttle motor power supply	018	Serial communications	029	Ground (logic 2)
008	Throttle motor power supply	019	ECM programming	030	
009	Throttle motor power supply	020	Speed control brake cancel request	031	Ground (throttle motor 2)
010	Refrigerant 4-way pressure switch high pressure	021	Ground (throttle motor 1)		
011	Air Conditioning (A/C) control module compressor clutch request	022	Refrigerant 4-way pressure switch high pressure		

EM81

Pin	Circuit	Pin	Circuit	Pin	Circuit
001		009	Accelerator Pedal Position (APP) signal 1	017	ECM switched power supply
002		010	Throttle Position (TP) sensor signal 1	018	APP signal 2
003	Engine management system controlled relay activate	011		019	TP sensor signal 2
004	Parallel (high) speed fan activate	012	Park/neutral confirmation	020	
005	Series (low) speed fan activate	013	Speed control on request	021	Ground (logic 1)
006		014	Speed control set +/-	022	Parking brake switch
007		015	Speed control cancel/resume	023	IAT sensor 2 signal
008	Ground (power)	016	Fuel Tank Pressure (FTP) sensor signal	024	Pedal position/TP sensor shield

EM82

Pin	Circuit	Pin	Circuit	Pin	Circuit
001	Sensor supply voltage 1	007	Sensors signal ground 1	013	ECM switched power supply 2
002	Engine crank	008	Brake switch	014	ECT signal
003	Fuel pump relay 2 activate	009	Ignition switched power supply	015	OK to start
004	HO2S, upstream bank 1 – variable current	010	HO2S, upstream bank 1 – constant	016	Security acknowledge
005	HO2S, upstream bank 2 – variable current	011	HO2S, upstream bank 2 – constant	017	IAT sensor signal
006	Throttle motor power relay activate	012	Inertia fuel shut-off switch activated		

EM83

Pin	Circuit	Pin	Circuit	Pin	Circuit
001		011	Ignition modules 1 bank 2, 2 bank 1, 3 bank 1, 4 bank 2 diagnostic monitor	021	HO2S bank 1 downstream
002		012	HO2S shield	022	HO2S bank 2 downstream
003		013	Sensors signal ground 2	023	Knock sensor bank 2 signal
004	Fuel pump relay activate	014	Knock sensor bank 1 signal	024	CAN network
005	Sensor supply voltage 2	015	CAN network	025	CAN network
006	Sensor shield	016	CAN network	026	MAP sensor ground
007	CKP sensor ground	017	CMP sensor bank 2 ground	027	MAP sensor ground
008	CKP sensor signal	018	CMP sensor bank 2 signal	028	MAP sensor signal
009	CMP sensor bank 1 ground	019	CMP sensor bank 1 signal		
010	Ignition modules 1 bank 1, 2 bank 2, 3 bank 2, 4 bank 1 diagnostic monitor	020	Battery power supply		

EM084

Pin	Circuit	Pin	Circuit	Pin	Circuit
001	Ground (downstream HO2S)	009	Ignition module 4 bank 1 switching	017	Ignition module 4 bank 2 switching
002	Injector 1 bank 1 activate	010	Ignition module 3 bank 1 switching	018	Ignition module 3 bank 2 switching
003	Injector 3 bank 2 activate	011	Ignition module 2 bank 1 switching	019	Ignition module 2 bank 2 switching
004	Injector 2 bank 2 activate	012	Ignition module 1 bank 1 switching	020	Ignition module 1 bank 2 switching
005	Injector 4 bank 1 activate	013	Injector 4 bank 2 activate	021	Injector 2 bank 1 activate
006	Injector 1 bank 2 activate	014	Injector 3 bank 1 activate	022	Ground (injectors 1 bank 2, 2 bank 1, 3 bank 1, 4 bank 2)
007	HO2S heater, downstream bank 1 control	015	HO2S heater, downstream bank 2 control		
008		016	Ground (injectors 1 bank 1, 2 bank 2, 3 bank 2, 4 bank 1)		

EM085

Pin	Circuit	Pin	Circuit	Pin	Circuit
001	HO2S heater, upstream bank 1 control	005	'Cool box' cooling fan activate	009	EGR stepper motor 'S3' winding supply
002	HO2S heater, upstream bank 2 control	006	Ground (HO2S upstream bank 1 heater)	010	EGR stepper motor 'S4' winding supply
003	EGR stepper motor 'S1' winding supply	007	Ground (HO2S upstream bank 2 heater)	011	
004	EGR stepper motor 'S2' winding supply	008	HO2S heaters OBD monitor	012	

4 Mode $06 Data

SAE J1979 Mode $06 Data			
Test ID	**Comp ID**	**Description**	**Units**
$02	$00	Catalyst system efficiency below threshold 1-bank (delay time)	Msec
$04	$00	Catalyst system efficiency below threshold 2-bank (delay time)	Msec
Conversion for TID $02 and $04: Multiply by 4 to get result in milliseconds.			
$06	$00	EVAP system leak detected (20 thou)	KPa
$07	$00	EVAP system leak detected (gross leak)	KPa
$08	$00	EVAP system leak detected (40 thou)	KPa
Conversion for TID $06 and $08: Multiply by 6.25/1024, then subtract 4.125 to get result in kPa. Conversion for TID $07: Multiply by 6.25/1024 to get result in kPa.			
$09	$00	EGR system flow malfunction (GA changing rate low)	g/sec
$0A	$00	EGR system flow malfunction (GA changing rate high)	g/sec
Conversion for TID $09 and $0A: Multiply by 400/65536, then subtract 200 to get result in g/sec. Result can be positive or negative.			
$0B	$00	EVAP system flow check	None
$0C	$00	EVAP system flow check	None
Conversion for TID $0B and $0C: Multiply by 0.5/65536.			
$0D	$00	EVAP system flow check	None
$0E	$00	EVAP system flow check	None
Conversion for TID $0D and $0E: Multiply by 2/65536.			
$0F	$00	EVAP system flow check	RPM
$10	$00	EVAP system flow check	RPM
$11	$00	EVAP system flow check	RPM
Conversion for TID $0F, $10 and $11: Multiply by 100/256 to get result in rpm.			
$12	$00	EVAP system flow check	g/sec
Conversion for TID $12: Multiply by 1/1024 to get result in g/sec.			
$17	$00	Air assist control valve (range/performance)	g/sec
Conversion for TID $17: Multiply by 400/65536, then subtract 200 to get result in g/sec. Result can be positive or negative.			

SAE J1979 Mode $06 Data – Continued			
Test ID	**Comp ID**	**Description**	**Units**
$1A	$00	Upstream HO2S 1 bank 1 lean to rich response time counter	msec
$1B	$00	Upstream HO2S 2 bank 1 lean to rich response time counter	msec
Conversion for TID $1A and $1B: Multiply by 64 to get result in msec.			
$1C	$00	Upstream HO2S 1 bank 1 minimum sensor current for test cycle	Ma
$1D	$00	Upstream HO2S 2 bank 1 minimum sensor current for test cycle	mA
$1E	$00	Upstream HO2S 1 bank 1 maximum sensor current for test cycle	mA
$1F	$00	Upstream HO2S 2 bank 1 maximum sensor current for test cycle	mA
Conversion for TID $1C, $1D, $1E and $1F: Multiply by 1/256, then subtract 128 to get result in mA. Result can be positive or negative.			
$21	$00	EGR system flow malfunction (MAP changing rate low)	kPa
$22	$00	EGR system flow malfunction (MAP changing rate high)	kPa
Conversion for TID $21 and $22: Multiply by 266.7/65536, then subtract 133.35 to get result in kPa. Result can be positive or negative.			

5 On Board Monitoring

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

5.1 Catalyst Efficiency Monitor

Catalytic converters oxidize unburned Hydrocarbons (HC) and CO by combining them with oxygen to produce water vapor, and reduce nitrogen oxides to nitrogen and oxygen. When the engine air fuel ratio is lean, the oxygen content of the catalytic converter reaches its maximum value. When the air fuel ratio is rich, the oxygen content is depleted. If the air fuel ration remains rich for an extended period, the converter may fail to convert the harmful gases.

The condition of the catalyst is determined using the difference between signals from the upstream and downstream oxygen sensors, and the time taken to switch from rich to lean.

5.1.1 Monitoring Procedure

Primary detection is based upon:

- Downstream oxygen sensor high frequency amplitude.
- The response delay time between upstream and downstream change.

A calculation of the average value of the downstream oxygen sensor high frequency amplitude is made; this is normal if the value falls below a given threshold. Should a failure judgment occur, the main feedback frequency will be adjusted and the response delay time from the upstream to downstream feedback signal monitored. If the response delay time is greater than the threshold then a normal judgment will be made less will incur a failure judgment.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Catalyst Efficiency Monitor Operation

Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Catalyst efficiency bank 1 Catalyst efficiency bank 2	P0420 P0430	Downstream delay time	Time	< 1000	Engine speed Vehicle speed Closed loop fuelling ECT IAT Airflow Altitude Airflow change Engine speed change Throttle angle change Idle Sub feedback compensation Air fuel ratio compensation Linear air fuel compensation	1100 to 2500 RPM 31 to 37 mph Active 80 to 110 ºC -8 to 100 ºC 5 to 30 g/s < 8000 feet < 15 g/s in 0.512s < 360 in 0.512s < 4 deg in 1.024s Inactive 0.9 to 1.1 0.75 to 1.25 0.5 to 1.5	23s	2 Drive cycles 2 Drive cycles
				Disable:	P0101-P0103, P1104, P0107, P0108, P0111- P0113, P0116-P0118, P0125, P0300-P0308, P0460, P0447, P0448, P0122, P0123, P0222, P0223, P0121, P1121-P1123, P1222- P1224, P1229, P1251, P1611, P1631, P1633, P1230, P1367, P1368, P1609, P1642, P0603, C1165, C1175, C1137, P1313, P1314, P1316, P0444, P0445			
				Disable (bank 1):	P0135, P0137, P0138, P0140, P0141, P0171, P0172, P0201, P0202, P0203, P0204, P0351, P0352, P0353, P0354			
				Disable (bank 2);	P0155, P0157, P0158, P0160, P0161, P0174, P0175, P0205, P0206, P0207, P0208, P0355, P0356, P0357, P0358			

5.2 Misfire Monitor

A misfire is caused by a failure of combustion. When this occurs, unburned hydrocarbons and excess oxygen are exhausted from the cylinder. Therefore, the catalytic converter may suffer damage through overheating as it tries to convert the excessive HC. Secondly, the oxygen sensor will report a lean condition to the ECM, which in turn will increase the injector pulse width and add more raw fuel to the exhaust stream.

Two algorithms running in parallel are used to detect misfire, by monitoring the variation in crankshaft period (speed).

