ON-BOARD DIAGNOSTICS
BOSCH M5.2.1 ENGINE MANAGEMENT

Vehicle Coverage:
Discovery Series II 1999 to 2004 MY
Range Rover 38A 1999 to 2002 MY

1 Contents

2 Introduction

The Engine Control Module (ECM) controls engine fuelling using sequential injection to all cylinders. Four double-ended ignition coils provide ignition. The ECM detects and corrects cylinder knock by advancing or retarding the ignition timing. In the event of a knock system failure a safe ignition map is used.

The ECM uses the inputs from sensors to control engine performance and restrict emissions in line with Onboard Diagnostics II (OBDII). These sensors include a Mass Air Flow (MAF) Sensor, Throttle Position (TP) Sensor, Engine Coolant Temperature (ECT) Sensor and Oxygen (O2) Sensors. The ECM also receives vehicle data, such as road speed from other control modules. The Central Processor Unit (CPU) within the ECM processes all of these inputs, applies correction factors, such as short and long term fuel trim, and issues commands to the engine actuators, injectors and coils.

On vehicles equipped with automatic transmissions the ECM is connected to the automatic Transmission Control Module (TCM) via the Controller Area Network (CAN) bus. The CAN bus conveys data, requests and messages between the control modules. Generally the automatic TCM passes OBD data and requests to the ECM, which stores freeze frame data and activates the Malfunction Indicator Lamp (MIL) when a fault occurs.

2.1 Diagnostic Trouble Codes and Freeze Frames

The ECM and automatic TCM software monitors each fault condition and allocates a mnemonic Diagnostic Trouble Code (DTC) to specific faults; e.g. P0170 fuel trim malfunction. The software also checks that the monitoring conditions are valid and the current status of the fault. There are common condition flags for each fault module.

Generally, an emission relevant fault is not reported as soon as it occurs, but only after it is flagged during a second valid drive cycle. A drive cycle is defined by a period of engine operation ∅ 10 seconds and the diagnostic fault path in question having been completed at least once. If the fault is still present on the subsequent drive cycle, the OBD system logs the fault and freeze frame data and illuminates the MIL.

If the fault is not present in the subsequent driving cycle, the system holds it as a temporary fault and counts a number of drive cycles before deleting it from the fault memory providing it does not reoccur. A re-occurring fault will be immediately logged as a permanent emissions fault, and may illuminate the MIL according to the type of fault.

When an emissions fault is recognised, the system monitors over Warm Up Cycles (WUC). A warm up cycle is defined by a period of engine operation where the ECT has increased by 21°C (40°F) and exceeds 71°C (160°F).

Monitoring during warm up is also relevant to permanent faults. If the flagged fault is not present in a subsequent drive cycle, the warm up cycle counter is started. If the fault is not flagged again, the MIL remains illuminated but is extinguished after 3 fault free WUC. The fault is finally deleted from the fault memory after 40 fault free WUC.

In the case of misfire monitoring two levels of misfire are checked:

- Emission relevant misfire is monitored over 1000 engine revolutions and 2 drive cycles.
- Catalyst damage misfire is monitored over 200 engine revolutions. If the threshold is exceeded in any 200 engine revolutions segment the MIL is immediately flashed to signal the driver to reduce engine load. When the misfire decreases below the catalyst damage threshold or ceases altogether the MIL is permanently illuminated.

If the freeze frame memory is free the first occurring fault will store freeze frame data regardless of the source. If a subsequent fault occurs, the current freeze frame data is not overwritten unless this fault is of higher freeze frame priority. CARB faults, freeze frame data and other parameters can be read through the diagnostic port via a generic scan tool.

2.2 System Interfaces

The M5.2.1 ECM has some bi-directional (input and output) interfaces, and these are as follows:

- Diagnostics interface via K - Line.
- CAN interface to the automatic TCM.

There are also interactions between the M5.2.1 ECM and other vehicle systems such as the Anti-lock Braking System (ABS) system.

2.3 Inputs and Outputs

Inputs

- Ignition Switch (position II)
- TP Sensor
- Immobiliser interface
- Engine Speed and Position Sensor (Crankshaft Sensor)
- Camshaft Position Sensor
- ECT Sensor
- Intake Air Temperature (IAT) Sensor (integrated into the MAF Sensor)
- MAF Sensor
- Knock Sensors (2 off)
- O2 Sensors (4 off)
- Fuel Tank Pressure Sensor (Except Discovery LEV Phase II and ULEV)
- Fuel Level Sensor (Discovery Series II, NAS Tier I and LEV Phase I)
- Self Levelling, Anti Lock Braking System (SLABS) Vehicle Speed (Discovery Series II only)
- SLABS Rough Road signal (Discovery Series II only)
- ABS Vehicle Speed (Range Rover 38A only)
- ABS Rough Road signal (Range Rover 38A only)

- Transfer Box MIL request (Range Rover 38A only)
- Thermostat Monitoring - bottom hose temperature (LEV Phase II and ULEV only)
- Diagnose Module - Tank Leakage (DMTL) 0.020" (0.5mm) Leak Detection (Discovery LEV Phase II and ULEV only)
- Analogue Fuel Level (Range Rover 38A, Discovery LEV Phase II and ULEV)
- Air Conditioning Standby
- Air Conditioning Request (Range Rover 38A only)

Outputs

- MIL
- Fuel Injectors (8 off)
- Ignition coils (4 Double Ended)
- O2 Sensor Heaters (4)
- Fuel Pump Relay
- Air Conditioning Compressor enable
- Air Conditioning Condenser Fans Relay
- Evaporative Emission Canister Vent Valve
- Evaporative Emission Canister Purge Valve
- Idle Speed Control Valve
- Instrument Pack "ECT Signal" – Pulse Width Modulation (PWM) signal (Discovery Series II only)
- SLABS Hill Decent Control (HDC) - Multiplexed PWM signal (Discovery Series II only)
- Engine Speed signal
- Environmental-Box (E-Box) Cooling Fan (Range Rover 38A only)
- Fuel Used signal (Range Rover 38A only)
- DMTL Pump – 0.020" (Discovery LEV Phase II and ULEV only)
- DMTL Valve – 0.020" (Discovery LEV Phase II and ULEV only)
- Secondary Air Injection Pump Relay (LEV Phase I, Phase II and ULEV only)
- Secondary Air Injection Control Valve (LEV Phase I, Phase II and ULEV only)

3 Mode $06 Data – In accordance with SAE J1979

Mode $06 enables access to the most current diagnostic results and thresholds of non-continuous diagnostic routines. Each individual parameter is identified by a Component Identifier (CID).

Following a power fail or after a delete error memory (Mode 3) request all values will be set to $00.

Values are stored in the battery backed RAM. Additional diagnostic results are available for LEV phase I, Phase II and ULEV vehicles.

TID $00

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

DATA 3: --> $FF (no significance)
Data is bit encoded across the remaining 4 data bytes
DATA 4: --> TID $01 .. TID $08 (Bit 7 corresponds to TID $01)
DATA 5: --> TID $09 .. TID $10
DATA 6: --> TID $11 .. TID $18
DATA 7: --> TID $19 .. TID $20 (Bit 0 corresponds to TID $20)

TIDs $20; $40; $60; $80; $A0; $C0 and $E0 respond similarly for their block of 32 TIDs.

For all supported TIDs the following applies: -

DATA 3: Bit 0 - 6: Number of the measuring path within the TID, i.e.; the component identifier (CID).
Bit 7: Type of test limit:
0 = Test limit is maximum value. The test fails if test value is greater than test limit
1 = Test limit is minimum value. The test fails if test value is less than test limit

DATA 4 + 5: 2- byte value of the measured value

DATA 6 + 7: 2- byte value of the threshold value

TID $01

Catalyst conversion

DATA 3 (TC6KATC/2): Bit 0 - 6: Number of the measuring path within the TID = CID.
Bit 7: Type of test limit:
0 = Test limit is maximum value. Test fails if test value > test limit
1 = Test limit is minimum value. Test fails if test value < test limit

DATA 4 + 5 (TC6KATW/2): 2- byte value of the measured value

DATA 6 + 7 (TC6KATS/2): 2- byte value of the threshold value

J1979 Mode $06 Data				
CID $ [h]	Fault Simulation	Test Value: Threshold	Indicated Fault	Display
05	B_szkat=0 Ą 1	ahkat > AHKATMX	Defective Catalyst Bank A	Pass/Fail
0A	B_szkat=0 Ą 1 AND B_fakat = true	ahkat > AHKTMXT	Defective Catalyst Bank A	Pass/Fail
08	B_szkat=0 Ą 1 AND (ahkat+ahkat2) >AHKATS AND ahkat>=ahkat2	ahkat > AHKATSB	Combined Fault Bank A	Pass/Fail
07	B_szkat=0 Ą 1 AND ahkat<=AHKATSB AND ahkat2<=AHKATSB	ahkat+ahkat2 >AHKATS	Combined Fault Banks A and B	Pass/Fail
06	B_szkat2=0 Ą 1	ahkat2 > AHKATMX	Defective Catalyst Bank B	Pass/Fail
0B	B_szkat2=0 Ą 1 AND B_fakat2 = true	ahkat2 > AHKTMXT	Defective Catalyst Bank B	Pass/Fail
09	B_szkat2=0 Ą 1 AND (ahkat+ahkat2) >AHKATS AND ahkat2>=ahkat	ahkat2 > AHKATSB	Combined Fault Bank B	Pass/Fail
07	B_szkat2=0 Ą 1 AND ahkat<= AHKATSB AND ahkat2<=AHKATSB	ahkat+ahkat2 >AHKATS	Combined Fault Banks A and B	Pass/Fail

TID $02

O2 Sensors
Not supported – covered by mode 5

TID $03

Secondary Air Injection System (Supported for LEV Phase I, Phase II and ULEV)

DATA 3 (TC6SLS/2): Bit 0 - 6:Number of the measuring path within the TID = CID.
Bit 7: Type of test limit:
0 = Test limit is maximum value. Test fails if test value > test limit
1 = Test limit is minimum value. Test fails if test value < test limit

DATA 4 + 5 (TC6SLSW/2): 2- byte value of the measured value

DATA 6 + 7 (TC6SLSS/2): 2- byte value of the threshold value

J1979 Mode $06 Data				
CID $ [h]	Fault Simulation	Test Value: Threshold	Indicated Fault	Display
05	AIOSLS = 55	ziosls < AIOSLS	Secondary Air Injection Functionality Fault Bank A	Pass/Fail
06	AIOSLS2 = 55	ziosls2 < AIOSLS2	Secondary Air Injection Functionality Fault Bank B	Pass/Fail
03	DFRMSLV = 0.05	dfrmsla > DFRMSLV	Control Valve Sealing Bank A	Pass/Fail
04	DFRMSLV = 0.05	dfrmsla2 > DFRMSLV	Control Valve Sealing Bank B	Pass/Fail
01	DFRMFC = 0.08	dfrmsla < DFRMFC	Flow Check Bank A	Pass/Fail
02	DFRMFC = 0.08	dfrmsla2 < DFRMFC	Flow Check Bank B	Pass/Fail

TID $04

Exhaust Gas Recirculation
Not fitted

TID $05

Evaporative Emission (EVAP) System - Vehicles with 0.040" (1.0mm) Leak Detection System

DATA 3 (TC6TESC): Bit 0 - 6: Number of the measuring path within the TID = CID.
Bit 7: Type of test limit:
0 = Test limit is maximum value. Test fails if test value > test limit
1 = Test limit is minimum value. Test fails if test value < test limit

DATA 4+ 5 (TC6TESW): 2- byte value of the measured value

DATA 6+ 7 (TC6TESS): 2- byte value of the threshold value

J1979 Mode $06 Data				
CID $ [h]	Fault Simulation	Test Value: Threshold	Indicated Fault	Display
22	TTEDST = 2.5s, TDTEGR = 1.0s	tdteab > TDTEGR	Large leak (timeout)	Pass/Fail
3	GFSTED (KL)	fldte > 1	Fine leak	Pass/Fail
24	DDPTEKU = -1.464hPa	pttrk < DDPTEKU	EVAP Canister Purge Valve leaking (seat)	Pass/Fail
25	DDPTEAV = -1.464hPa	pttr > DDPTEAV	EVAP Canister Vent Solenoid Valve blocked	Pass/Fail
11	TTEDWU = 20s	Tdteudw > TTEDWU	EVAP Canister Vent Solenoid Valve blocked (residual vacuum)	Pass/Fail
12	TTEDOZG = 20s	tdteozg > TTEDOZG	Fuel Tank Pressure Sensor	Pass/Fail
13	TTEDST = 2.5s	tdteab > TTEDST	Fuel Tank Pressure Sensor	Pass/Fail
26	DDPTETV = -15.62hPa	pttr < DDPTETV	EVAP Canister Purge Valve seat leakage	Pass/Fail
27	GGRTED = 0.305hPa/s	gudauf < GGRTED	Large leak (low vacuum build up)	Pass/Fail
23	DPTEAAV = -14.64hPa	pte < DPTEAAV	EVAP Canister Vent Solenoid Valve blocked	Pass/Fail

TID $05

EVAP System - Vehicles with 0.020" (0.5mm) Leak Detection System

EVAP Canister Purge Valve

DATA 3 (TC6TESC): Bit 0 - 6: Number of the measuring path within the TID = CID.
Bit 7: Type of test limit:
0 = Test limit is maximum value. Test fails if test value > test limit
1 = Test limit is minimum value. Test fails if test value < test limit

DATA 4+ 5 (TC6TESW): 2- byte value of the measured value

DATA 6+ 7 (TC6TESS): 2- byte value of the threshold value

J1979 Mode $06 Data				
CID $ [h]	Fault Simulation	Test Value: Threshold	Indicated Fault	Display
01	B_dteabbv 0 Ą 1	dfrdte < DFDTEF	EVAP Canister Purge Valve – Oxygen Sensor control rich threshold	Pass/Fail
01	B_dteabbv 0 Ą 1	dfrdte > DFDTEM	EVAP Canister Purge Valve – Oxygen Sensor control lean threshold	Pass/Fail
0F	B_minflr 0 Ą 1	dqsdte < DQSTED	Change of Idle Speed Control Actuator air not great enough	Pass/Fail

DMTL Module

DATA 3 (m6cddmtl): Bit 0 - 6: Number of the measuring path within the TID = CID.
Bit 7: Type of test limit:
0 = Test limit is maximum value. Test fails if test value > test limit
1 = Test limit is minimum value. Test fails if test value < test limit

DATA 4+ 5 (m6wddmtl_w): 2- byte value of the measured value

DATA 6+ 7 (m6sddmtl_w): 2- byte value of the threshold value

J1979 Mode $06 Data			
CID $ [h]	Test Value: Threshold	Indicated Fault	Display
12	iptref_w < IPTREFU	DMTL module failure – minimum	Pass/Fail
17	nkfl > NKLDIPFMX	Signal fault – Current fluctuations	Pass/Fail
13	iptref_w > IPTREFO	DMTL module failure – maximum	Pass/Fail
14	iptumv_w > iptsumv_w	DMTL valve not switched over	Pass/Fail
21	iptgl_w < iptsgl_w	Large leak detected	Pass/Fail
18	iptglv_w < iptsglv_w	Large leak detected after extended detection time	Pass/Fail
16	iptkl_w < iptref_w	Small leak detected	Pass/Fail

TID $06

O2 Sensor heating
Not supported – continuous monitor

TID $07

Catalyst heater
Not fitted

TID $08

Camshaft shift
Not fitted

TID $09

Thermostat Diagnosis

DATA 3 (m6cthm): Bit 0 - 6:Number of the measuring path within the TID = CID.
Bit 7: Type of test limit:
0 = Test limit is maximum value. Test fails if test value > test limit
1 = Test limit is minimum value. Test fails if test value < test limit

DATA 4 + 5 (m6wthm): 2- byte value of the measured value

DATA 6 + 7 (m6sthm): 2- byte value of the threshold value

J1979 Mode $06 Data			
CID $ [h]	Test Value: Threshold	Indicated Fault	Display
0A	dthmtmka < DTHMDTKA	Temperature difference too small	Pass/Fail

J1979 Mode $06 Data – Parameter Descriptions	
Parameter	Description
AHKAT	Mean value of the amplitude sensor signal post catalyst corrected by KB, Bank A
AHKAT2	Mean value of the amplitude sensor signal post catalyst corrected by KB, Bank B
AHKATMX	Threshold value catalyst defect, AHKAT >AHKATMX
AHKATS	Threshold value for sum AHKAT, AHKAT2 (stereo)
AHKATSB	Threshold value for error of adding range (stereo)
AHKTMXT	Threshold value catalyst defect at tester’s request
AIOSLS	Number of correct measurements at Secondary Air Injection diagnosis, Bank A
AIOSLS2	Number of correct measurements at Secondary Air Injection diagnosis, Bank B
B_FAKAT	Condition function request catalyst monitoring, Bank A
B_FAKAT2	Condition function request catalyst monitoring, Bank B
B_SZKAT	Cycle time and error bank A run out
B_SZKAT2	Cycle time and error bank B run out
CDSLS	Code word secondary air system in OBDII mode (inv: Europe mode)
DDPTEAV	Pressure difference for detection of clogged EVAP Canister/Shut-off Valve
DDPTEKU	Maximum pressure decrease for compensation gradient
DDPTETV	Pressure difference for detection of open EVAP Canister Purge Valve
DFDTEF	Delta Fr threshold ’rich correction’ for check OK
DFDTEM	Delta Fr threshold ’lean correction’ for check OK
DFRDTE	Delta factor lambda control for EVAP Canister load test
DFRMFC	Threshold control factor change for flow check at Secondary Air Injection diagnosis
DFRMSLA	Delta of Lambda control factor and Reference value for diagnosis Secondary Air Injection, Bank A
DFRMSLA2	Delta of Lambda control factor and Reference value for diagnosis Secondary Air Injection, Bank B
DFRMSLV	Threshold for control factor change for valve check at Secondary Air Injection diagnosis
DPTEAAV	Pressure threshold for EVAP Canister Vent Solenoid Valve failure detection
DQSDTE	Change of Idle Speed Control Actuator air during EVAP Canister Purge Valve opening
DQSTED	Delta air for TE diagnosis o.k. (Idle Speed Control Actuator air test)
DTHMDTKA	Threshold temperature difference TMOT to TKA for detection of faulty thermostat
DTHMTMKA	Delta between Engine Coolant and Radiator Outlet water temperature in diagnosis thermostat
FLDTE	Leakage factor of leak diagnosis
GGRTED	Gradient threshold for detection of DMTL rough leak
GUDAUF	Vacuum built-up gradient
IPTGL_W	DMTL Pump motor current at the end of rough leak detection
IPTGLV_W	DMTL Pump motor current at the end of extended rough leak detection

J1979 Mode $06 Data – Parameter Descriptions	
Parameter	Description
IPTKL_W	DMTL Pump motor current at the end of smallest leak detection
IPTREF_W	DMTL Pump motor current with reference leak
IPTREFO	Upper limit of DMTL pump current during reference measurement
IPTREFU	Lower limit of DMTL pump current during reference measurement
IPTSGL_W	DMTL Pump motor current threshold at rough leak detection
IPTSGLV_W	DMTL Pump motor current threshold at extended rough leak detection
IPTSUMV_W	DMTL Pump motor current threshold at DMTL valve check
IPTUMV_W	DMTL Pump motor current at DMTL valve check
M6CDDMTL	Mode 6 – Memory: Component ID for DMTL tank leakage detection
M6CTHM	Mode 6 – Memory: Component ID for thermostat monitoring
M6SDDMTL_W	Mode 6 – Memory: Threshold value for DMTL tank leakage detection
M6STHM	Mode 6 – Memory: Threshold value for thermostat monitoring
M6WDDMTL_W	Mode 6 – Memory: Measured value for DMTL tank leakage detection
M6WTHM	Mode 6 – Memory: Measured value for thermostat monitoring
NKLDIPFMX	Upper limit of stop DMTL smallest leak detection in case of motor current fluctuation
PTE	Fuel Tank pressure (from ADC)
PTTR	Reference value of differential Fuel Tank pressure
PTTRK	Fuel Tank pressure for measurement of compensation gradient
TC6KATC	Output code SCAN-tool mode 6 from catalyst diagnosis
TC6KATS	Output threshold SCAN-tool mode 6 from catalyst diagnosis
TC6KATW	Output test threshold SCAN-tool mode 6 from catalyst diagnosis
TC6MTLC	Output code SCAN tool mode 6 from DMTL diagnosis
TC6MTLS	Output threshold SCAN-Tool mode 6 from DMTL diagnosis
TC6MTLW	Output check value SCAN tool mode 6 from DMTL diagnosis
TC6SLSC	Output code SCAN-Tool mode 6 from Secondary Air Injection diagnosis, Bank A
TC6SLSC2	Output code SCAN-tool mode 6 from Secondary Air Injection diagnosis, Bank B
TC6SLSS_W	Output threshold value SCAN-Tool mode 6 from Secondary Air Injection diagnosis, Bank A
TC6SLSS2	Output threshold SCAN-tool mode 6 from Secondary Air Injection diagnosis, Bank B
TC6SLSW_W	Output check value SCAN-Tool mode 6 from Secondary Air Injection diagnosis, Bank A
TC6SLSW2_W	Output check value SCAN-tool mode 6 from Secondary Air Injection diagnosis, Bank B
TC6TESC	Output code SCAN tool mode 6 from EVAP Canister Purge control diagnosis
TC6TESS	Output threshold SCAN tool mode 6 from EVAP Canister Purge control diagnosis
TC6TESW	Output check value SCAN tool mode 6 from EVAP Canister Purge control diagnosis
TDTEAB	Time for detection of ”broken hose”

