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

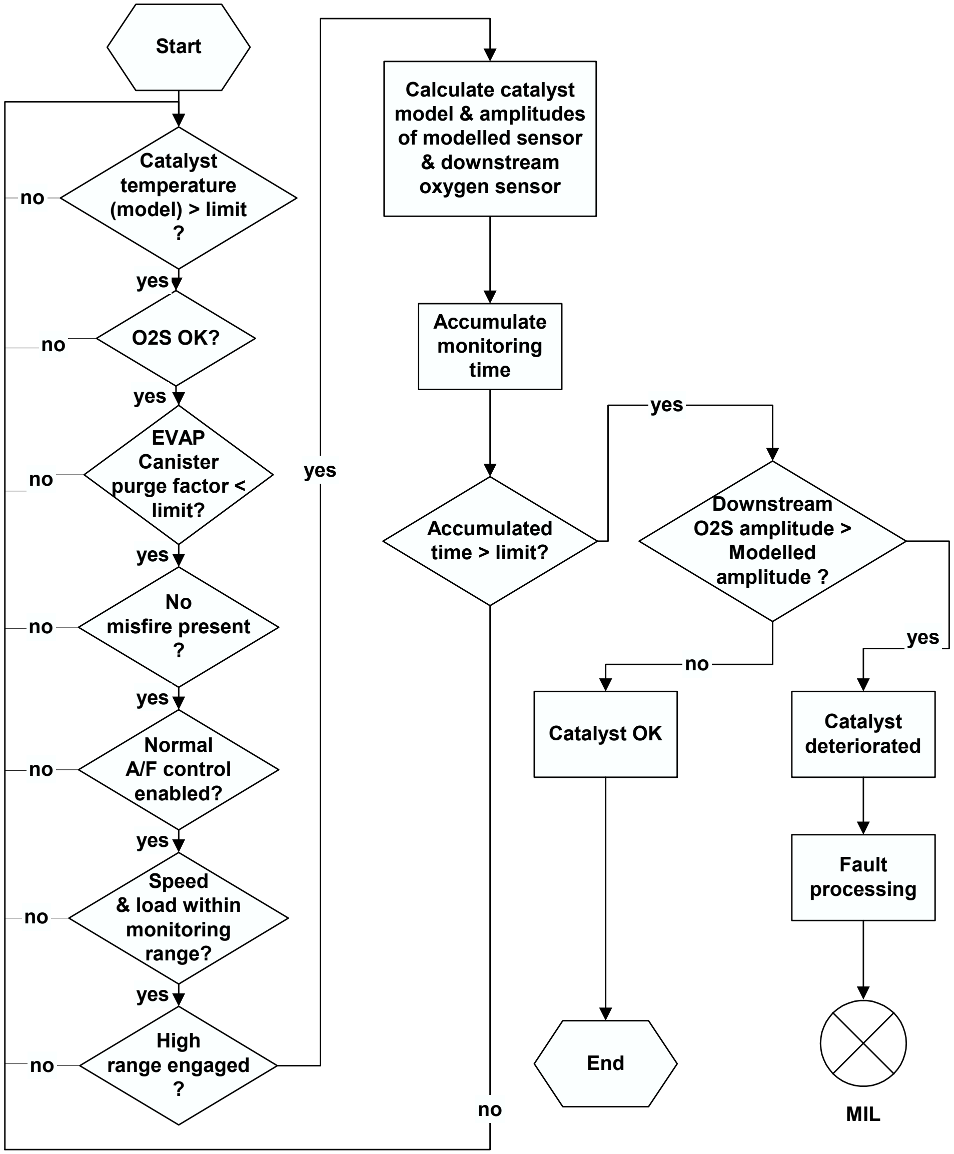
4.1.1 Description

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

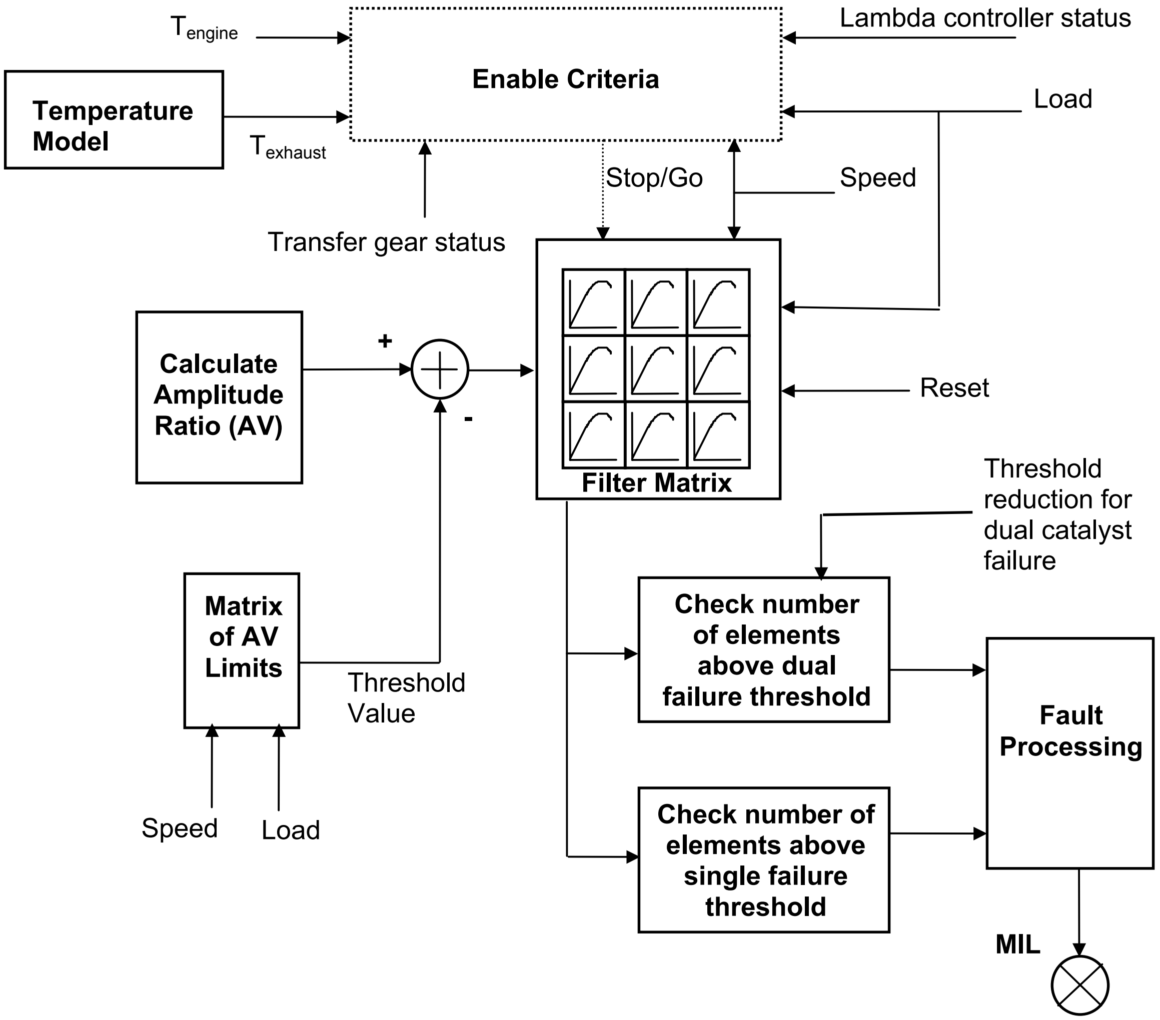
The accumulated information about the amplitude ratio becomes more and more reliable as different load and speed ranges are used during a driving cycle. If the amplitude ratio is greater than fixed map values a fault is detected and an internal fault flag will be set. If the fault is detected again in 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					engine speed	1200 < rpm < 1800	100 sec/ once per driving cycle	two driving cycles
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 load	between 1.8 and 3.8 msec at 1200 Rpm to between 1.9 and 4.15 msec at 1800 rpm		
					catalyst temperature (model)	> 332 °C		
					transfer gears	high range		
Bank 2	P0430			> 0.4023	fuel system status	closed loop		
					EVAP canister purge vapour factor	< 10.0		
					enable conditions	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	1000 < rpm < 2800	250 sec/ once per driving cycle	two driving cycles
					engine load	1.2< TL msec <4.0		
					catalyst temperature (model)	> 300 °C		
					IAT	> -9.75 °C		
Bank 1 or 2 (Single catalyst deterioration)				> 0.75 (min. 4 of 4 samples for one cylinder bank)	transfer gears	high range		
					fuel system status	closed loop		
					EVAP canister purge vapour factor	< 10.0		
					time after start	> 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.