One algorithm detects misfire rates less that would cause excess emissions. The other algorithm detects misfire rates that would cause permanent damage to the catalyst. Variations in crankshaft period are compared to the respective speed and load limits, if the changes exceed the limit then a misfire has occurred.

Faults are detected if the number of misfires in 200 or 1000 revolutions of the crankshaft exceed the limits.

In the event of a catalyst damage misfire being detected a cylinder misfire will also be detected.

The system is disabled during transient conditions, which could give false indications of a misfire.

Note: For the purposes of misfire detection, “steady-state” is defined as:

- At least 2 seconds since fuel cut-off was last invoked.
- At least 2 seconds since gear change ignition retard was last invoked.
- At least 2 seconds since acceleration ignition retard was last invoked.
- At least 2 seconds since fuel cut-off ignition retard was last invoked.
- At least 2 seconds since ISC feedback status (on or off) changed.
- At least 2 seconds since A/C status (on or off) changed.
- At least 2 seconds since electrical load status (on or off) changed.
- At least 2 seconds since traction control ignition retard was last invoked.
- Rate of change of engine speed less than 250 RPM/0.064s.
- Rate of change of engine load has been less than 0.1 g/revolution for at least 20 engine revolutions.
- Rate of change of throttle angle is less than 1deg/0.008s.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Misfire Monitor Operation								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Random misfire	P0300	Crank speed fluctuation	Catalyst/emissions damage		Steady state Engine speed	See note above 500 to 2500 RPM	1000 revolutions	1+2 Drive cycles
Misfire cylinder 1	P0301				ECT IAT	-8 to 120ºC -8 to 100ºC		1+2 Drive cycles
Misfire cylinder 2	P0302				Altitude Load	< 8000 feet See table		1+2 Drive cycles
Misfire cylinder 3	P0303					MOMFGNT		1+2 Drive cycles
Misfire cylinder 4	P0304							1+2 Drive cycles
Misfire cylinder 5	P0305							1+2 Drive cycles
Misfire cylinder 6	P0306							1+2 Drive cycles
Misfire cylinder 7	P0307							1+2 Drive cycles
Misfire cylinder 8	P0308							1+2 Drive cycles
Misfire catalyst damage 1	P1313		Catalyst damage %	See table MOTLST			200 revolutions	
Misfire catalyst damage 2	P1314		Catalyst damage %	See table MOTLST			200 revolutions	
Misfire excess emissions	P1316		Emissions failure %	3.60%			1000 revolutions	
				Disable:	P0101-P0103, P1104, P0111-P0113, P0116-P0118, P0125, P0107, P0108, P0336, P0460, P0603, P0121-P0123, P0222, P0223, P1121-P1123, P1222, P1223, P1224, P1229, P1230, P1251, P1516, P1609, P1611, P1631, P1633, P1637, P1642, P0128, P0106, C1165, C1175, C1137			

MOMFGNT												
ECT (ºC)	Engine Speed (RPM)											
	650	700	1100	1500	2000	2500	3000	3750	4500	5250	6000	7000
-8.1	0.65	0.74	0.80	0.73	0.75	0.76	0.77	0.88	0.99	1.10	1.21	1.35
20	0.54	0.63	0.70	0.64	0.66	0.66	0.68	0.78	0.89	1.00	1.11	1.25
50	0.43	0.52	0.59	0.55	0.55	0.56	0.58	0.67	0.78	0.89	1.00	1.14
85	0.30	0.39	0.45	0.42	0.40	0.41	0.43	0.54	0.65	0.76	0.87	1.01

Note: The values in the table have units of g/revolution.

MOTLST												
Load (g/s)	Engine Speed (RPM)											
	700	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000
0.60	200	152	134	125	111	255	255	255	255	255	255	255
1.20	200	125	118	112	91	255	255	255	255	255	255	255
1.80	200	100	80	74	67	255	255	255	255	255	255	255
2.40	100	70	70	61	48	255	255	255	255	255	255	255
3.00	255	255	255	255	255	255	255	255	255	255	255	255
3.60	255	255	255	255	255	255	255	255	255	255	255	255

Note: figures in the table denote the number of misfires in 200 engine revolutions corresponding to catalyst damage misfire failure.

5.3 Heated Oxygen Sensor Monitor

An oxygen sensor comprises of a gas-tight zirconium dioxide ceramic tube covered with thin layer of platinum. One end of the tube is open to atmosphere; the other end is sealed and protrudes into the exhaust. When the tube is filled with oxygen rich atmospheric air, and the outer walls are exposed to the oxygen depleted exhaust gases, a chemical reaction takes place and produces a voltage. The voltage output reflects the differences in oxygen concentrations on either side of the ceramic sensor element. As the oxygen content decreases, the voltage increases. As the oxygen content increases, the voltage decreases.
The oxygen content of the exhaust gas stream is directly related to the air fuel mixture supplied to the engine. The voltage output by the oxygen sensor is typically 800 to 1000mV for rich mixtures, and around 100mV for lean mixtures.

The ceramic material in the sensor becomes sensitive to the presence of oxygen in the exhaust gas stream at around 600 degrees Fahrenheit (315 degrees Celsius). An internal heater is used to bring the sensor quickly up to the operating temperature.

5.3.1 Monitoring Procedure

The sensor outputs are monitored during steady driving with a fully warm engine.

If the downstream sensors indicate a lean air fuel ratio and the fuel system has judged that the fueling is rich then the upstream sensor is judged to have failed high voltage.

The upstream sensor is judged to have failed low voltage by comparison of its output with that of the downstream sensor.

Upstream slow response judgments are made when any of the following switching rates remain above a threshold: low to high switch time from one mid point of the switching cycle to the next mid point.

Downstream sensor slow, high and no activity judgments are similar to upstream but the mapped values are different. If no activity is seen the air fuel ratio is enriched to force a response, and a failure judgment is made should this be unsuccessful.

Downstream high and low voltage judgments are made after the sensor has remained above or below predetermined thresholds for a long period.

Heater circuit judgments are made by comparing the expected heater drive state with the actual state. If these states are different for too long then the heater circuits are judged faulty.

For all the above diagnostics, the relevant DTC is stored if the failure judgment is made on two successive trips.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Heated Oxygen Sensor Monitor Operation								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Low voltage bank 1 upstream	P0131	Element current	Element current stuck low and fuel system lean failure	< -15.0mA	After start Disable:	> 0.896s P0132	Ref. fuel system lean	2 Drive cycles
Low voltage bank 2 upstream	P0151	Element current	Element current stuck low and fuel system lean failure	< -15.0mA	After start Disable:	> 0.896s P0152	Ref. fuel system lean	2 Drive cycles
High voltage bank 1 upstream	P0132	Element current	Element current stuck high and fuel system rich failure	> -15.0mA	After start Disable:	> 0.896s P0131	Ref. fuel system lean	2 Drive cycles
High voltage bank 2 upstream	P0152	Element current	Element current stuck high and fuel system rich failure	> -15.0mA	After start Disable:	> 0.896s P0151	Ref. fuel system lean	2 Drive cycles
Slow response bank 1 upstream	P0133	Response time to fuel reinstatement	Response rate time	6 s	Engine speed Airflow Vehicle speed ECT	600 to 2500 RPM 4 to 16 g/s 18.6 to 68 mph 80 to 110 ºC	<= 6s	2 Drive cycles
Slow response bank 2 upstream	P0153	Response time to fuel reinstatement	Response fate time	6 s	IAT Altitude Element impedance Throttle closed Fuel cut time Closed loop fuelling	-8 to 80 ºC < 8000 feet 20 to 80 ohm ISC = 1 <= 30s Active	<= 6s	2 Drive cycles
				Disable:	P1316, P0107, P0107, P0108, P0116-P0118, P0125, P0128, P1367, P1368, P0444, P0445, P0111-P0113, P1104, P1230, P0101-P0103, P1637, P1642, P0603, P0460, P1609, C1165, C1175, C1137, P1224, P1229, P1121-P1123, P1222, P1223, P0121-P0123, P0222, P0223, P1251, P1631, P1611, P1633, P0300-P0308, P1313, P1314, P0444, P0445, P1104			
				Disable (bank 1):	P0132, P0131, P0137, P0138, P0140, P0172, P0171, P0351-P0354, P0210-P0204, P0135			
				Disable (bank 2):	P0151, P0152, P0157, P0158, P0160, P0174, P0175, P0355-P0358, P0205-P0208, P0155			

Heated Oxygen Sensor Monitor Operation - Continued								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Low voltage bank 1 downstream	P0137	Sensor voltage stuck low	Sensor voltage circuit no activity Diagnostic	< 0.1 volts Failed	After start	> 1.9s	Sensor no activity	2 Drive cycles
Low voltage bank 2 downstream	P0157	Sensor voltage stuck low	Sensor voltage circuit no activity Diagnostic	< 0.1 volts Failed	After start	> 1.9s	Sensor no activity	2 Drive cycles
				Disable:	P0101-P0103, P1104, P0107, P0108, P0111-P0113, P0116-P0118, P0125, P0121-P0123, P0222, P0223, P0444, P0445, P0460, P0603, P1121-P1123, P1222-P1224, P1229, P1230, P1251, P1316, P1367, P1368, P1609, P1633, P1637, P1642, P0300-P0308, P1313, P1314, P1631, P1611, C1165, C1175, C1137			
				Disable (bank 1):	P0131-P0133, P0135, P0171, P0172, P0201-P0204, P0141, P0351-P0354, P0138			
				Disable (bank 2):	P0151-P0153, P0155, P0174, P0175, P0205-P0208, P0161, P0355-P0358, P0158			

Heated Oxygen Sensor Monitor Operation – Continued								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
High voltage bank 1 downstream	P0138	Sensor voltage stuck high during fuel cut-off	Sensor voltage	> 0.9 volts	After start Fuel cut-off Closed loop compensation Air fuel ratio feedback	> 1.9s > 3.8s 0.75 to 1.25 0.5 to 1.5	3.8s	2 Drive cycles
High voltage bank 2 downstream	P0158	Sensor voltage stuck high during fuel cut-off	Sensor voltage	> 0.9 volts	Compensation Closed loop compensation average Closed loop fuelling ECT IAT	 0.9 to 1.1 Executing (>60s) 70ºC > -8ºC	3.8s	2 Drive cycles
					Disable:	P0101-P0103, P1104, P0107, P0108, P0111-P0113, P0116-P0118, P0125, P0121-P0123, P0222, P0223, P0444, P0445, P0460, P0603, P1121-P1123, P1222-P1224, P1229, P1230, P1251, P1316, P1367, P1368, P1609, P1633, P1637, P1642		
					Disable (bank 1):	P0131-P0133, P0135, P0171, P0172, P0201-P0204, P0141, P0351-P0354, P0137		
					Disable (bank 2):	P0151-P0153, P0155, P0174, P0175, P0205-P0208, P0161, P0355-P0358, P0157		