J1979 Mode $06 Data – Parameter Descriptions	
Parameter	Description
TDTEGR	Maximum time for detection of DMTL rough leak
TDTEOZG	Timer for rationality check of Fuel Tank Pressure Sensor
TDTEUDW	Time for Fuel Tank pressure signal at lowest value
TKA	Radiator Outlet Temperature
TMOT	ECT
TTEDOZG	Overall test time for rationality check of Fuel Tank Pressure Sensor
TTEDST	Time for monitoring of Fuel Tank Pressure Sensor
TTEDWU	Waiting time if Fuel Tank Pressure Sensor at lower limit
ZIOSLS	Counter for good diagnosis tests of Secondary Air Injection System
ZIOSLS2	Counter for good diagnosis tests of Secondary Air Injection System

4 Onboard Monitoring

4.1 Catalyst Monitoring

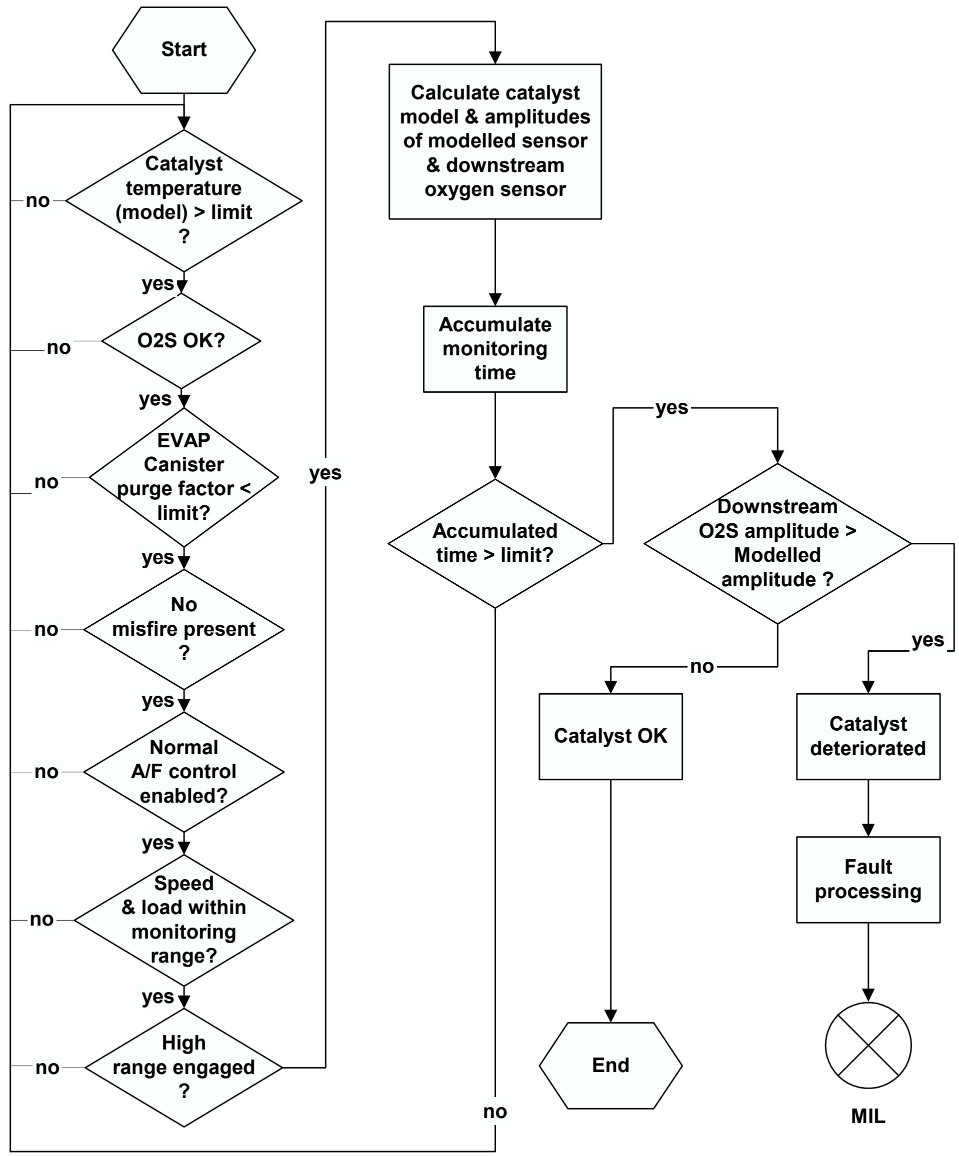
4.1.1 Description

Catalyst monitoring is based on the monitoring of oxygen storage capability. The engine closed loop feedback control generates Lambda* (air fuel ratio) oscillations in the exhaust gas. These oscillations are damped by the oxygen storage activity of the catalyst. The amplitude of the remaining Lambda oscillations downstream of the catalyst indicates the storage capability.

In order to determine catalyst efficiency, the amplitude ratio of the signal oscillations of the upstream and downstream Lambda sensors is determined. This information is evaluated separately in different engine load and speed ranges. If there is an indication of low storage capability in a certain number of operating ranges, a defective catalyst is diagnosed.

*Definition of Lambda: The stoichiometric air fuel ratio is the mass ratio of 14.7 kg of air to 1kg of gasoline theoretically necessary for complete combustion. The excess air ratio ς (Lambda) indicates the deviation of the actual air fuel ratio from the theoretical air fuel ratio. Thus ς = actual inducted air mass/ theoretical air requirement

4.1.2 Monitoring Structure



Computation of the Amplitude Ratio

The first step is the computation of the amplitude of the signal oscillations of the oxygen sensors upstream and downstream of the catalyst. This is accomplished by extracting the oscillating signal component, computing the absolute value and averaging over time. The result of dividing the downstream amplitude value by the upstream amplitude value is called the Amplitude Ratio (AV). This AV value is the basic information necessary for catalyst monitoring. It is computed continuously over a certain engine load and speed range. The signal paths for both sensor signals are identical, so that variations, like an increase in the control frequency, affect both signal paths in the same way and are compensated for by the division.

Post Processing

The actual amplitude ratio is compared with a limit value according to the load and speed range the engine is operating in. The result of this comparison, which is the difference of the two values, is accumulated separately for each range. Thus, even short time periods of driving in a certain range yield additional information.

By using separate load and speed ranges in combination with the accumulation of information a monitoring result can be obtained during a Federal Test Procedure (FTP) cycle.

Fault Evaluation

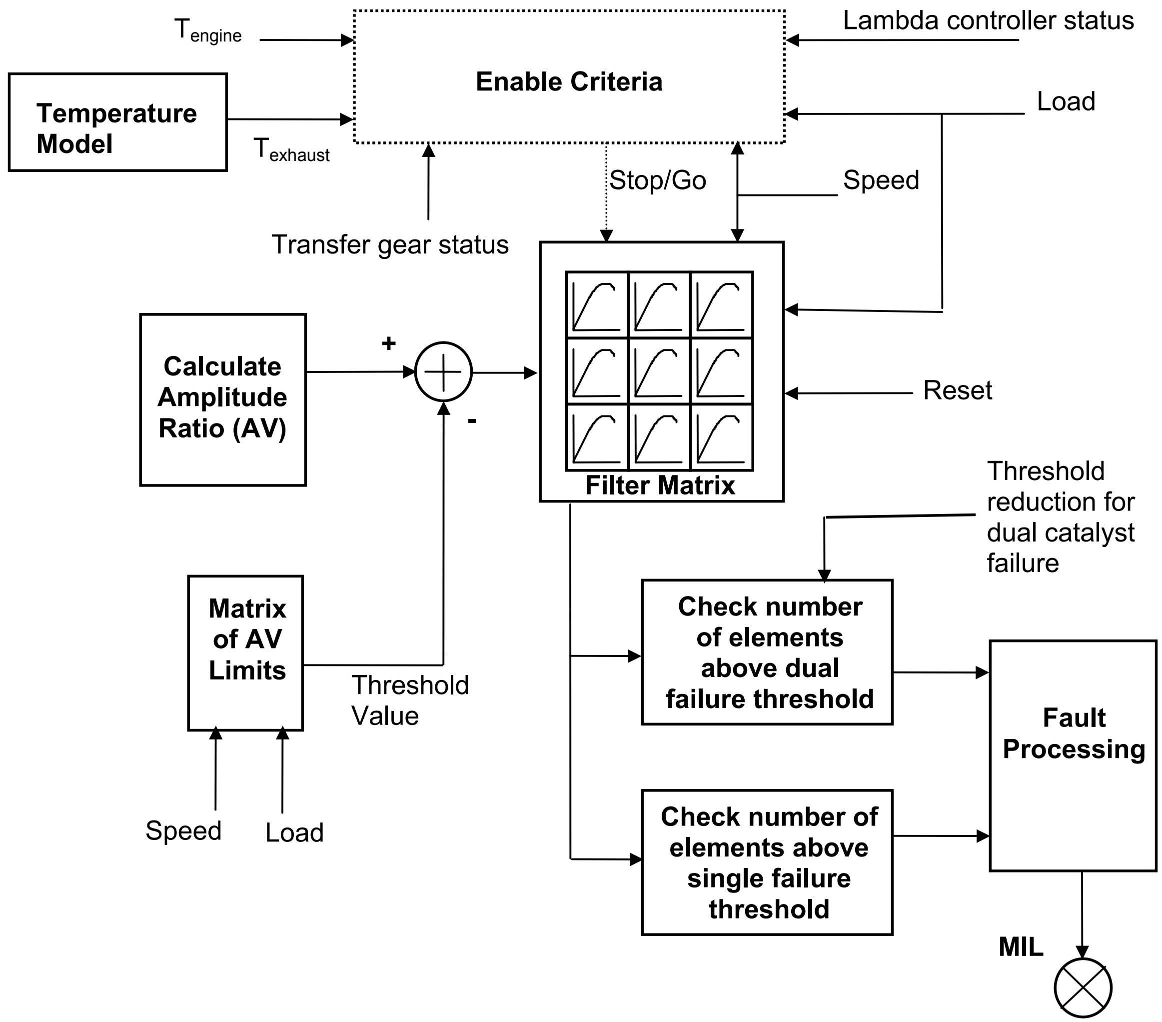
The accumulated information about the amplitude ratio becomes more and more reliable as different load and speed ranges are used during a driving cycle. If the amplitude ratio is greater than fixed map values a fault is detected and an internal fault flag will be set. If the fault is detected again in the next driving cycle the MIL will be illuminated.

Since the monitored engine has a catalyst for each of two cylinder banks, two evaluations are made with differing fault thresholds, one test is for deterioration in one of the catalysts and the second is at a reduced threshold to check for deterioration in both catalysts.

Check of Monitoring Conditions

The monitoring principle is based on the detection of relevant oscillations of the downstream oxygen sensor signal during regular Lambda control. It is necessary to check the driving conditions to ensure that regular lambda control is possible, e.g. fuel cut off not present. For a certain time after enabling Lambda control, the computation of the amplitude values and their post processing is halted, in order to avoid a distortion of the monitoring information.

4.1.3 Block Diagram of system Operation



Catalyst Monitoring Operation – Discovery Series II

Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Catalyst Bank 1	P0420	oxygen storage capability	rear oxygen sensor amplitude exceeds the modelled amplitude of a borderline catalyst (1.75 x standard (Hydrocarbon - (HC) emissions))	> 0.4023	engine speed engine load catalyst temperature (model) transfer gears	1200 < rpm < 1800 between 1.8 and 3.8 msec at 1200 Rpm to between 1.9 and 4.15 msec at 1800 rpm > 332 °C high range	100 sec/ once per driving cycle	two driving cycles
Bank 2	P0430			> 0.4023	fuel system status EVAP canister purge vapour factor enable conditions	closed loop < 10.0 valid for > 0.8 sec		

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

Catalyst Monitoring Operation – Range Rover 38A

Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Catalyst Banks 1 and 2 (Dual catalyst deterioration)	P0420 P0430	oxygen storage capability	amplitude ratio of O2S, rear/front (1.5 x standard + 4K (HC emissions))	> 0.5 (min. 4 of 4 samples per cylinder bank)	engine speed engine load catalyst temperature (model) IAT	1000 < rpm < 2800 1.2< TL msec <4.0 > 300 °C > -9.75 °C	250 sec/ once per driving cycle	two driving cycles
Bank 1 or 2 (Single catalyst deterioration)				> 0.75 (min. 4 of 4 samples for one cylinder bank)	transfer gears fuel system status EVAP canister purge vapour factor time after start	high range closed loop < 10.0 > 69.12 sec		

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

4.2 Misfire Monitoring

4.2.1 Description

The method of engine misfire detection is based on evaluating engine speed fluctuations.

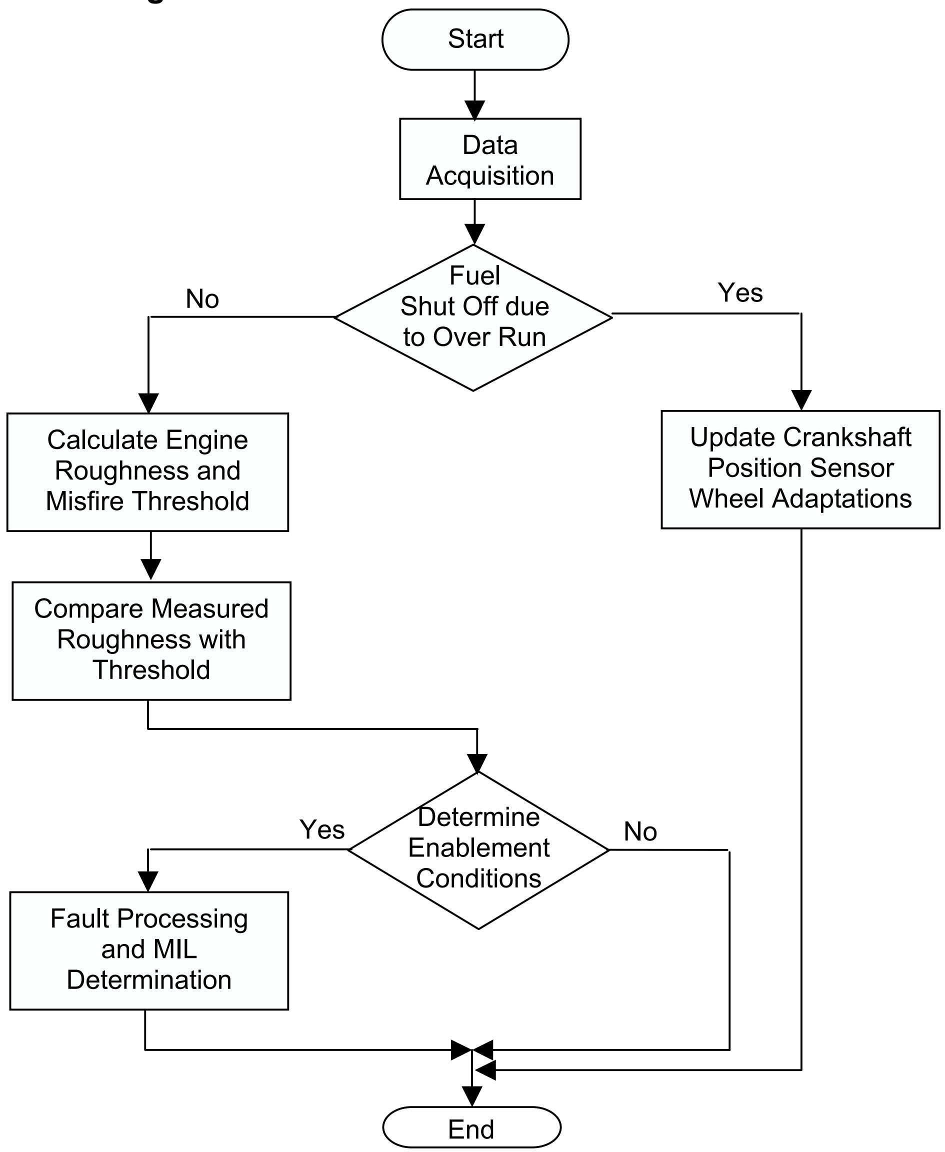
In order to detect misfiring in any cylinder, the torque of each cylinder is evaluated by recording the time between two ignition events; this is a measure of the mean value of the speed for this angular segment. Since a change in the engine torque results in a change of the engine speed. Additionally, the influence of the load torque at the wheels needs to be determined. This is to take account of the influences of different road surfaces, e.g. pavement, pot holes etc.

If the mean engine speed is measured, influences caused by road surfaces have to be eliminated.

This method consists of the following main parts:

- Data acquisition, including adaptation of the sensor wheel.
- Calculation of engine roughness.
- Comparison with a threshold, which depends on the operating conditions.
- Identification of extreme conditions, during which misfire detection cannot be enabled due to a risk of falsely detecting misfire.
- Fault processing, counting procedure of single misfire events, recording of any diagnostic trouble codes and MIL illumination.

4.2.2 Monitoring Structure



1. Data Acquisition

The duration of the crankshaft segments is measured continuously for every combustion cycle.

2. Crankshaft Position Sensor Wheel Adaptation

Within a defined engine speed range and during fuel cut-off, the adaptation of the crankshaft position sensor wheel tolerances is performed. As the adaptation process progresses, the sensitivity of the misfire detection is increased. The adaptation values are stored in non-volatile memory and are taken into consideration during the calculation of the engine roughness.

3. Misfire Detection

The following steps are performed for each measured segment, corrected by the appropriate crankshaft position sensor wheel adaptation.

3.1 Calculation of the engine roughness

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

3.2 Detection of multiple misfiring

If several cylinders are misfiring (e.g. alternating one combustion/one misfire event), the calculated engine roughness values may be so low, that the threshold is not exceeded during misfiring and, therefore, misfiring would not be detected.

Based on this fact, the periodicity of the engine roughness value is used as additional information during multiple misfiring. The engine roughness value is filtered and a new multiple filter value is created. If this filter value increases due to multiple misfiring, the roughness threshold is decreased. By applying this strategy, multiple misfiring can be detected.

3.3 Calculation of the engine roughness threshold value

The engine roughness threshold value consists of the base value, which is determined from a load and speed dependent map. During warm-up an ECT dependent correction value is added. For multiple misfiring the threshold is reduced by an adjustable factor. Before sufficient crankshaft position sensor wheel adaptation has occurred, the engine roughness threshold is limited to a speed dependent minimum value. A change of the threshold towards a smaller value is limited by a variation constant.

4.0 Determination of misfiring

Misfire detection is performed by comparing the engine roughness threshold with the engine roughness value.

4.1 Statistics, fault processing

Within an interval of 1000 crankshaft revolutions the detected misfire events are summed for each cylinder. If the sum of all cylinder misfire incidents exceeds a predetermined value, the preliminary diagnostic trouble code for emission relevant misfiring is stored. If only one cylinder is misfiring, a cylinder selective diagnostic trouble code is stored. If more than one cylinder is misfiring, the diagnostic trouble code for multiple misfiring is also stored. If the misfire is again detected on a subsequent drive cycle, then the MIL is illuminated and the appropriate diagnostic trouble code is stored.

Within an interval of 200 crankshaft revolutions the detected number of misfiring events is weighted and calculated for each cylinder. The weighting factor is determined by a load and speed dependent map.

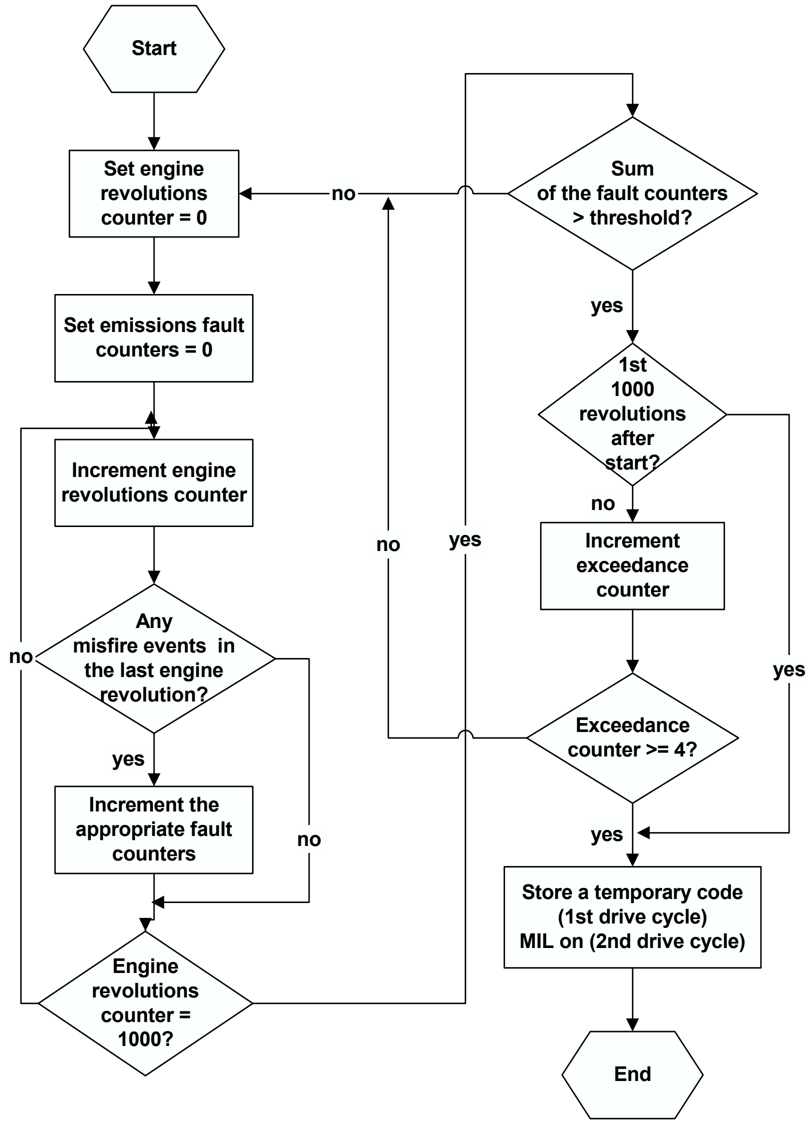
If the sum of cylinder misfire incidents exceeds a predetermined value the diagnostic trouble code for indicating catalyst damage relevant misfiring is stored and the MIL is illuminated at once (flashing).

