# 4 Onboard Monitoring

## 4.1 Catalyst Monitoring

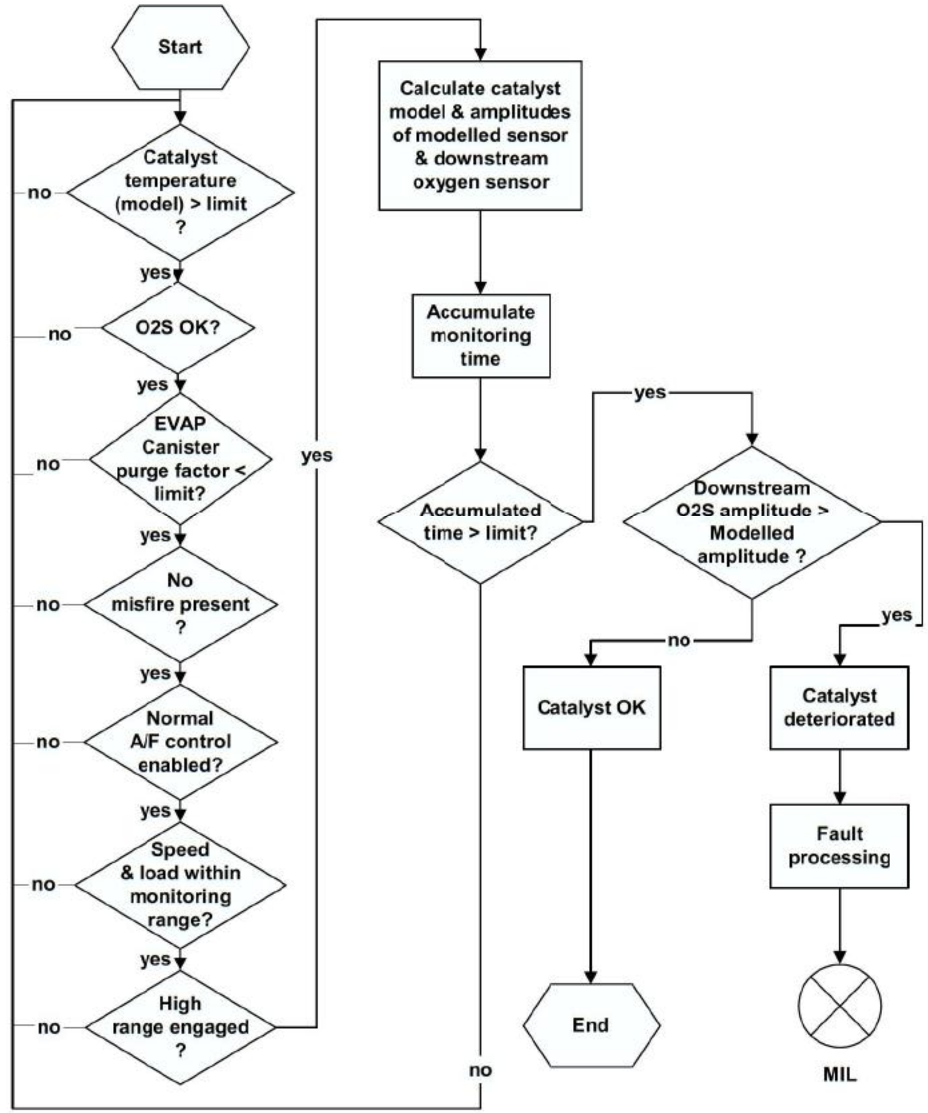
### 4.1.1 Description

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 • •(Lambda) indicates the deviation of the actual air fuel ratio from the theoretical air fuel ratio. Thus • •= 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