Heated Oxygen Sensor Monitor Operation – Continued

Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
No activity bank 1 downstream	P0140	Sub feedback compensation values			Linear air fuel compensation	0.75 to 1.25		
					Air fuel feedback Compensation	0.5 to 1.5		
No activity bank 2 downstream	P0160	Sub feedback compensation values			Sub feedback control	Executing		
					Atmospheric pressure	< 8000 feet		
		No activity check 1	Sub feedback compensation	< Sub feedback adaptive value – minimum sub feedback clamp value	Airflow	10 to 90g/s	140s	2 Drive cycles
			or Sub feedback compensation	> Sub feedback adaptive value + maximum clamp value	Airflow	10 to 90g/s	140s	2 Drive cycles
			or Sub feedback compensation	> 1.1	Airflow	10 to 90g/s	140s	2 Drive cycles
			or Sub feedback compensation	> 0.90	Airflow	10 to 90g/s	140s	2 Drive cycles
		No activity check 2	Difference between initial and present sub feedback compensation	> 0.03	Sub feedback adaptive control	Executing	0.1s	2 Drive cycles
		No activity check 3	Difference between initial and present sub feedback compensation	> 0.03	Sub feedback adaptive control	Not executing	0.1s	2 Drive cycles
			Disable:	P0101-P0103, P1104, P1230, P0107, P0108, P0111, P0113, P0116-P0118, P0125, P0300-P0308, P1367, P1368, P1313, P1314, P1316, P0444, P0445, P0460, P0603, P1609, P1637, P1642, C1137-C1165, C1175, P0121-P0123, P0222-P0223, P1121-P1123, P1222-P1224, P1229, P1251, P1611, P1631, P1633				
			Disable (bank 1):	P0131, P0132, P0135, P0141, P0171, P0172, P0201-P0204, P0351-P0354				
			Disable (bank 2):	P0152, P0152, P0155, P0161, P0174, P0175, P0205-P0208, P0355-P0358				

Heated Oxygen Sensor Monitor Operation – Continued								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Control module failure 1	P3007	Control module hardware check	Heater failure Sensor open circuit	Failed Failed	Ignition on	On	8.0s 8.0s	2 Drive cycles
Control module failure 2	P3008	Control module hardware check	Sensor short circuit Module failure	Failed Failed	Control executed	Executed	8.0s 8.0s	2 Drive cycles

5.3.2 Oxygen Sensor Heaters

The HO2S heaters are connected to the ECM. Hardware detection checks the commanded state of each heater against the actual state. If the commanded and actual states remain different for more than 0.4 seconds then the fault is logged. The hardware detection also checks for open and short circuit conditions.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Heated Oxygen Sensor Heater Operation								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Heater malfunction bank 1 upstream	P0135	Control module monitors heater for open or short circuit faults	Heater open or short circuit		Upstream sensor control	Executing	3.58s	2 Drive cycles
Heater malfunction bank 2 upstream	P0155	Control module monitors heater for open or short circuit faults	Heater open or short circuit		Upstream sensor control Disable:	Executing P0603, P1609	3.58s	2 Drive cycles
Heater malfunction bank 1 downstream	P0141	Hardware check	Commanded versus actual	Wrong			0.384	2 Drive cycles
Heater malfunction bank 2 downstream	P0161	Hardware check	Commanded versus actual	Wrong			0.384	2 Drive cycles

5.4 Fuel System Monitor

The fuel system monitor detects rich or lean fuelling conditions likely to result in excessive exhaust emissions. It does this by utilizing a closed loop control strategy that automatically meters fuel to the engine in proportion to the oxygen content of the exhaust gases. The output of the H02S is used by the ECM to adjust the Pulse Width Modulation (PWM) that determines the fuel air ratio at the injectors. Oxygen Sensors (O2S) are heated to raise them quickly to the operating temperature 350 ºC. If the H02S reads rich, the PWM duty cycle is decreased to make the fuel air mixture leaner. A corresponding increase in the width of the PWM results if the H02S reads lean and fuel/air mixture is made richer.

Rich

If during steady state driving the fuel system continually indicates a total air fuel ratio closed loop compensation value below a set failure limit, the EVAP canister purge valve will close. Should the value remain below the failure threshold the fuel system is judged to have failed rich.

Lean

Should the air fuel ratio closed loop compensation value stay above the set failure threshold limit for too long the fuel system will be judged to have failed lean. For both rich and lean diagnostics, the relevant DTC is stored if the judgment is made on two successive trips.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Fuel System Monitor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Fuel too lean (bank 1)	P0171	Feedback compensation clamp value	Long term + short term	> 1.29	ECT IAT	> 75 ºC > -8 ºC	32.6s	2 Drive cycles
Fuel too rich (bank 1)	P0172		Long term + short term	< 0.77	Airflow Closed loop fuelling	> 6 g/s Active	48.0s	2 Drive cycles
Fuel too lean (bank 2)	P0174		Long term + short term	> 1.29	Time after start	> 30s	32.6s	2 Drive cycles
Fuel too rich (bank 2)	P0175		Long term + short term	< 0.77			48.0s	2 Drive cycles
					Disable:	P0101-P0103, P1104, P0106, P0108, P0107, P0128, P0111-P0113, P0116-P0118, P0125, P0444, P0445, P0460, P0603, P1367, P1368, P1230, P1609, P0300-P0308		
					Disable (bank 1):	P1313, P1314, P1316, P1642, P0135, P0137, P0138, P0140, P0141		
					Disable (bank 2):	P0201-P0204, P0351-P0354, P0133, P0155, P0157, P0158, P0160, P0161, P0205-P0208, P0355-P0358, P0153		

5.5 Evaporative Emissions System

5.5.1 System Description

To reduce the emission of fuel vapor the fuel tank is vented to atmosphere through an activated EVAP canister that collects the fuel vapor. The EVAP canister is periodically purged of fuel vapor when the EVAP canister purge valve opens the vapor line between the EVAP canister and the air intake induction elbow. This action allows manifold depression to draw air through the EVAP canister atmospheric vent, taking up the deposited fuel vapor from the charcoal absorber inside the EVAP canister and burning the resulting fuel vapor in the engine.

There are two variants of the EVAP system. All systems use the charcoal absorber storage EVAP canisters and purge valve and operate as described above. The specific features of each system are described below.

The EVAP systems are designated as:

- Vehicles with on board refueling vapor recovery.
- Vehicles without on board refueling vapor recovery.

Vehicles with On Board Refueling Vapor Recovery

The system has the following features:

- On board refueling vapor recovery to reduce the fuel vapor vented directly to atmosphere from the filler nozzle when refueling.
- An FTP sensor and an EVAP canister vent solenoid are fitted to allow the OBD facility to test for leaks in the fuel and EVAP system.

The EVAP canister vent solenoid is a solenoid-operated device controlled by the ECM. The valve is normally open and is closed only during the leak test sequence. The FTP sensor provides a voltage to the ECM, which is proportional to tank vapor pressure.

Operation of On Board Refueling Vapor Recovery

The on board refueling vapor recovery system enables fuel vapor generated during refueling to be collected by the EVAP canisters. During normal running of the vehicle, the vapor is collected and purged in the same way as for vehicles without on board refueling vapor recovery.

The on board refueling vapor recovery system features are:

- Narrow fuel filler pipe and tank check valve.

- Fuel level vent valve fitted to the fuel vapor vent valve housing and consisting of a two stage shut-off valve with rollover protection and a pressure relief valve.
- Grade vent valve with rollover protection, fitted to the fuel vapor vent valve housing and with an outlet pipe connected to the fuel level vent valve vapor outlet pipe.
- Large bore vapor vent pipes.

The fuel filler pipe has a reduced diameter between the nozzle guide and the tank, providing a liquid seal when refueling and preventing the fuel vapor venting directly to atmosphere. There is no breather tube fitted between the tank and the filler nozzle. To prevent spit back when refueling, a check valve is fitted at the lower end of the filler pipe inside the tank.

During refueling, the tank is vented via the fuel level vent valve, large bore vapor pipes and the EVAP canisters. The fuel level vent valve incorporates a float valve, which is closed by the rising fuel level, creating a back pressure and causing the fuel delivery to stop. In the closed position, the fuel level vent valve also sets the fuel level.

With the fuel level vent valve closed (tank full), any increase in pressure or overfilling is relieved by a separate rollover protected grade vent valve. The outlet from this valve feeds into the main fuel level vent valve vapor outlet pipe, bypassing the closed fuel level vent valve.

When the fuel level is below full, the fuel level vent valve opens to allow unrestricted venting via the canisters.

A pressure relief valve is incorporated into the fuel level vent valve assembly and has an outlet pipe to the filler nozzle. If a blockage or other restriction occurs in the vapor vent system, the pressure relief valve opens to allow venting to atmosphere via the filler nozzle guide and fuel filler cap.

Vehicles without On Board Refueling Vapor Recovery

This system uses one EVAP canister (two EVAP canisters and Rochester valve fitted on vehicles used in high altitude environments). The vapor outlet from the fuel tank is taken via a rollover valve fitted to the removable flange at the top of the tank.

EVAP Canister Purge Valve

The EVAP canister purge valve controls the flow rate of fuel vapor drawn into the engine during the canister purge operation. The valve is opened by a vacuum feed from the induction elbow: the vacuum feed is controlled by the integral valve solenoid and is applied when the solenoid is energized. The solenoid is pulsed on (energized) and off by a fixed frequency (100Hz) variable PWM control signal. By varying the pulse on to off time, the ECM controls the duty cycle of the valve (time that the valve is open to time closed) and thus the vapor flow rate to the engine.

With no ECM signal applied to the valve solenoid, the valve remains closed.

EVAP Canister Purge Operation

The following pre-conditions are necessary for purging to commence:

- After battery disconnection/reconnection, engine management adaptations must be re-instated.
- Engine has run for at least 8 seconds.
- ECT is not less than 70 °C.
- Engine not running in the fuel cut off condition (e.g. overrun).
- The adaptive fuel correction function has not registered a rich or lean failure.
- The EVAP leak test has not failed.
- No faults have been diagnosed in the relevant sensor and valve circuits – MAF sensor, ECT sensor, EVAP canister purge valve and EVAP canister vent solenoid.

If these conditions have been satisfied, purging is started. If any failures are registered, purging is inhibited.

The canister(s) is purged during each drive cycle at various rates in accordance with the prevailing engine conditions. The engine management software stores a map of engine speed (RPM) against engine load (grams of air inducted/revolutions). For any given engine speed and load, a vapor purge rate is assigned (purge rate increases with engine speed and load).

The preset purge rates are based on the assumption of a vapor concentration of 100%. The actual amount of vapor is measured by the closed loop fueling system. The input of evaporative fuel into the engine causes the outputs from the upstream O2S to change. The amount of change provides a measure of the vapor concentration. This feedback causes the original purge rate to be adjusted and also reduces the amount of fuel input via the injectors to maintain the correct air fuel ratio.

