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Technical OBD description for VW / Audi / Bentley with ME7 ECMs

This description applies for the following OBD groups and test groups:

OBD Group Name	Test group	Engine	Models	Standard	Controller / OBD II strategy
CVW-W	CBEXV06.0501	6.0 W12T - 2 bank	Continental	LEV II Bin 5	Bosch ME7.1.1 VW-W

In case of monitors which are applicable only for specific OBD group(s) or test group(s) the specific OBD group(s) or test group(s) is noted against the relevant part of the description.

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1 CATALYST MONITORING

The diagnostic function used for monitoring the catalyst efficiency is based on measuring the Oxygen within the catalyst determined by at least two Oxygen sensors. This function can be correlated between Oxygen / Hydrocarbon and Oxygen / Oxides of Nitrogen.

1.1 General description

The catalyst monitor is based on the determination of oxygen storage capability (OSC). The correlation between conversion efficiency and the OSC has been investigated on catalysts with various characteristics specifically concerning stages of aging correlated to exhaust emissions (HC/NOx). Therefore, the catalyst is diagnosed by comparing its storage capability against the storage capability of a borderline catalyst.

The oxygen storage capability (OSC) can be determined by one of the following two methods:

1 Oxygen reduction after fuel-cut (Quick pass of the monitor)

Oxygen is stored in the catalyst during fuel-cut conditions happening while driving the vehicle. After fuel-cut, the catalyst is operated with a rich air-fuel ratio (A/F) and the amount of removed oxygen is determined. If this passive test indicates an OSC value highly above the borderline catalyst, the catalyst is diagnosed without an error. This monitoring path can only generate a "pass" result.

2 Determination of Oxygen storage (Active test)

For purposes of monitoring, the ECM cycles the A/F ratio by commanding a rich and a lean fuel mixture as follows.

- First, a rich A/F ratio is commanded by ECM until a minimum of oxygen has been removed (cumulated rich gas > threshold).
- Then, the catalyst is operated with a lean A/F ratio commanded by ECM and the Oxygen Storage Capability is calculated from the oxygen mass stored in the catalyst as follows:
 - $OSC = \int \text{air mass flow} * \text{lean mixture} (\lambda - 1) * dt$
- The catalyst is operated in this mode until the oxygen stored in the catalyst exceeds a calibrated limit or the downstream oxygen sensor indicates that the catalyst is completely saturated with oxygen.
- The catalyst is then diagnosed by comparing its oxygen storage capability to the calibrated threshold of a borderline catalyst.

1.2 Monitoring Structure

Refer to Figure 1. According to the operating principle described above the following main parts of the monitor can be distinguished:

- Monitoring the amount of removed oxygen after fuel cut off
- Check of monitoring conditions for active test
- Lambda request (interface to lambda controller)
- Mixture enrichment in order to remove any stored oxygen
- Measurement of oxygen storage capacity (OSC) by lean A/F ratio operation
- Processing
- Fault detection

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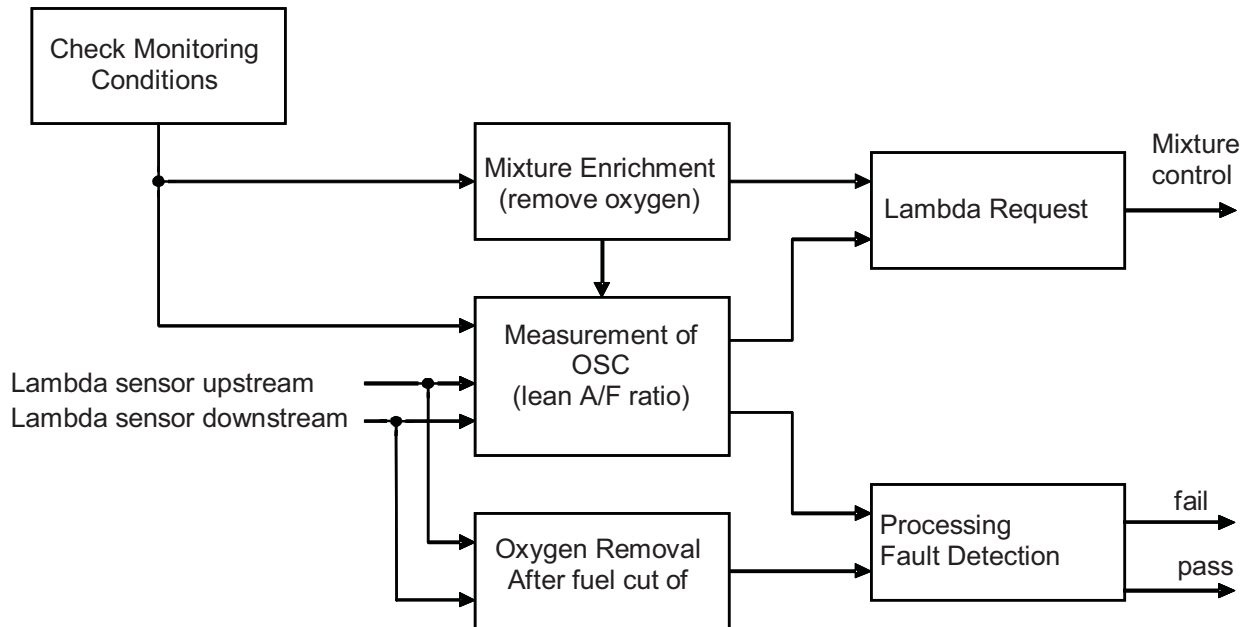


Figure 1: Active measurement of OSC – monitoring structure

1.2.1 Processing

After the measurement of the OSC, the OSC-value is normalized to the OSC-value of the borderline catalyst, which is taken from a map, depending on exhaust gas mass flow and catalyst temperature.

The final diagnostic result is calculated by averaging several, normalized OSC-values and compared to the threshold. The measurement of OSC can be carried out consecutive or stepwise.

For a catalyst system with 3 Oxygen-Sensors (see Figure 2) this measuring procedure can be applied to different portions. See Figure 3. The different alternatives are shown in the table below.

OBD Group Name	Test group	Engine	Models	Standard	Oxygen Sensor Configuration
CVW-W	CBEXV06.0501	6.0 W12T - 2 bank	Continental	LEV II Bin 5	2 sensors x 2 banks

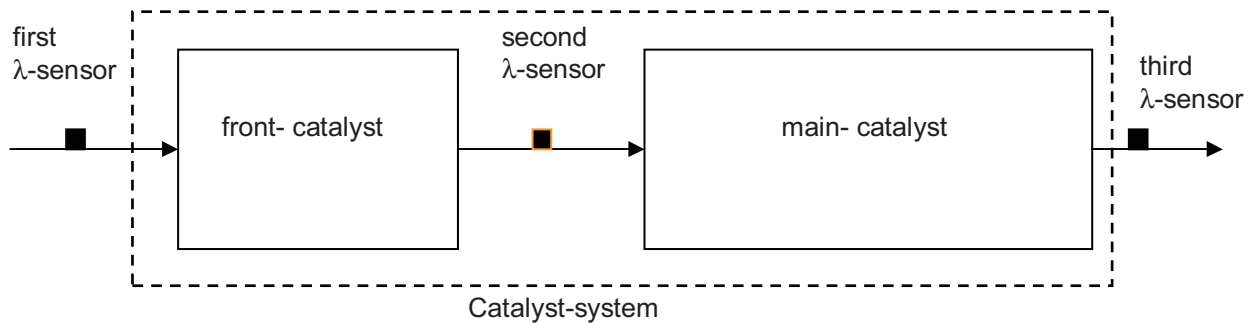


Figure 2: Catalyst system with three oxygen sensors

secondary parameters	front-catalyst	main-catalyst	catalyst-system
- first λ-sensor is active - second λ-sensor is active - modeled exhaust gas temp. in range	quick pass		
- first λ-sensor is active - second λ-sensor is active - third λ-sensor is active - modeled exhaust gas temp. in range		quick pass	
- first λ-sensor is active - second λ-sensor is active - third λ-sensor is active - modeled exhaust gas temp. in range	{quick pass	quick pass}	=> quick pass
- first λ-sensor is active - second λ-sensor is active - modeled front exhaust gas temp. in range - modeled main exhaust gas temp. in range - exhaust- gas mass flow in range - exhaust- gas mass dynamic in range	measurement of OSC-calculation		
- first λ-sensor is active - second λ-sensor is active - third λ-sensor is active - modeled front exhaust gas temp. in range - modeled main exhaust gas temp. in range - exhaust- gas mass flow in range - exhaust- gas mass dynamic in range		measurement of OSC-calculation	
- first λ-sensor is active - third λ-sensor is active - modeled front exhaust gas temp. in range - modeled main exhaust gas temp. in range - exhaust- gas mass flow in range - exhaust- gas mass dynamic in range			measurement of OSC-calculation

Figure 3: Necessary conditions to check the different catalyst volume

If the secondary parameters for the different catalyst portions are met at the same time, the diagnostic functions can run simultaneously.