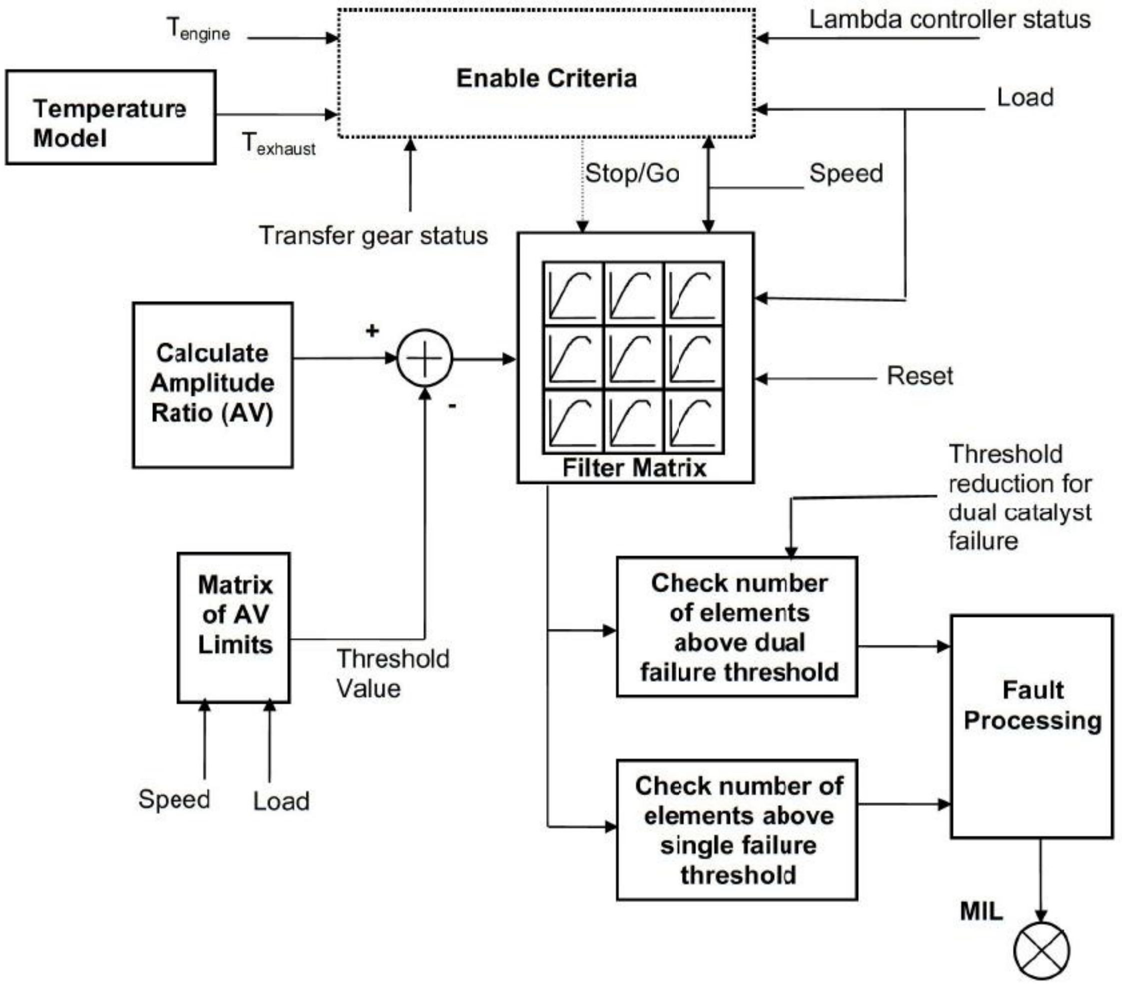
The accumulated information about the amplitude ratio becomes more and more reliable as different load and speed ranges are used during a driving cycle. If the amplitude ratio is greater than fixed map values a fault is detected and an internal fault flag will be set. If the fault is detected again in 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**<br>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<br>engine load<br>catalyst temperature (model)<br>transfer gears<br>fuel system status<br>EVAP canister purge vapour factor<br>enable conditions | 1200 < rpm < 1800<br>between 1.8 and 3.8 msec at 1200 Rpm to between 1.9 and 4.15 msec at 1800 rpm<br>> 332 °C<br>high range<br>closed loop<br>< 10.0<br>valid for > 0.8 sec | 100 sec/ once per driving cycle | two driving cycles |
| Bank 2 | P0430 | | | > 0.4023 | | | | |

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**<br>Banks 1 and 2 (Dual catalyst deterioration) | P0420<br>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<br>engine load<br>catalyst temperature (model)<br>IAT<br>transfer gears<br>fuel system status<br>EVAP canister purge vapour factor<br>time after start | 1000 < rpm < 2800<br>1.2< TL msec <4.0<br>> 300 °C<br>> -9.75 °C<br>high range<br>closed loop<br>< 10.0<br>> 69.12 sec | 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) | | | | |

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.