If the cylinder selective count exceeds the predetermined threshold the following measures are instituted:

- The oxygen sensor closed loop system is switched to open loop.
- The appropriate cylinder selective DTCs is/are stored.
- If more than one cylinder is misfiring, the DTC for multiple misfire is also stored.

All misfire counters are reset after each interval.

4.2.3 Fault Processing for Emissions Relevant Misfire



Misfire Monitoring Operation - Discovery

Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Misfire	P0301 to P0308 P0300 P1300	crankshaft speed fluctuation multiple misfire	Federal Test Procedure (FTP) emissions Threshold	> 1.875 %/ 1000 revolutions	engine speed load change (after start) speed change (after start)	520 < rpm < 5400 < 1.20 ms/rev (< 130.8 ms/rev) < 4000 rpm/sec (< 20 000 rpm/sec)	1000 revolutions up to twice in one drive cycle/ continuous	two driving cycles
			catalyst damage	8.6 to 16.8 % at 600 rpm 7.4 to 14.6 % at 1000 rpm 2.0 to 10.7 % at 2000 rpm 1.9 to 9.9 % at 3000 rpm 1.8 to 8.3 % at 4000 rpm 1.8 to 5.0 % at 5000 rpm	engine load rough road (ABS) gear change traction control transfer gears re-enablement delay (not active after engine start)	Positive not set not active not active high range 20 revolutions	200 revolutions/ continuous	immediately

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

Misfire Monitoring Operation – Range Rover

Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Misfire	P0301 to P0308 P0300 P1300	crankshaft speed fluctuation multiple misfire	FTP emissions threshold	> 2.0 %/ 4000 ignitions	engine speed load change	520 < rpm < 5400 < 0.10 ms/ignition	1000 revolutions/ continuous	two driving cycles
			catalyst damage 4.0 litre 4.6 litre	 4.0 % to 15.9 % 3.8 % to 19.3 % for the speeds and loads encountered during the FTP	speed change engine load rough road (ABS) traction control transfer gears time after start	< 720 rpm/sec positive not set not active high range > 5.0 sec	200 revolutions/ continuous	immediately

Misfire Monitoring Operation – Range Rover								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
	P1319	low fuel level check	Fuel level	< 15%	misfire detection status	diagnostic trouble code stored	Immediately/ continuous	immediately

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

4.3 Secondary Air Injection System Monitoring

4.3.1 Description

The secondary air injection system consists of an electric pump that is controlled by the ECM via a relay. Air is supplied by the pump to two vacuum operated control valves, one per cylinder bank. From each of the control valves air is delivered to the exhaust ports of the centre two cylinders of each cylinder bank. The vacuum signal is switched via an ECM controlled solenoid valve. A vacuum reservoir ensures that there is always sufficient depression to operate the control valves.

Diagnosis of the secondary air injection system can take place in two steps. There is a passive diagnostic which checks for a lean shift in the signals from the front oxygen sensors during secondary air injection operation and there is an active check, which only runs if the passive check fails to achieve sufficient test results in any drive cycle. The active test has two parts; firstly the secondary air injection pump will be run with the control valves shut. If the valves are leaking or stuck open, the feedback fuelling will shift lean and a fault will be detected. If the valve check is passed, then the valves will be opened and if sufficient secondary airflow exists, then the fuelling will be shifted lean. If the lean shift is less than the required threshold, then a fault is stored.

Additionally, a total absence of secondary injection airflow does not cause the vehicle to exceed the appropriate monitoring threshold. Therefore the system only requires a functional check for the presence of secondary air.

Passive Secondary Air Injection Diagnostic

For this test to run the front O2 sensors must have been ready for operation for longer than a certain time, the secondary air injection system must be operating, the engine speed and load must be within a pre-determined window, engine airflow must be less than an altitude dependent threshold and the ECT must be greater than a threshold.

The front O2 sensors are monitored over a time period and the minimum voltage value recorded. When a second timer expires, a test counter is incremented and the minimum sensor value is compared with a threshold. If the voltage is less than the threshold then a counter of good test results is incremented. When the test counter reaches a threshold, the number of good test results is compared with a limit value. If the number of good results is greater than the limit then the Secondary Air Injection system is functioning correctly, otherwise a fault is stored and the MIL is illuminated on the next drive cycle, if the fault is again present.

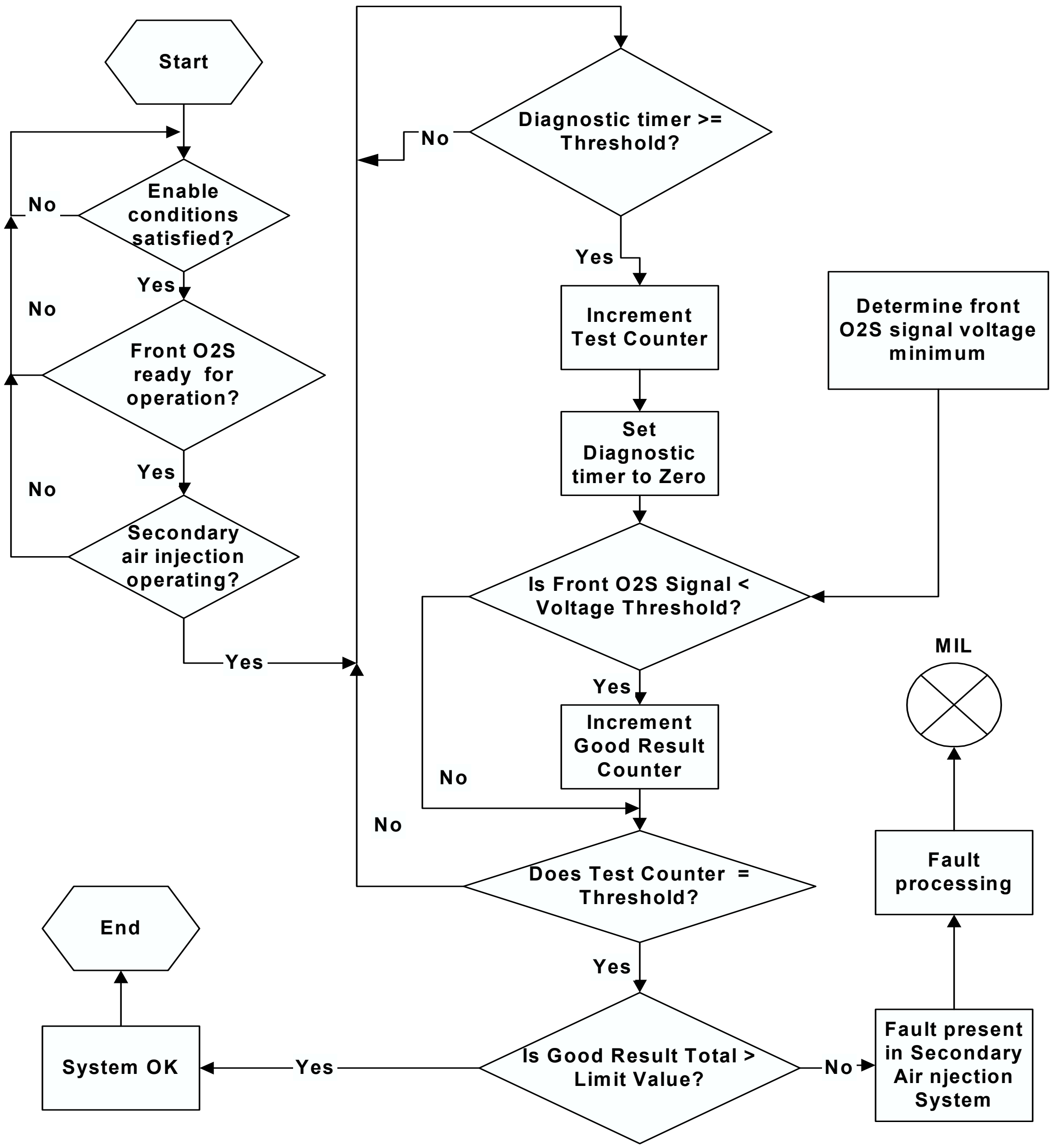
Active Secondary Air Injection Diagnostic

If on any drive cycle during which secondary air injection operation has occurred, there are insufficient passive diagnostic test results for fault determination. The system will then attempt to perform an active check of the secondary air injection system. For an active test to occur, the vehicle must be at rest with the engine idling, feedback fuel control enabled, below an altitude threshold, with the engine having been running for longer than a pre-determined time and secondary air injection not operating. If the EVAP canister purge is operating, then it will be ramped down to zero.

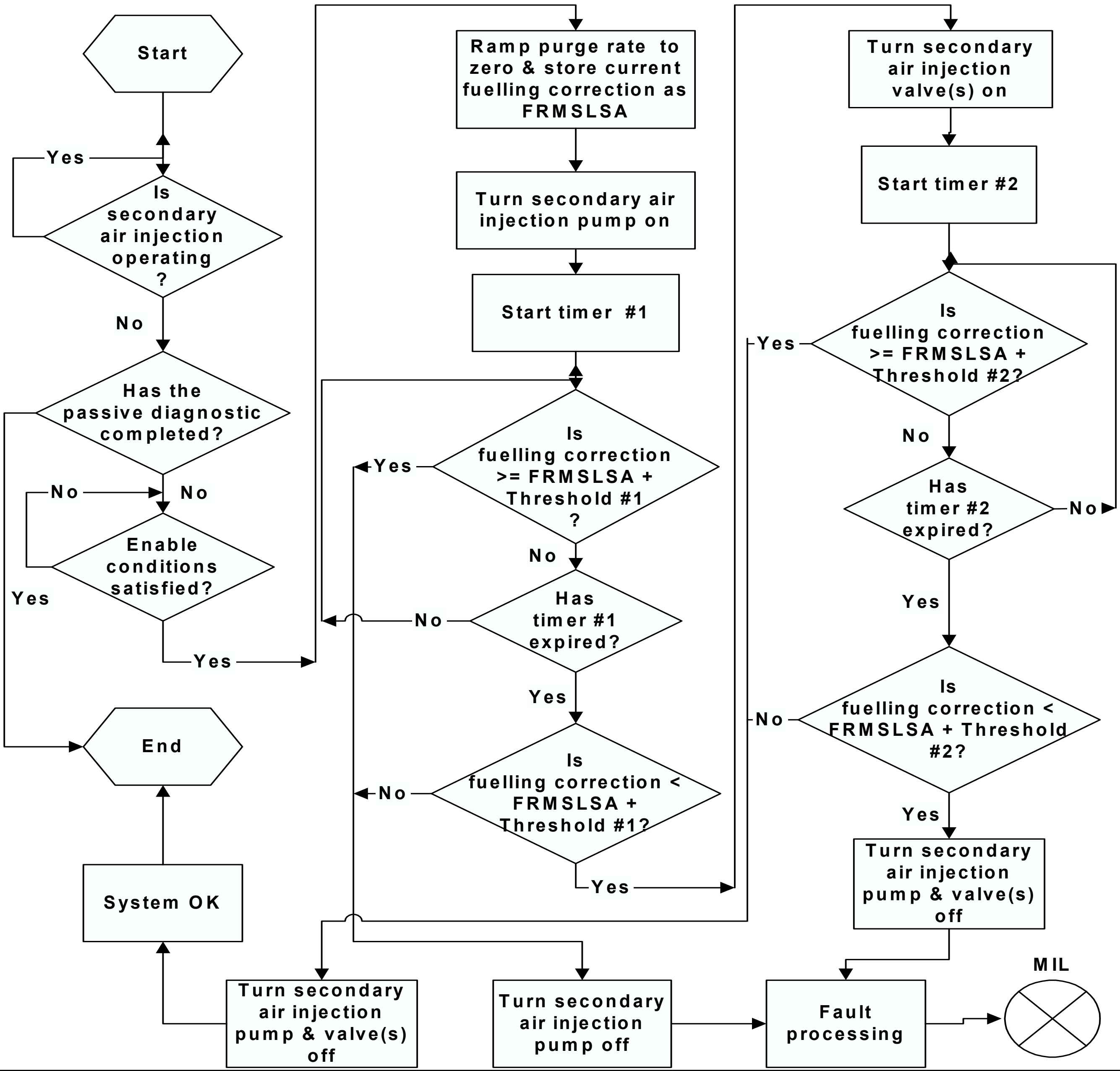
The active test is in two parts. First the current feedback correction factor is recorded and the secondary air injection pump turned on, but with the control valves shut. If the fuelling enriches by more than a threshold, then the valves are leaking or stuck open, but if after a timer has elapsed the feedback correction is below the threshold, then the system proceeds with a flow check.

For the second part of the active diagnostic the valves are opened and if after a time limit, the feedback has not enriched the fuelling by more than a second threshold, then a problem exists with the system and if it is present again on a subsequent drive cycle, a fault is stored and the MIL illuminated.

4.3.2 Passive Secondary Air Injection Diagnostic Monitoring Structure



4.3.3 Active Secondary Air Injection Diagnostic Monitoring Structure



Secondary Air Injection System Monitoring Operation

Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Secondary Air Injection Pump Relay	P0418	circuit continuity - short to battery positive circuit continuity - short to ground circuit continuity - open circuit	voltage - drive on voltage - drive off voltage - drive off	voltage > 1/2 * Battery positive voltage < 1/3 * Battery positive 1/3 * Battery positive< voltage < 2/3 * Battery positive	engine speed battery voltage	> 80 rpm 7.5V < B+ < 17V	immediately/ continuous	two driving cycles
Secondary Air Injection Valve Vacuum Solenoid Drive	P0412 P0414 P0413	circuit continuity - short to battery positive circuit continuity - short to ground circuit continuity - open circuit	voltage - drive on voltage - drive off voltage - drive off	voltage > 1/2 * Battery positive voltage < 1/3 * Battery positive 1/3 * B+ < voltage < 2/3 * Battery positive	engine speed battery voltage	> 80 rpm 7.5V < B+ < 17V	immediately/ continuous	two driving cycles
Secondary Air Injection System (Passive Test) Bank 1 Bank 2	 P1412 P1415	the front O2S voltage Minimum value is sampled over a time of 0.100 sec .If this value is greater than a threshold, then the system is ok	system is OK if:- bank 1 O2S Value and bank 2 O2S Value	< 0.501 V (for > 55 times in 80 Samples) < 0.399 V (for > 55 times in 80 samples)	engine speed engine load engine airflow ECT front O2S secondary air time after engine start altitude factor	520 < rpm < 2520 1.5 < TL ms < 4.0 < 55.56 g/sec > 8 °C ready for operation for > 10.0 sec operating < 655 sec > 0.711	14 sec/ once per driving cycle	two driving cycles
Secondary Air Injection System		valve check:- run the secondary air	change in fuelling correction	Ó 0.05	vehicle speed engine state secondary air	= 0 mph Idle not operating, but	10.5 sec/ once per driving cycle	two driving cycles

Secondary Air Injection System Monitoring Operation								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
(Active Test) Bank 1 Bank 2 Bank 1 Bank 2	 P1413 P1416 P1414 P1417	injection pump with the control valves shut and monitor the Fuelling Correction flow check:- if the valve check is successful, continue running the pump, but with the valves open and monitor the Fuelling correction.	change in fuelling correction	< 0.08	injection fuel system status passive secondary air diagnostic altitude factor time after engine start purge status active test counter	has operated this drive cycle Closed loop not completed > 0.711 > 580 sec ramped to zero & wait 3.0 sec > 0		

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

4.4 Evaporative Emission System Monitoring – 0.040” (1.0mm) Diameter

4.4.1 Description

The evaporative emission system monitoring permits the detection of leaks in the fuel evaporative emission control system with a diameter of 0.040” or larger.

For this purpose, a system pressure check is performed at idle with the vehicle stationary. Since vapour generation in the fuel tank could cause the false detection of a system leak, the first step is to close the EVAP canister purge valve and EVAP canister vent solenoid valve. Any pressure build-up is then measured, so that later results can be compensated for this fuel evaporation effect.

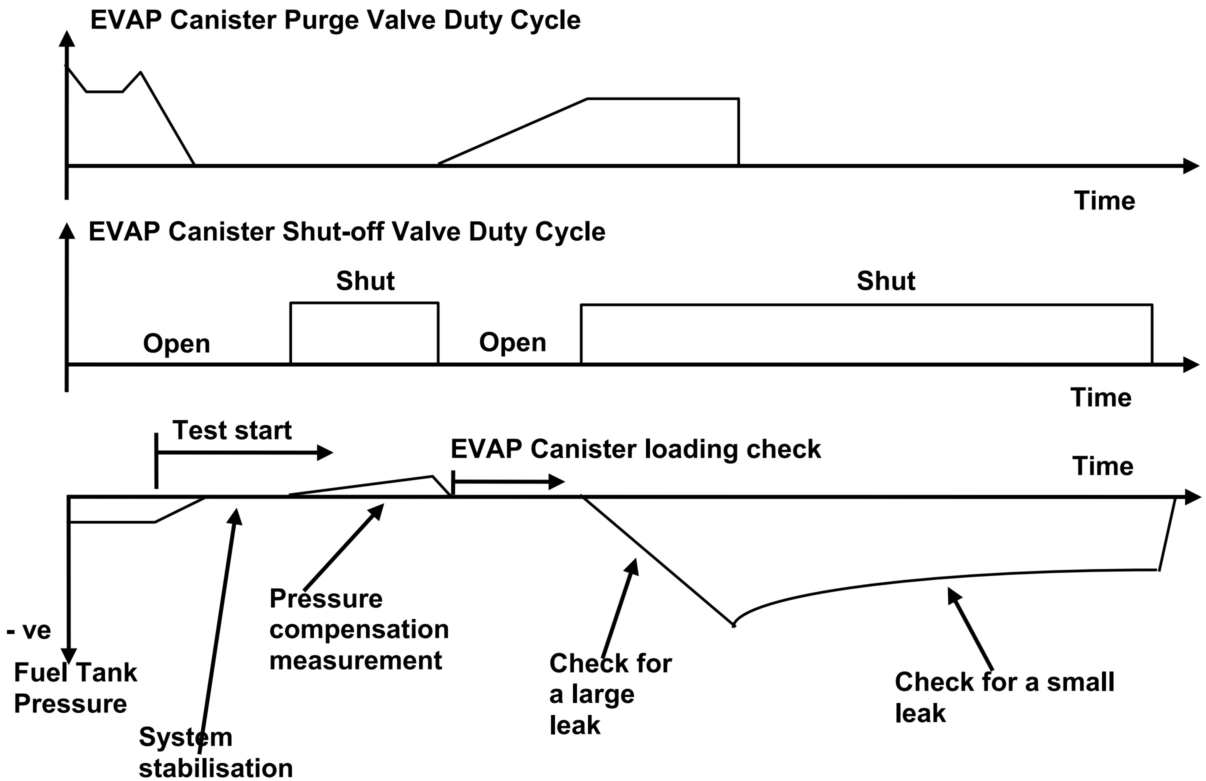
The EVAP canister purge valve is opened and the EVAP canister vent solenoid valve is closed. With this procedure a vacuum in the tank is created, which is measured by the fuel tank pressure sensor.