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According to Figure 3 the following result combinations are described in Figure 4.

front catalyst	main catalyst or catalyst system	result
quick pass	quick pass	Both = pass
quick pass	measurement of OSC- calculation < threshold	front catalyst = pass main catalyst = fail
quick pass	measurement of OSC- calculation > threshold	Both = pass
measurement of OSC- calculation < threshold	quick pass	front catalyst = fail main catalyst = pass
measurement of OSC- calculation > threshold	quick pass	Both = pass
measurement of OSC- calculation < threshold	measurement of OSC- calculation < threshold	Both = fail
measurement of OSC- calculation > threshold	measurement of OSC- calculation > threshold	Both = pass
measurement of OSC- calculation > threshold	measurement of OSC- calculation < threshold	front catalyst = pass main catalyst = fail
measurement of OSC- calculation < threshold	measurement of OSC- calculation > threshold	front catalyst = fail main catalyst = pass

Figure 4: Results which can be obtained after diagnosis of different catalyst volumes

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1.3 Flow chart catalyst monitoring

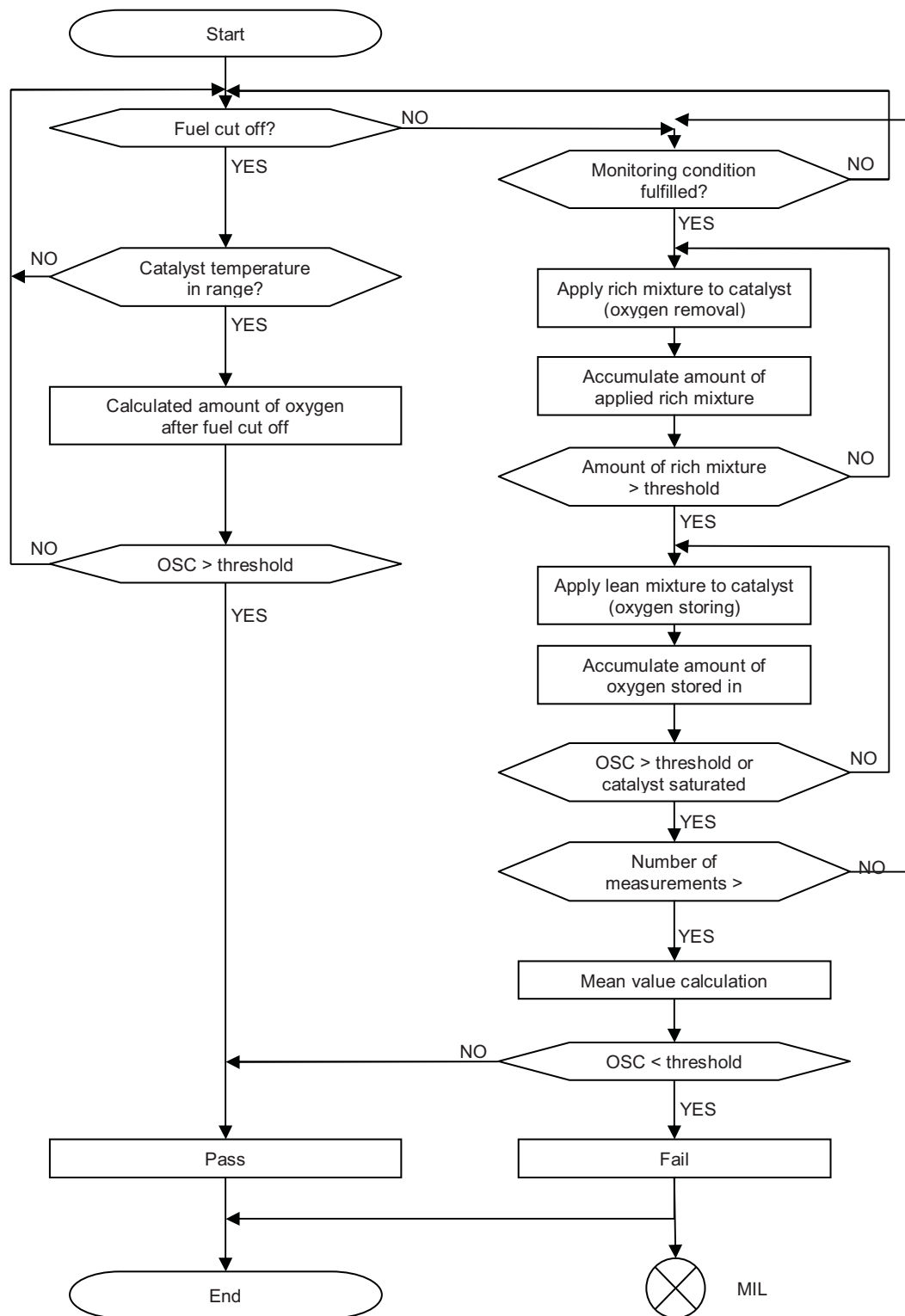


Figure 5: Flow chart catalyst monitoring

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2 HEATED CATALYST MONITORING

Not applicable

3 MISFIRE MONITORING

3.1 General Description

The method of engine misfire detection is based on evaluating the engine speed fluctuations. In order to detect misfiring at any cylinder, the torque of each cylinder is evaluated by metering the time between two ignition events, which is a measure for the mean value of the speed of this angular segment. This means, a change of the engine torque results in a change of the engine speed.

Additionally the influence of the load torque will be determined.

When the mean engine speed has been measured, influences caused by different road surfaces have to be eliminated (e.g. pavement, pot holes etc.).

This method consists of the following main parts:

- Correction of normal changes of engine rpm and engine load
- Data acquisition, adaptation of sensor wheel and typical engine behaviour is included
- Calculation of engine roughness
- Comparison with a threshold depending on operating point
- Fault processing, counting procedure of single or multiple misfire events

3.2 Monitoring function description

3.2.1 Misfire Monitoring

Refer Figure 6

Data acquisition

The duration of the crankshaft segments is measured continuously for every combustion cycle and stored in a memory.

Sensor wheel adaptation

Within defined engine speed and load ranges the adaptation of the sensor wheel tolerances and the typical engine behaviour is carried out, if no misfire events are detected. With progressing adaptation the sensitivity of the misfire detection is increasing. The adaptation values are stored in a non-volatile memory and taken into consideration for the calculation of the engine roughness.

Misfire detection

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

Calculation of the engine roughness

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

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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 values are 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 is detected reliably.

Calculation of the engine roughness threshold value

The engine roughness threshold value consists of the base value, which is determined by a load/speed dependent map.

During warm-up, a coolant-temperature-dependent correction value is added. In case of multiple misfiring the threshold is reduced by an adjustable factor.

Without sufficient sensor wheel adaptation 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 of filter value (low pass filter).

3.2.2 Determination of misfiring

Random misfire

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

If the engine roughness value is greater than the roughness threshold value a single misfire is detected. With this misfire determination it is possible to identify misfiring cylinders individually.

Random misfire without valid adaptation

To eliminate the influence of the missing flywheel adaptation each engine roughness value is compared with that one on the same flywheel segment on the intermittent revolution. Therefore single misfire events are detected reliable without determination of the flywheel tolerances.

Continuous misfire on one or multiple cylinders

To avoid noise effects, all engine roughness values are low pass filtered and the detection threshold is corrected by the mean value of the filters. Therefore the amplitude to noise ratio improves and the sensitivity for misfire detection of continuous misfiring cylinders increases.

3.2.3 Statistics, Fault processing:

Refer to Figure 7. Within an interval of 1,000 crankshaft revolutions, the detected number of misfiring events is totalled for each cylinder. If the sum of cylinder fault counters exceeds a predetermined value, a fault code for emission relevant misfiring is preliminary stored after completion of the first interval after engine has been started or the forth interval during a driving cycle where misfire has been detected. In the case of misfire detection for one cylinder, the fault is determined by a cylinder selective fault code otherwise the fault code for multiple misfire will be stored additionally.

Within an interval of 200 crankshaft revolutions, the detected numbers of misfire events is weighted and totalled for each cylinder. The weighting factor is determined by a load/speed dependent map.

If the sum of cylinder fault counters exceeds a predetermined value, the fault code for indicating catalyst damage relevant misfiring is stored and the MIL is illuminated with on/off"-sequence once per second (blinking).

In case of misfire detection for one cylinder the fault is determined by a cylinder selective fault code otherwise the fault code for multiple misfiring will be stored additionally.

If catalyst damaging misfire does not occur any longer during the first driving cycle, the MIL will return to the previous status of activation (e.g. MIL off) and will remain illuminated continuously during all subsequent driving cycles if catalyst related misfire is detected again. However all misfire events

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where the catalyst can be damaged are indicated by a blinking MIL. If catalyst damage is not detected under similar conditions in the subsequent driving cycle the temporary fault code will be deleted.

In the case of catalyst related misfire, the Lambda closed loop system is switched to open-loop condition according to the basic air/fuel ratio calculation ($\text{Lambda}=1$).

All misfire counters are reset after each interval.