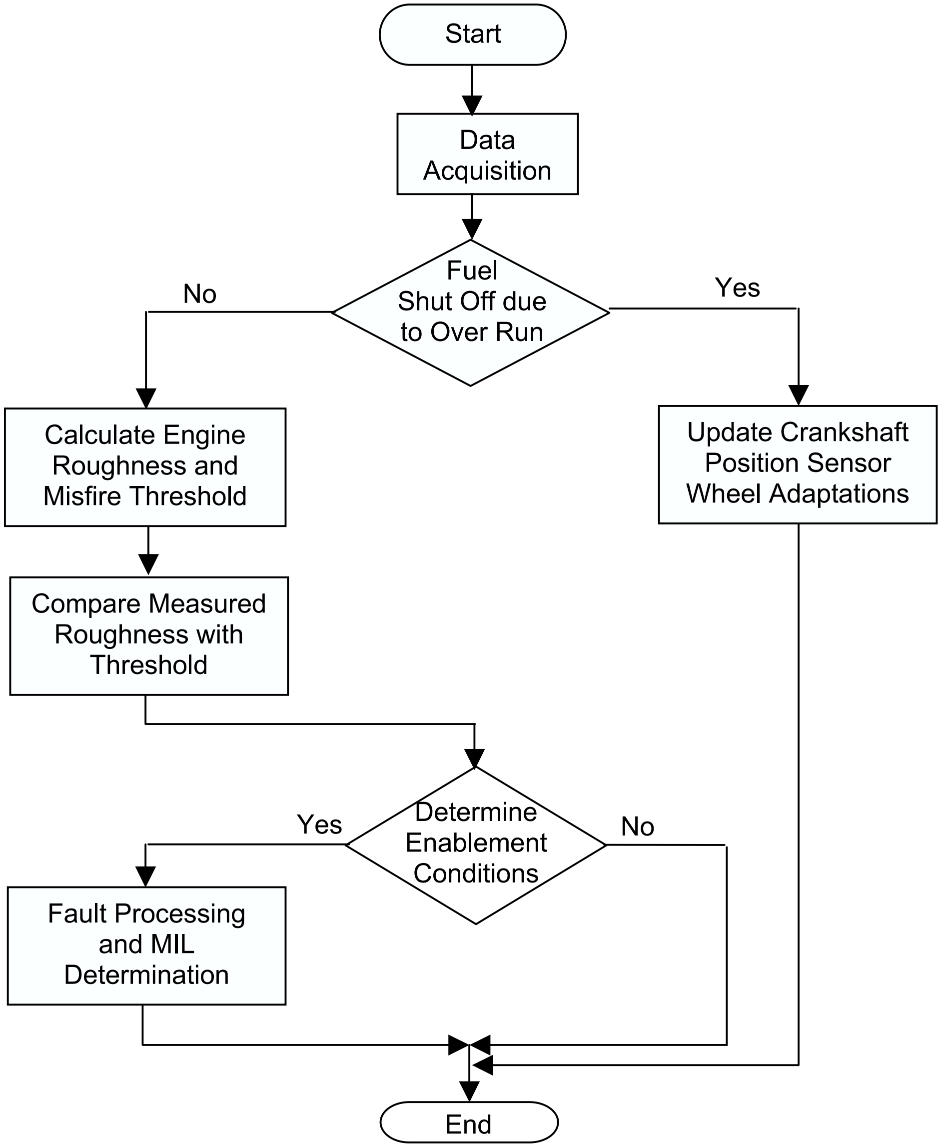
In order to detect misfiring in any cylinder, the torque of each cylinder is evaluated by recording the time between two ignition events; this is a measure of the mean value of the speed for this angular segment. Since a change in the engine torque results in a change of the engine speed. Additionally, 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.