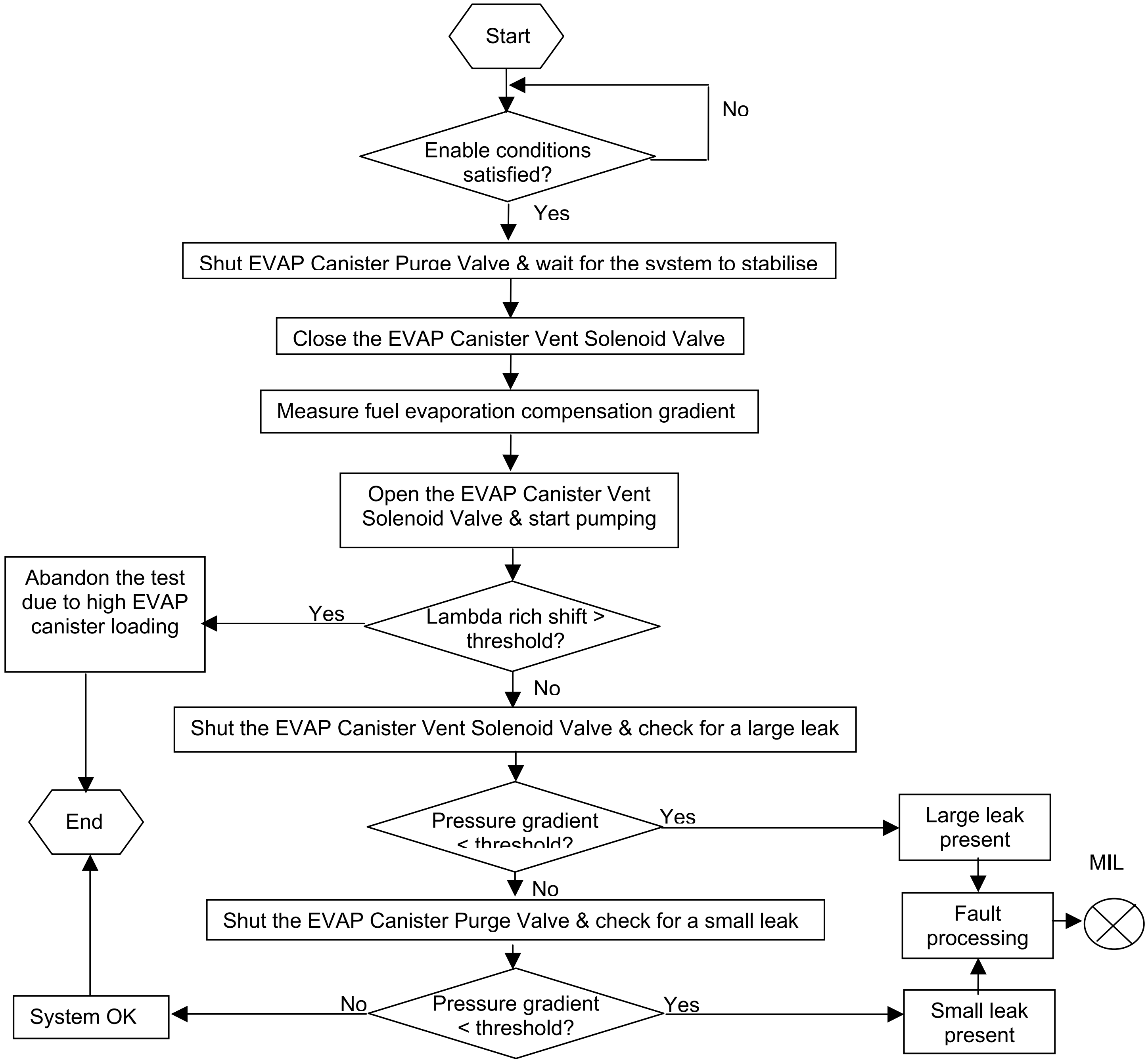
If no vacuum is detected, a large leak is assumed and the diagnosis is halted. If a large lean correction of the oxygen sensor controller is detected during the vacuum build-up, then the check is also halted, since fuel vapour is present in the system due to a high EVAP canister loading and idle instability will occur if the test is continued.

At a pre-determined vacuum the EVAP canister purge valve is closed, and the system is now considered "closed". From the gradient of the vacuum decay and the previously measured fuel vapour generation pressure rise, the presence of a leak can be inferred. The decay of the vacuum gradient also depends on the fuel level in the tank. The fuel level is roughly derived from the gradients of the vacuum build-up and vacuum decay and this information is also used when determining if a leak is present.

4.4.2 Monitoring Structure

Typical fuel tank pressure characteristic during the diagnostic test




Start
No
Enable conditions satisfied?
Yes
Shut EVAP Canister Purge Valve & wait for the system to stabilise
Close the EVAP Canister Vent Solenoid Valve
Measure fuel evaporation compensation gradient
Open the EVAP Canister Vent Solenoid Valve & start pumping
Abandon the test due to high EVAP canister loading
Yes
Lambda rich shift > threshold?
No
Shut the EVAP Canister Vent Solenoid Valve & check for a large leak
End
Pressure gradient < threshold?
Yes
Large leak present
MIL
No
Shut the EVAP Canister Purge Valve & check for a small leak
Fault processing
System OK
No
Pressure gradient < threshold?
Yes
Small leak present

Evaporative Emission System Monitoring – 0.040" (1.0mm) Diameter

Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Evaporative Emission Canister Purge Valve	P0443	Circuit continuity - short to battery positive	voltage - drive on	voltage > 1/ 2 * Battery positive	engine speed battery voltage	> 80 rpm 7.5V < Battery positive < 17V	immediately/ continuous	two driving cycles
	P0445	Circuit continuity - short to ground	voltage - drive off	voltage < 1/3 * Battery positive				
	P0444	circuit continuity - open circuit	voltage - drive off	1/3 * B+ < voltage < 2/3 * Battery positive				
	P0440	Functional check – valve open or Leaking	fuel tank pressure during pressure compensation measurement for the EVAP Purge system check	< - 1.464 hPa	see evaporative emission system purge check		up to 24.5 sec/once per driving cycle	two driving cycles
			fuel tank pressure at the end of the large system leak test	< - 15.62 hPa			up to 36.5 sec/once per driving cycle	
Evaporative Emission Purge System	P0455	vacuum check uses the EVAP canister vent solenoid valve & the fuel tank pressure sensor	large system leak (e.g. missing filler cap)	vacuum build up gradient < 0.305 hPa/sec	EVAP canister purge vapour factor fuel tank pressure lambda control engine state battery voltage vehicle speed altitude factor intake air temperature engine load fuel tank level	< 5.0 Ò 15.13 hPa active idle Ó11.0V Zero Ó0.73 Ó-12.0 °C Ò2.80 msec not empty	up to 36.5 sec/once per driving cycle	two driving cycles
	P0442		small system leak (Ó1mm)	vacuum decay grad. - (pressure comp. grad. * comp. factor) > Threshold			up to 41.5 sec/once per driving cycle	

Evaporative Emission System Monitoring – 0.040" (1.0mm) Diameter

Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
					engine air flow rate ECT at engine start time after engine start transfer gears	Ò40.0 kg/hr -12.0 °C < start temp. < 65.25 °C > 960 sec high range		
Evaporative Emission Canister Vent Solenoid Valve	P0449	circuit continuity - short to battery positive	voltage - drive on	voltage > 1/2 * Battery positive	engine speed battery voltage	> 80 rpm 7.5V < Battery positive < 17V	immediately/ continuous	two driving cycles
	P0448	circuit continuity - short to ground	voltage - drive off	voltage < 1/3 * Battery positive				
	P0447	circuit continuity - open circuit	voltage - drive off	1/3* Battery positive < voltage < 2/3* Battery positive				
	P0446	functional check for a blocked EVAP canister vent solenoid valve	fuel tank pressure too low during large system leak test	tank pressure < - 1.464 hPa	see evaporative emission purge system check		up to 36.5 sec/once per driving cycle	
			fuel tank pressure too low during stabilisation phase of EVAP system check	tank pressure < - 14.64 hPa			20 sec/ once per driving cycle	
Fuel Tank Pressure Sensor	P0452 P0453	fuel tank pressure signal high/low	fuel tank pressure (min) fuel tank pressure (max)	< -28.30 hPa > 29.52 hPa	transfer gears	high range	5.0 sec/ continuous	two driving cycles
	P0451	sensor functional check	filtered pressure reading	Ó 15.13 hPa	transfer gears engine state ECT at engine start	high range idle Ò 35.25 °C	5.0 sec/ once per driving cycle	two driving cycles

Evaporative Emission System Monitoring – 0.040" (1.0mm) Diameter								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
					time after start time for stabilisation	Ò 20.0 sec Ó 10.0 sec		

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

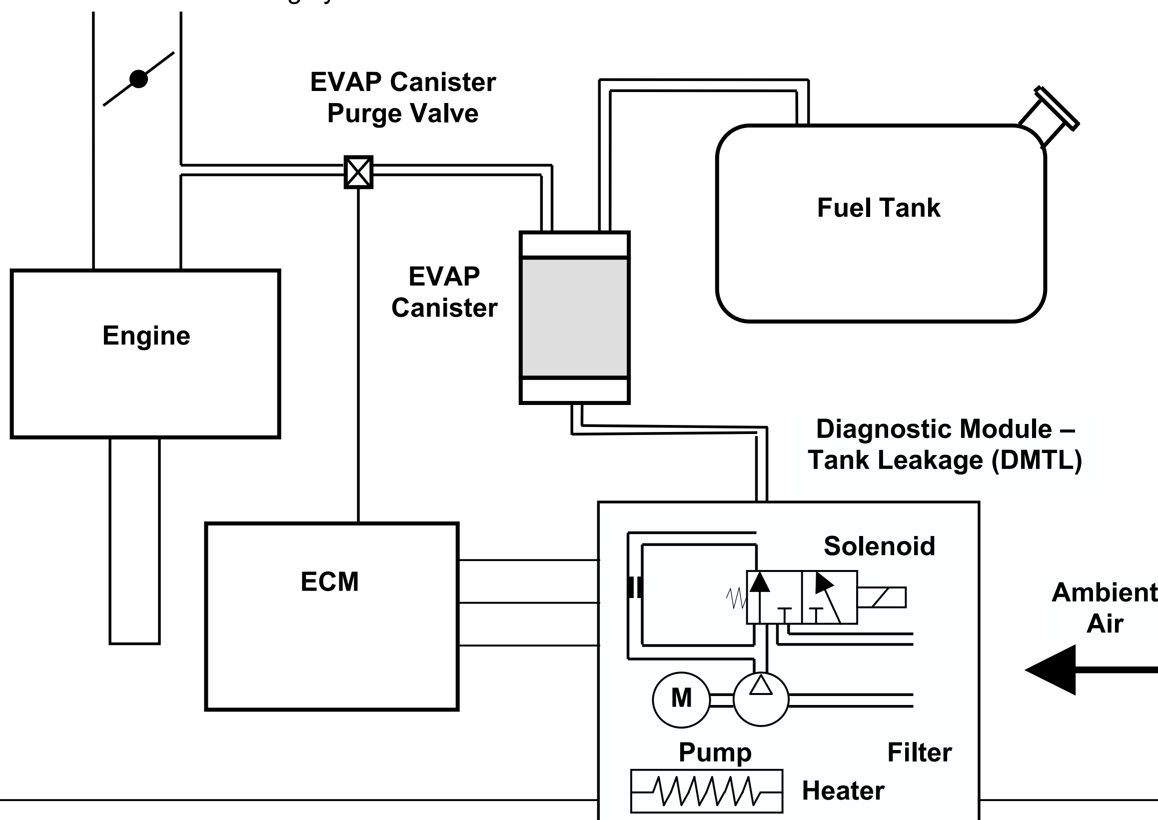
4.5 Evaporative Emission System Monitoring - 0.020” (0.5mm) Diameter

4.5.1 Description

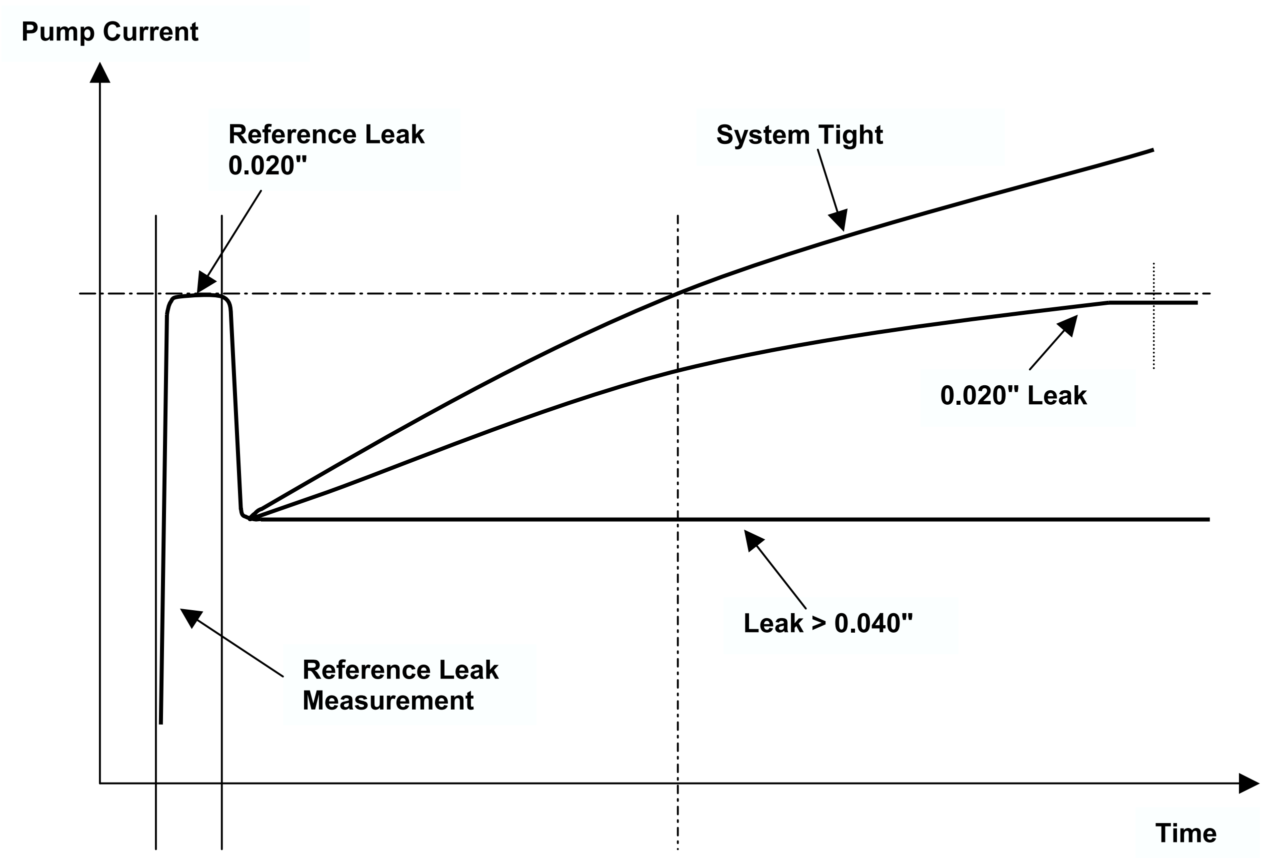
The evaporative emission monitoring system used for the Discovery 2001MY onwards permits the detection of leaks with a diameter of 0.020" or greater. This is achieved by means of a pressure test of the system. This is performed by the DMTL, which is an electrically operated pump fitted to the atmospheric air intake of the EVAP Canister. From the 2002MY this unit contains an electric heater to prevent condensate formation.

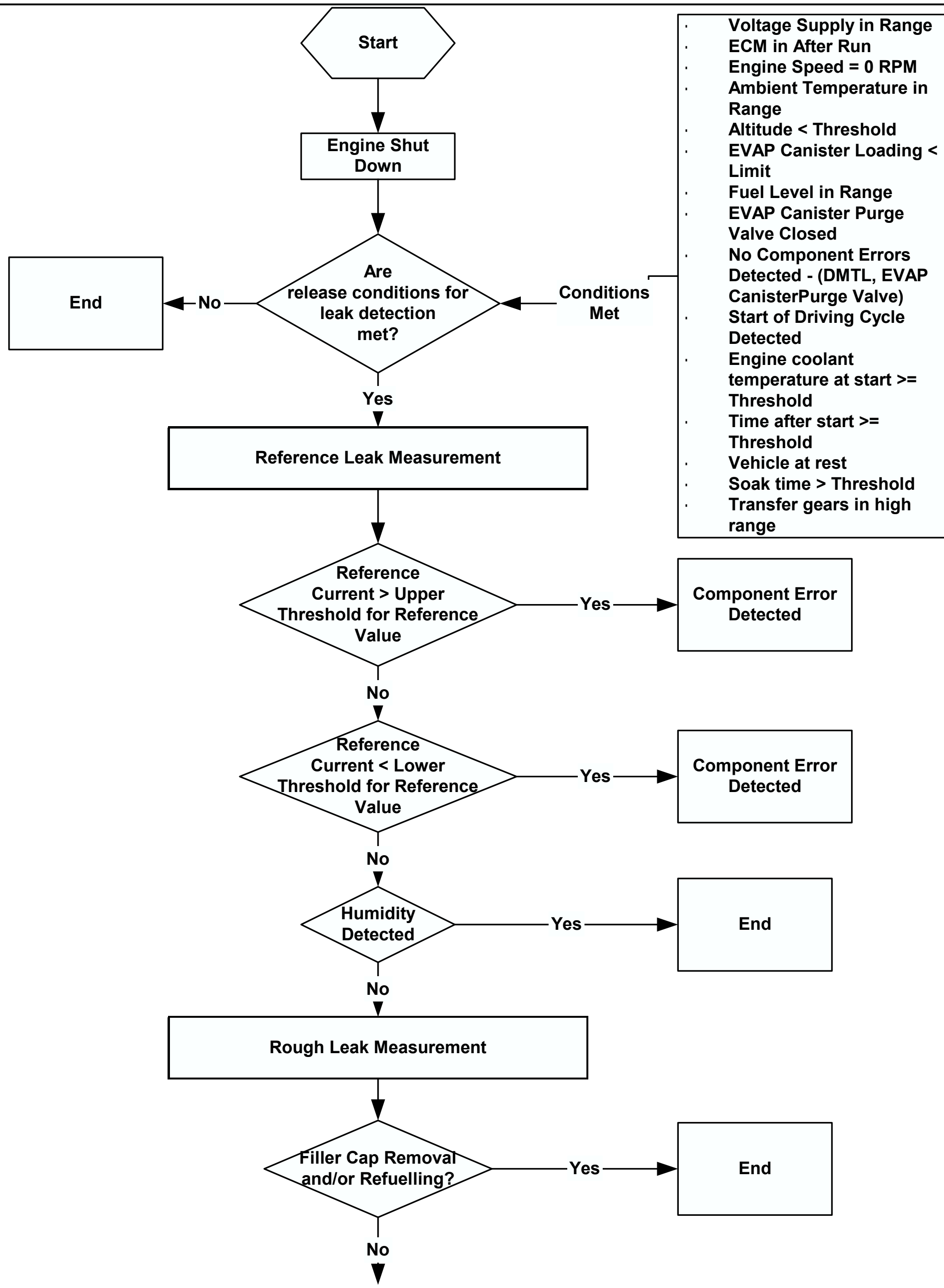
The test proceeds in 2 stages:-

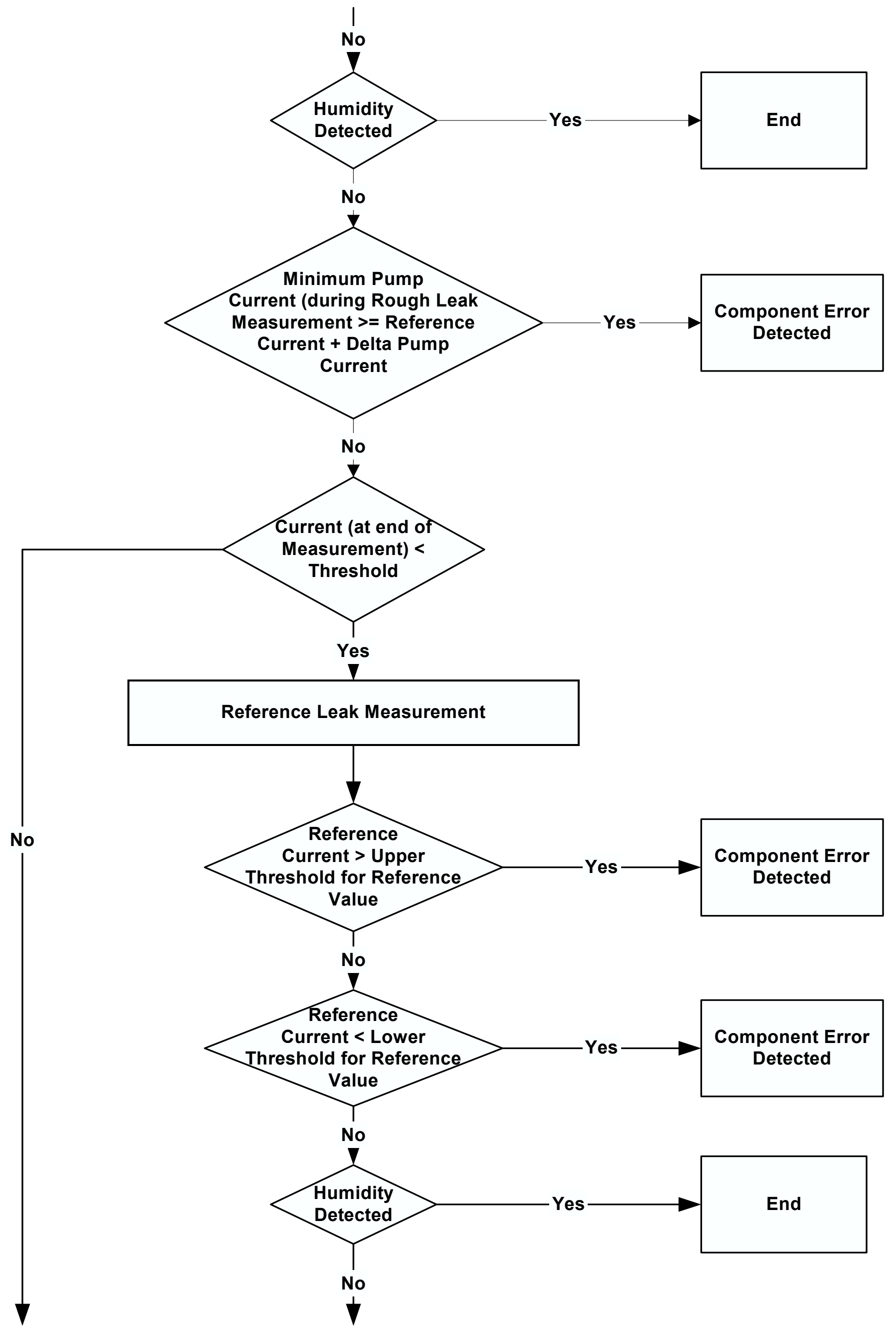
- Reference Leak Measurement - The pump operates against the reference restriction within the DMTL. The ECM measures the current consumption of the pump motor during this phase.
- Leak Measurement (see diagram below) - The solenoid in the DMTL is operated in order to shut off normal purge airflow into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