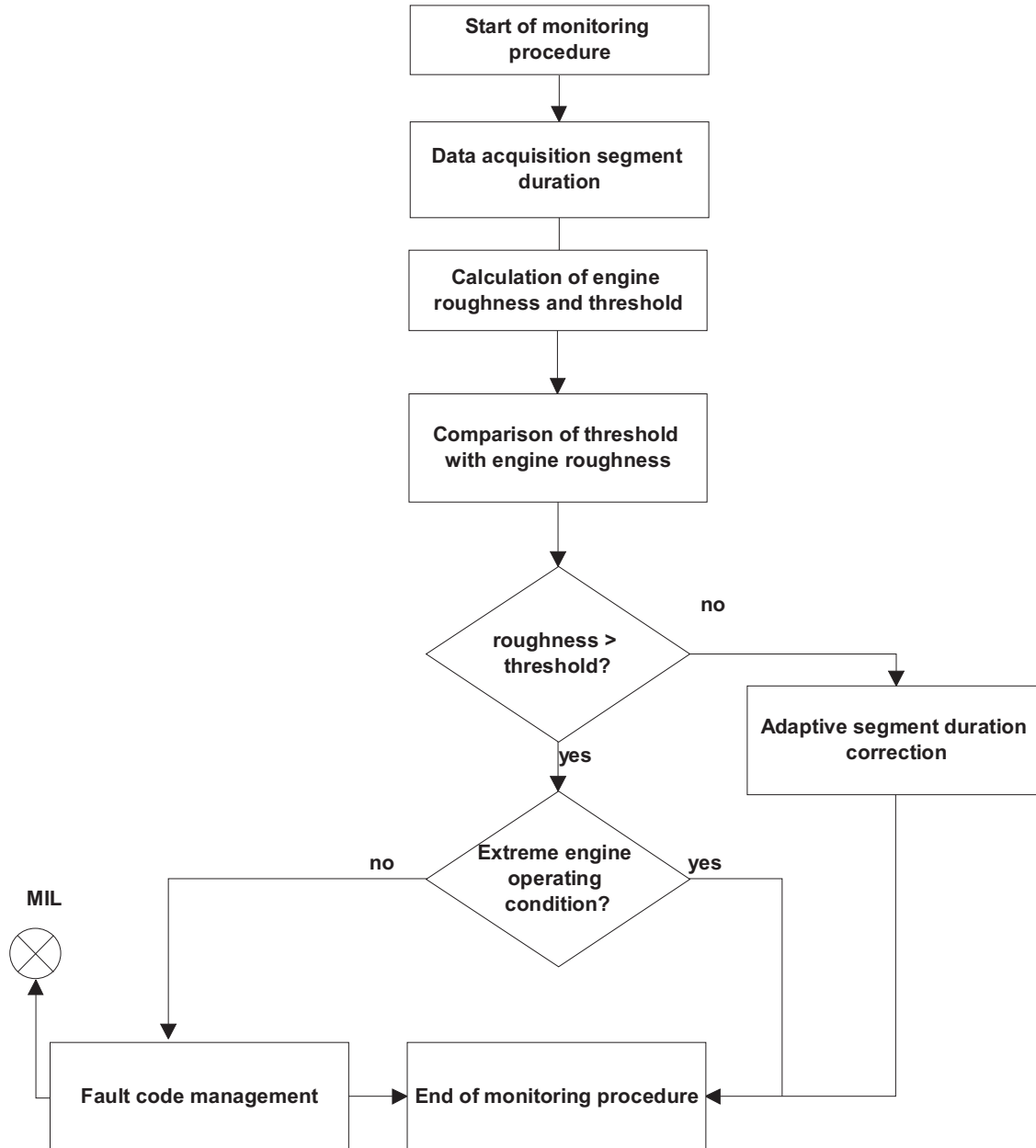


Figure 6: Flow chart: misfire monitoring

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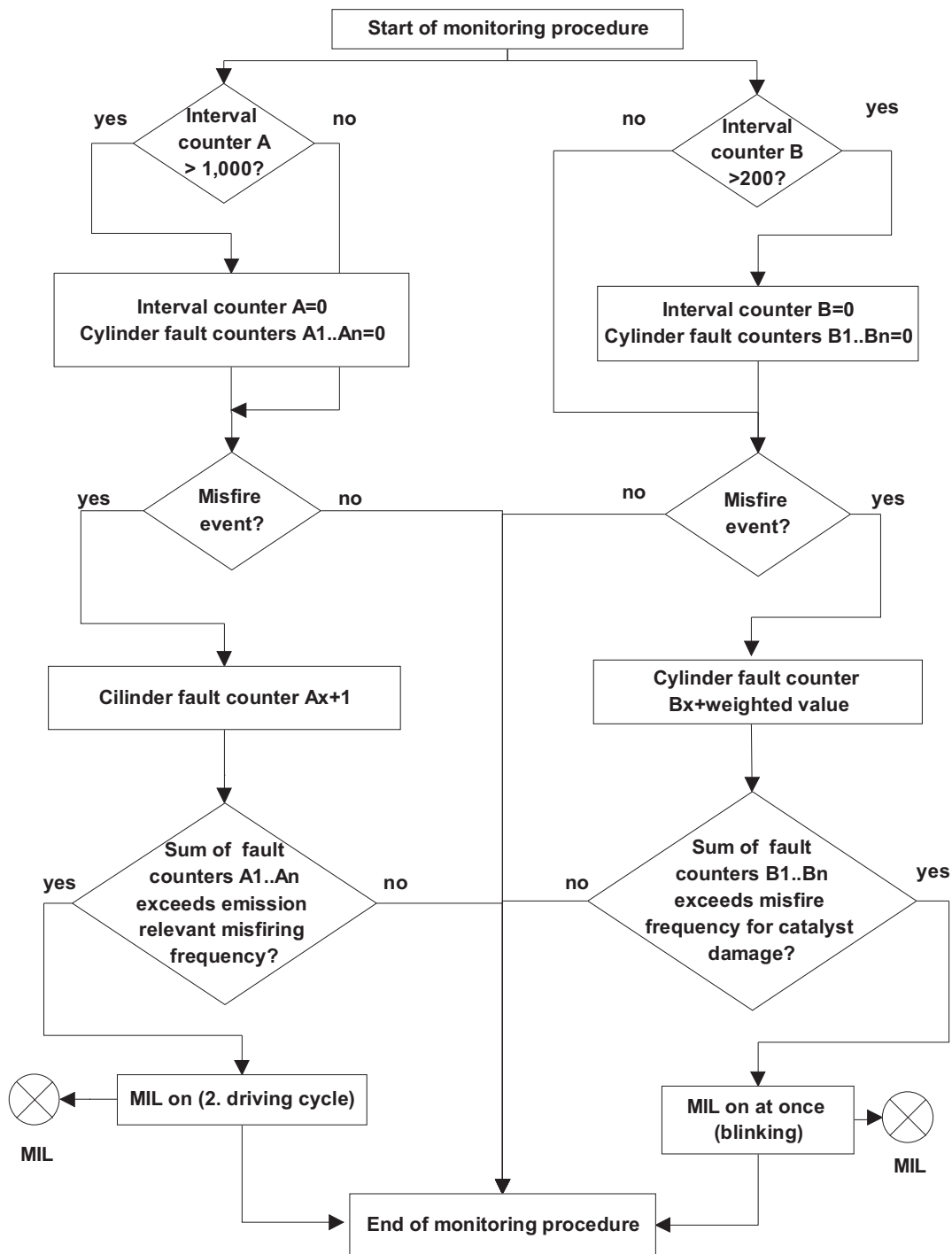


Figure 7: Flow chart: Paths for misfire and catalyst damaging misfire rate monitoring

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4 EVAPORATIVE SYSTEM MONITORING

4.1 Leakage Check

4.1.1 General description

The leakage diagnosis procedure is a pressure check of the EVAP system. In order to perform the check, the EVAP system will be sealed and pressure applied by the leakage diagnosis pump (LDP). The pressure variation time is analysed by the ECM.

4.1.2 Monitoring function description

Refer to Figure 8

The diagnosis procedure consists of the following steps:

1. Tank pressure check

The first step of leakage diagnostics is the pressure check of fuel tank system by testing the reed switch. In case of an open reed switch, the fuel tank system has sufficient pressure for the sealed check and no further pressure has to be supplied to the fuel tank system by the LDP.

The diagnosis is waiting until the EVAP purge valve is opened in order to purge the carbon canister. In case the reed switch remains open or the reed switch stuck open, the reed switch is defective.

In the case the reed switch is closed, the LDP is switched on in order to supply pressure to the fuel tank system and the diagnostic is continued with the step 2 to 3 (as described below).

2. LDP Self-check procedure

Closed check

LDP control is disabled and the reed switch has to be closed otherwise the reed switch is defective.

Close to open check

LDP control is switched on once and the diaphragm has to move to the upper position. The time is measured between closed and open position of diaphragm detected by the reed switch. When the final upper position of diaphragm is reached in a certain time, then the check will be passed.

3. Leak check of EVAP system

Fast pulse

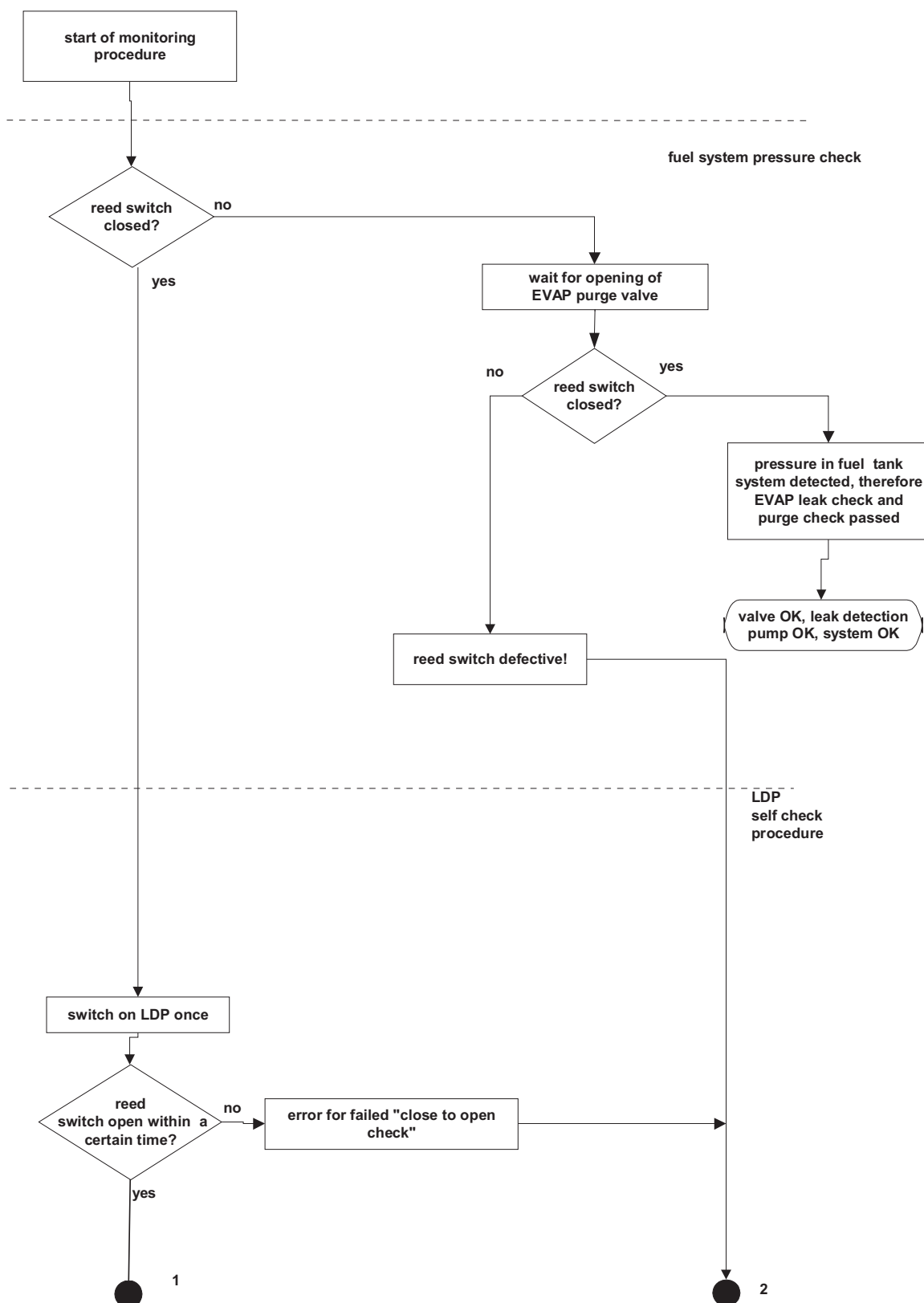
After the self check procedure, the LDP control supplies pressure to the fuel tank system with a pressure dependent number of compression strokes in a certain time. In order to supply pressure to the fuel tank system, the LDP can perform compression strokes in several attempts.

EVAP system sealed check, measure stroke and measure phase

The decrease of fuel tank pressure is measured via time of diaphragm movement followed by a compression stroke. Within a certain time, the LDP control is determined within at least four measurement strokes. The averaged time is a measure for the tightness of fuel tank system.