Engine speed/load mapping and the corresponding purge rates are different for vehicles fitted on board refueling vapor recovery and vehicles without on board refueling vapor recovery.

5.5.2 Evaporative Emissions System Monitors

Vapor Leak

The leak test will be initialized when a number of entry conditions are satisfied. They will include ECT, IAT, engine load, vehicle speed, vapor concentration and purge amount.

When the entry conditions are satisfied the purge valve will be closed and the EVAP canister closure valve will then close. The EVAP system is now sealed and the FTP sensor will take the initial value of pressure (P1). After a period the FTP sensor will take a further reading (P2). The difference between P1 and P2 becomes the first pressure rise.

EVAP Canister Close Valve

A hardware check of the EVAP canister close valve circuit is performed by the ECM hardware diagnostics. The commanded state of the valve is compared to the actual state both at ignition on and during a leak test. If in either case the actual state of the valve does not match the commanded state a timer is started. If when the timer exceeds its limit the states still do not match then the fault is logged.

Fuel Tank Pressure Sensor Out of Range

These are continuous monitors. The voltage from the sensor is compared to a failure threshold defined in the software.

If the voltage is below the low threshold, then a timer starts to increment. Once this timer exceeds another threshold, then a failure flag is set and a DTC is stored. If the voltage is over the high threshold defined in the software, then a timer starts to increment. Once this timer exceeds a threshold, then a failure flag is set and a DTC is stored.

EVAP Canister Purge Valve

The actual state of the EVAP canister purge valve is monitored against its commanded state by the ECM hardware diagnostic monitor. If the commanded and actual state are different for longer than a defined period a fault is logged.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Evaporative Emissions System Monitor

Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Gross leak detected	P0455	FTP during purge on, EVAP canister close valve open and EVAP canister close valve closed conditions	Pressure change over time	Time/pressure	Vehicle speed	12.4 to 62 mph	120s approximately	2 Drive cycles
					Time after start	> 750s		
					Fuel level	15 to 85%		
					Altitude change	> 625 feet		
					Altitude	< 8000 feet		
0.040" leak detected	P0442	FTP during purge on, EVAP canister close valve open and EVAP canister close valve closed conditions	Pressure change over time	See table TOEVPT2 below	IAT	0 to 100 ºC	120s approximately	2 Drive cycles
					Fuel level change	< 3%		
					Airflow	3.0 to 35.0 g/s		
					ECT	75 to 110 ºC		
					Purge amount accumulative	200		
					Tank pressure	> -2.00 kPa		
					Disable:	P0101-P013, P1104, P0107, P0108, P0111-P0113, P0116-P0118, P0125, P0128, P0201-P0208, P0300-P0308, P0351-P0358, P0444, P0445, P0447, P0448, P0452, P0453, P0460, P0603, P1609, P1637, P1642, P1637, P1638, C1137, C1165, C1175, P1313, P1314, P1316		

Evaporative Emissions System Monitor – Continued								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
EVAP canister close valve open	P0447	Hardware check	Commanded versus actual	Wrong	Ignition on		1.28s	2 Drive cycles
EVAP canister close valve closed	P0448	Hardware check	Commanded versus actual	Wrong	Leak check active Disable:	P0603, P1609	1.28s	2 Drive cycles
EVAP canister close valve control valve malfunction	P0446	Incorporated into P0455/P0442	Pressure change/time	<-0.4 kPa			150s approximately	2 Drive cycles
FTP sensor low input	P0452	Out of range check	Sensor voltage	> 4.95 volts	Ignition on		5s	2 Drive cycle
FTP sensor high input	P0453	Out of range check	Sensor voltage	< 0.10 volts	Ignition on Disable:	P0603, P1241,	5s	2 Drive cycle
FTP sensor malfunction	P0450	Incorporated into P0455/P0442	Sensor activity	< -0.03 kPa		P1242, P1243, P1642, P1609		
Purge valve open	P0444	Hardware check	Commanded versus actual	Wrong	Battery voltage Purge valve duty cycle	< 16 volts < 0.051	3.07s	2 Drive cycles
Purge valve short	P0445	Hardware check	Commanded versus actual	Wrong	Battery voltage Purge valve duty cycle	< 16 volts > 0.797	3.07s	2 Drive cycles
Purge valve control malfunction	P0443	Incorporated into P0455/P0442	Pressure change	-2 kPa	Disable:	P0603, P1609		

Calculated Pressure Change for P0442 - TOEVPT2										
Fuel level	14	15	30	40	50	60	70	80	85	86
Value (kPa)	395.87	0.66	0.68	0.81	0.87	0.90	0.93	0.95	0.97	395.87

5.6 Exhaust Gas Recirculation System (Supercharged Vehicles Only)

The function of the EGR system is to reduce emissions by re-circulating exhaust gases back into the inlet manifold thus reducing peak combustion temperatures and nitrogen oxide emissions.

The system comprises of an EGR valve and transfer pipe. The EGR valve is fitted to the rear of the induction elbow below the throttle body. The transfer pipe connects the right exhaust manifold to the EGR valve.

An integral four-pole (60-step) stepper motor controlled from the ECM drives the EGR valve.

The valve is cooled by the coolant return from the electronic throttle body.

5.6.1 Exhaust Gas Recirculation System Monitor

Two tests are performed on the EGR system:

Manifold Pressure Check

This monitor uses the manifold absolute pressure sensor to detect changes in manifold depression when the EGR valve is open and closed. When the entry conditions have been met the EGR valve is opened and the manifold pressure is monitored. If the MAP sensor does not indicate a response within the required time limit then a failure is logged.

Valve Circuit

The ECM hardware diagnostic monitors the drive signals to the EGR stepper motor. If a hardware failure is detected more than 5 times then a failure is logged.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Exhaust Gas Recirculation System Monitor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
EGR valve blocked	P0400	Calculation of manifold pressure failure judgment (high/low)	Manifold pressure	< 1.5 kPa	Fuel cut-off Altitude Linear air fuel compensation Engine speed Smoothed wheel speed Mass airflow Engine load Delta throttle angle Throttle angle Water temperature Airflow Monitoring execution EVAP monitoring EGR valve actual step Delta MAF Disable;	Active < 8000 feet 0.75 to 1.25 1300 to 2500 RPM 37.3 to 74.6 mph 5 to 8 g/s 0.1 to 0.3 g/revolutions 0.4 deg 3.5 deg 60 to 110 ºC -8 to 100 ºC Not executing Not executing 0 step 0.5 g/s None	2.3s	2 Drive cycles
EGR valve circuit low input	P0405	Hardware check	Wrong	5 times	Ignition on Disable:	 Monitoring inhibit flag		2 Drive cycles
EGR valve circuit high input	P0406	Hardware check	Wrong	5 times	Ignition on Disable:	 Monitoring inhibit flag		2 Drive cycles

6 Comprehensive Component Monitor

The comprehensive component monitor looks at sensor inputs from components that are likely to affect emissions: IAT, ECT, cylinder head temperature, MAF, TP and Fuel Tank Temperature (FTT). These components are monitored for circuit continuity, out of range values and functionality. There are different strategies for monitoring inputs and outputs. One involves checking certain input signals at the analogue/ digital (A/D) converter inside the ECM for out of range values and electrical faults.

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

6.1 Crankshaft/Camshaft Position

~~6.1.1~~6.1.1 Engine Speed and Crankshaft Position Sensor

Engine speed and CKP are monitored by a sensor, which is mounted on the cylinder block (flywheel housing) in front of the crankshaft drive plate. It indicates rotational speed in the form of 35 pulses per crank revolution. Engine speed is used for synchronization of fuel and ignition systems, as well as other functions.

6.1.2 Camshaft Position Sensor

A CMP sensor is mounted at the rear of each cylinder head on the intake side and each provides four signals every 720 degrees of crankshaft rotation. The combination of signals from both sensors can indicate to the ECM when a particular piston is approaching top dead center on the compression stroke. Normally only bank 1 sensor is used in conjunction with the CKP sensor for normal fuelling and ignition functions.

On supercharged engines, only one sensor is used. It is mounted at the rear of the bank 1 cylinder head on the intake side. It provides one signal every 720 degrees of crankshaft rotation. The signal, in conjunction with the signals from the CKP sensor, indicates to the ECM that the piston of cylinder 1 bank 1 is approaching top dead center on the compression stroke.

6.1.3 Crankshaft/Camshaft Position Monitoring

The CKP and CMP sensors are continually monitored for loss of signal. Depending on the engine condition, the time taken to detect a loss of signal condition will vary.

The CKP signals are cross-checked with those from the CMP sensor. If CMP signals are detected which indicate engine rotation above a given speed without any signal from the CKP sensor then a fault is registered.

Additionally if the crankshaft gear teeth count is incorrect by more than one tooth then a fault event is recorded. If the number of fault events exceeds the limit without the engine synchronizing then a crankshaft range performance fault is registered.

The crank signal from the ECM to the starter relay is checked for two conditions.

- An engine speed greater than 600 RPM has been detected without a crank signal being initiated.
- The vehicle is in motion above 12.4 mph with the engine running and the crank signal is still active.

Both of the above conditions would indicate a problem with the crank circuit from the ECM to the starter motor relay.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Crankshaft/Camshaft Position Sensors								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
CKP sensor circuit malfunction	P0335	1. CKP sensor at engine start 2. CKP sensor during engine running	Time to crank pulse Time to crank pulse	No Pulse No Pulse	Cranking Battery voltage Engine speed	Operation 6 to 10.5 volts > 1000 RPM	2.0s 0.1s	2 Drive cycles
CKP sensor circuit range/ performance	P0336	CKP sensor pulses judged between missing tooth	Number of pulses	Incorrect number of pulses	Engine speed Disable:	> 500 RPM P1245, P1246, P0603, P1609	1revolution	2 Drive cycles
CMP sensor malfunction bank 1	P0340	1. CMP sensor at engine start 2. CMP sensor during engine running	Time to camshaft pulse Time to camshaft pulse	No pulse No pulse	Cranking Battery voltage Engine speed	Operation 6 to 10.5 volts > 600 RPM	5s 5s	2 Drive cycles
CMP sensor malfunction bank 2	P1340	1. CMP sensor at engine start 2. CMP sensor during engine running	Time to camshaft pulse Time to camshaft pulse	No pulse No pulse	Cranking Battery voltage Engine speed	Operation 6 to 10.5 volts > 600 RPM	5s 5s	2 Drive cycles
CMP sensor range/ performance bank 1	P0341	Detection of camshaft pulse between crank missing teeth	Pulse detected	No pulse	Engine speed	> 500 RPM	2 revolutions	2 Drive cycles
CMP sensor range/ performance bank 2	P0341	Detection of camshaft pulse between crank missing teeth	Pulse detected	No pulse	Engine speed	> 500 RPM	2 revolutions	2 Drive cycles
					Disable:	P0335, P0336, P0603, P1245, P1246, P1642, P1643, P1609, P1795-P1797, P1793, P1798, P1603, P1605, P1608, P1732, P0702, P0706, P1720, P1726, P0715, P1722, P0741-P0743, P1745-P1748, P0711-P0713, P0753, P0758, P0763, P1733, P0731-P0735		

Comprehensive Component Monitor - Crankshaft/Camshaft Position Sensors – Continued								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Crank signal low input	P1245	Start without crank input	Started, no crank		Engine speed Vehicle speed	> 600 RPM < 2 mph		2 Drive cycles
Crank signal high input	P1246	Running with crank input held	Running with crank	5 Times	Engine speed Speed Airflow Disable:	1200 to 3000 RPM > 12.4 mph > 15 g/s P0101-P0103, P1104, P0603, P1516, P1609, P1637, P1642, C1165, C1175, C1137		2 Drive cycles

6.2 Mass Airflow Sensor

The MAF sensor contains a hot wire resistance element that forms part of a Wheatstone bridge. Air flowing around the hot-wire cools it, so altering the value of its resistance. The consequent change in the voltage dropped across the resistance is compared with the voltage dropped by the other resistance arms of the Wheatstone bridge to determine the airflow. This signal is input to the ECM.

