



3 On Board Monitoring

3.1 Catalyst Monitoring

3.1.1 Description

1. Diagnostic Trouble Codes:

Bank 1:	P0420
Bank 2:	P0430

The On Board Diagnostic (OBD) II system uses a 2 stage catalyst monitoring procedure. Stage 2 will only be invoked when the catalyst fails stage 1. Both stages are described in detail below.

2. Monitoring Procedure - Stage 1

During Stage 1 monitoring, lambda feedback control uses the upstream oxygen sensors as normal. When specified monitoring conditions are satisfied, the catalyst diagnostics module will obtain a count of downstream and upstream oxygen sensor peak edges OXY SENSOR MEAS EDGE COUNT D and OXY SENSOR MEAS EDGE COUNT U respectively. When OXY SENSOR MEAS EDGE COUNT U equals CAT UPS PEAK MAX, a difference is obtained between CAT UPS PEAKS MAX, and OXY SENSOR MEAS EDGE COUNT D to give CAT PEAKS DIFF.

The calculation repeats until the number of CAT PEAKS DIFF values calculated equals CAT CUSUM FULL. Each value of CAT PEAKS DIFF is subtracted from a threshold value CAT STAGE1 THRESH and a sum of the differences obtained CAT PKCUSUM.

If, before OXY SENSOR MEAS EDGE COUNT U equals CATS UPS PEAKS MAX, vehicle conditions change and the conditions listed in section 3 of this document are no longer satisfied, then the module stops receiving peak counts and the current count is discarded. The calculation of CAT PKCUSUM is held until the monitoring conditions are again satisfied, when its calculation is resumed with a new count of peak edges, until the number of CAT PEAKS DIFF included in CAT PKCUSUM equals CAT CUSUM FULL.

The cumulative sum CAT PKCUSUM is then compared against a threshold value CAT PKCUSUM THRESH. If it exceeds the threshold then the catalyst is suspected and Stage II is invoked, otherwise the catalyst is OK.

The two thresholds CAT STAGE1 THRESH and CAT PKCUSUM THRESH are related via the number of measurements in the cumulative sum, as follows:

$$\text{CAT PKCUSUM} = \sum_1^{\text{CAT CUSUM FULL}} \max(0, (\text{CAT STAGE1 THRESH} - \text{CAT PEAKS DIFF}))$$

A flow chart describing the above procedure has been included.

3. Primary Detection Parameter - Stage 1

Edge Counts difference - derived from two oxygen sensors before and after the catalyst.

4. Criteria for Determining failing Stage 1

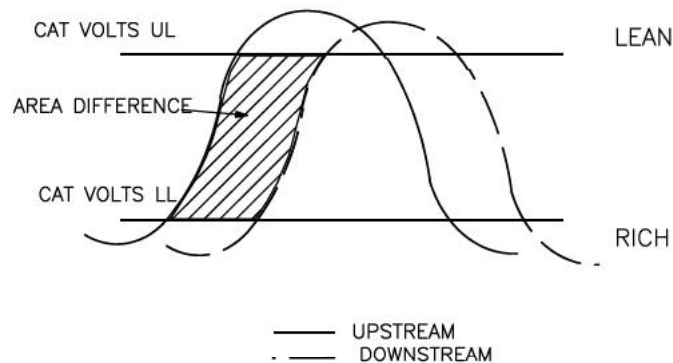
CAT PKCUSUM => CAT PKCUSUM THRESH = 20

CAT STAGE1 THRESH = 5

5. Monitoring Procedure - Stage 2

Catalyst Monitoring uses the integrated area-difference technique to give an accurate measure of the condition of the catalyst. This technique measures the differences in the waveforms from oxygen sensors immediately before and after the catalyst. During Stage 2 monitoring lambda feedback control is switched to use the downstream oxygen sensors.

From each monitored catalyst, two oxygen sensor voltages are obtained at regular time intervals. The voltages are clipped between CAT VOLTS LL and CAT VOLTS UL to give CAT LAMBDA DNS CLIP and CAT LAMBDA UPS CLIP. On the rich to lean transition the downstream clipped signal is subtracted from the upstream one. The difference is retained only if it yields a positive result. The differences are summed while the upstream oxygen sensor voltage is less than CAT VOLTS UL, and the resulting value gives a measure of the area CAT SUM OF DIFFS.



The value of CAT SUM OF DIFFS is then corrected for Air Mass Flow Rate (AMFR) by multiplying it by the following expression: $AMFR / (CAT\ MAXIMUM\ AMFR - AMFR)$ where CAT MAXIMUM AMFR is a constant set to the largest value that AMFR can reach for that engine. The corrected value is called CAT NORM AREA DIFF.

This is averaged over a number of sensor switches, provided that the engine is operating at speed and load conditions, which are defined, as valid for catalyst monitoring. If the current value of CAT NORM AREA DIFF is taken from outside the valid speed and load conditions, then this value is discarded and the system prepares for the next oxygen sensor peak.

The value of CAT NORM AREA DIFF calculated as described above, is used to set up a Cumulative Sum (CAT ADCUSUM) to decide whether catalyst performance has deteriorated below the required level. This involves subtracting each value of CAT AREA DIFF received from a threshold value of area difference (CAT AREA DIFF THRESH), and summing the differences. When the number of CAT AREA DIFF values included in the sum equals CAT CUSUM FULL, then CAT ADCUSUM is compared against a threshold value (CAT ADCUSUM THRESH), and if it is greater than the threshold, then the catalyst is faulty. If CAT ADCUSUM is lower than this threshold then the catalyst is not faulty.

6. Primary Detection Parameter - Stage 2

Area Difference - measured in Volt seconds taken from two oxygen sensors before and after the catalyst.

7. Fault Criteria Limits - Stage 2

CAT AREA DIFF THRESH = 1200 (internal units) i.e.: 0.146 Volt seconds



CAT ADCUSUM THRESH = 3000 (internal units) i.e.: 0.366 Volt seconds

8. Monitoring Conditions

Engine speed and engine load must be in the highlighted area of the map:

Speed (RPM x1000)	Load (unitless)							
	0	1	2	3	4	5	6	7
0								
1								
2								
3								
4								
5								
6								
7								

Road speed must be greater than 20 mph.

Steady engine conditions must be true

The catalyst must be deemed to have reached "light off" indicated by the following:

Engine Coolant Temperature is $> 70^{\circ}\text{C}$ AND Average Oxygen Sensor Heater Supply $< 90\%$.

9. Monitoring Time Length / Frequency of Checks

The time taken for catalyst monitoring to complete the test depends on the switching frequency of the feedback control system, which in stage 2 depends on the catalyst's performance. If the switching frequency is taken as an average of 1.5 Hz then the stage 2 catalyst monitoring test will take $7 \times 15 \times 1 / 1.5 = 70$ seconds at stable valid conditions.

Stage 1 will take a similar amount of time to complete.

10. Criteria for Storing Diagnostic Trouble Code

Two successive trips where the catalyst monitoring system indicates a failed catalyst.

11. Criteria for Illuminating MIL

Two successive trips where the catalyst monitoring system indicates a failed catalyst.

12. Criteria for Determining Out of Range Input Signals

The oxygen sensors are subject to minimum and maximum voltage limits of 15mV and 4.985V respectively.