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4.1.3 Chart(s) and Flow Chart(s)



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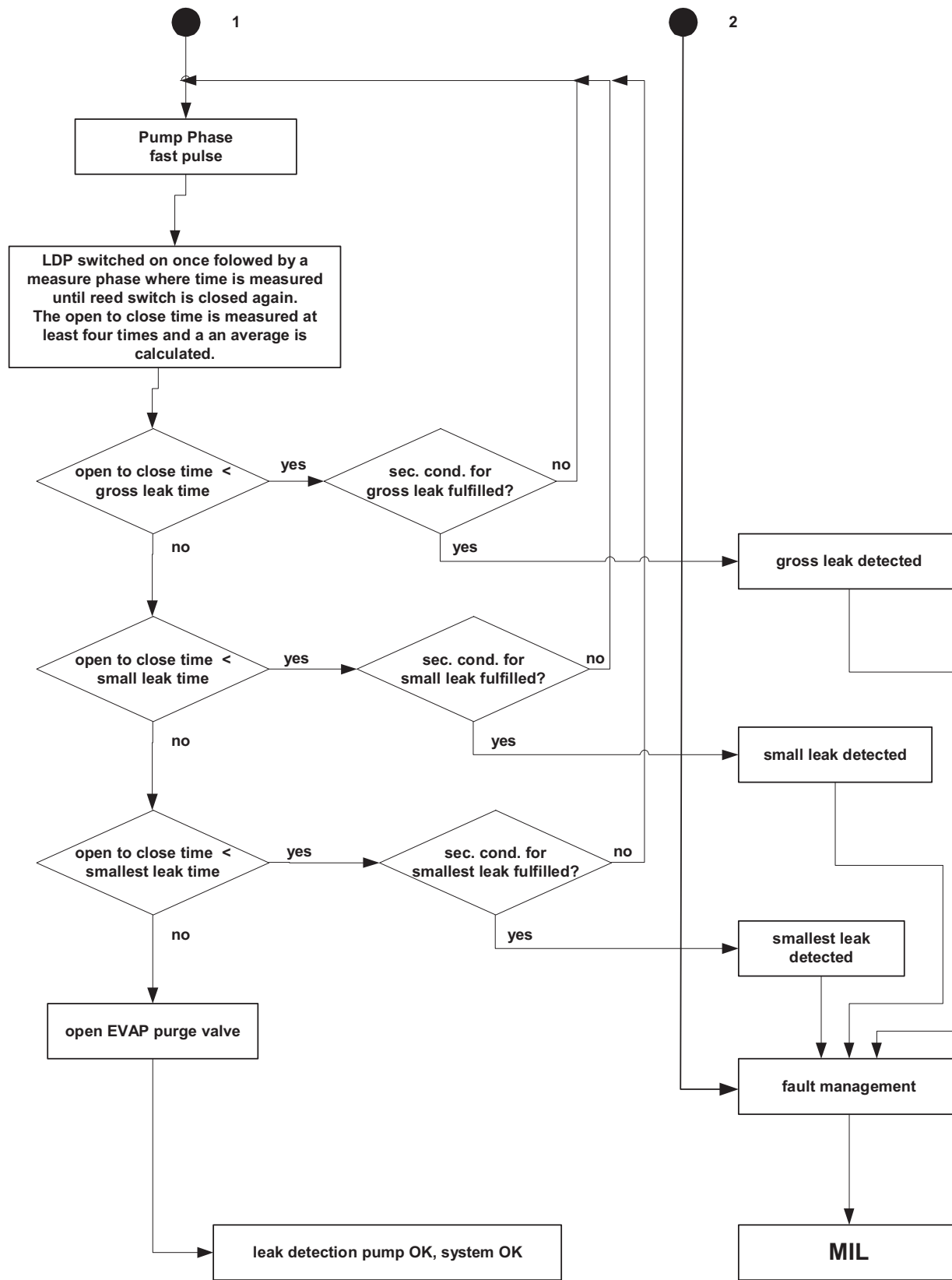


Figure 8: Flow chart: Leakage check

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4.2 Purge Check

4.2.1 General description

The purge flow through the EVAP Purge Valve (see **Figure 9**) is checked when the vehicle is at rest during an idle condition and the Lambda controller is active.

The EVAP Purge Valve is opened while monitoring the Lambda controller and the airflow through the throttle unit.

For rich or lean mixture through the EVAP Purge Valve:

Flow through the EVAP Purge Valve is assumed as soon as the Lambda controller compensates for a rich or lean shift.

After this procedure the EVAP Purge Valve is reset and the diagnosis is completed.

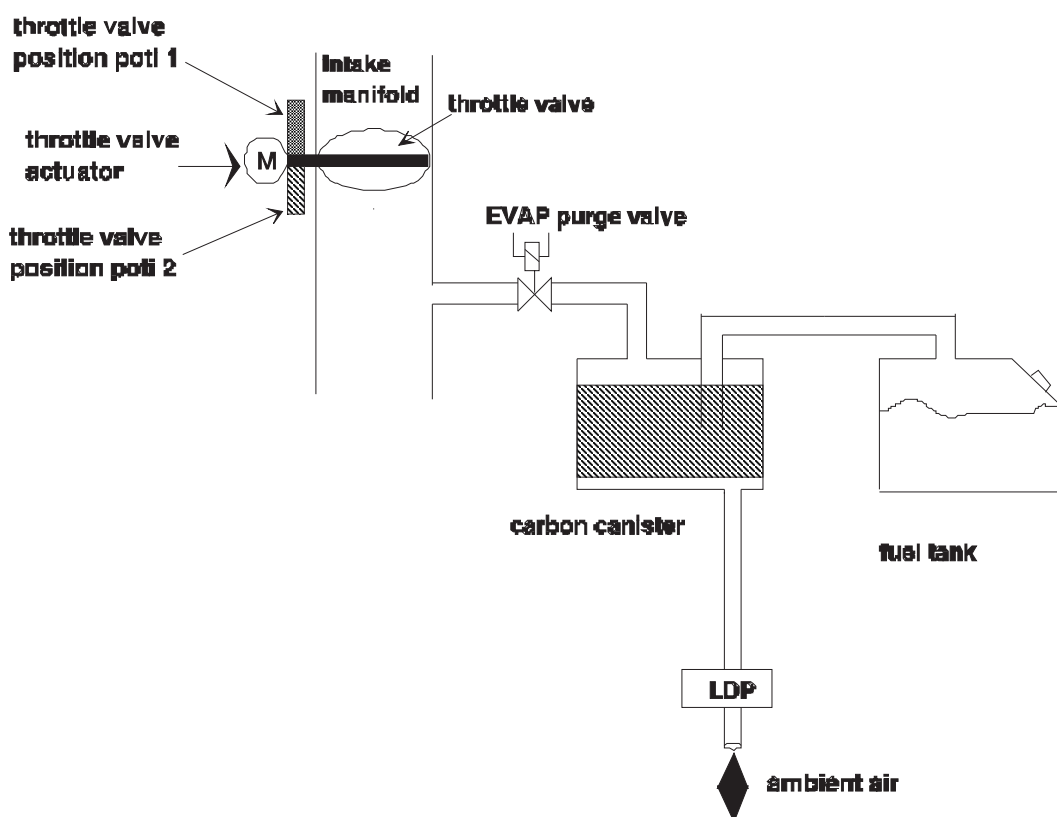


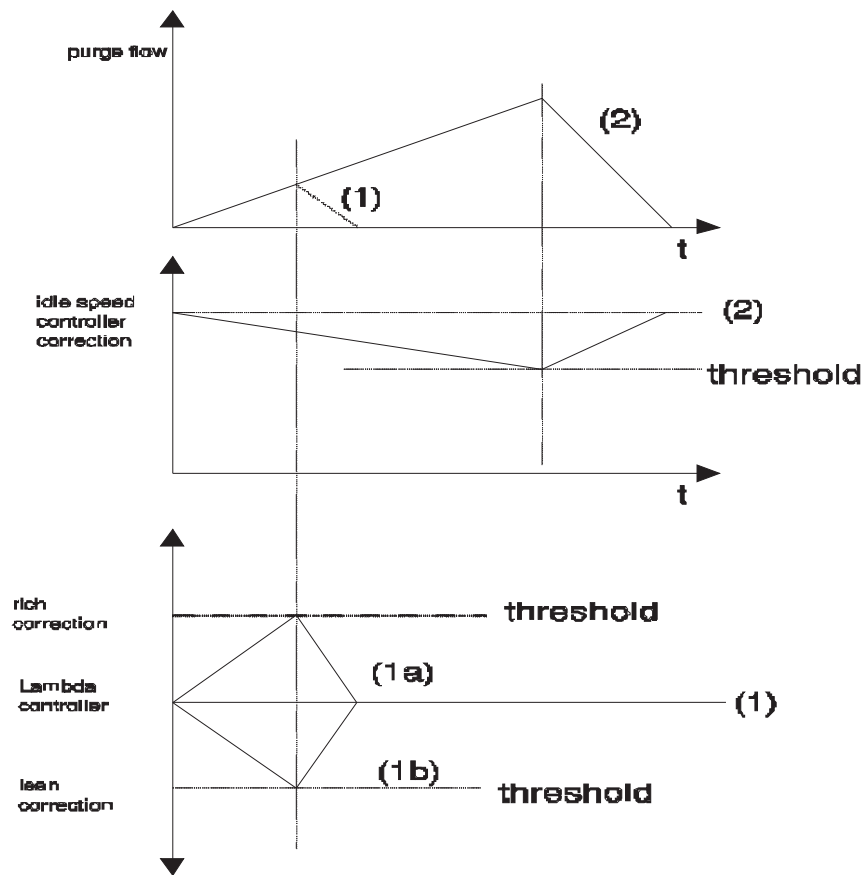
Figure 9: EVAP Purge System

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4.2.2 Monitoring function description

For stoichiometric mixture flow through the EVAP Purge Valve:

In this case, the Lambda controller does not need to compensate for a deviation. However, when the EVAP Purge Valve is completely opened, the cylinder charge increases significantly. Therefore, flow through the throttle unit must be decreased in order to maintain the desired idle speed. Flow through the EVAP Purge Valve is assumed when the flow through the throttle unit is reduced by idle control. If both mixture compensation and reduction of the airflow through the throttle unit does not occur for two diagnosis cycles, then a defective EVAP Purge Valve is assumed and the MIL is illuminated.



Open purge valve and monitor effects of purge flow:

- (1) Lambda purge flow $\neq 1$: Abort if fresh air (1a) or HC (1b) detected
- (2) Lambda purge flow = 1: Throttle unit actuator will reduce the flow rate through the throttle due to additional flow through purge valve

MIL will be illuminated if none of said effects occurs.