The MAF sensor is continually monitored by OBD routines. A DTC is recorded if the input signal from the sensor to the ECM is outside pre-defined thresholds at the high or low end of the scale.

The MAF sensor is supplied with a regulated ground reference from the ECM. A ground feedback path is also supplied via a separate pin to the ECM. If the ECMs OBD identifies a drift of greater than 1 volt above actual battery negative on the ground feedback for longer then a defined period then a ground open circuit fault is logged.

Actual MAF entering the engine is compared with data stored in the ECM memory for ideal airflow under stable throttle conditions. Compensation is made for altitude. If the difference between actual and ideal airflow is greater than a calibrated value, a DTC is stored in the ECM.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Mass Airflow Sensor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
MAF high voltage	P0103	Out of range check	MAF voltage	4.9 volts		Ignition on	0.512s	2 Drive cycles
MAF low voltage	P0102	Out of range check	MAF voltage	0.2 volts		Ignition on	0.512s	2 Drive cycles
MAF ground open	P1104	Out of range check	MAF ground voltage	1 volt		Ignition on	0.512s	2 Drive cycles
MAF range/ performance	P0101	Rationality versus throttle position	MAF actual versus Calculated	>50g/s	Engine speed ECT IAT Altitude TP Fuel level TP change Vehicle speed Disable:	1500 to 2500 RPM 70 to 110 ºC -8 to 100 ºC < 8000 feet 7 to 20 degrees > 10 % < 0.35 deg/0.008s 43.3 to 59 mph P0102, P0103, P1104, P0107, P0108, P0111-P0113, P0116-P0118, P0125, P0121-P0123, P0222, P0223, P0201-P0208, P0351-P0358, P0300-P0308, P1367, P1368, P0460, P0603, P1609, P1637, C1165, C1175, C1137, P1313, P1314, P1316	5.24s	2 Drive cycles

6.3 Barometric Pressure Sensor

The barometric pressure sensor measures the pressure of surrounding air at any given temperature. It is part of the ECM and is therefore not separately serviceable.

The monitor checks for out or range voltage signals from the sensor. If the voltage is outside the limits for longer than the defined time, a fault is logged.

An out of range check is performed by comparing the absolute pressure with manifold pressure, measured by the manifold pressure sensor, when the ignition is on but the engine not running. If the difference in the two pressures is greater than the defined limit then a failure is logged.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Barometric Pressure Sensor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Sensor range /performance	P0106	Out of range check	Atmospheric versus manifold pressure	< 7Kpa	Engine speed Vehicle speed Battery voltage Delta manifold Pressure Cranking Manifold pressure Disable:	< 0 RPM < 0 mph > 10 volts < 2 kPa No Crank 74.7 to 103 kPa P0108, P0107, P1105, P1107, P1108	0.512s	2 Drive cycles
Sensor low input	P0107	Out of range check	Sensor voltage	< 0.10 volts	Ignition on		0.512s	2 Drive cycles
Sensor high input	P0108	Out of range check	Sensor voltage	> 4.90 volts	Ignition on		0.512s	2 Drive cycles

6.4 Manifold Absolute Pressure Sensor

When fitted the EGR system comprises of an EGR valve and exhaust manifold to EGR valve tube. The EGR system allows a measured quantity of exhaust gas to be directed back in to the intake manifold. The exhaust gas is introduced to the incoming charge in the intake manifold, where it mixes with the air fuel mixture and lowers the peak gas temperature, reducing nitrogen oxide exhaust emissions. The gas is drawn through the exhaust manifold to the EGR valve tube from the exhaust to the inlet manifold via the EGR valve. The EGR valve is electrically operated and is controlled via an input from the ECM.

The EGR valve is retained on the throttle body elbow.

A MAP sensor is incorporated within the EGR system. The ECM can monitor the operation of the EGR system by receiving inputs from the MAP sensor. The MAP sensor monitors the EGR flow by the change in intake manifold pressure when the EGR valve is operated. If at any time the input signal to the ECM exceeds pre-defined thresholds due to a low pressure reading for a calibrated period, a DTC is recorded. The MAP sensor is retained on the bulkhead, connecting to the throttle body via a vacuum hose.

The MAP sensor is monitored continuously for out of range conditions at both the high and low voltage end of its operating range. Is it also monitored during steady state closed loop idle to ensure it is above a minimum pressure threshold.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Manifold Absolute Pressure Sensor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Circuit low input	P1107	Out of range check	MAP voltage	< 0.12 volts				
Circuit high input	P1108	Out of range check	MAP voltage	> 4.86 volts				
Range/ performance	P0105	Out of range check	Manifold pressure @ idle max pressure	> 15 kPa	Atmospheric pressure Engine speed Vehicle speed Manifold pressure Idle speed Closed loop Idling set Acceleration flag Failure counter Delta throttle angle Disable:	> 74.7 kPa < 850 RPM = 0 mph < 50 kPa Operating Operating Operating Operating 0.192 – 0.420s >= 9 deg P0108, P0107, P0106, P1107, P1108		

6.5 Intake Air Temperature Sensor

The IAT sensor is a temperature dependent resistor which has a negative temperature coefficient (its resistance changes inversely with respect to ambient temperature) and is exposed to inlet air. The sensor is an integral part of the MAF sensor and is not separately serviceable.

The sensor range is checked for values outside either the low or high limits. If the value is outside the limits for more than a defined period then a failure is registered.

<u>Range Performance – 1 Monitor</u>

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

<u>Range Performance – 2 Monitor</u>

The diagnostic flags any large fluctuations in voltage inputs from the IAT sensor to the ECM. Any large fluctuations would be uncharacteristic of a properly functioning engine. If the indicated temperature changes by more than 20 ºC in 2 seconds then a failure judgment is made.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Intake Air Temperature Sensor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
IAT #1 high input	P0113	Out of range check	IAT voltage	<0.12 volts		Ignition on	0.512s	2 Drive cycles
IAT #1 low input	P0112	Out of range check	IAT voltage	>4.86 volts		Ignition on	0.512s	2 Drive cycles
IAT #1 range / performance	P0111	1 – Rationality versus run time	IAT voltage	>0.33 volts	Engine speed	> 1000 RPM	18s	2 Drive cycles
					ECT	< 40 ºC		
					Airflow	> 5 g/s		
		2 – Two sided other check	IAT voltage change/2s	20 ºC		Ignition on	2.048s	
					Disable:	P0112, P0113, P0116-P0118, P0125, P0603, P1243, P1609, P1642		

6.6 Intake Air Temperature Sensor 2

IAT sensor 2 is only fitted to vehicles with supercharged engines, it is used to monitor the temperature of the air in the charge air coolers. The sensor is fitted to the outlet of the bank 1 charge air cooler. The sensor provides an input to the ECM.

The voltage from the sensor is compared to a failure threshold defined in the software.

If the voltage is below the low threshold, then a timer starts to increment. Once this timer exceeds another threshold, a failure flag is set and a DTC is stored.

If the voltage is over the high threshold defined in the software, then a timer starts to increment. Once this timer exceeds a threshold, a failure flag is set and a DTC is stored.

Comprehensive Component Monitor - Intake Air Temperature Sensor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
IAT #2 high input	P1113	Out of range check	IAT voltage	<0.12 volts		Ignition on	0.512s	2 Drive cycles
IAT #2 low input	P1112	Out of range check	IAT voltage	>4.86 volts		Ignition on	0.512s	2 Drive cycles

6.7 Engine Coolant Temperature Sensor

The sensor is a temperature dependent resistor with a negative temperature coefficient (resistance changes inversely with respect to temperature) and is constantly monitored by the ECM. It is mounted in the engine block coolant system.

The ECT sensor is continually monitored for high and low inputs and range and performance errors.

An out of range check is performed to monitor for sensor output voltages falling outside of the maximum operating range.

A rationality check is performed on the sensor during warm up. This monitor checks the time for the ECT to rise to 70 ºC. If the rise in temperature is not observed within the time required then a fault is logged.

Abnormal fluctuations in temperature are checked, if the temperature changes by more than 20 °C in 2 seconds a fault is registered.

A time to warm up test checks that the sensor is responding to the rise in ECT in the running engine and ensures that closed loop fuelling is entered within a specific time limit. This check monitors for a ECT required for closed loop fuelling within a maximum period of time dependant on starting conditions.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Engine Coolant Temperature Sensor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
ECT high input	P0118	Out of range check	ECT voltage	< 0.12 volts		Ignition on	0.512s	2 Drive cycles
ECT low input	P0117	Out of range check	ECT voltage	> 4.86 volts		Ignition on	0.512s	2 Drive cycles
ECT range/ performance	P0116	1. - Rationality during warm up	ECT/time	See table TOTCCA1	Engine speed (RPM) Airflow Idle ECT IAT	> 1500 RPM for 120s > 10 g/s for 120s Inactive -8 to 100 ºC > -8 ºC	See table TOTCCA1	2 Drive cycles
		2. – Two sided other check	ECT voltage change/2 seconds	30 ºC		Ignition on	2.048s	2 Drive cycles
ECT range/ performance	P0125	Closed loop flags set	Closed loop fuelling entry time	See table TOTCCA	Engine speed (RPM) Airflow Idle ECT IAT	> 1500 for 120s > 10 g/s for 120s Inactive -8 to 100 ºC > -8 ºC	See table TOTCCA	2 Drive cycles
					Disable:	P0107, P0108, P0111-P0113, P0117, P0118, P0135, P0155, P0201-P0208, P0351-P0358, P0603, P1367, P1368, P1243, P1609, P1642		

TOTCCA1											
ECT at engine start (ºC)	-8.1	0	10	20	30	40	50	60	70	80	80	100
Time (seconds)	120	1110	950	800	650	550	450	400	30	30	30	30

TOTCCA												
ECT at engine start (ºC)	-8.1	0	10	20	30	40	50	60	70	80	80	100
Time (seconds)	400	350	235	120	120	120	120	120	30	30	30	30

6.8 Engine Oil Temperature Sensor

The Engine Oil Temperature (EOT) sensor is installed at the right front of the structural sump adjacent to the pressure switch. It indicates to the ECM the temperature of the engine oil, for use in the variable valve timing computation.