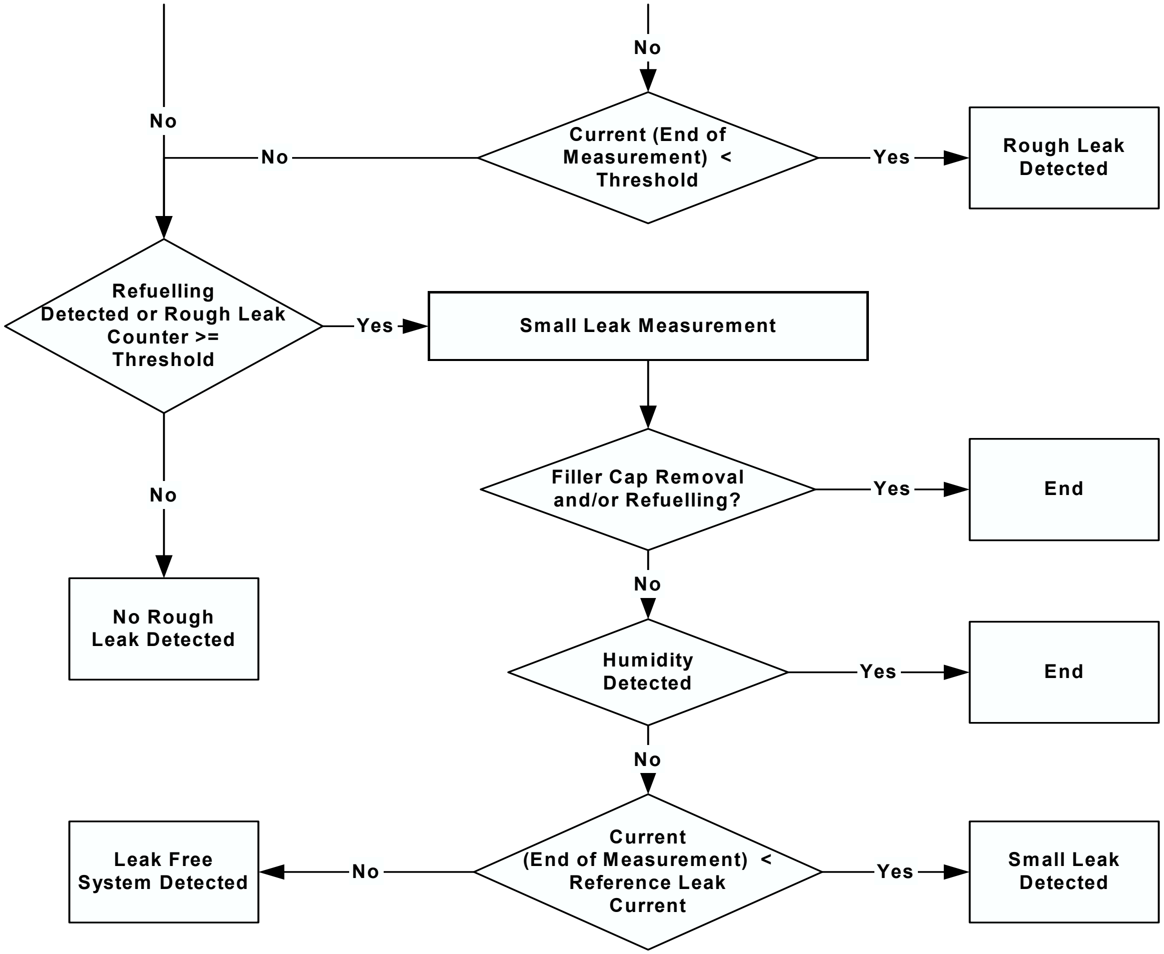


Typical Pump Current




Start
Engine Shut Down
Are release conditions for leak detection met?
No
End
Conditions Met
Voltage Supply in Range
ECM in After Run
Engine Speed = 0 RPM
Ambient Temperature in Range
Altitude < Threshold
EVAP Canister Loading < Limit
Fuel Level in Range
EVAP Canister Purge Valve Closed
No Component Errors Detected - (DMTL, EVAP CanisterPurge Valve)
Start of Driving Cycle Detected
Engine coolant temperature at start >= Threshold
Time after start >= Threshold
Vehicle at rest
Soak time > Threshold
Transfer gears in high range
Yes
Reference Leak Measurement
Reference Current > Upper Threshold for Reference Value
Yes
Component Error Detected
No
Reference Current < Lower Threshold for Reference Value
Yes
Component Error Detected
No
Humidity Detected
Yes
End
No
Rough Leak Measurement
Filler Cap Removal and/or Refuelling?
Yes
End
No


No
Humidity Detected
Yes
End
No
Minimum Pump Current (during Rough Leak Measurement >= Reference Current + Delta Pump Current
Yes
Component Error Detected
No
Current (at end of Measurement) < Threshold
Yes
Reference Leak Measurement
No
Reference Current > Upper Threshold for Reference Value
Yes
Component Error Detected
No
Reference Current < Lower Threshold for Reference Value
Yes
Component Error Detected
No
Humidity Detected
Yes
End
No


No
No
No
Current (End of Measurement) < Threshold
Yes
Rough Leak Detected
Refuelling Detected or Rough Leak Counter >= Threshold
Yes
Small Leak Measurement
No
Filler Cap Removal and/or Refuelling?
Yes
End
No Rough Leak Detected
No
Humidity Detected
Yes
End
No
Leak Free System Detected
No
Current (End of Measurement) < Reference Leak Current
Yes
Small Leak Detected

Evaporative Emission System Monitoring – 0.020" (0.5mm) Diameter								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Evaporative Emission Canister Purge Valve	P0443 P0445 P0444	circuit continuity - short to battery positive circuit continuity - short to ground circuit continuity - open circuit	voltage - drive on voltage - drive off voltage - drive off	voltage > 1/ 2 * Battery positive voltage < 1/3 * Battery positive 1/3 * Battery positive < voltage < 2/3 * Battery positive	engine speed battery voltage	> 80 rpm 7.5V < Battery positive < 17V	immediately/ continuous	two driving cycles
Evaporative Emission Canister Purge Valve	P0441	functional check - no purge flow detected. Open EVAP canister purge valve and check for feed-back shift, if shift is within a window, check for stoichiometric purge by monitoring idle speed control. If air flow has not changed due to the purge flow then a fault exists	feedback correction factor OR AND idle air flow change	Ò 1.125 > 0.875 Ò0.17 g/sec	engine state ECT at start altitude factor engine load engine air flow vehicle speed speed fluctuation (time after start) OR (time after start & mixture adapt. & purge factor & ISC diagnostic)	Idle Ó-12.0 °C Ó0.7266 Ò2.80 msec Ò12.5 g/sec 0 mph Ò80 rpm > 1000 sec > 590 sec complete Ò3.0 complete	15 sec/ once per driving cycle	two driving cycles
Leak Detection	P1451	circuit continuity - open circuit	voltage - drive off	1/3 * Battery positive < voltage < 2/3 * Battery positive	engine speed battery voltage	> 80 rpm 7.5V < Battery	0.5 sec/ continuous	two driving cycles

Evaporative Emission System Monitoring – 0.020" (0.5mm) Diameter

Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Pump Power Stage		circuit continuity - short to ground	voltage - drive off	voltage < 1/3 * Battery positive		positive <17V		
		circuit continuity - short to battery positive	voltage - drive on	> 3.998V	battery voltage	Ò15.47V (max for pump control)	0.07 sec/ continuous	
Leak Detection Pump Heater Circuit	P1483	circuit continuity - short to battery positive	voltage - drive on	voltage > 1/2 * Battery positive	engine speed battery voltage	> 80 rpm 7.5V < Battery positive< 17V	immediately/ continuous	No MIL illumination (leak detection defaults to enabled)
	P1482	circuit continuity - short to ground	voltage - drive off	voltage < 1/3 * Battery positive				
	P1481	circuit continuity - open circuit	voltage - drive off	1/3 * Battery positive < voltage < 2/3 * Battery positive				
EVAP Canister Purge System (Discovery only)		over-pressure system using an ECM driven Pump			ECM state engine state altitude factor ECT at engine start ambient temp. (calculated) EVAP canister purge vapour factor time after start vehicle speed battery voltage	In After Run for > 3.0 sec At Rest Ó0.7266 Ó2.25 °C 0.0 °C < Amb Temp < 40.0 °C < 3.0 Ó1200 sec 0 mph 10.94V < Battery positive <14.52V (for 3.0 sec)		four driving cycles
	P1452	Pump hardware Fault	pump ref. current	< 15.002 mA				
	P1453	Pump hardware Fault	pump ref. current	> 40.002 mA				
	P1450	Pump hardware Fault	pump current (during rough leak)	Ó ref current - 2.002 mA				

Evaporative Emission System Monitoring – 0.020" (0.5mm) Diameter								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
					fuel level in window transfer gears	15 % < fuel level < 85 % high range		
	P0455	rough leak Measurement	pump current at end of test stage 1 stage 2	< idle current + K1(ref. current - idle current) < ref. current + K2(ref current - idle current) K1 = 0.26 +/- 0.09 K2 = 0.52 +/- 0.13	soak time no gas cap removal (during test) no re-fuelling (during test)	Ó9000 sec change of pump current< -0.598 mA change of pump current > 0.598 mA	160 sec/ once per driving cycle	
	P0442	small leak Measurement	pump current	Òreference Current OR	re-fuelling (prior to test) rough leak counter no gas cap removal (during test) no re-fuelling (during test)	detected Ó14 change of pump current < -0.598 mA change of pump current > 0.598 mA	rough leak + 375 sec/ once per driving cycle	

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

4.6 Fuel System Monitoring

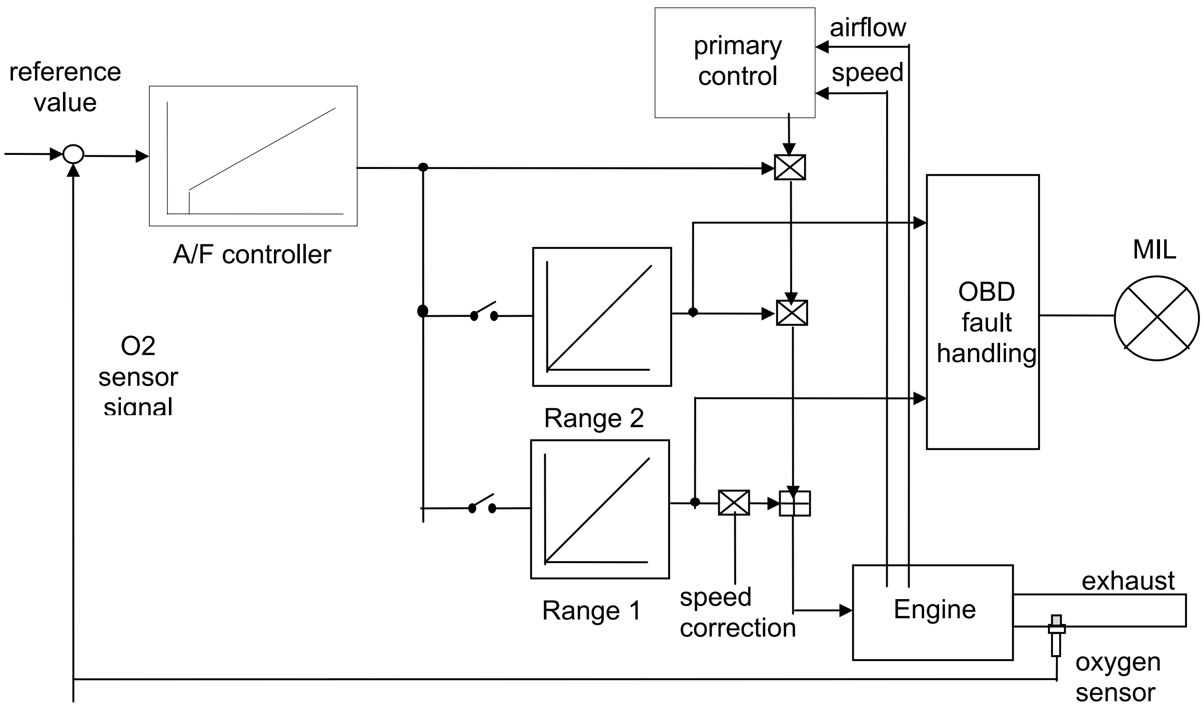
4.6.1 Description

Primary Mixture Control

The air mass taken in by the engine and the engine speed are measured. These signals are used to calculate an injection signal. This primary mixture control follows fast load and speed changes.

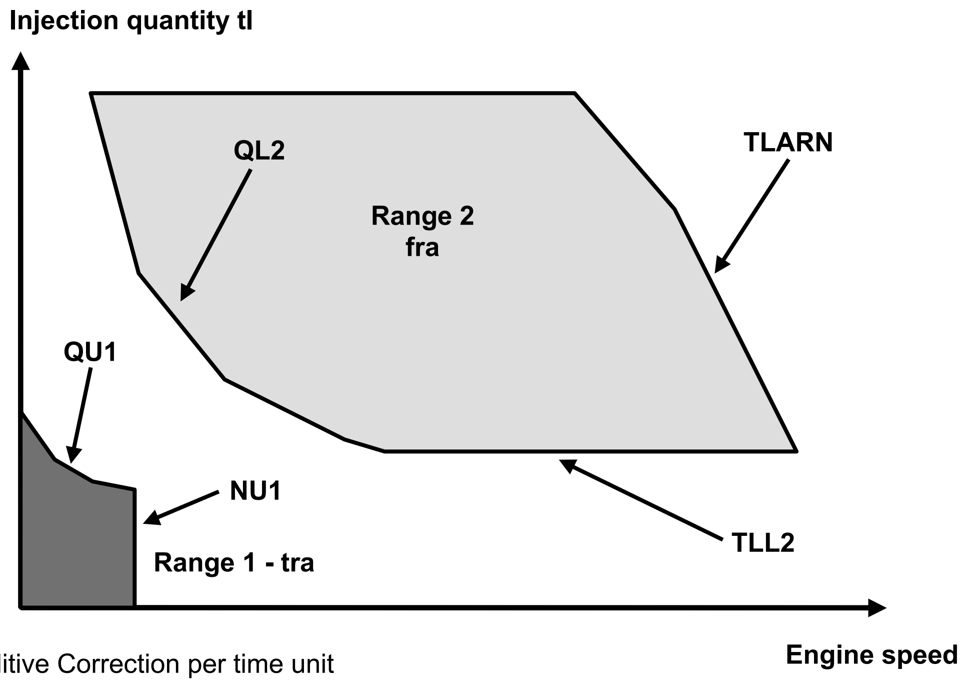
Lambda-control

The ECM compares the oxygen sensor signal upstream of the catalyst with a reference value and calculates a correction factor for the primary control.



Adaptive Control

Drifts and faults in the sensors and actuators of the fuel delivery system, as well as un-metered air leakage into the intake system influence the primary control. This causes deviations in the air to fuel ratio. The adaptive control determines the controller correction in two different ranges.



Range 1 - Additive Correction per time unit
Range 2 - Multiplicative Correction

Lambda deviations in range 1 are compensated by an additive correction value multiplied by an engine speed term. By this means an additive correction per time unit is derived.

Lambda deviations in range 2 are compensated by a multiplicative factor.

Each value is determined only within its corresponding range. But each adaptive value corrects the primary control within the whole load and speed range of the engine. After the next start, the stored adaptive values are included in the calculation of the primary fuel control; just before closed-loop fuelling control is activated.

Abbreviations for the Fuel Delivery System:

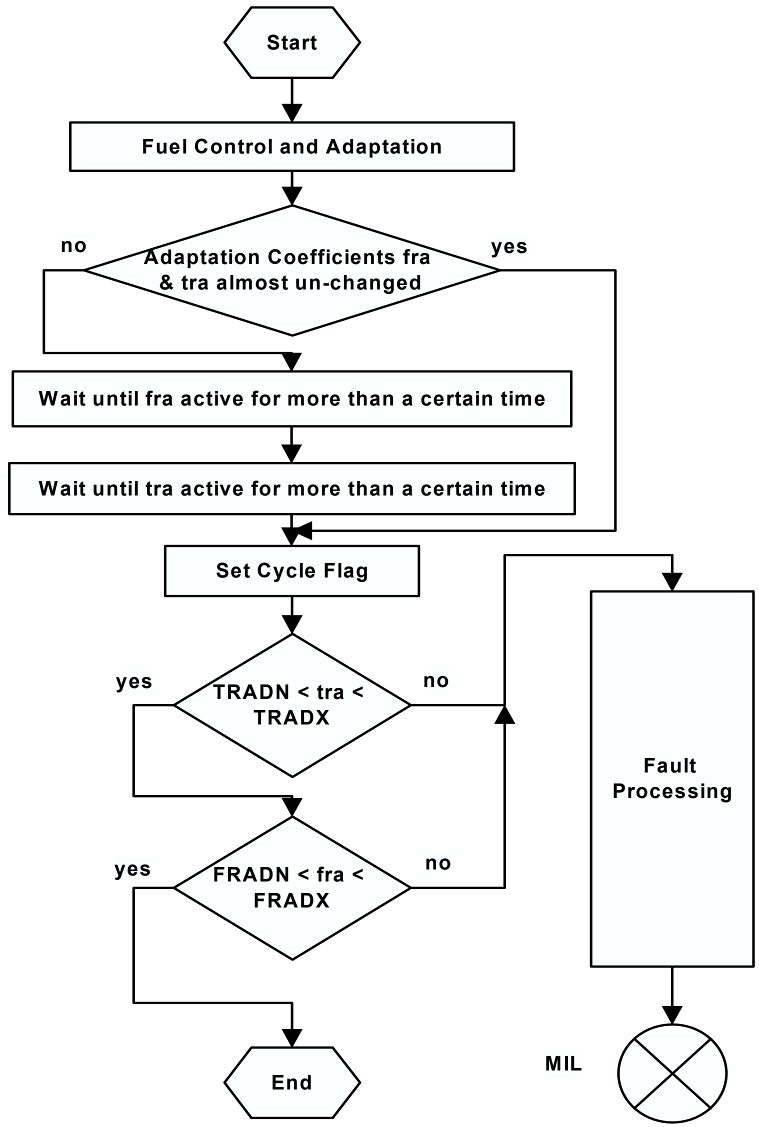
QU1 upper airflow threshold range 1
NU1 upper engine speed threshold range 1

tra	additive learning correction coefficient per time unit (range 1)
TRADN	lower diagnosis threshold of tra
TRADX	upper diagnosis threshold of tra
TLARN	upper engine load threshold f(n), range 2
QL2	lower airflow threshold range 2
TLL2	lower engine load threshold range 2
fra	multiplicative learning correction coefficient (range 2)
FRADN	lower diagnosis threshold of fra
FRADX	upper diagnosis threshold of fra

Diagnosis of Fuel Delivery System

Faults in the fuel delivery system can occur which cannot be compensated for by the adaptive control. In this case the adaptive values leave a predetermined range. If the adaptive value is outside this predetermined range, and then if the condition is again present on a subsequent drive cycle, the MIL is illuminated and the appropriate diagnostic trouble codes are stored.