Figure 10: Flow chart Purge Check threshold

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5 SECONDARY AIR SYSTEM MONITORING

5.1 System monitoring based on pressure sensor – 2 bank independent secondary air circuits

Applicable only for OBD group:

OBD Group Name	Test group	Engine	Models	Standard	Controller / OBD II strategy
CVW-W	CBEXV06.0501	6.0 W12T - 2 bank	Continental	LEV II Bin 5	Bosch ME7.1.1 VW-W

5.1.1 General Description

After a cold start condition (e.g. 5 - 40°C) the air system blows for a certain time air into the exhaust manifold. The exhaust gases will be enriched with oxygen and a post-combustion of HC and CO occurs. By this exothermic reaction the exhaust system will be heated and the time to reach the light-off temperature of the catalyst will be accelerated.

The system comprises two airflow-independent secondary air injection circuits; one for each bank of the W12 cylinder engine. Refer to Figure 11.

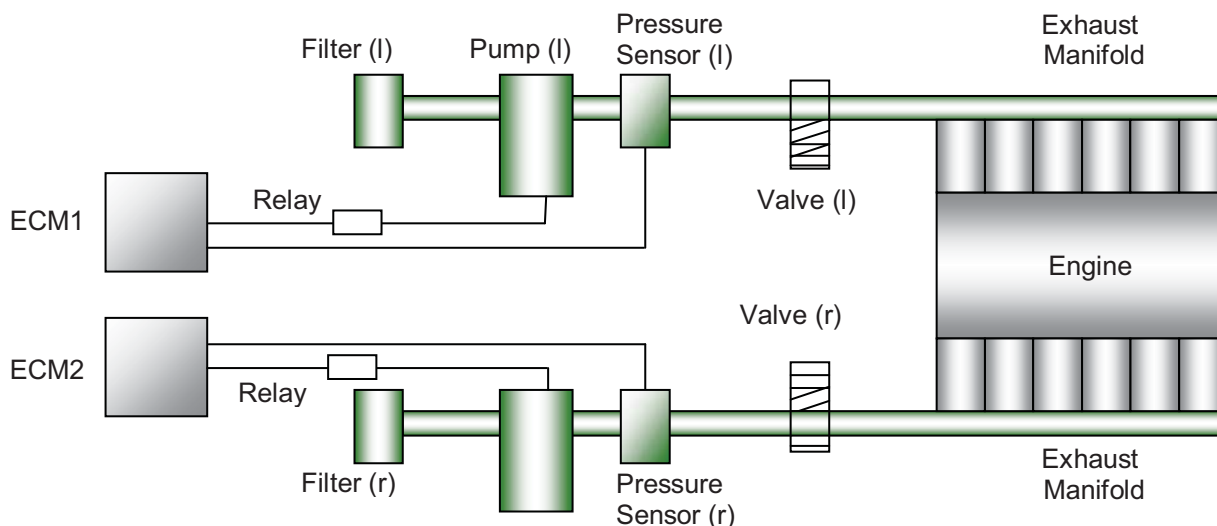


Figure 11: W12 Engine Secondary Air System components

5.1.2 Monitoring Structure

The monitor of the secondary air system comprises a passive function that is carried out during normal secondary air injection while the engine is cold started.

At idle state or under part load engine condition, the secondary air pumps are switched on and the valves open under the pressure of the pumps. The pressure sensors evaluate the pressure of each bank between the air pump and air valve.

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5.1.3 Monitoring Conditions

To start the monitoring function the following conditions have to be satisfied:

- Pressure sensor readiness
- Engine coolant temperature below threshold (e.g. 60°C)
- No output stage error from secondary air pump relay

Monitoring Function Description (refer to Figure 12 and Figure 13)

Phase 0

During ECM initialization the measured atmospheric pressure is measured and stored. An initial rationality check is conducted through comparison of the pressure readings on the air pressure sensor to the atmospheric pressure. If the variance between these sensors is outside a diagnostic threshold then a fault code will be stored indicating a defective pressure sensor.

Phase 1

During catalyst heat up the secondary air pump is switched, the air valve opens and the absolute pressure reading from the secondary air pressure sensor is taken. This is compared with the ambient pressure to generate a pressure bias measure. If this value is greater than a given maximum threshold a fault code will be generated to record an emission related block within the system. If the value is below a diagnostic threshold, a leak fault code will be generated.

Phase 2

Following air pump switch off (air valve closed) the air pressure value at the pressure sensor is taken again and again compared to the atmospheric measure. If the calculation returns a result showing this value to be lower than a minimum threshold then a defective air pressure sensor reading will be recorded, whilst if the value is above a maximum threshold then a pump fault code will be stored.

In addition, a secondary air valve check is performed during Phase 2. If the mean secondary air pressure value exceeds a threshold and fluctuation of the pressure outside minimum and maximum thresholds is present, then a leakage of the valve is indicated.

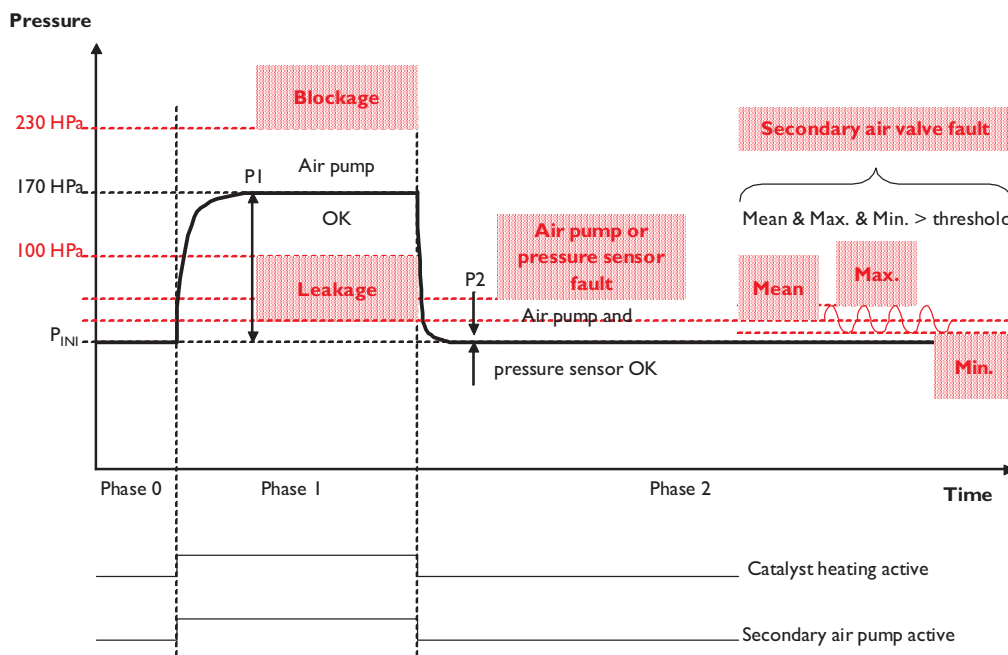
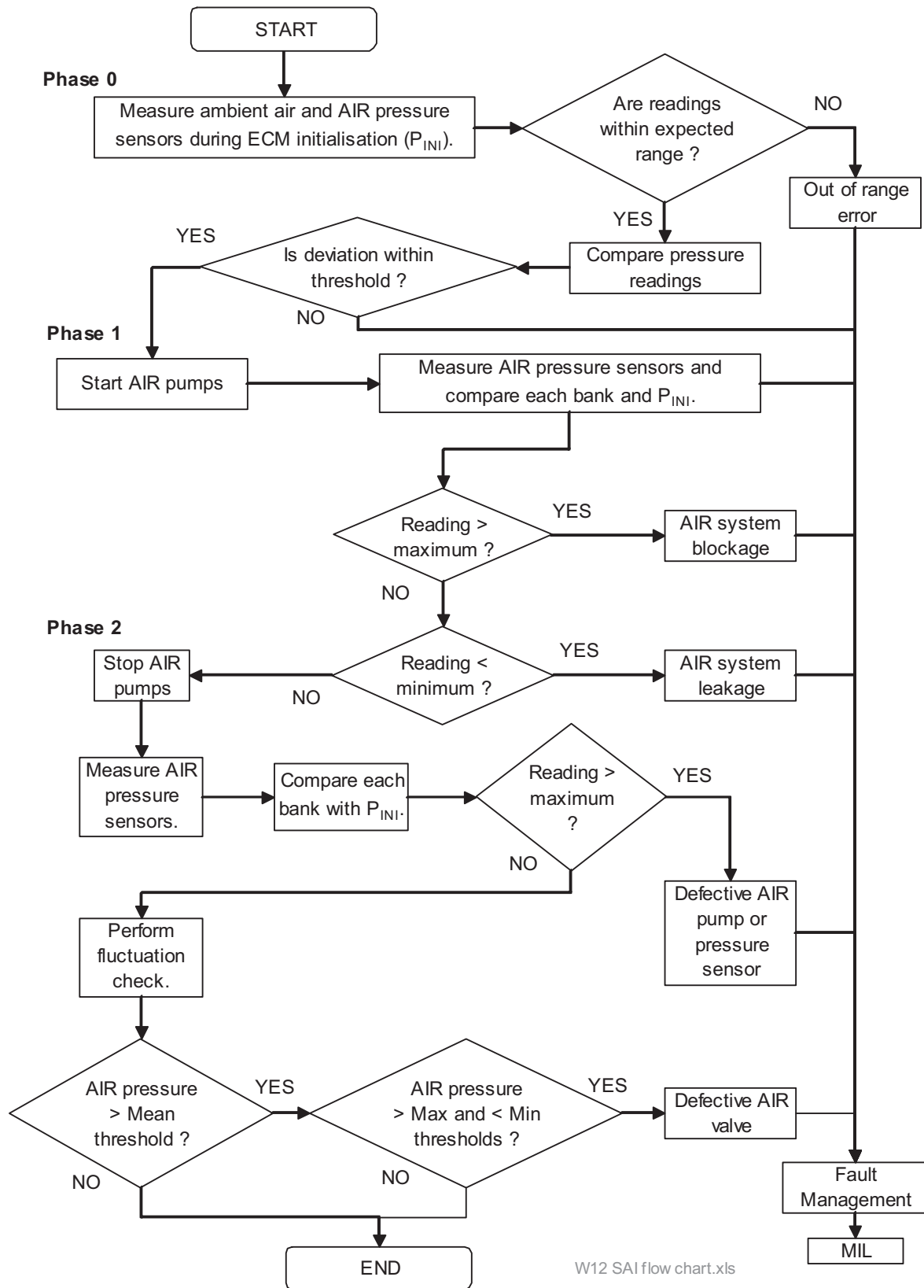


Figure 12: Phases of AIR system Monitoring (W12)

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W12 SAI flow chart.xls

Figure 13: Flow chart Secondary Air System monitoring

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6 FUEL SYSTEM MONITORING

6.1 Lambda-Control Strategies

Tests with current catalysts show, that the conversion of rich gases like HC and CO can better be achieved, the more the air / fuel ratio is on the lean side. On the other hand, the conversion efficiency for NOx is better, the more the air / fuel ratio is on the rich side. Therefore, the modulation of the engine-out air / fuel ratio has the effect, that inside the catalyst are sections which have an excess of stored oxygen and some which have a lack of stored oxygen.