The sensor circuit is continually monitored for out of range high and low conditions. If the voltage input to the ECM is outside of the limits for longer than the defined period then a failure is registered.

During vehicle warm up the rise in EOT is compared to the rise in ECT. If the rise in oil temperature is less than 25 ºC with a corresponding ECT rise of 45 ºC, then an EOT range performance failure is registered.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Engine Oil Temperature Sensor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Low input	P0197	Out of range check	Sensor voltage	< 0.03 volts		Ignition on	0.524s	2 Drive cycles
High input	P0198	Out of range check	Sensor voltage	> 4.61 volts		Ignition on	0.524s	2 Drive cycles
Range/ performance	P0196	Rationality versus ECT	Oil temperature rise too low compared to ECT rise	< 25ºC	ECT IAT Disable:	-8 to 100 ºC -8 to 100 ºC P0116-P0118, P0125, P0111-P0113, P0603	ECT rise = 45ºC	2 Drive cycles

6.9 Thermostat Monitor

Controlling the coolant flow through the radiator, the thermostat starts to open at 80 °C to 84 °C and is fully open at 96 °C. From the pump, coolant flows into each bank of the cylinder block. In each bank, approximately 50% of the coolant cools the cylinder bores and the remainder is diverted through the bypass gallery to the cylinder head. With the thermostat closed, coolant returns directly to the pump through the bypass on the thermostat housing. With the thermostat open, coolant returns to the pump via the radiator.

The thermostat monitor uses the input from the ECT sensor. The expected ECT is compared to the actual temperature over a wide range of conditions. The difference or error is continually summed. If the total error between the actual and expected temperatures exceeds the defined limit then a failure is registered.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Thermostat Monitor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Thermostat monitor	P0128	Comparison of ECT and model response	Summation of error between ECT and model response maps		ECT IAT Airflow Engine speed ECT @ start Disable:	-8 to 100 ºC -8 to 80 ºC < 100 g/s < 8000 RPM -8 to 40 ºC P0603, P1241, P1242, P1243, P1609, P1642		

6.10 Throttle Position Sensor

The TP sensor is a dual hall effect device mounted on the motor end of the electronic throttle body. It senses the angle of the throttle plate and provides 2 outputs to the ECM providing a level of redundancy should one output signal fail.

The outputs are continuously monitored for out of range conditions and rationality between the two signals.

If the signal from either sensor is out of range for longer than a defined time period then an out of range failure is registered.

If the difference between the two signals exceeds a threshold dependent on the target throttle angle for longer than the defined period then a range performance failure is registered.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Throttle Position Sensor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
TP sensor 1 low input	P0122	Out of range check	Output voltage	< 0.35 volts	Ignition on		0.096s	2 Drive cycles
TP sensor 1 high input	P0123	Out of range check	Output voltage	> 4.85 volts	Ignition on		0.128s	2 Drive cycles
TP sensor 2 low input	P0222	Out of range check	Output voltage	< 0.34 volts	Ignition on		0.096s	2 Drive cycles
TP sensor 2 high input	P0223	Out of range check	Output voltage	> 4.85 volts	Ignition on		0.128s	2 Drive cycles
TP sensor 1(2) range/ performance	P0121	Rationality of 1 to 2	Signal 1 versus 2	See table TOTADIF	Ignition on Battery voltage Disable:	 > 9 volts P1241, P1242,	0.40s	2 drive cycles

TOTADIF								
Target throttle angle (deg)	0	10	20	30	40	50	65	85
Value (deg)	11.4	12.2	12.9	13.7	14.7	16.0	20.8	30.0

6.11 Electronic Throttle Control

In addition to the TP sensor, detailed in the previous section, the main features of the motorized electronic throttle assembly are:

- Fully motorized control of the throttle valve from the ECM. - The throttle valve is coupled to a dc motor, via reduction gears and quadrant, and is positively driven by the engine management system between the fully closed and fully open positions, in both directions, without any intervening mechanisms. A twin potentiometer sensor on the motor end of the throttle shaft provides direct feedback of the actual valve angle to the ECM and is similar to the TP sensor in operation.
- Mechanical, cable operated 'limp home' mode with restricted throttle opening. - The limp home mechanism consists of the accelerator input shaft link lever and the two throttle shaft levers, all three levers being interlocked for limp home operation. If a failure in the throttle mechanism or control system results in the engine management system selecting the limp home mode, motor power is cut by de-energizing the motor supply relay and/or by de-activating the PWM motor control signal. In limp home mode, the throttle valve is operated mechanically from the drivers pedal and throttle opening is restricted to a range from idle to a maximum of approximately 30 degrees.
- Air assisted fuel injection control valve with integral air feed. - The air assist injection improves the atomization of the fuel spray pattern during cold temperatures. This reduces the HC produced by combustion. Improving combustion stability when cold, allows the use of increased ignition retardation for faster catalyst warm up, providing a further reduction of HC emissions.

The throttle body also has an Accelerator Pedal Position (APP) sensor consisting of twin potentiometers which provide separate analogue input signals, proportional to driver demand to the ECM. As a further safety feature, the two potentiometers have different input/output characteristics for unique signal identifications and any corrupt signal between the expected outputs will cause the ECM to switch the throttle to limp home mode. To provide the power required by the DC throttle motor a separate throttle motor relay is control by the ECM. When commanded this supplies an ignition switched power supply to the ECM which is internally switched to drive the DC throttle motor.

6.11.1 Electronic Throttle Monitor

The electronic throttle system monitor uses three distinct monitoring strategies, they are detailed below:

- Throttle motor relay. - The input to the ECM from the throttle motor relay is checked both when switched on and off. A rationality check is performed to ensure that the actual state of the input agrees which the commanded state. If the commanded and actual states do not agree within a defined period then a failure is registered.
- Position error. – The actual position of the throttle valve as indicated by the TP sensor is continually checked against the target position. If the voltage output from the sensor is not consistent with the target position for longer than a given time a failure is registered. The time limit itself is dependent on the battery voltage at the time the judgment is made, at lower battery voltages the throttle motor will respond more slowly.
- Circuit fault. - The circuit fault monitor checks the drive circuit of the throttle motor. When the entry conditions have been met the monitor starts by performing over current tests using dedicated diagnostic hardware internal to the ECM. If this over current test fails more then 3 times then a circuit failure is registered.

If the hardware test passes the ECM then performs an over current test using the OBD software, this is specifically looking for currents of greater than 8.3 Amps for longer than a defined period. Again, if this test fails then a circuit failure is registered. The final step monitors the duty cycle of the drive signal, if the duty cycle is stuck at 100% for longer than a defined period then the circuit fault is registered. If all of the checks pass then a normal judgment is made and the test restarts.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Electronic Throttle Control								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Electronic throttle control position error	P1224	Rationality sensor out versus target	Sensor out versus target	> 1.001 volts		Ignition on	See table TOS1TOUT	2 Drive cycles
Electronic throttle control circuit fault	P1229	1. Detection of over current by hardware	Number of times over current	3		Ignition on	0.048s	2 Drive cycles
		2. Detection of over current by software	Over current detected	8.3A		Ignition on	1s	2 Drive cycles
		3. Duty cycle 100% failure	100% duty cycle		Battery voltage	Ignition on > 9 volts	See table TOMDUTYF	2 Drive cycles
Throttle motor relay off failure	P1251	Rationality, commanded versus actual	Commanded versus actual	Different	Disable:	Ignition on P0603	0.496s	2 Drive cycles
Throttle motor relay driver on failure	P1631	Rationality, commanded versus actual	Commanded versus actual	Different	Battery voltage Disable:	Ignition on > 9 volts P0603	0.496s	2 Drive cycles

TOS1TOUT				
Battery voltage (volts)	6.48	8.98	9.06	12.03
Time for failure judgment (ms)	0.992	0.992	0.496	0.496

TOMDUTYF			
Battery voltage (volts)	6.48	8.98	9.06
Time for failure judgment (s)	0.010	0.010	0.001248

6.12 Accelerator Pedal Position Sensor

The throttle body has an APP sensor consisting of twin potentiometers which provide separate analogue input signals, proportional to driver demand to the ECM. As a further safety feature, the two potentiometers have different input/output characteristics for unique signal identifications and any corrupt signal between the expected outputs will cause the ECM to switch the throttle to limp home mode.

Both inputs to the ECM are checked for out of range conditions and for rationality with each other.

The out of range check monitors the sensor outputs for voltages outside of the expected operating range. If an out of range condition persists then an appropriate failure is registered.

The rationality check compares the position of the two APP sensor inputs. If the difference in angle detected by the sensors is greater than the defined limit for more than 0.4 seconds then a range/performance failure is registered.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Pedal Demand								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Sensor 1(2) range/ performance	P1121	Rationality 1 to 2	Sensor 1 versus sensor 2	See table TOS3DIF	Battery voltage Disable:	Ignition on > 9v P1241, P1242	0.400s	2 Drive cycles
Sensor 1 low input	P1122	Out of range check	Output voltage	< 0.3 volts		Ignition on	0.128s	2 Drive cycles
Sensor 1 high input	P1123	Out of range check	Output voltage	> 4.85 volts		Ignition on	0.128s	2 Drive cycles
Sensor 2 low input	P1222	Out of range check	Output voltage	< 0.3 volts		Ignition on	0.128s	2 Drive cycles
Sensor 2 high input	P1223	Out of range check	Output voltage	> 4.85 volts		Ignition on	0.128s	2 Drive cycles

TOS3DIF						
Sensor angle (Deg)	1.999	2.129	4.250	9.003	31.998	86.998
Value (Deg)	3.000	4.003	6.103	8.153	9.078	9.078

6.13 Fuel Injectors

The injector monitor operates on a continuous basis. Open and short detection of each injector is possible by comparing the actual injection signal with a target injection signal. The actual injection signal is derived from a change in injector voltage when the injector is turned off and the target injection signal is derived from an injection set flag.