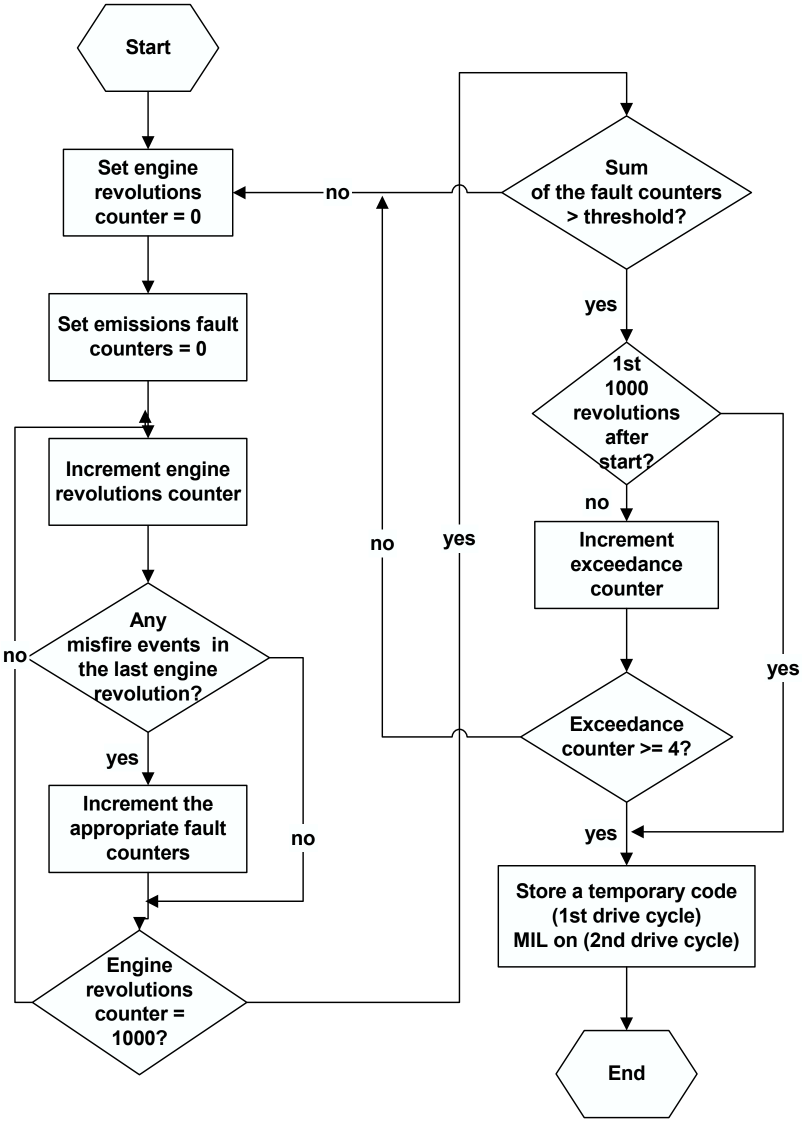
If the sum of cylinder misfire incidents exceeds a predetermined value the diagnostic trouble code for indicating catalyst damage relevant misfiring is stored and the MIL is illuminated at once (flashing).

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) engine load rough road (ABS) gear change traction control transfer gears re-enablement delay (not active after engine start)	520 < rpm < 5400 < 1.20 ms/rev (< 130.8 ms/rev) < 4000 rpm/sec (< 20 000 rpm/sec) Positive not set not active not active high range 20 revolutions	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			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 speed change engine load rough road (ABS) traction control transfer gears time after start	520 < rpm < 5400 < 0.10 ms/ignition < 720 rpm/sec positive not set not active high range > 5.0 sec	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			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.