In the sections with oxygen excess, this oxygen can be released, bringing the air / fuel ratio onto the lean side and leading to improved HC / CO conversion. In the sections with a lack of oxygen, this brings the air / fuel ratio to the rich side and leads to improved NOx conversion. Due to the trim control with the downstream sensor, it is ensured that the mean air fuel ratio inside the catalyst stays at the stoichiometric point.

There are three different Lambda control strategies. They are different in the main control variables. The application of one of these control strategies is optimized for specific assembly of catalysts and oxygen sensors.

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6.1.1 Fixed Frequency

Applicable to OBD groups:

OBD Group Name	Test group	Engine	Models	Standard	Controller / OBD II strategy
CVW-W	CBEXV06.0501	6.0 W12T - 2 bank	Continental	LEV II Bin 5	Bosch ME7.1.1 VW-W

General description

In this lambda control strategy the main control variable is the lambda value. Because of best catalyst conversion of exhaust gases the engine should operate with a lambda = 1 air / fuel mixture. The catalyst is able to equalize little variation of lambda because of its oxygen storage capability.

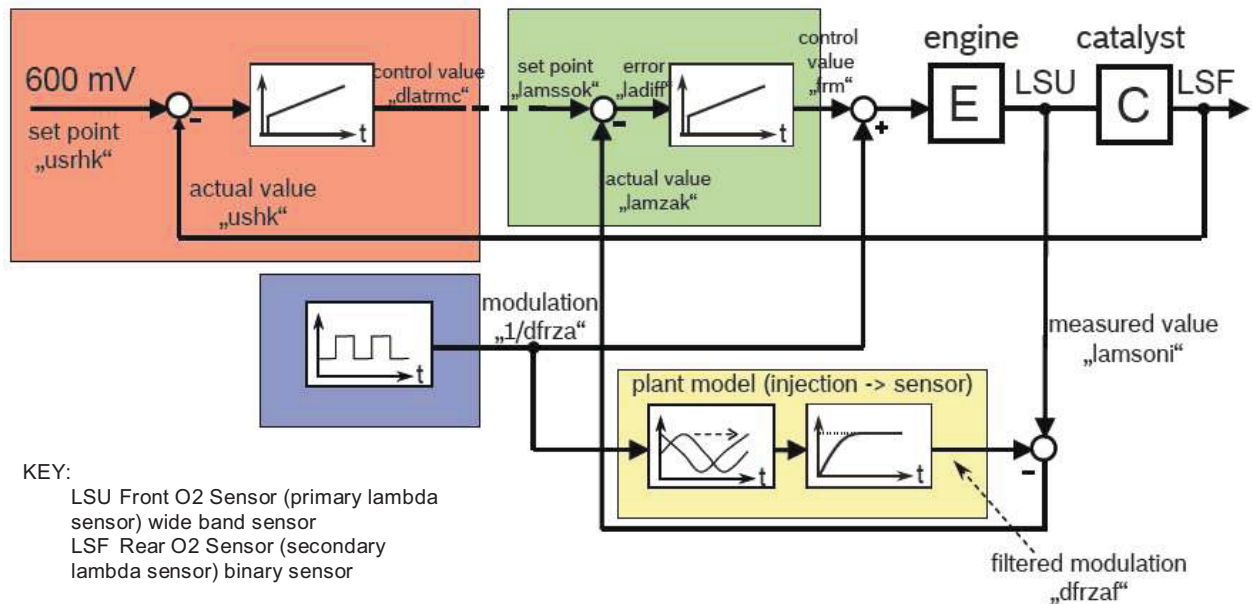


Figure 14: Overview of modulation with fixed frequency

An overview of lambda modulation with fixed frequency is given above (Figure 14). The green box shows the "inner" control, which is responsible for adjusting lambda to value 1. This control loop is also called lead control.

- Lambda = 1 so that the catalyst has the best conversion efficiency
- The catalyst's oxygen storage capacity (OSC) allows it to balance small lambda variations
- Two controls in series
- Inner control regulates lambda = 1 (lead control)
- Fixed frequency: Forced modulation (according to fixed frequency) in inner control loop to optimise conversion (controlled variable is lambda)
- Outer control regulates trim control to 600 mV (setpoint)
- The outer control loop is intended to ensure stoichiometric mixture on a long term basis

Below is an example measurement of modulation with fixed frequency (Figure 15).

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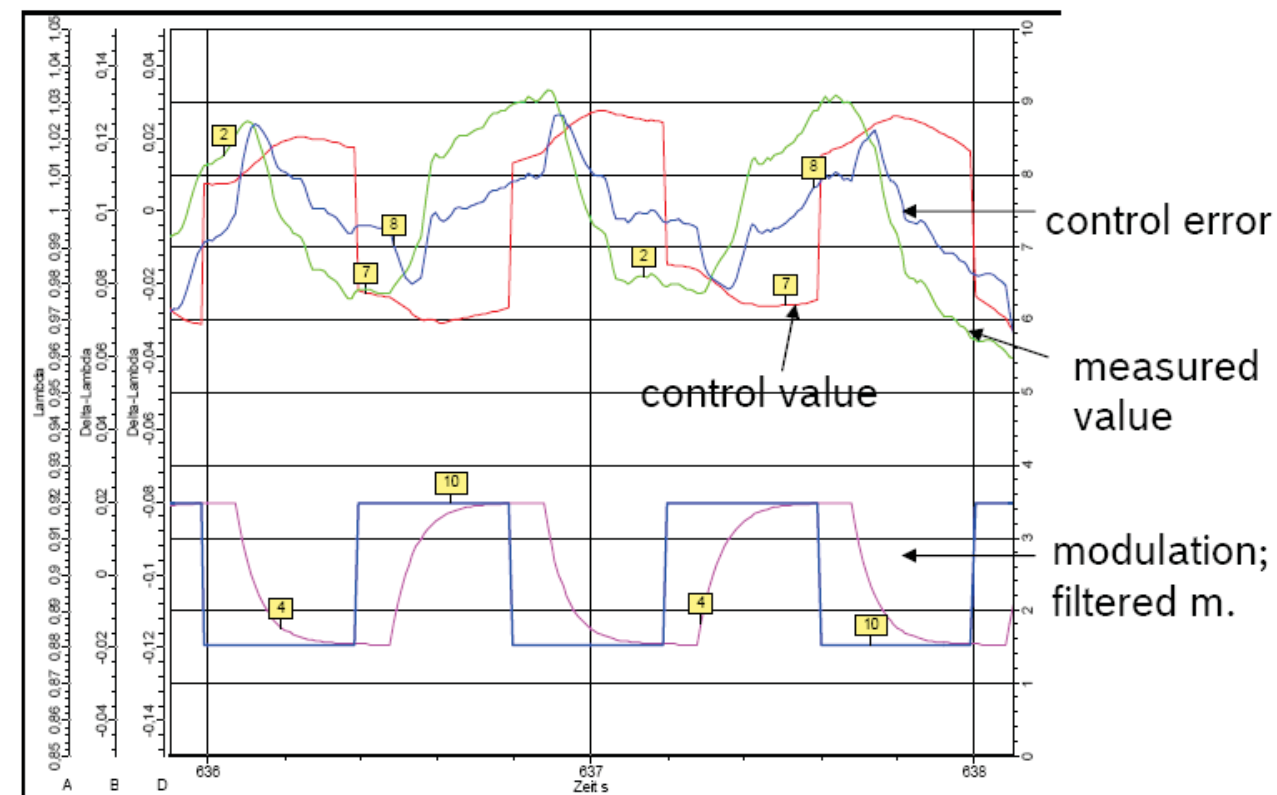


Figure 15: Measurement of modulation with fixed frequency

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6.2 Air / fuel system monitoring

6.2.1 General Description

6.2.1.1 Mixture Pilot Control

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

6.2.1.2 Lambda-controller

The ECM compares the Oxygen sensor signal upstream the catalyst with a reference value and calculates a correction factor for the pilot control.

6.2.2 Monitoring function description

6.2.2.1 Adaptive pilot control

Drifts and faults in sensors and actuators of the fuel delivery system as well as unmeasured air leakage influence the pilot control. The controller corrects amplitudes increases. If there is different correction values needed in different load speed ranges, a certain time passes until the correction is complete. The correction values will be determined in three different ranges.

6.2.2.2 Fuel trim

Refer to Figure 16 and Figure 18.

The basic air/fuel ratio control using the signal from the front O₂ sensors(s) is corrected by an adaptation calculation. This adaptation results in a factor which is applicable for the whole working range. (e.g. 20%)

A further trim control based on the signal(s) from the rear O₂ sensor(s) is correcting the adaption factor. Therefore this trim control is working in the same way in the whole range.

If the trim control reaches the allowed limit (e.g. 2%) the fault code for fuel delivery trim control is set.

Any deviation from the characteristic curve of oxygen sensor upstream catalyst due to poison will be detected by the control loop downstream catalyst.

6.2.2.3 Fuel Trim Rationality Fault

A rationality fault is set when the absolute value of the integrated portion of the air / fuel mixture control (continuous) on the downstream side of the main catalyst exceeds a calibration.

Monitoring Conditions for Rationality Fault:

- the condition for air / fuel mixture closed loop control is fulfilled **and**
- a delay time has elapsed.