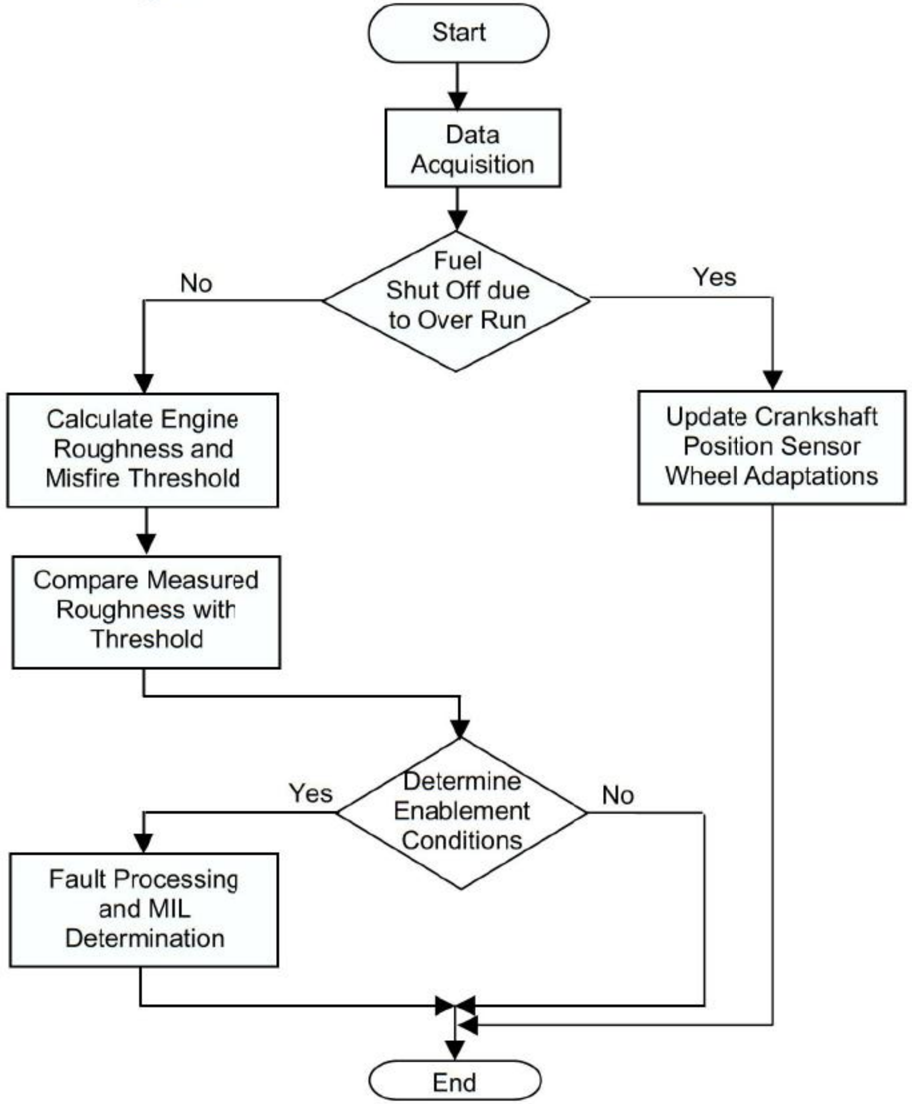
In order to detect misfiring in any cylinder, the torque of each cylinder is evaluated by recording the time between two ignition events; this is a measure of the mean value of the speed for this angular segment. Since a change in the engine torque results in a change of the engine speed. Additionally,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