4.6.2 Monitoring Structure



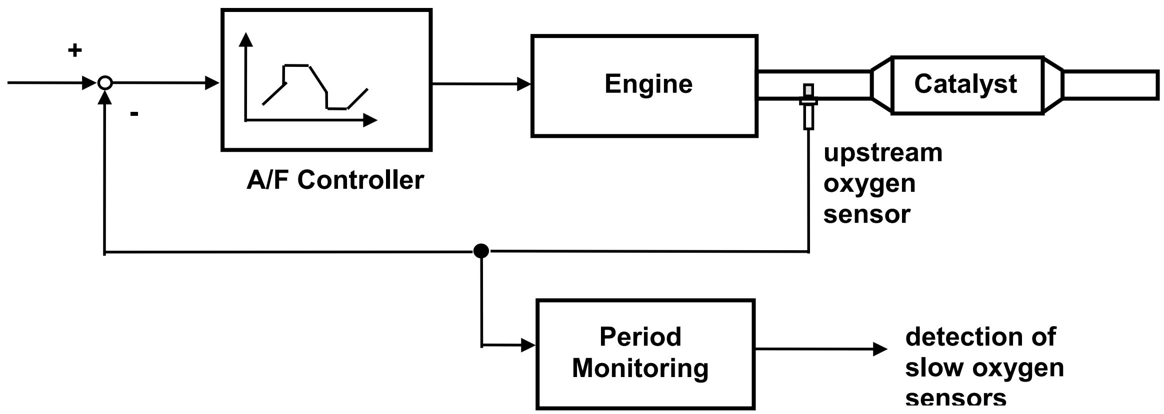
Fuel System Monitoring								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Fuel System		fuel trim limits exceeded			fuel system status ECT IAT transfer gears purge diagnosis	closed loop+part load > 80.25 °C Ò 69.75 °C high range not active		two driving cycles
	P0171/2 P0174/5	bank 1 lean/rich bank 2 lean/rich	fra value (multiplicative correction) outside limit	> ± 22.7 %	engine speed engine load engine airflow rate	< 3800 rpm 2.0 < TL ms < 10.0 > 16.67 g/sec	10.0 sec	
	P1171/2 P1174/5	bank 1 lean/rich bank 2 lean/rich	tra value (additive correction) outside limit	> ± 0.452 ms /engine rev	engine speed engine airflow rate	< 960 rpm < 8.33 g/sec	8.0 sec	

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

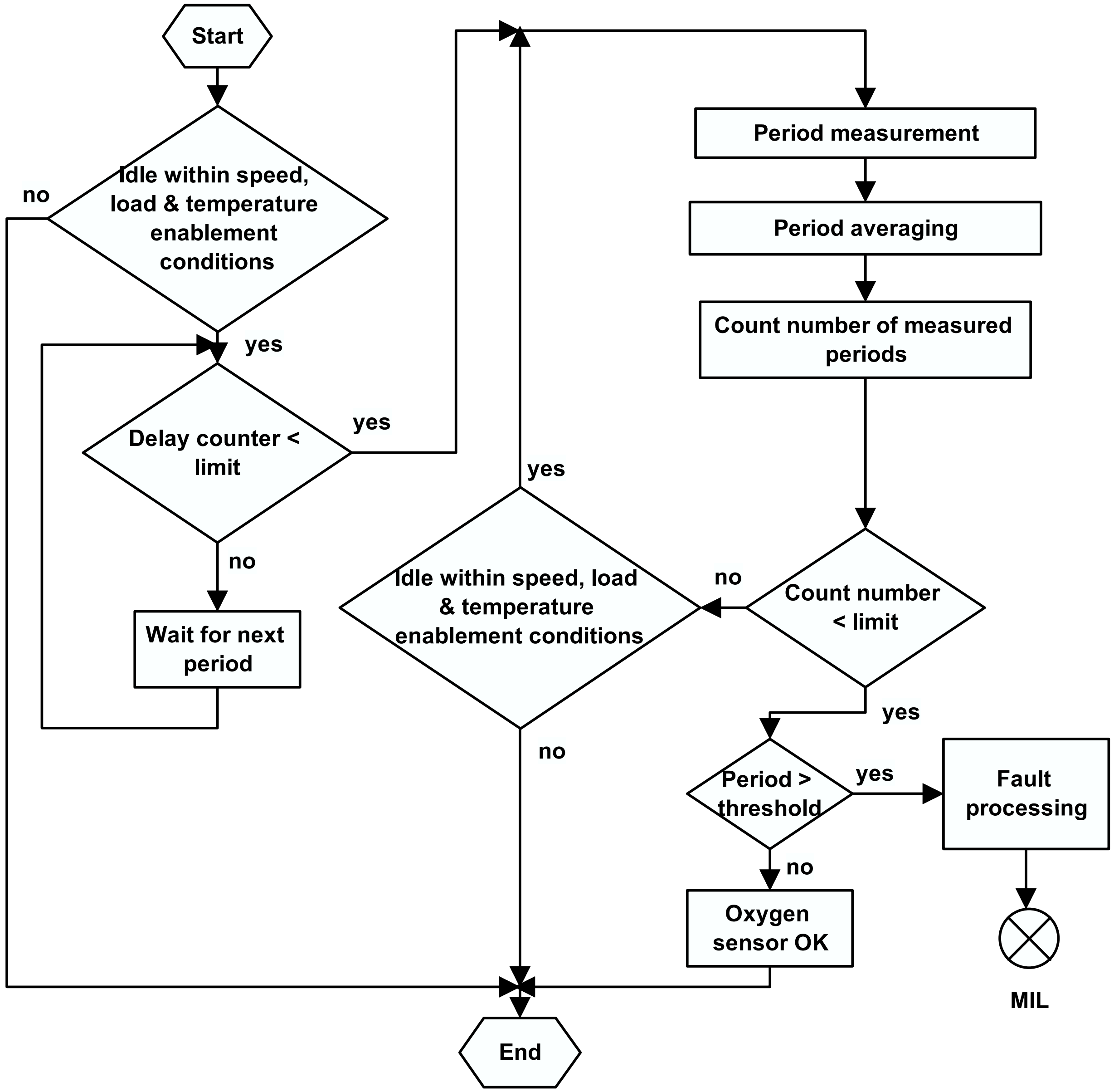
4.7 Oxygen Sensor Monitoring

4.7.1 Description

The response rates of the upstream O2 sensors are monitored by measuring the period of the Lambda control oscillations. This period monitoring allows the detection of a slow O2 sensor.



4.7.2 Monitoring Structure



4.7.3 Oxygen Sensor Heater Monitoring Description

For proper functioning of an oxygen sensor, its element must be heated. A non-functioning heater delays the oxygen sensor's readiness for closed loop control and influences emissions.

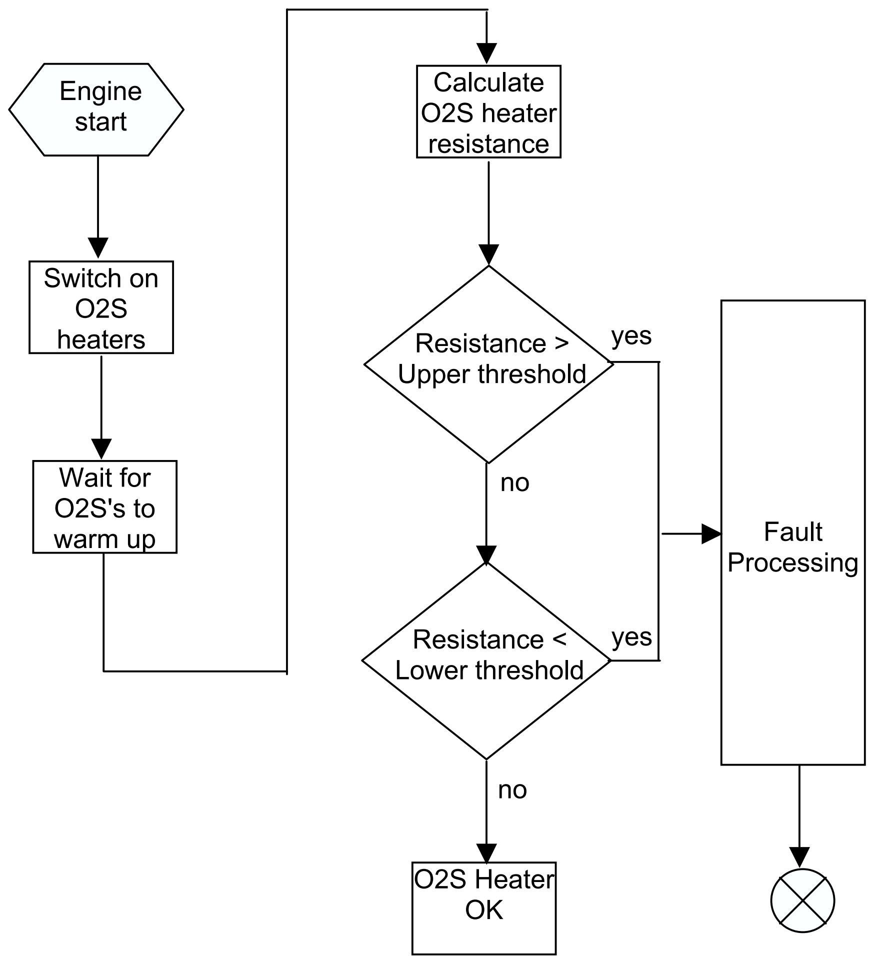
The monitoring function measures both oxygen sensor heater current (voltage drop over a shunt) and the heater voltage (heater supply voltage), so that the oxygen sensor heater resistance can be calculated. If the oxygen sensor heater resistance is exceeds a minimum or maximum threshold an oxygen sensor heater fault is detected.

The monitoring function is activated once per drive cycle, as long as the heater has been switched on for a certain time period and the current has stabilized.

Characteristics:-

- ECM controlled switching of the oxygen sensor heater.
- One shunt for each pair of oxygen sensors upstream and downstream of the catalysts for current measurement.

4.7.4 Oxygen Sensor Heater Monitoring Structure



The oxygen sensor heater resistance is calculated from the following equation:-

$$\text{Resistance}_{\text{sensor heater}} = \frac{\text{Voltage}_{\text{battery}}}{\text{Voltage}_{\text{shunt}}} \Delta \, \text{Resistance}_{\text{shunt}}$$

Oxygen Sensor Circuit Monitoring

Monitoring for electrical faults in the oxygen sensors both upstream and downstream of the catalyst.

Implausible voltages:

- Analogue to Digital Converter (ADC) voltages exceeding the maximum threshold VMAX are caused by a short circuit to battery positive.
- ADC voltages falling below the minimum threshold VMIN are caused by a short circuit of the oxygen sensor signal or oxygen sensor ground to the ECM ground.
- An open circuit of the oxygen sensor can be detected if the ADC voltage remains within a specified range after the oxygen sensor has been heated for a certain time.

Oxygen Sensor Monitoring – Discovery Series II

Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold Value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Oxygen Sensor (front)	P0133/53	response rate	oxygen sensor signal period (over 50 periods)	> 2.2 sec	engine speed engine load catalyst temperature (model) IAT EVAP canister purge status transfer gears	1400< rpm <2600 2.0< TL msec <5.0 > 340 °C Ò 65.25 °C Off or on > 20 sec high range	immediately/ once per driving cycle	two driving cycles
	P1170/73	sensor ageing	rich shift delay Time	< -1.0 or > 1.0 sec	O2S post catalyst control transfer gears	active high range	30 sec	
	P1129	exchanged oxygen sensors connector	fuel control factor **or**	bank 1 > 1.22 and bank 2 < 0.77 bank 1 < 0.77 and bank 2 > 1.22			8.0 sec	
					heater on transfer gears	> 90 sec high range		
	P0134/54	O2S circuit continuity	voltage **or** voltage (front & rear)	0.399V < voltage <0.598V voltage > 0.199V	over run fuel cut off	> 3.0 sec	15 sec/continuous 0.1 sec/continuous	
	P0132/52	range check (high)	voltage	voltage > 1.081V			5.1 sec/continuous	
	P0130/50	O2S short circuit	voltage	voltage < 0.0399V	O2S post catalyst voltage	Ó 0.501V	20 sec/continuous	
				Or	ECT battery voltage time after start ECT at power down	< 39.75 °C > 8.016V > 1.0 sec > 60 °C	0.1 sec/continuous	
				0.062V Ò voltage < 0.399V	O2S post catalyst voltage	Ó 0.501V	20 sec/continuous	

Oxygen Sensor Monitoring – Discovery Series II

Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold Value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
				0.598V Ò voltage Ò 1.081V	O2S post catalyst voltage	< 0.102V	10 sec/continuous	
Heater	P0135/55	O2S heater current circuit continuity	calculated resistance voltage	resistance < 2.453 Ý **or** resistance > 10.06 Ý	after engine start up transfer gears	> 180 sec high range	10 sec/continuous	
Oxygen Sensor (rear)					O2S heater on transfer gears	> 90 sec high range		two driving cycles
	P0140/60	O2S circuit continuity	voltage	0.399V < voltage < 0.501V			500 sec/ continuous	
	P0138/58	range check (high)	voltage	voltage > 1.081V			5.1 sec/continuous	
	P0137/57	range check (low)	voltage	voltage < 0.501V	engine air flow O2S post catalyst control	> 16.67 g/sec Active	210 sec/ continuous	
	P0136/56	O2S short circuit	voltage	voltage < 0.0399	O2S post catalyst control	Active	200 sec/ continuous	
	P0139/59	oscillation capability check			O2S post catalyst control catalyst temperature (model) engine air flow rear O2S ready for at least rear O2S heater test rear O2S rich & lean flags not set	Active > 300 °C > 13.89 g/sec 30.0 sec completed successfully > 120 sec		
			if rear O2S voltage not Ó 0.625V for	enrichment request still present after 25 sec	catalyst temperature (model)	> 300 °C	2.0 sec/continuous	

Oxygen Sensor Monitoring – Discovery Series II

Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold Value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
			0.52 se c request enrichment					
			if rear O2S voltage not Ò 0.625 V for 0.52 sec wait for over run fuel cut off (ORFCO)	rear O2S voltage > 0.200V	fuel system status integrated engine air flow whilst in ORFCO front O2S check	in over run fuel cut off (ORFCO) for > 4.0 sec > 35.0 g completed successfully	0.20 sec/ continuous	
Heater	P0141/61	O2S heater current circuit continuity	calculated resistance voltage	resistance < 2.453 Ý **<u>or</u>** resistance > 10.06 Ý	after engine start up transfer gears	> 180 sec high range	10 sec/continuous	

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

Oxygen Sensor Monitoring – Range Rover

Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold Value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Oxygen Sensor (front)	P0133/53	response rate	O2S signal period (over 30 periods)	> 2.2 sec	engine speed engine load catalyst temperature (model) intake air temperature EVAP canister purge status	1400 < rpm < 2600 2.0 < TL msec < 5.0 > 340 °C Ò 69.75 °C off <u>or</u> on > 20 sec	Immediately/ once per driving cycle	two driving cycles

Oxygen Sensor Monitoring – Range Rover

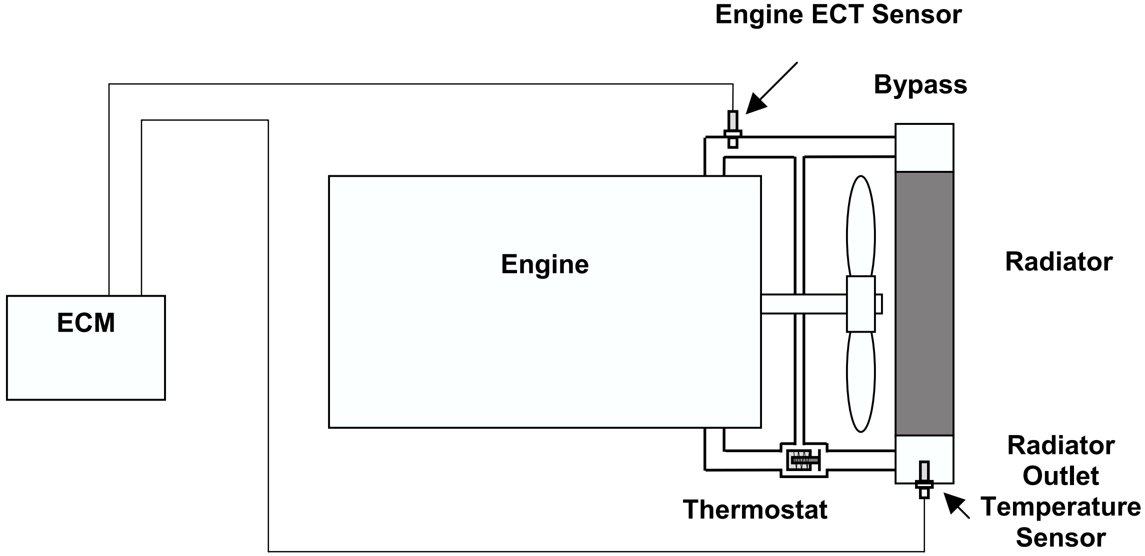
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold Value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
					transfer gears	high range		
	P1170/73	O2S ageing	rich shift delay time	< -1.0 or > 1.0 sec	O2S post catalyst control transfer gears	active high range	30 sec	
	P1129	exchanged O2S connectors	fuel control factor **or**	bank 1 > 1.22 and bank 2 < 0.77 bank 1 < 0.77 and bank 2 > 1.22	O2S heater on transfer gears	> 120 sec high range	8.0 sec	
	P0134/54	O2S circuit continuity	voltage **or** voltage (front & rear)	0.399V< voltage < 0.598V voltage > 0.199V	over run fuel cut off	> 3.0 sec	15 sec/continuous 0.1 sec/continuous	
	P0132/52	range check (high)	voltage	voltage > 1.081V			5.1 sec/continuous	
	P0130/50	O2S short circuit	voltage	voltage < 0.0399	O2S post catalyst voltage	>= 0.501V	20 sec/continuous	
				Or	ECT battery voltage time after start ECT at power down	< 39.75 °C > 8.016V > 1.0 sec > 80.25 °C	0.1 sec/continuous	
				0.062V Ò voltage< 0.399V	O2S post catalyst voltage	Ó 0.501V	20 sec/continuous	
				0.598VÒ voltage Ò 1.081V	O2S post catalyst voltage	< 0.102V	10 sec/continuous	
Oxygen Sensor (front) Heater	P0135/55	O2S heater current circuit continuity	calculated resistance voltage	resistance < 2.453 Ý **or** resistance > 10.06 Ý	after engine start up transfer gears	> 185 sec high range	10 sec/continuous	two driving cycles
Oxygen Sensor (rear)	P0140/60	O2S circuit continuity	voltage	0.399V < voltage< 0.501V			500 sec/ continuous	two driving cycles
	P0138/58	range check (high)	voltage	voltage > 1.081V			5.1 sec/continuous	
	P0137/57	range check (low)	voltage	voltage < 0.501V	engine air flow post-cat control	> 60 kg/hr Active	210 sec/ continuous	
	P0136/56	O2S short circuit	voltage	voltage < 0.0399	post-cat control	Active	100 sec/ continuous	

Oxygen Sensor Monitoring – Range Rover								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold Value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
	P0139/59	oscillation capability check			O2S post catalyst control catalyst temperature (model) engine air flow rear O2S ready for at least rear O2S heater test rear O2S rich & lean flags not set	Active > 300 °C > 50 kg/h 30.0 sec completed successfully > 120 sec		
			if rear O2S voltage not Ó 0.625v for 0.52 sec request enrichment	enrichment request still present after 25 sec	catalyst temperature (model)	> 300 °C	2.0 sec/continuous	
			if rear O2S voltage not Ò 0.625v for 0.52 Sec wait for ORFCO	rear O2S voltage > 0.20V	fuel system status integrated engine air flow whilst in ORFCO front O2S check	in ORFCO for>4.0sec > 35.0 grams completed successfully	0.20 sec/ continuous	
Oxygen Sensor (rear) Heater	P0141/61	O2S heater current circuit continuity	calculated resistance voltage	resistance < 2.453 Ý **<u>or</u>** resistance > 10.06 Ý	after engine start up transfer gears	> 185 sec high range	10.0 sec/ continuous	two driving cycles

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

4.8 Thermostat Monitoring

4.8.1 Description



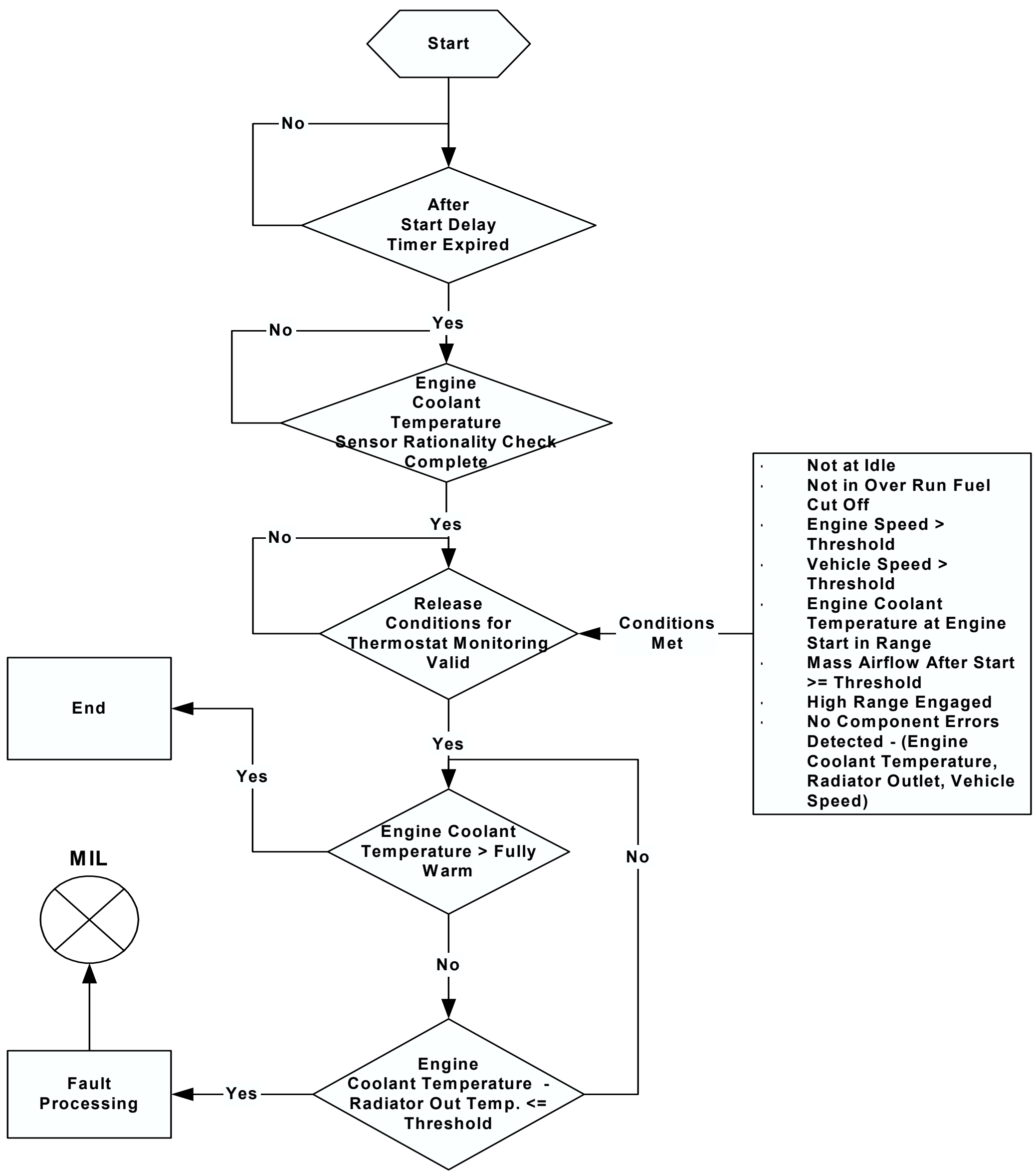
The diagnostic checks for a partially open thermostat, under conditions when the thermostat would be expected to be shut.