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6.2.3 Chart(s) and flow chart(s)

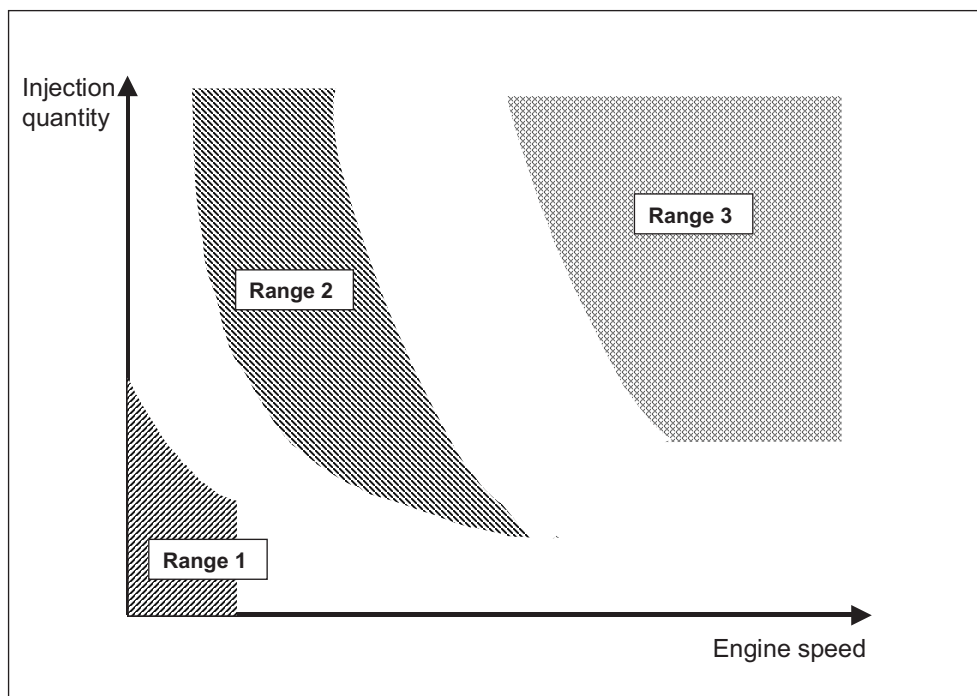


Figure 16: Lambda range – Fuel Trim

Lambda deviations in **range 1** are compensated by an additive correction value multiplied by an engine speed term. This creates an additive correction per time unit.

Lambda deviations in **range 2** are compensated by multiplication of a factor.

Lambda deviations in **range 3** are compensated by multiplication of a factor (optional depending on individual calibration).

A combination of all two (three) ranges will be correctly separated and compensated.

Each value is adapted in its corresponding range only. But each adaptive value corrects the pilot control within the whole load/speed range by using a linear interpolation formula. The stored adaptive values are included in the calculation of the pilot control just before the closed loop control is active.

Diagnosis of the fuel delivery system

Faults in the fuel delivery system can occur which cannot be compensated for by the adaptive pilot control.

In this case, the adaptive values exceed a predetermined range.

If the adaptive values exceed their plausible ranges, then the MIL is illuminated and the fault is stored.

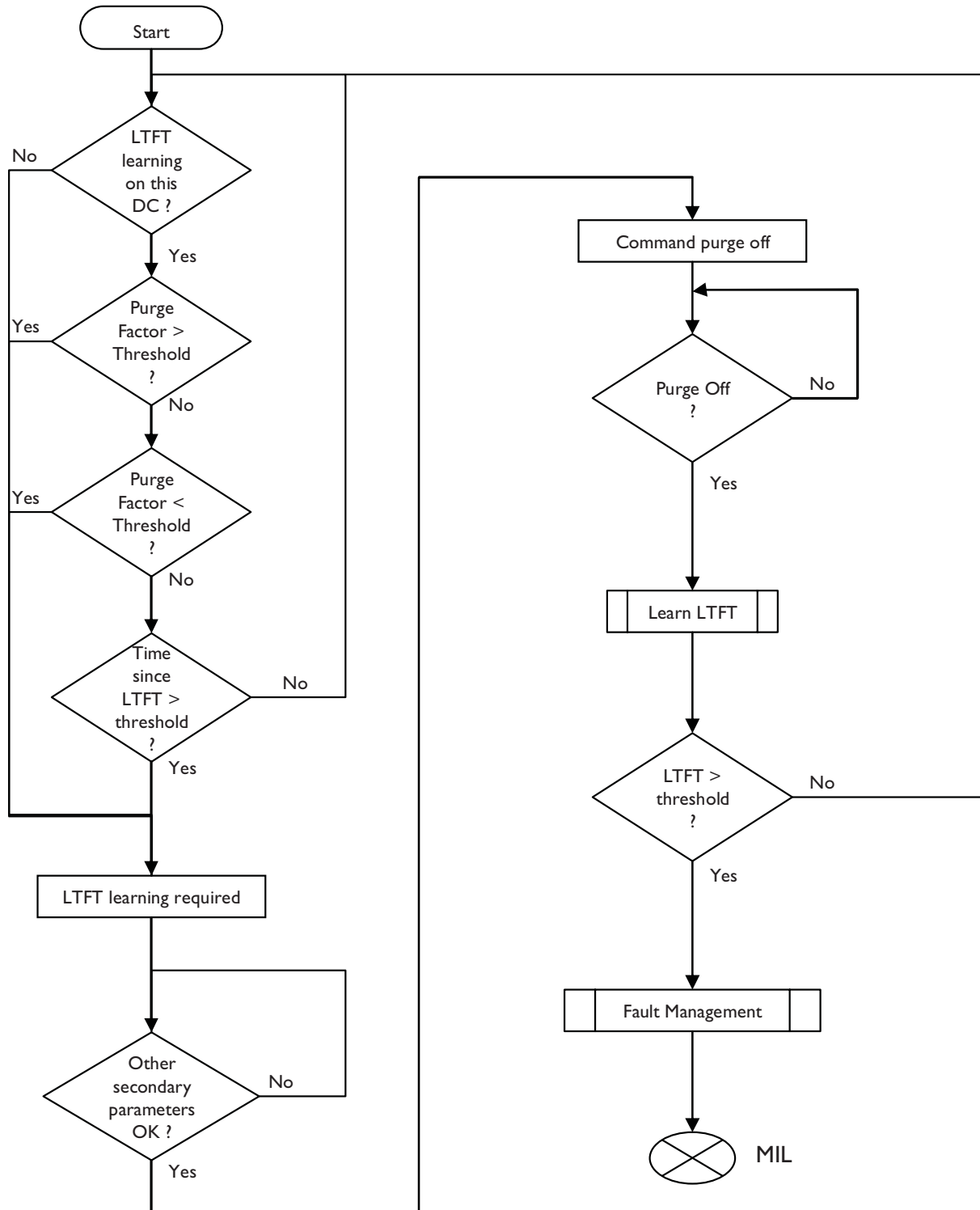


Figure 17: Flow chart: Fuel System monitoring

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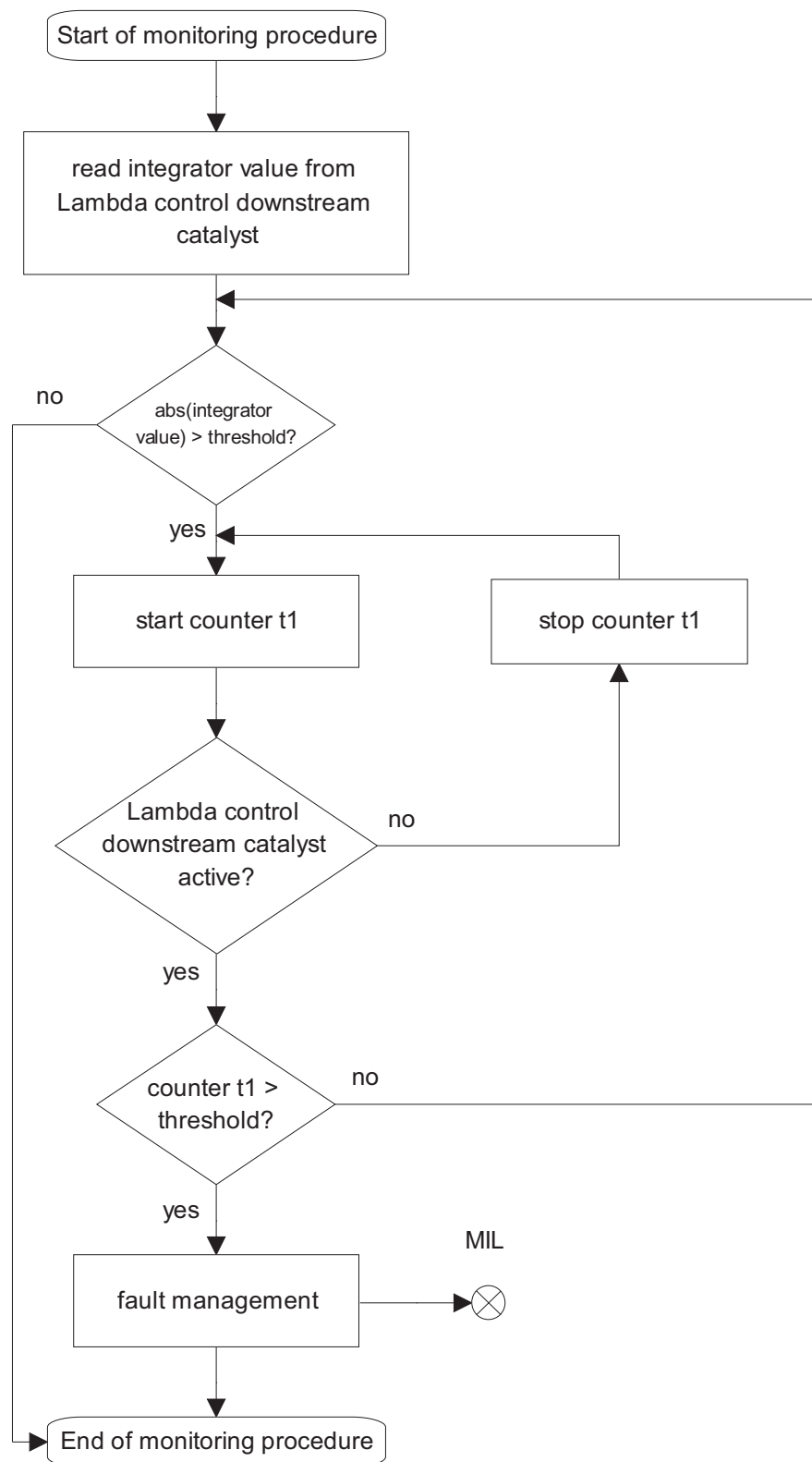


Figure 18: Flow chart: Fuel Trim

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7 EXHAUST GAS (OXYGEN) SENSOR MONITORING

The table shows the different oxygen sensor configurations applicable to different OBD and Test groups. All concepts use the Bosch LSU "universal" or "wide band" sensor for upstream (primary) fuelling control and the Bosch LSF "switching" sensor for downstream (secondary) fuel trim and monitoring purposes. In general, the monitoring strategies are common for each configuration; where differences exist specific descriptions are provided with tables to indicate applicability.