A normal judgment is made when the injector voltage moves from the on to off position i.e. on the signal edge. If the target signal and the actual signal are both set to one, a normal judgment is made. This process is repeated for each injector in firing order. A failure is registered when no injector signal edge is detected i.e. no change in voltage but the injector has been triggered.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Fuel Injectors								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Cylinder 1 injector circuit	P0201	Drive hardware check	Commanded versus actual	10 times	Engine speed ECT	500 to 2500 RPM > 80 ºC	20 revolutions	2 Drive cycles
Cylinder 2 injector circuit	P0202		Commanded versus actual	10 times	IAT Airflow	> -30 ºC 4 to 50 g/s		2 Drive cycles
Cylinder 3 injector circuit	P0203		Commanded versus actual	10 times	After start Airflow change	> 30 sec < 2 g/s in 0.065s		2 Drive cycles
Cylinder 4 injector circuit	P0204		Commanded versus actual	10 times	Injector pulse Battery voltage	2.7 to 0.075s 10 to 16 volts		2 Drive cycles
Cylinder 5 injector circuit	P0205		Commanded versus actual	10 times	TP change	2 deg/0.010s		2 Drive cycles
Cylinder 6 injector circuit	P0206		Commanded versus actual	10 times	Fuel cut-off	Not active		2 Drive cycles
Cylinder 7 injector circuit	P0207		Commanded versus actual	10 times				2 Drive cycles
Cylinder 8 injector circuit	P0208		Commanded versus actual	10 times				2 Drive cycles
				Disable:	P0111-P0113, P0121-P0123, P0222, P0223, P0336, P0351-P0358, P1367, P1368, P0603, P1122, P1123, P1222, P1223, P1121, P1224, P1229, P1251, P1609, P1611, P1631, P1633, P1637, P1642, C1165, C1175, C1137			

6.14 Fuel Pump

The fuel pump is controlled by the ECM via a fuel pump relay. The relay control circuit is continually monitored by the ECM for the correct state of operation. Open and short detection of each relay drive circuit is possible by comparing the actual relay signal with a target relay signal. The actual signal is derived from a change in voltage when the relay is turned off and the target signal is derived from a relay set flag.

If the target and commanded relay states do not match then a failure is registered.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Fuel Pump								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Fuel pump relay 1 malfunction	P1230	Rationality versus command (relay energized)	Commanded versus actual	Wrong	Battery voltage Fuel pump relay Ignition Disable:	> 6.0 volts On On P0603, P1609	0.192s	2 Drive cycles
Fuel pump relay 2 malfunction	P1646	Rationality versus command (relay de-energized)	Commanded versus actual	Wrong	Battery voltage Fuel pump relay Ignition Disable:	> 6.0 volts Off On P0603, P1609	0.192s	2 Drive cycles

6.15 Fuel Level Sensor

The fuel level sensor mounted on the fuel tank vertical face, reacts to level changes via a float and pivot, which is connected to a potentiometer. As the fuel level drops, the resistance increases. Signals from the sensor are received by the Instrument Pack (IPK), then transmitted on the CAN for the ECM to monitor and perform diagnostics.

The ECM constantly monitors the fuel used and rationalizes this with the fuel level signal from the instrument pack via the CAN. Should the monitored amount of fuel used not equate to a proportional fall in the fuel level then a failure will be registered.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Fuel Level Sensor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Fuel level sensor circuit	P0460	Rationality versus fuel used	Fuel used versus time	< 6%	Fuel used After start Battery volts Disable:	> 80 Liters > 40s 8 to 15 volts P0603, P1609, P16242,P1638	N/A	2 Drive cycles

6.16 Knock Sensor

'Knocking' or 'pinking' is caused by uncontrolled combustion and can result in engine damage as well as excessive emissions. Knocking noises are essentially vibrations with frequencies that are detected by a piezo-electric sensing element and converted into electrical signals. Two knock sensors are fitted to the cylinder block on the inboard side of each cylinder bank. The flying lead of each sensor is secured to a bracket on (or near to, depending on the model) the thermostat housing. These piezo-electric sensors provide inputs to the ECM to indicate the detection and location of detonation during combustion. A separate knock sensor processor within the ECM processes the data from the sensors and informs the main processor of the required action.

The knock sensor processor performs out of range checks on both sensors. If the sensor voltage is outside of the maximum operating range for longer than 8 engine revolutions then the knock sensor processor will report a failure to the main processor which in turn will register an appropriate out of range failure. The knock sensor processor also performs and reports on internal self-tests to the main processor.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Knock Sensor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Knock sensor 1 low input	P0327	Out of range check	Sensor output low and knock sensor processor reporting failure	< 1.25 volts	Time after start Engine speed	> 3s > 500 RPM	8 revolutions	2 Drive cycles
Knock sensor 1 high input	P0328	Out of range check	Sensor output high and knock sensor processor reporting failure	> 3.75 volts	Time after start Engine speed	> 3s > 500 RPM	8 revolutions	2 Drive cycles
Knock sensor 2 low input	P0332	Out of range check	Sensor output low and knock sensor processor reporting failure	< 1.25 volts	Time after start Engine speed	> 3s > 500 RPM	8 revolutions	2 Drive cycles
Knock sensor 2 high input	P0333	Out of range check	Sensor output high and knock sensor processor reporting failure	> 3.75 volts	Time after start Engine speed	> 3s > 500 RPM	8 revolutions	2 Drive cycles
Processor failure	P1648	Knock sensor processor self-check	Knock sensor processor reporting failure		Time after start Engine speed Disable:	> 3s > 500 RPM P0603, P1609	8 revolutions	2 Drive cycles

6.17 Ignition Coil

Ignition timing is controlled primarily as a function of engine load and speed. Engine load is sensed by the MAF sensor located in the engine air intake before the throttle housing. A CKP sensor senses engine speed. The ECM processes the inputs from the MAF sensor and the CKP sensor and accesses ignition timing from the ignition timing strategy.

Eight individual “on-plug” ignition coils are located above each spark plug. Each ignition coil-on-plug comprises an encapsulated ignition control module and a direct push on connection to the spark plug. Each output of the ECM controls four of the spark plug mounted ignition coils, two on each bank. The correct firing sequence and timing of the individual on-plug ignition coils is determined by the ECM from the cylinder synchronization input provided by the CMP sensor and the CKP sensor.

Internal hardware detection circuits in the ECM, monitor the individual and group outputs to the coil primaries for incorrect current conditions. If a failure is repeatedly noted over a period then a failure of the appropriate coil or group circuit is registered.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Ignition Coil								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Ignition coil 1 malfunction	P0351	Hardware check	Primary coil current		Engine speed Battery	< 2500 RPM > 10 volts	1.2s	2 Drive cycles
Ignition coil 2 malfunction	P0352	Hardware check	Primary coil current		Disable:	P1642, P1609, P0336, P0603		2 Drive cycles
Ignition coil 3 malfunction	P0353	Hardware check	Primary coil current					2 Drive cycles
Ignition coil 4 malfunction	P0354	Hardware check	Primary coil current					2 Drive cycles
Ignition coil 5 malfunction	P0355	Hardware check	Primary coil current					2 Drive cycles
Ignition coil 6 malfunction	P0356	Hardware check	Primary coil current					2 Drive cycles
Ignition coil 7 malfunction	P0357	Hardware check	Primary coil current					2 Drive cycles
Ignition coil 8 malfunction	P0358	Hardware check	Primary coil current					2 Drive cycles
Ignition fail group 1	P1367	Hardware check	Primary coil current				0.6s	2 Drive cycles
Ignition fail group 2	P1368	Hardware check	Primary coil current				0.6s	2 Drive cycles

6.18 Variable Valve Timing (Normally Aspirated Engines Only)

For each intake camshaft there is a VVT unit, a bush carrier assembly and a solenoid/shuttle valve.

It is an infinitely variable system (within the prescribed operating range) operating on the intake camshafts only. There is the equivalent of 48° of crankshaft movement between the retarded and advanced positions. Engine oil pressure operates the system under the control of the ECM.

The VVT system improves low speed and high speed engine performance, engine idle quality and exhaust emissions. Engine idle is improved due to the ECM being able to retard the valve timing by an additional 10° compared to the system fitted to previous Jaguar engines. This also reduces the internal EGR at idle, where it is not required. However, the internal EGR system is improved at normal engine running speeds to reduce nitrogen oxide emission and eliminate the need for any external EGR system components.

6.18.1 Valve Timing Unit

The valve timing unit turns the intake camshaft relative to the primary chain to advance or retard the timing.

The unit consists of a body and sprocket assembly separated from an inner sleeve by a ring piston and two helical ring gears; the inner sleeve is bolted to the camshaft.

The two helical ring gears are part of the cylindrical extension of the piston. One gear on the outer bore (meshing with the helical gear, which is on the inner bore of the body and sprocket assembly) and one on the inner bore (meshing with the inner sleeve).

As engine oil pressure moves the piston in the advance direction the helical ring gear on the outer bore of the piston causes the whole piston assembly to turn as well as moving to the right. In the same way, the movement of the piston to the right, combined with the rotation caused by the outer helical gear assembly, causes the inner sleeve and hence the camshaft to rotate to the right in the advanced direction. The procedure is identical, but in the opposite direction for retarding the timing.

A light bias spring in the retard direction is provided along with anti-backlash springs.

The solenoid/shuttle valve assembly is bolted to the bush carrier and protrudes through the camshaft cover. Electrical connection to the solenoid is from the engine harness. The valve timing solenoid controls the position of the shuttle valve relative to the two ports in the bush carrier. The shuttle valve, depending on its position set by the solenoid at any instant, directs engine oil pressure to either the retard side or the advance side of the piston assembly. The position of the solenoid/shuttle valve is controlled by a return spring and a 300 Hz PWM signal provided by the ECM.

6.18.2 Variable Valve Timing Monitor

The VVT monitor performs two checks on each solenoid these are: -

- Hardware check. – The internal diagnostic hardware checks the duty ratio of the PWM signal to the solenoid and compares it to the target duty solenoid. If the two do not match for more than 3 seconds then a failure is registered.
- Camshaft position. – The CMP sensors are used to monitor the actual level of camshaft advance/retard against the target level. If the target and actual values do not match for more than 10 seconds a failure is registered.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Variable Valve Timing								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Circuit malfunction bank 1	P1392	Hardware check	Commanded versus actual	Oil control valve duty cycle	30 to 70%		3s	2 Drive cycles
Circuit malfunction bank 2	P1397	Hardware check	Commanded versus actual	Oil control valve duty cycle	30 to 70%		3s	2 Drive cycles
Solenoid malfunction bank 1	P1396	CMP	Target versus actual	Target error			10s	2 Drive cycles
Solenoid malfunction bank 2	P1384	CMP	Target versus actual	Target error			10s	2 Drive cycles
					Disable:	P0335, P0336, P0603, P1609, P0196, P0197, P0198		
					Disable (bank 1):	P0340, P0341		
					Disable (bank 2):	P1341, P1341		

6.19 Idle Speed control

The actual idle speed reported by the crankshaft speed sensor is continually monitored against target idle speed when the engine is in steady state idle conditions.