A second ECT sensor is installed in the outlet from the radiator. If the enablement criteria are met and the ECT is less than the normal thermostat opening temperature the diagnostic will run.

The diagnostic compares the difference between ECT and the radiator outlet temperature. This gives the temperature drop across the radiator.

If the temperature drop is less than a threshold, and there is flow across the radiator, this is caused by leakage through the thermostat.

4.8.2 Monitoring Structure



Thermostat Monitoring								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold Value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Thermostat stuck open	P0126	engine not fully warm and temperature drop across the radiator less than a threshold	engine coolant temperature - radiator outlet temperature (TKA)	Ò 45°C @ -10 °C TKA Ò 40 °C @ 0 °C TKA Ò 45 °C @ 10 °C TKA Ò 30 °C @ 20 °C TKA Ò 30 °C @ 30 °C TKA Ò 25 °C @ 40 °C TKA Ò 25 °C @ 50 °C TKA Ò 25 °C @ 60 °C TKA	ECT sensor plausibility test ECT time after Start engine Speed vehicle Speed ORFCO engine State airflow after start ECT at start transfer Gears	complete < 81.75 °C > from 220 sec @ 40 °C TKA to 270 sec @ -10 °C TKA > 400 rpm > 15.54 mph not True not Idle Ó from 3.0 kg @ 40 °C TKA to 10.0 kg @ -10 °C TKA -9.75 °C Ò start temperature Ò 81.75°C high Range	1.0 sec/ continuous	two driving cycles
Radiator Outlet Temperature Sensor	P1118	circuit continuity range check (max)	voltage resistance	> 140.25 °C			1.0 sec/ continuous	two driving cycles
	P1117	range check (min)		< -33.0 °C	intake air temperature	> -32.25 °C		
Engine Coolant Temperature Sensor High Sided Rationality Check Range Rover Only	P0116	checks for higher than expected engine temperature. Potential fault determined by the Power	<u>power up check</u> engine coolant temperature at start	> ECT at stop - (50.25 x Factor) intake air temp at start | factor -30 °C | 0.9961 -15 °C | 0.9727 0 °C | 0.9492	radiator outlet temperature at start absolute value of (radiator outlet temperature at start - intake air temperature at start) time after start	< 39.75 °C < 9.75 °C < 2.0 s	7.54 sec/ continuous	two driving cycles

Thermostat Monitoring									
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold Value		Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
		up check at engine start and confirmed by driving check		10 °C 15 °C 20 °C 25 °C 30 °C 35 °C 45 °C 55 °C 65 °C	0.9180 0.8984 0.8789 0.8477 0.8203 0.8516 0.7617 0.6758 0.3008	radiator outlet temperature at stop ECT at stop transfer gears	> -9.75 °C > 66.75 °C high range		
			driving check engine coolant temperature	> 102.0 °C		engine load engine speed calculated ECT vehicle speed time after start intake air temperature radiator outlet temperature transfer gears	2.0 < TL msec < 4.0 1200 < rpm < 2120 0́60.0 °C 0́40 km/h > 290 sec 0̀60 °C 0̀55.5 °C high range		

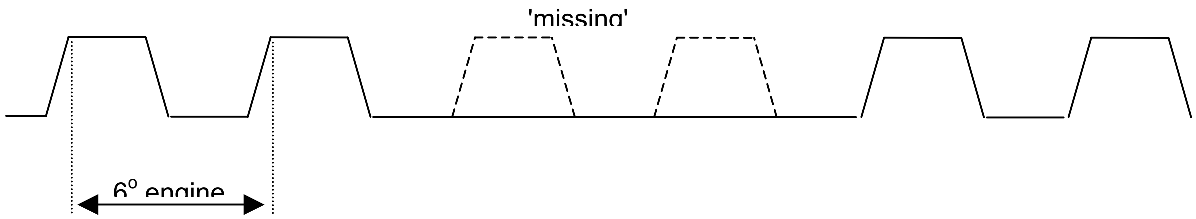
If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.

4.9 Engine Speed and Position Sensor (Crankshaft Sensor)

4.9.1 Description

This sensor is the most important sensor on the vehicle, without it the engine cannot run. There is no backup strategy or limp home facility should it fail. The sensor produces the signal which enables the ECM to determine the angle of the crankshaft, and the engine rpm. From this, the point of ignition, fuel injection, etc. is calculated. If the signal wires are reversed a 3° advance in timing will occur, as the electronics within the ECM uses the falling edge of the signal waveform as its reference/timing point for each tooth.

The reluctor is machined and has a tooth pattern based on 60 teeth at 6° intervals and 3° wide: two of the teeth are removed to provide a hardware reference mark which is 60 degrees before top dead centre No. 1 cylinder.



The sensor operates by generating an output voltage caused by the change in magnetic field, which occurs as the teeth pass in front of the sensor. The output voltage varies with the speed of the teeth passing the sensor; the higher the engine speed, the higher the output voltage. Note that the output is also dependent on the air gap between the sensor and the teeth (the larger the gap, the weaker the signal, the lower the output voltage).

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

1. The hardware reference mark created by the missing teeth is outside the search window and the engine speed is greater than 500 rpm.
2. The hardware reference mark is outside the search window by more than one tooth and the engine speed is greater than 500 rpm.

The ECM transmits the engine speed to the automatic TCM using CAN, while all other control modules are hardwired.

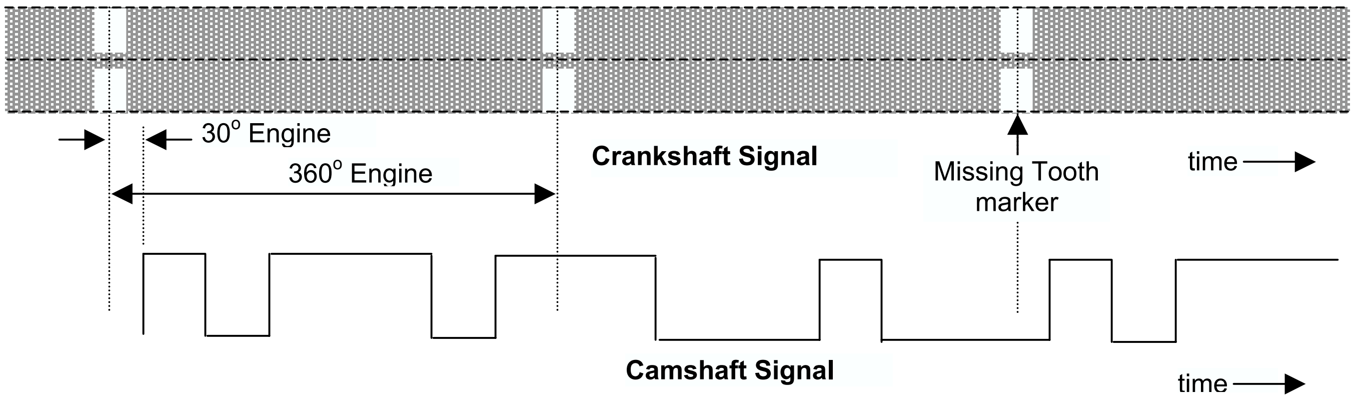
Engine Speed and Position Sensor								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Engine Speed and Position Sensor	P0335	rationality check	reference mark outside search window	> 2 occurrences	engine speed	> 500 rpm	2 revolutions/continuous	two driving cycles
	P0336		counted teeth – actual number of teeth	+ 1 tooth			1 revolution/continuous	

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

4.10 Camshaft Position Sensor

4.10.1 Description

This is a Hall effect sensor producing four pulses for every two engine revolutions. The sensing element is positioned between 0 and 2mm from the side of the cam gear wheel. The sensor is, in effect, a magnetically operated electrical switch, switching a battery supply level voltage on or off dependent on the position of the cam gear wheel with respect to the sensor.



The cam gear wheel has four slots machined in it enabling cylinder identification every 90°. The signal is used for cylinder recognition; enabling sequential fuel injection, knock control and cylinder identification for diagnostic purposes.

The system checks the camshaft position sensor signal at every software reference mark i.e., 54° before top dead centre (2 teeth after the reluctor 2nd missing tooth). A fault condition is recognised if the signal does not change state (high to low or low to high voltage) every crankshaft revolution.

Camshaft Position Sensor								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Camshaft Position Sensor	P0340	rationality check	signal sequence	incorrect signal	crankshaft revolutions	> 100 revolutions	0.500 sec/ continuous	two driving cycles

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

4.11 Engine Coolant Temperature Sensor

4.11.1 Description

This sensor is a temperature dependant resistor (thermistor), which is a Negative Temperature Co-efficient (NTC) type, i.e. resistance decreases with increasing temperature. The sensor forms part of a voltage divider chain with a pull up resistor within the ECM. The change in resistance relates to change in the ECT.

The sensor is vital to the correct running of the engine as a richer mixture is required at lower block temperatures for good quality starts and smooth running, leaning off as the temperature rises to maintain emissions and performance. Should the sensor fail there is a software ECT warm-up model which will supply a changing default value during the warm up stage of the engine, based upon IAT. After the software model reaches 60^{o}C ECT, a fixed default value of 85^{o}C is used. The model also forms part of the diagnostics for the ECT sensor, in conjunction with open and short circuit tests.

A fault condition is recognised if the ECM is powered up and the ECT sensor resistance exceeds a minimum or maximum threshold, or the difference between the ECT model and the temperature indicated by the ECT sensor is greater than a threshold.

Engine Coolant Temperature Sensor								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold Value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Engine Coolant Temperature Sensor		circuit continuity	voltage				0.180 sec/ continuous	two driving cycles
	P0117	range check (min)	resistance	> 34.166 kÝ (-35.25°C)				
	P0118	range check (max)		< 70.96Ý (139.5°C)				
	P0116	rationality check (temperature model = ƒ [IAT, air mass, time])	difference to model temperature	> -20.25°C			2.54 sec/ continuous	

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

4.12 Mass Airflow Sensor and Intake Air Temperature Sensor

The MAF sensor is a combined MAF sensor and IAT sensor.

4.12.1 Mass Airflow Sensor

4.12.2 Description

Airflow is determined by the cooling effect of the intake air passing over a “hot film” element contained within the device. The higher the air flow the greater the cooling effect and the lower the electrical resistance of the “hot film” element. The signal from the device is then used by the ECM to calculate the MAF into the engine.

The measured airflow is used in determining the fuel quantity to be injected in order to maintain the stoichiometric air fuel ratio required for correct operation of the engine and exhaust catalysts. Should the device fail there is a software backup strategy that will be evoked once a fault has been diagnosed. A fault is detected if the MAF signal exceeds the maximum or minimum threshold for a given speed range or the difference between the calculated load and the actual MAF signal is too great.

Mass Airflow Sensor								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Mass Airflow Sensor	P0102	range check (min)	air flow verses engine Speed	<2.43 g/sec(@ 800 rpm) To 8.96 g/sec(@ 5000 rpm)	engine speed	> 400 rpm > 200 rpm (for > 0.3 sec)	0.5 sec/ continuous	two driving cycles
	P0103	range check (max)	4.0 litre 4.6 litre	>40.0g/sec to 224.5g/sec > 46.7g/sec to 248.9g/sec (1000 RPM to 5400 rpm)		> 200 rpm (for > 0.3 sec)	0.3 sec/ continuous	
	P0101	rationality check (low/high)	comparison of calculated load (engine speed and throttle position) to actual MAF signal	adaptation factor (af) 1.5 < af < 0.35	engine speed engine load ECT	800< rpm< 4000 2<TL msec<6.5 > -9.75° C	immediately/ continuous	

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

4.12.3 Intake Air Temperature Sensor

4.12.4 Description

The IAT sensor is a temperature dependent resistor (thermistor), i.e. the resistance of the sensor varies with temperature. The thermistor is an NTC type element, which means that the sensor resistance decreases as the sensor temperature increases. The sensor forms part of a voltage divider chain with an additional resistor in the ECM. The voltage from this network changes as the sensor resistance changes, relating the IAT to the voltage measured by the ECM.

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

Intake Air Temperature Sensor								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Intake Air Temperature Sensor	P0113	circuit continuity range check (max)	voltage resistance	<82.7Ý (>139.5°C)			0.20 sec/ continuous	two driving cycles
	P0112	range check (min)		>29.9kÝ (<-35.25°C)	time after start engine load fuel system status	> 180 sec idle not in ORFCO (all above for > 10 sec)		

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

4.13 Knock Sensor

4.13.1 Description

The ECM uses active knock control, which serves to prevent engine damaging pre-ignition or detonation under all operating conditions enabling the engine to operate without additional safety margins. For the ECM to be able to determine the point at which a cylinder is pre-detonating, 2 piezo ceramic sensors are mounted on the engine block. Each sensor monitors all 4 cylinders in a bank (i.e. cylinders 1, 3, 5 & 7, and cylinders 2, 4, 6 and 8) by converting the engine block noise into a suitable electrical signal, which is then transmitted back to the ECM via a shielded cable. The signal is then processed within the ECM to identify the data that characterises knocking.

There are three knock sensor diagnostic checks during which a fault is detected if: -

1. The sensor signal is less than the minimum engine rpm dependant threshold.
2. The sensor signal is greater than the maximum engine rpm dependant threshold.
3. The error counter for the verification of knock internal circuitry is exceeded.

Knock Sensor								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold Value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Knock Sensor **Bank 1** **Bank 2**	P0327 P0332	sensor reference voltage check	sensor reference voltage (10 samples)	from <2.44 mV at 2000 rpm to <25.02mV at 5200 rpm	knock control engine speed	active (for at least 50 engine revolutions) > 2200 rpm (and not changing dynamically)	approximately 20 engine revolutions/ continuous	No MIL illumination
Bank 1 **Bank 2**	P0328 P0333			from>207.5mV at 2000 rpm to >622.6mV at 5200 rpm				
	P0606	response to test Signal	integrator output (3 samples)	< 3.51V	ECT	> 60 °C	approximately 740 engine revolutions/ continuous	
		null test **OR**	integrator output (3 samples) integrator change **AND** engine speed	> 0.353V > 45.5V/sec < 4200 rpm				

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

4.14 Throttle Position Sensor

4.14.1 Description

The sensor is a variable resistor, which is used to determine the position of the throttle plate and the rate of change in its angle. A software strategy within the ECM enables the closed throttle position to be learnt, enabling the sensor to be fitted without the need for adjustment. The signal is used by the ECM as part of the transient fuelling strategy and to determine the closed throttle position for idle speed control, in conjunction with road speed.

The signal is not only checked for range (exceeds a minimum or maximum threshold), but also for plausibility against MAF. If the load-monitoring fault is stored, it is indicative of a blocked air filter or collapsed air intake duct etc. It is also probable that the altitude adaptation factor is incorrect under these conditions.

Throttle Position Sensor								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Throttle Position Sensor	P0122 P0123	range check (min) range check (max)	voltage	< 0.195V (3.9%) > 4.83V (96%)	engine speed	> 400 rpm (for > 2.0 sec)	0.05 sec/ continuous	two driving cycles
	P0101	rationality check (low/high)	comparison of calculated load (engine speed and throttle position) to actual MAF signal	adaptation factor 1.5 < af < 0.35	engine speed engine load ECT	800< rpm <4000 2.0<TL msec< 6.5 > -9.75° C	immediately/ continuous	

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

4.15 Engine Control Module Self Test

4.15.1 Description

The ECM performs a number of self-test integrity diagnostics on its internal hardware and software to check for faults. An error is detected if the ECM receives no CAN messages for at least 0.8 seconds, the calculated checksums at power down do not match the values stored in flash Electrically Erasable Programmable Read Only Memory (EEPROM) or the internal or external RAM fails a read/write test.

Engine Control Module Self Test								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
ECM	P0600	bus check	no CAN messages	> 0.800 sec			immediately/ continuous	two driving cycles
	P0601	self check of ROM contents	invalid checksum		at power down		0.20/0.30 sec	
	P0603	external RAM check	fails read/write test					
	P0604	internal RAM check	fails read/write test		at power up			

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

4.16 Fuel Level Sensor

4.16.1 Description

This input is required as part of the misfire detection system in order to record if a 'low fuel' situation was present when misfire was detected and logged as a fault. On Range Rover 38A the ECM is required to read an analogue fuel level input and determine the 'low fuel' condition from this signal. Discovery Series II had an active high digital input until 2000MY, at which point this input also became an analogue signal.

There are three fuel level input diagnostic checks, during which a fault is detected if: -

1. The input signal is less than a minimum voltage threshold.
2. The input signal is greater than a maximum voltage threshold.
3. The percentage difference between the fuel consumption calculated by the ECM and the change in the fuel tank level is greater than a threshold.

Fuel Level Sensor								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Fuel Level Sensor	P0460	rationality check between the fuel consumption calculated by the ECM and the change in fuel tank level	calculated fuel consumption - change in fuel tank level	< -21.5% **or** > 20.4% (37.6% if tank full, which is defined as tank level > 91.4%)	total fuel used distance traveled transfer gears	> 21.5% > 0.62 miles high range	immediately/ continuous	no MIL illumination (leak detection defaults to enabled)
	P0462	range check (min)	voltage	< 0.49V			10.0 sec/ continuous	
	P0463	range check (max)		> 4.294V				

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

4.17 Vehicle Speed Signal

4.17.1 Description

The vehicle speed signal is transmitted from either the Self Levelling, Anti-lock Braking System (SLABS) or the ABS control module. This signal is then passed by the ECM to the automatic TCM via the CAN bus. The ECM has input diagnostics for this signal; the SLABS/ABS signal is compared to the vehicle speed signal on CAN from the automatic TCM, derived from the main gearbox output shaft speed; if the difference is greater than a threshold then a fault is detected.

Vehicle Speed Signal								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Vehicle Speed Signal	P0501	plausibility check	difference to calculated speed	> 31.1 mph	vehicle speed	> 49.7 mph	10.0 sec/ continuous	two driving cycles

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

4.18 Power Supplies

4.18.1 Description

The ECM requires a permanent battery level voltage supply and a switched battery level voltage supply. The switched voltage supply is controlled by the ECM via a relay based on the condition of the ignition switch input (key position 2). At “key off” the ECM will maintain the switched supply active until various internal self-checks have been completed.

There are three battery voltage plausibility checks during which a fault is detected if: -

1. The battery voltage supply is less than a minimum voltage threshold.
2. The battery voltage supply is greater than a maximum voltage threshold and a jump-start condition has not been detected.
3. The battery voltage supply is less than a voltage threshold 60 seconds after the engine has been started.

Battery Voltage								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Battery Voltage	P0560	battery voltage plausibility checks	battery voltage	< 2.55V			immediately/ continuous	no MIL illumination
	P0562		battery voltage	< 9.05V	time since engine start	> 60.0 sec		
	P0563		battery voltage	> 16.03V	jump start (vehicle speed = 0 and voltage > 15.0V)	not detected		

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

4.19 Rough Road signal

4.19.1 Description

The SLABS/ABS control module transmits a PWM signal indicating rough road for misfire detection disablement. The ECM has input diagnostics for this signal.

There are three plausibility checks of the PWM signal during which a fault is detected if: -

1. The PWM signal is greater than a threshold indicating an electrical short to battery positive.
2. The PWM signal is less than a threshold indicating an electrical short to ground.
3. The PWM signal is greater than 44.92% but less than 55.08% indicating an error with the SLABS/ABS control module.