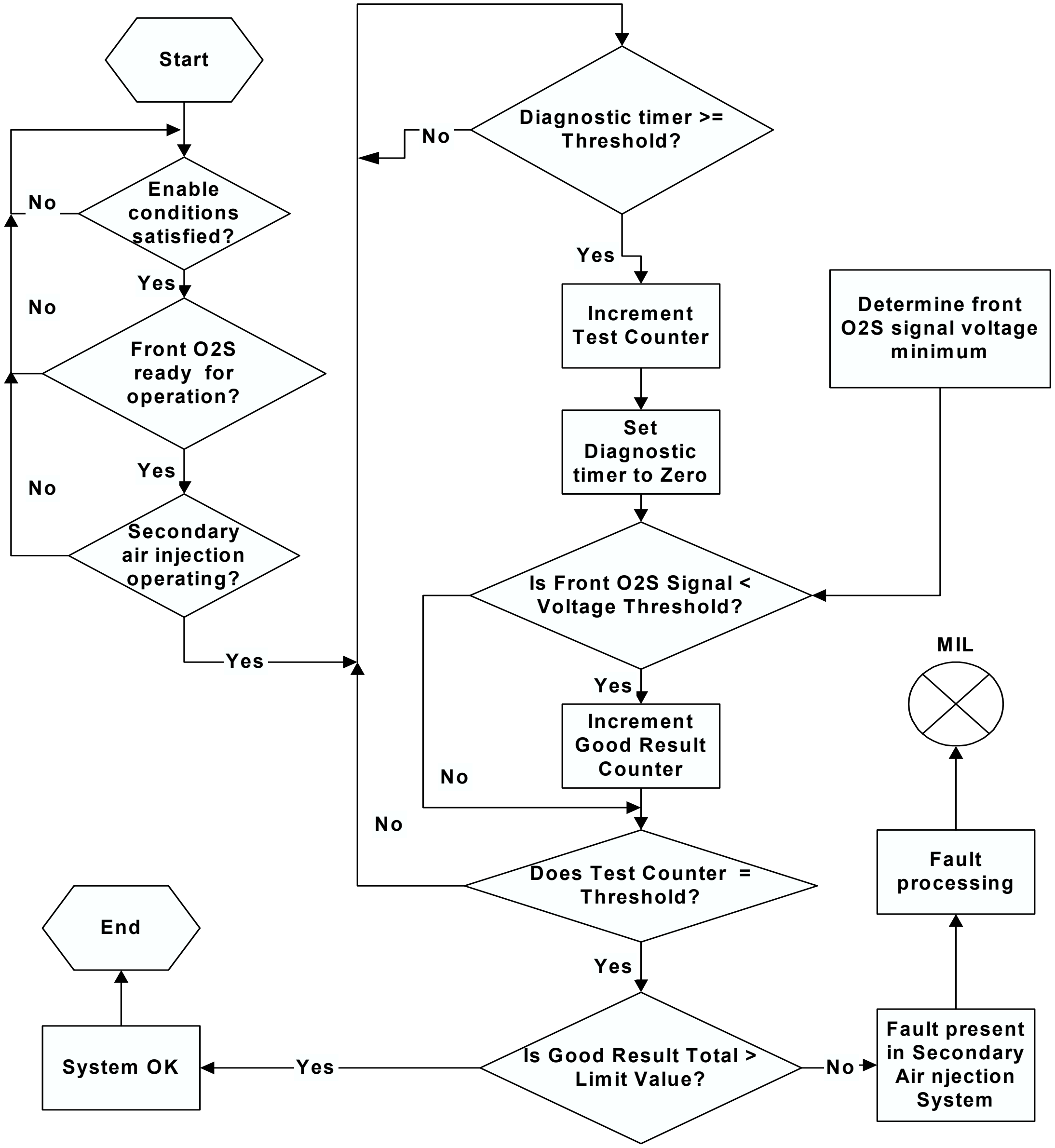
Active Secondary Air Injection Diagnostic

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