If all the entry conditions are satisfied, then the monitor will start execution.

If the actual engine is speed more than 100 RPM lower than the target engine speed then a counter is started and once this exceeds the failure time limit a failure judgment is made for idle speed lower than expected.

If the actual engine speed is greater than 200 RPM higher than the target engine speed then a counter is started and once this exceeds the failure time limit a failure judgment is made for idle speed higher than expected.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Idle Speed Control								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
ISC	P0506	Idle speed lower than expected	Idle speed versus target	100 RPM	ECT	80 to 95 °C	2.816s	2 Drive cycles
					Altitude	< 8000 feet		
	P0507	Idle speed higher than expected	Idle speed versus target	200 RPM	Time after start	> 13.76s	2.816s	
					TFT	40 to 215 °C		
					IAT			
					ISC	-8 to 90 °C		
					Stable condition	Active > 4.86s		
						See note below		
					Disable:	P0106-P0108, P0111-P0113, P0116-P0118, P0125, P0121-P0123, P0222, P0223, P0460, P0603, P1121-P1123, P1223, P1224, P1229, P1251, P1611, P1631, P1633, P1516, P1642, P1537, P1643, P1609, C1165, C1175, C1137 P0336, P1241, P1242		

Note: For the purposes of ISC diagnosis, stable engine conditions are defined as:

- At least 2 seconds have passed since a change in state (on or off) of each of the following parameters:
    - Neutral or Drive range.
    - Heated front or rear screen status.
    - A/C status.
    - Radiator fans status.
    - Headlamp status.
    - Main beam status.
    - Side light status.
    - Brake switch status.

6.20 Park/Neutral Position Switch

The ECM receives a transmission park/neutral signal from the transmission range sensor.

A rationality check is performed on the signal. When cranking the switch is monitored to ensure it is indicating a park or neutral position.

When the vehicle is in moving, the position switch is monitored to ensure it is not in the neutral position. If either of these conditions are identified then a fault is logged.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Park/Neutral Position Switch								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Park/neutral driving malfunction	P1516	Rationality versus load/speed	Neutral range	Active	Engine speed Vehicle speed ECT Load Disable:	1800 to 2200 RPM 50 to 62 mph > 80°C > 0.5g/revolutions Primary: P0101-P0103, P1104, P0116-P0118, P1245, P1246, P0335, P1637, C1137, C1165, C1175, P1642	30s	2 Drive cycles
Park/neutral start malfunction	P1517	Start versus neutral range	Neutral range	Inactive	Cranking		0.128s	None

6.21 Charge Air Cooler Water Pump

The charge air cooler is only fitted to supercharged vehicles. The pump is monitored continuously by the ECM. The actual state of the pump drive is checked against the commanded state, if the two do not match within a defined period then a fault is logged.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Charge Air Cooler Water Pump								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Charge air cooler water pump circuit	P1474	Hardware check	Commanded versus actual	Wrong Wrong	Ignition off (ECM on) Ignition on		3.1s 3.1s	2 Drive cycles

6.22 Engine Control Module

Engine management and exhaust emissions are controlled by the ECM, which has the following main functions:

- Fuel injection
- ISC
- Ignition
- EVAP loss system
- Engine cooling fans
- Climate control compressor clutch demand

The microprocessor within the ECM receives signals from various sensors and other modules and uses a pre-determined program to compute engine management functions.

Adaptive functions are incorporated in the ECM to cater for continuous adjustments to its computations to suit prevailing conditions. Because the system also controls emissions to suit all modes, neither CO levels nor idle speed require service attention or adjustment, except if an error or component failure should occur.

Should either the ECM or TCM fail, ensure that the control housing cooling fan is operating correctly. Failure of the cooling fan must be rectified before renewing a control module and details of a fan failure should accompany a returned control module.

The ignition supply is the main power source for the ECM; an inertia fuel shut-off switch will disconnect this supply if the vehicle is subject to a violent deceleration, as in a collision. The ECM has separate ignition and battery supply inputs. The battery input maintains the ECM memory as long as the vehicle battery is connected.

The ECM monitors the following internal functions: -

- Sensor supplied – The ECM provides regulated power supplies for many of the sensors in the engine management system. The supplies are continually monitored for out of range conditions as long as the ignition is on. If all of the sensors using one of the supplies fail with low voltages then the supply is also judged to have failed. Additionally if the input signals from the supplies are found to be irrational (both APP signals low with both TP sensor signal high) then a failure is registered.
- Analog ground supply – In addition to a 5 volt power supply the ECM also provides a regulated ground supply for the sensors. The ground supply is monitored by checking the sensor signals to the ECM and if all relevant sensor inputs are high then a ground fault is registered.
- Every data value stored in the Electrically Erasable Programmable Read Only Memory (EEPROM) is duplicated in a 'mirror' EEPROM location. If all the data values and their mirrors match, a normal judgment is made. If any of the EEPROM data values differ from the value stored in their mirror location then a failure judgment is made and a failure is logged.
- Power supply – The ECM continually compares the battery voltage and ignition voltage supplies. If a significant difference in voltage is detected for longer than 30 seconds then a failure is registered.
- Keep alive memory error – The keep alive memory data is mirrored in two locations. The mirror data is continually checked against the keep alive memory. If any differences are found then a failure is logged, as the ECMs memory is no longer reliable.
- Processor to processor communications – The ECM uses two processors to perform its calculations. The two processors are continually communicating with each other to transfer critical information. Internal diagnostic hardware continuously monitors the communication between the two processors for errors. If the level of errors exceeds a defined limit then a failure is registered.
- Sub processor error – Calculations relating to throttle control are simultaneously performed by both the main processor and sub (secondary) processor (sometimes using different calculation methods). The results of the calculations are cross-checked if errors are detected that exceed defined thresholds then a sub processor failure is registered.
- Main processor – At regular intervals, the validity of all Random Access Memory (RAM) data is checked. Any corruption of RAM data will result in a monitoring failure being registered. If all RAM data is verified then a monitoring normal judgment is made.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Comprehensive Component Monitor - Engine Control Module								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Sensor power supply malfunction	P1240	APP, TP and FTP sensor voltage values irrational	Output voltages: APP sensor 1 APP sensor 2 TP sensor 1 TP sensor 2 FTP	 < 0.3 volts < 0.3 volts > 4.8 volts > 4.8 volts < 0.5 volts			3s	2 Drive cycles
Sensor power supply low input	P1241	Out of range check	Output voltage	< 3.0 volts	Ignition on		3s	2 Drive cycles
Sensor power supply high input	P1242	Out of range check	Output voltage	> 4.5 volts	Ignition on		3s	2 Drive cycles
Analog ground malfunction	P1243	APP, TP, FTP, IAT and ECT sensor voltage values	Output voltages APP sensor 1 APP sensor 2 TP sensor 1 TP sensor 2 FTP IAT sensor ECT sensor	 > 4.9 volts > 4.9 volts > 4.9 volts > 4.9 volts > 4.9 volts > 4.9 volts > 4.9 volts	Disable:	P0603, P1609, P1642	1.048s	2 Drive cycles
Battery voltage malfunction	P0560	Comparator check	No input voltage	< B+ x 0.45	Ignition on Disable:	 P0603, P1609, P1642	30s	2 Drive cycles
Keep alive memory error	P0603	Mirror check	Mirror check	Not OK	Ignition on Disable:	 P0603, P1609, P1642	1.024s	1 Drive cycle
Processor communications error	P1609	Internal communications check	Keyword	Not OK	Ignition on Disable:	 P0603	5s	2 Drive cycles

Comprehensive Component Monitor - Engine Control Module Continued

Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Sub processor error	P1611	Throttle target calculation error	Sub processor throttle target calculation versus main processor	See note below	Speed control Throttle motor relay Processor to processor communications	Not active On No failure	0.2s	2 Drive cycles
		Throttle offset voltage differential failure	Differential of valve offset voltage 1 too large	> 0.19 volts	Throttle motor relay Processor to processor communications	On No failure	0.2s	2 Drive cycles
		Throttle target differential failure	Differential of target voltage too large	> 3.361 volts	Traction control, speed control Throttle motor relay Processor to processor communications	Not active On No failure	0.2s	2 Drive cycles
		Throttle valve angle input failure	Sub processor throttle angle calculation versus main processor	> 5.35 deg	Throttle motor relay Processor to processor communications	On No failure	0.2s	2 Drive cycles
		Pedal angle input failure	Sub processor pedal angle calculation versus main processor	> 8 deg	Throttle motor relay Processor to processor communications	On No failure	0.2s	2 Drive cycles
		Digital servo control failure	Throttle sensor 1 output voltage versus final target voltage	> 1 volt	Throttle motor relay Processor to processor communications	On No failure	0.992s	2 Drive cycles
		Total sub processor calculation failure	Throttle valve angle versus accelerator pedal angle		Throttle motor relay	On	0.992s	2 Drive cycles
		Speed control mode cancel failure	Speed control active with park neutral switch set or brake switch set or park brake on or vehicle speed < 16 mph		Throttle motor relay Processor to processor communications	On No failure	0.492s	2 Drive cycles

Comprehensive Component Monitor - Engine Control Module Continued								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Main processor failure	P1633	RAM/ROM checks	Failure detected in RAM check, ROM check, sequence check or mirror data check				0.08s	2 Drive cycles
System check not complete	P1000						N/A	None
System check complete	P1111						N/A	None

Note: The throttle angle threshold (target versus demand) is calibrated as:

In neutral range and during gearshift: value = 250 deg.

1ST And Reverse Gears				
Vehicle speed (mph)	6.2	12.4	18.6	24.8
Value (degrees)	15	17	17	17

2ND Gear				
Vehicle speed (mph)	6.2	12.4	24.8	49.6
Value (degrees)	17	19	21	21

3RD, 4TH, And 5TH Gears				
Vehicle speed (mph)	6.2	12.4	24.8	49.6
Value (degrees)	20	20	27	35

6.23 Communications Network Monitors

If the ECM does not receive any messages from the required module for a set time, then a fault is flagged.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Communications Network Monitors								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
CAN circuit malfunction	P1642		CAN circuit failure		Ignition on Disable:	 P0603, P1609	1.048s	1 Drive cycle
CAN ECM/ TCM circuit malfunction	P1643		No TCM CAN signal		Ignition on		1.048s	2 drive cycles
CAN ECM/ Anti-lock Braking System (ABS) circuit malfunction	P1637		No ABS CAN signals	1	Ignition on		1.048s	2 Drive cycles
CAN ECM/ IPK circuit malfunction	P1638		No IPK CAN signals	1	Ignition on Disable:	 P0603, P1609, P1642	1.048s	1 drive cycles