Rough Road Signal								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold Value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Rough Road Signal	P1590	plausibility checking of the PWM signal from the anti-lock brake ECM	PWM signal	44.92 % < signal < 55.08 %	ignition engine state	on not starting	2.0 sec/ continuous	no MIL illumination (misfire defaults to enabled)
	P1591		PWM signal	signal < 10.16 %				
	P1592		PWM signal	signal > 89.84%				

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

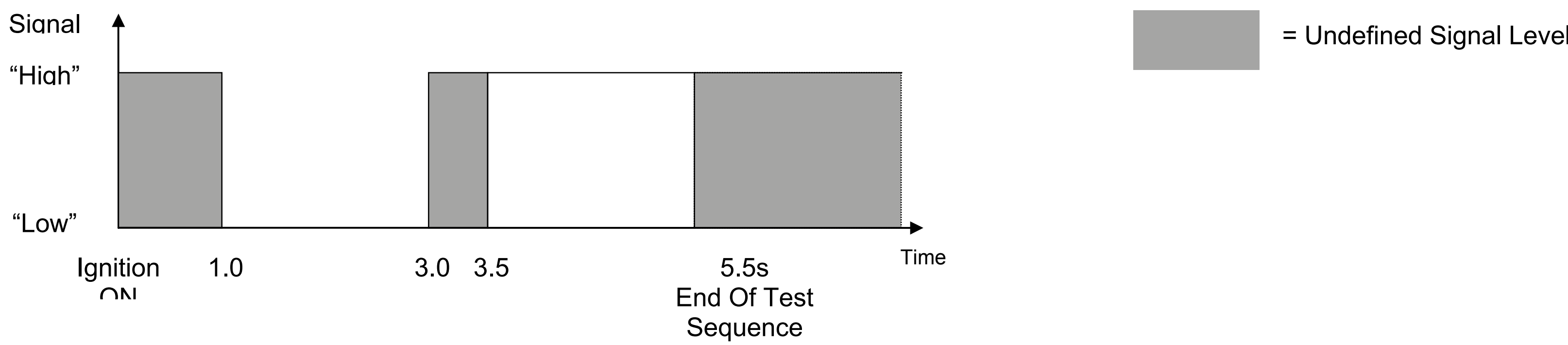
4.20 Transfer Box Malfunction Indicator Lamp Request (Range Rover 38A Only)

4.20.1 Description

This input indicates to the ECM that there is an OBD relevant error within the transfer box control module. The ECM will illuminate the MIL and store the P1701 DTC whenever this signal is true. The ECM carries out an integrity check on this signal following an 'ignition on' condition as shown below and detects a fault if any of the following conditions are satisfied: -

1. The line voltage is high during the low test.
2. The line voltage is low during the high test.
3. The line voltage is in an undefined state, neither high nor low.

Ignition on Integrity Check Waveform



Transfer Box Malfunction Indicator Lamp Request

Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Transfer Box Functionality (Range Rover Only)	P1701	MIL request from the transfer box control module			battery voltage	> 8.02V	5.5 sec/ continuous	two driving cycles
	P1702	plausibility checking of the link from the transfer box control module	line voltage	undefined state	ignition	On	performed once at ignition on	
	P1703		line voltage	high during low test	reset counter	= 0		
	P1708		line voltage	low during high test				

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

4.21 Air Conditioning System (Discovery Series II Only)

4.21.1 Description

The air conditioning system comprises of the Heating and Ventilation Control (Air Conditioning) Module (HeVAC), the air conditioning compressor and the condenser fans. The ECM controls the compressor clutch via a relay.

The control strategy of the relay features hysteresis to avoid the compressor clutch cycling while the engine is running. When there is a need for the compressor to be activated, the HeVAC module sends a request signal to the ECM, which in turn activates the compressor clutch relay. The condenser fan relay is controlled separately by both the ECM and the HeVAC module, and again, the control strategy features hysteresis to avoid the cooling fans cycling while the engine is running and the engine coolant and/or condenser temperatures fluctuate around a given threshold. When there is a need for condenser cooling for air conditioning performance the HeVAC module sends a request signal to the condenser fan relay. If there is a requirement for condenser cooling due to ECT, the ECM will send the request signal to the condenser fan relay.

When the HeVAC module requests air conditioning, the signal it sends to the ECM is through two binary switches, which sense the minimum and maximum refrigerant pressure and an evaporator thermostat. If the pressure or the temperature is below or above certain levels the binary switches will be open circuit and effectively disable the A/C request line to the ECM, which in turn will disengage the compressor clutch.

The air conditioning system is in standby mode if the HeVAC module is on and economy mode is not selected.

There are four diagnostic checks of the air conditioning system during which a fault is detected if: -

1. The A/C compressor clutch relay short circuit to battery positive, i.e. the driver voltage is greater than half the battery voltage when the driver is on.
2. The A/C compressor clutch relay short circuit to ground, i.e. the driver voltage is less than one third of the battery voltage when the driver is off.
3. The A/C compressor clutch relay is open circuit, i.e. the driver voltage is greater than one third of the battery voltage but less than two thirds of the battery voltage when the driver is off.
4. A/C has been requested when the system is not in standby mode, i.e. a signal rationality check.

Air Conditioning System

Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold Value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Air Conditioning System	P1538	circuit continuity - short to battery positive	voltage - drive on	voltage > 1/2 * Battery positive	battery voltage	7.5V < Battery positive < 17V	immediately/ continuous	no MIL illumination
	P1537	circuit continuity - short to ground	voltage - drive off	Voltage < 1/3 * Battery positive				
	P1536	circuit continuity - open circuit	voltage - drive off	1/3* Battery positive < voltage < 2/3* Battery positive	engine speed	> 80 rpm		
	P1535	signal rationality check	A/C requested when not in standby mode				0.5 sec	

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

4.22 Fuel Injectors

4.22.1 Description

The engine is fitted with 8 fuel injectors (one per cylinder), each of which is directly driven by the ECM. The Injectors are fed from a common fuel rail as part of a return less fuel system, with the fuel rail pressure constant at 3.5 bar (52 psi). The Fuel Pressure Regulator is integral to the fuel pump module, within the fuel tank. There is no reference signal line to the intake manifold.

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

1. Fuel injector driver short circuit to battery positive, i.e. the driver voltage is greater than half the battery voltage when the driver is on.
2. Fuel injector driver short circuit to ground, i.e. the driver voltage is less than one third of the battery voltage when the driver is off.
3. Fuel injector driver open circuit, i.e. the driver voltage is greater than one third of the battery voltage but less than two thirds of the battery voltage when the driver is off.

Fuel Injectors								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold Value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Fuel Injector	P0201 to P0208	circuit continuity - open circuit	voltage - drive off	1/3* Battery positive < voltage < 2/3* Battery positive	engine speed battery voltage	> 80 rpm 7.5V < Battery positive < 17V	immediately/ continuous	two driving cycles
	P0261/4/7 P0270/3/6 P0279/82	circuit continuity - short to ground.	voltage - drive off	voltage < 1/3 * Battery positive				
	P0262/5/8 P0271/4/7 P0280/3	circuit continuity - short to battery positive	voltage - drive on	voltage > 1/2 * Battery positive				

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

4.23 Idle Speed Control Actuator

4.23.1 Description

The load on an idling engine is a combination of both internal and external engine loads such as engine friction, water pump, air conditioning etc., which all change with time and operating conditions. The idle speed control actuator is required to enable closed loop idle speed control to compensate for these changing conditions, by regulating the airflow into the engine.

The device consists of two coils which use opposing PWM signals to control the position of opening / closing of the rotary valve. If one circuit fails the other is switched off by the ECM as soon as it recognises the fault. This prevents the valve going to a maximum or minimum setting. There is a default position, which is determined by a permanent magnet. In the default condition the idle speed is raised and remains fixed at approximately 1200 rpm with no load.

There are eight idle speed control actuator diagnostic checks: -

1. Opening winding driver short circuit to battery positive, i.e. the driver voltage is greater than half the battery voltage when the driver is on.
2. Opening winding driver short circuit to ground, i.e. the driver voltage is less than one third of the battery voltage when the driver is off.
3. Opening winding driver open circuit, i.e. the driver voltage is greater than one third of the battery voltage but less than two thirds of the battery voltage when the driver is off.
4. Closing winding driver short circuit to battery positive, i.e. the driver voltage is greater than half the battery voltage when the driver is on.
5. Closing winding driver short circuit to ground, i.e. the driver voltage is less than one third of the battery voltage when the driver is off.
6. Closing winding driver open circuit, i.e. the driver voltage is greater than one third of the battery voltage but less than two thirds of the battery voltage when the driver is off.
7. Blocked Idle Air Control (IAC) valve – rpm error low, i.e. the engine speed is 100 rpm less than the target speed.
8. Blocked IAC valve – rpm error high, i.e. the engine speed is 180 rpm greater than the target speed.

Idle Air Control Valve

Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Idle Air Control Valve opening	P1510	circuit continuity - Open circuit	voltage - drive off	1/3 * Battery positive < voltage <2/3 * Battery positive	engine speed battery voltage	> 80 rpm 7.5V < Battery positive < 17V	immediately/ continuous	two driving Cycles
	P1513	circuit continuity - short to ground	voltage - drive off	voltage < 1/3 * Battery positive				
	P1514	circuit continuity - Short to battery positive	voltage - drive on	voltage > 1/2 * Battery positive				
closing	P1551	circuit continuity - open circuit	voltage - drive off	1/3 * Battery positive < voltage <2/3 * Battery positive				
	P1552	circuit continuity - short to ground	voltage - drive off	voltage < 1/3 * Battery positive				
	P1553	circuit continuity - short to battery positive	voltage - drive on	voltage > 1/2 * Battery positive				
	P0505	functional check	actual - desired RPM	> +180 rpm < -100 rpm	vehicle speed ECT IAT altitude adaptation transfer gears engine load	= 0 mph > 80.25° C > -9.75° C > 0.712 high range < 2.5 m sec	2.0 to 3.0 sec/once per driving cycle	

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

4.24 Fuel Pump Relay

4.24.1 Description

The Land Rover V8 engine has a return-less fuel system. The fuel pressure regulator and filter are fitted to the 'in tank fuel pump module'. The system pressure is maintained at a constant 3.5 bar (52 Psi), with no reference to intake manifold pressure. The ECM compensates for the non-constant pressure drop across the injector nozzles.

The fuel is supplied to the injectors from a fuel pump fitted within the fuel tank. The electrical supply to this fuel pump is controlled by the ECM via a relay and an Inertia fuel shutoff switch, which will turn off the fuel supply upon vehicle impact. The fuel system is pressurised to 3.5 bar as soon as the ECM is powered up, the pump is then switched off until engine start has been achieved. If the pump runs but the fuel pressure is out of limits, adaptive fuel faults are stored.

The ECM monitors the output power stage of the fuel pump relay drive for electrical faults. A fault is detected if any of the following conditions is satisfied: -

1. Fuel pump relay driver short circuit to battery positive, i.e. the driver voltage is greater than half the battery voltage when the driver is on.
2. Fuel pump relay driver short circuit to ground, i.e. the driver voltage is less than one third of the battery voltage when the driver is off.
3. Fuel pump relay driver open circuit, i.e. the driver voltage is greater than one third of the battery voltage but less than two thirds of the battery voltage when the driver is off.

Fuel Pump Relay								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Fuel Pump Relay	P1232	circuit continuity - short to battery positive	Voltage - drive on	voltage > 1/2 * Battery positive	battery voltage	7.5V < Battery positive < 17V	immediately/	no MIL
					engine speed	> 80 rpm	continuous	illumination
	P1231	circuit continuity – short to ground	Voltage - drive off	voltage < 1/3 * Battery positive	time after fuel pump off	> 0.5 sec		
	P1230	circuit continuity – open circuit	Voltage - drive off	1/3 * Battery positive < voltage < 2/3 * Battery positive				

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

4.25 Malfunction Indicator Lamp

4.25.1 Description

The OBD system interfaces with the driver via the MIL, which is located in the instrument pack. A bulb check takes place every time the ignition is switched to ignition position II and until the engine is cranked.

The ECM monitors the driver junction temperature to detect an electrical fault. A fault is detected if the following condition is satisfied: -

1. MIL driver short circuit to battery positive, i.e. the driver stage junction temperature exceeds a temperature threshold.

Malfunction Indicator Lamp								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Malfunction Indicator Lamp	P0650	short circuit to battery positive	drive stage junction temperature	> 150 °C	engine speed battery voltage	> 80 rpm 7.5V < Battery positive < 17V	immediately/ continuous	no MIL illumination

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

4.26 Hill Descent Control Signal – Discovery Series II Only

4.26.1 Description

HDC operates in conjunction with the anti-lock braking system to provide greater control in off-road situations if necessary. HDC can be selected with the vehicle in any gear, but will only operate when low range gears are engaged with the vehicle traveling at less than 31 mph. During a descent, if engine braking is insufficient to control the vehicle speed, HDC (if selected) automatically operates the brakes to slow the vehicle and maintain a speed relative to the selected gear and the accelerator pedal position.

The ECM transmits throttle angle, engine torque, engine identification (V8 Thor) and transmission type to the SLABS control module to support the HDC system. This information is transmitted via a multiplexed PWM waveform.

The ECM has power stage diagnostics for the signal, with a fault being detected if any of the following conditions is satisfied: -

1. HDC link to the SLABS control module short circuit to battery positive, i.e. the driver voltage is greater than half the battery voltage when the driver is on.
2. HDC link to the SLABS control module short circuit to ground, i.e. the driver voltage is less than one third of the battery voltage when the driver is off.
3. HDC link to the SLABS control module open circuit, i.e. the driver voltage is greater than one third of the battery voltage but less than two thirds of the battery voltage when the driver is off.

Hill Decent Control Signal								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Hill Decent Control Signal	P1665	circuit continuity - short to battery positive	voltage - drive on	voltage > 1/2 * Battery positive	engine speed battery voltage	> 80 rpm 7.5V < Battery positive < 17V	immediately/ continuous	two driving cycles
	P1664	circuit continuity – short to ground	voltage - drive off	voltage < 1/3 * Battery positive				
	P1663	circuit continuity – open circuit	voltage - drive off	1/3 * Battery positive < voltage < 2/3 * Battery positive				

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

4.27 Engine Speed Signal

4.27.1 Description

The engine speed signal is sent by the ECM to the instrument pack, Body Control Module (BCM) and SLABS/ABS control module via a direct hardwired connection.

The ECM has power stage diagnostics for this signal with a fault being detected if any of the following conditions is satisfied: -

1. Engine speed signal driver short circuit to battery positive, i.e. the driver voltage is greater than half the battery voltage when the driver is on.
2. Engine speed signal driver short circuit to ground, i.e. the driver voltage is less than one third of the battery voltage when the driver is off.
3. Engine speed signal driver open circuit, i.e. the driver voltage is greater than one third of the battery voltage but less than two thirds of the battery voltage when the driver is off.

Engine Speed Signal								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Engine Speed Signal	P0654	circuit continuity - short to battery positive	voltage - drive on	voltage > 1/2 * Battery positive	engine speed battery voltage	> 80 rpm 7.5V < Battery positive <17V	immediately/ continuous	no MIL illumination
	P0654	circuit continuity – short to ground	voltage - drive off	voltage < 1/3 * Battery positive				
	P0654	circuit continuity – open circuit	voltage - drive off	1/3 * Battery positive < voltage < 2/3 * Battery positive				

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

4.28 Environmental-Box Cooling Fan – Range Rover 38A Only

4.28.1 Description

This function is required to control the Environmental-Box (E-Box) mounted cooling fan. This fan provides cabin air into the E-Box to provide a cool temperature environment for the ECM fitted in the under-bonnet mounted E-Box. The temperature is determined by an internally (to the ECM) mounted temperature sensor. The fan will be switched on at 40 ^{o}C ∂ 15^{o}C and also tested for 2 seconds every engine start.

The ECM has power stage diagnostics for this signal with a fault being detected if any of the following conditions is satisfied: -

1. E-Box cooling fan driver short circuit to battery positive, i.e. the driver voltage is greater than half the battery voltage when the driver is on.
2. E-Box cooling fan driver short circuit to ground, i.e. the driver voltage is less than one third of the battery voltage when the driver is off.
3. E-box cooling fan driver open circuit, i.e. the driver voltage is greater than one third of the battery voltage but less than two thirds of the battery voltage when the driver is off.

Environmental-Box Cooling Fan – Range Rover 38A Only								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
E-Box Cooling Fan (Range Rover 38A only)	P1671	circuit continuity - short to battery positive	voltage - drive on	voltage > 1/2 * Battery positive	engine speed battery voltage	> 80 rpm 7.5V < Battery positive < 17V	20 sec/ continuous	two driving cycles
	P1670	circuit continuity – short to ground	voltage - drive off	voltage < 1/3 * Battery positive				
	P1669	circuit continuity – open circuit	voltage - drive off	1/3 * Battery positive < voltage < 2/3 * Battery positive				

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

4.29 Low Range Signal

4.29.1 Description

The transmission range switch information and calculated range data are transmitted from the automatic TCM via the CAN bus.

The ECM performs a rationality test between these signals, a fault is detected if one the following conditions are satisfied: -

1. The transmission range switch information indicates low range and the calculated range information indicates high.
2. The transmission range switch information indicates high range and the calculated range information indicates low.

Low Range Signal								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Low Range Signal	P1700	plausibility check of the transfer gear signal	**or**	lever position = low range and gear information = high range lever position = high range & gear information = low range	throttle position vehicle speed engine load engine speed time after start	> 19.92% > 62.15 mph > 4.0 msec > 2000 rpm > 5.0 sec	5.0 sec/ continuous	no MIL illumination (diagnostics all default to enabled)

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

4.30 Controller Area Network System

4.30.1 Description

The CAN is a high-speed serial interface for sharing dynamic signals between control modules. CAN communications are 'self checked' for errors, if an error is detected the message is ignored by the receiving control module. Due to the high rate of information exchange (500K baud) the system has a high degree of latency. This allows for a high amount of errors to be present without reducing the data transfer rate.

The CAN communication system is a differential bus using a twisted pair, which is normally very reliable. If either or both of the wires of the twisted pair CAN bus is open or short-circuited a CAN time out fault will occur and the automatic TCM defaults to third gear. In order to alert the driver the 'sport' and 'manual' warning lights in the instrument pack will flash alternatively.

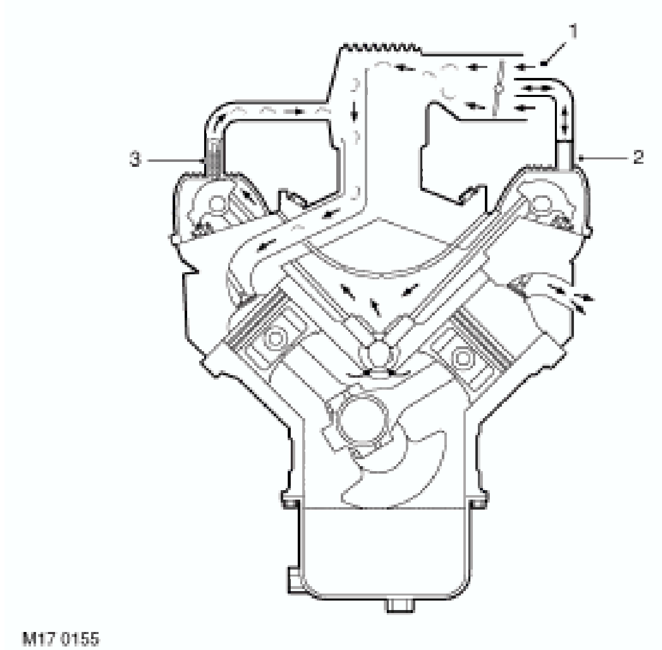
An error is detected if the ECM receives no CAN messages for at least 0.8 seconds or the duration of the automatic TCM retard request is greater than 10 seconds.

CAN System								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Transmission Interface	P1776	TCM ignition retard plausibility test	duration of retard request	> 10.0 sec	vehicle speed	> 24.86 mph	10.0 sec/ continuous	no MIL illumination (MIL request by TCM)
	P0600	CAN Time-out (bus check)	no CAN messages	> 0.80 sec			immediately/ continuous	two driving cycles

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

4.31 Positive Crankcase Ventilation System Monitoring

4.31.1 Description



1. Intake air
2. Left hand rocker cover breather tube
3. Oil separator in right hand rocker breather tube

A spiral oil separator is located in the stub pipe to the ventilation hose on the right hand cylinder head rocker cover, where oil is separated and returned to the cylinder head. The rubber ventilation hose from the right hand rocker cover is routed to a port on the right hand side of the inlet manifold plenum chamber where the returned gases mix with the fresh intake air passing through the throttle butterfly valve. This pipe is primarily for part-load breathing and is connected to the engine via a restrictor that prevents an excessive vacuum building up in the crankcase at small throttle openings.

The stub pipe on the left hand rocker cover does not contain an oil separator or a restrictor and the ventilation hose is routed to the throttle body housing at the air inlet side of the butterfly valve. This pipe is for breathing at higher loads. Flow through this second pipe is negligible under normal driving conditions.

The ventilation hoses are attached to the stub pipes by metal band clamps.

Disconnection of the part-load breather is likely to result in a tendency of the engine to stall when returning to idle and the quantity of un-metered air, which flows into the intake manifold, will result in the detection of a fuel system fault by the OBD system.

For this reason, there are no separate monitors for compliance with the requirements of Positive Crankshaft Ventilation (PCV) monitoring.