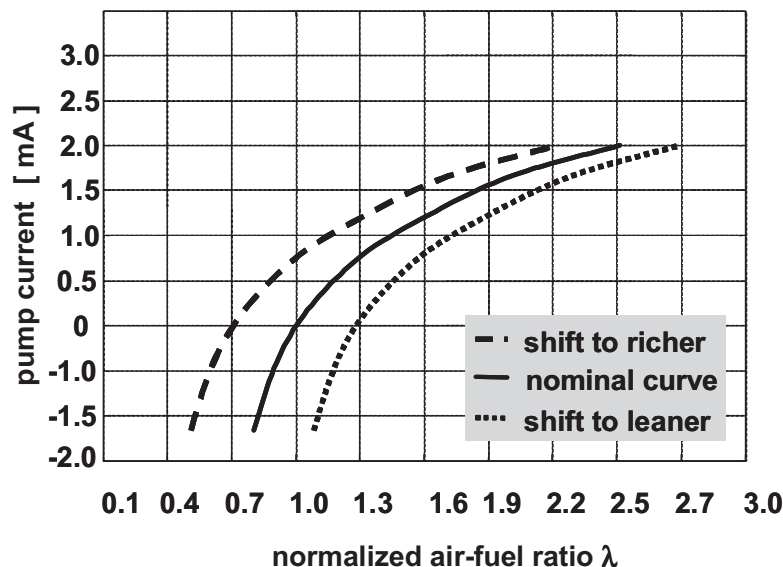
OBD Group Name	Test group	Engine	Models	Standard	Oxygen Sensor Configuration
CVW-W	CBEXV06.0501	6.0 W12T - 2 bank	Continental	LEV II Bin 5	2 sensors x 2 banks

7.1 Oxygen Sensor Functional Monitoring

7.1.1 Rationality check of the upstream (primary) oxygen sensor

This document describes the sum of all possible rationality checks of the upstream oxygen sensor (HO2S). Depending on the exact system configuration only a subset of the described checks, monitoring conditions, IUMPR functions and flowcharts might be performed.

This diagnostic function continuously checks the heated upstream oxygen sensor's response signal by comparing it with that of the downstream oxygen sensor or by utilizing technical parameters of the engine control system. A faulty sensor signal is implied when the characteristic lambda curve derived from the upstream HO2S's response signal (see Figure 19 below) indicates an air-fuel mixture that is leaner or richer than that expected from the nominal curve.



Curves are not drawn to scale.

Figure 19: Illustration of shifts in the characteristic lambda curve of the upstream oxygen sensor's (LSU) response signal.

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7.1.1.1 Offset check

Refer to Figure 20.

The integral component of the downstream lambda controller is interpreted as a sensor/fuel trim system fault. A shift is acceptable (because of tolerances) only when it lies between a calibrated minimum and maximum threshold value.

If the integral component of the downstream lambda controller exceeds the calibrated maximum 'sensor' threshold value for a calibrated de-bouncing delay, an unacceptable 'shift to lean' is detected and a maximum fault PLLSU is set.

If the integral component of the downstream lambda controller exceeds the calibrated maximum 'fuel trim' threshold value for a calibrated de-bouncing delay, an unacceptable 'shift to lean' is detected and a maximum fault FTDLA is set.

If the integral component of the downstream lambda controller lies below the calibrated minimum 'sensor' threshold value for a calibrated de-bouncing delay, an unacceptable 'shift to rich' is detected and a minimum fault PLLSU is set.

If the integral component of the downstream lambda controller lies below the calibrated minimum 'fuel trim' threshold value for a calibrated de-bouncing delay, an unacceptable 'shift to rich' is detected and a minimum fault FTDLA is set.

Note:

Normally the rationality check monitors aging effects of the HO2S or other effects in the exhaust system. This aging effect develops very slowly. Due to this reason the integral component of the downstream lambda controller will change slowly too. Emissions are quite well during this behavior. If the integral component exceeds an irrational threshold a 'fuel trim' fault is set. Such a malfunction can not be found in one FTP test cycle.

To detect suddenly occurring faults a step function is implemented. On basis of the control difference of the rear sensor voltage and the control value of the downstream lambda controller a predicted magnitude of failure is made which results in a strongly reduced diagnosis time.

Monitoring conditions for offset check:

- engine start has finished
- no critical misfire rate
- lambda control active for calibrated period of time
 - after critical misfire rate **or**
 - in case of second driving cycle to confirm P-code
- diagnoses of downstream HO2S performed without any fault
- diagnosis of upstream HO2S' voltage performed without faults
- diagnosis of 'exchanged upstream HO2S' performed without faults
- no fault of 'heater influence on upstream HO2S' diagnostic
- no fault of 'upstream HO2S' response rate' diagnostic
- no fault of 'CJ125 evaluation IC of the upstream HO2S' diagnostic (i.e. no electrical faults and no communication errors)
- no fault of 'upstream HO2S heater' diagnostic
- no fault of 'upstream HO2S heater power stage' diagnostic
- no lean shift fault in last driving cycle without cooled off sensor
- no fault de-bouncing active
- downstream HO2S switches from lean to rich or vice versa during de-bouncing
- enabled by diagnostic scheduler

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7.1.1.2 Rationality check with help of upstream and downstream HO2S signals

The following checks determine, in selected operating points, if the deviation of the upstream HO2S signal is out of certain limits using upstream and downstream oxygen sensor signals and closed loop controller condition as main parameters. Refer to Figure 20 and Figure 21.

7.1.1.3 Rationality check - shift to lean

A shift of the upstream HO2S characteristic lambda curve towards lean will cause a rich A/F ratio at the downstream HO2S. Because of an airtight exhaust system the mixture at position of upstream HO2S and the mixture at position of downstream HO2S have to be equal. So lean mixture at upstream and rich mixture at downstream HO2S is not rational and shows a malfunction.

The following methods are performed.

Method A1 - shift to lean

If the upstream HO2S measures a lean mixture and the downstream HO2S measures a rich mixture and the monitoring conditions are simultaneously fulfilled, a malfunction is detected and a rationality fault PLLSU is set after de-bouncing.

Monitoring conditions:

- both the upstream and downstream oxygen sensors are ready for operation
- one of the following 2 conditions are fulfilled
 1. The following conditions are fulfilled:
 - Integral component and the proportional component both have the same sign, or the absolute value of the proportional component is greater than (Integral component + calibration).
 - The proportional component of the downstream lambda controller is active.
 - de-bouncing is finished (see the following conditions):
 - > integrated mass airflow exceeds calibrated threshold
 - > downstream HO2S switches from lean to rich or vice versa
 2. The following conditions are fulfilled:
 - Desired normalized A/F-ratio set point value exceeds calibrated threshold (lean region).
 - Closed loop lambda control is active.
 - de-bouncing is finished (see the following conditions):
 - > integrated mass airflow exceeds calibrated threshold
 - > downstream HO2S switches from lean to rich or vice versa

Method B1 – shift to lean

If the normalized A/F-ratio set point value of the upstream HO2S lies in a desired region (see monitoring conditions) and the downstream HO2S measures a rich mixture and the monitoring conditions are simultaneously fulfilled for a calibrated period of time a malfunction is detected and a rationality fault PLLSU is set after de-bouncing.

Monitoring condition:

- both the upstream and downstream oxygen sensors are ready for operation
- the lambda controller has not reached its limit in the lean direction
- diagnoses of downstream HO2S performed without any fault
- one of the following 2 conditions is fulfilled
 1. The following conditions are fulfilled:
 - desired normalized A/F-ratio setpoint value equals one
 - the absolute value of the proportional component of the rear controller is greater than calibration and the integral component and the proportional component both have the same sign, or the absolute value of the proportional component is greater than (Integral component + calibration).
 - the proportional component of the downstream lambda controller is active
 - de-bouncing is finished (see the following conditions):
 - > integrated mass airflow exceeds calibrated threshold
 - > downstream HO2S switches from lean to rich or vice versa

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2. The following conditions are fulfilled:
 - desired normalized A/F-ratio setpoint value exceeds calibrated threshold (lean region)
 - closed loop lambda control is active
 - de-bouncing is finished (see the following conditions):
 - > integrated mass airflow exceeds calibrated threshold
 - > downstream HO2S switches from lean to rich or vice versa

7.1.1.3.1 Rationality check - shift to rich

A shift of the upstream HO2S characteristic lambda curve towards rich will cause a lean A/F ratio at the downstream HO2S. Because of an airtight exhaust system the mixture at position of upstream HO2S and the mixture at position of downstream HO2S have to be equal. So rich mixture at upstream and lean mixture at downstream HO2S is not rational and shows a malfunction.

The following methods are performed.

Method A2 - shift to rich

If the upstream HO2S measures a rich mixture and the downstream HO2S measures a lean mixture and the monitoring conditions are simultaneously fulfilled, a malfunction is detected and a signal fault PLLSU is set after de-bouncing.

Monitoring conditions:

- Both the upstream and downstream oxygen sensors are ready for operation.
- One of the following 2 conditions is fulfilled
 1. The following conditions are fulfilled:
 - The lambda controller has reached its limit in the lean direction.
 - de-bouncing is finished (see the following conditions):
 - > integrated mass airflow exceeds calibrated threshold
 2. The following conditions are fulfilled:
 - Diagnosis of downstream HO2S performed without any fault.
 - The proportional component of the downstream lambda controller is active.
 - The absolute value of the proportional component of the rear controller is greater than calibration and the integral component and the proportional component both have the same sign, or the absolute value of the proportional component is greater than (Integral component + calibration).
 - de-bouncing is finished (see the following conditions):
 - > integrated mass airflow exceeds calibrated threshold

Method B2 - shift to rich

If the normalized A/F-ratio set point value of the upstream HO2S lies in a desired region (see monitoring conditions) and the downstream HO2S measures a lean mixture and the monitoring conditions are simultaneously fulfilled for a calibrated period of time, a malfunction is detected and a rationality fault PLLSU is set after de-bouncing.

Monitoring conditions:

- Both the upstream and downstream oxygen sensors are ready for operation.
- The lambda controller has not reached its limit in the rich direction.
- Diagnoses of downstream HO2S performed without any fault.
- one of the following 2 conditions is fulfilled
 1. The following conditions are fulfilled:
 - Desired normalized A/F-ratio set point value equals one.
 - The absolute value of the proportional component of the rear controller is greater than calibration and the integral component and the proportional component both have the same sign, or the absolute value of the proportional component is greater than (Integral component + calibration).
 - The proportional component of the downstream lambda controller is active.
 - de-bouncing is finished (see the following conditions):
 - > integrated mass airflow exceeds calibrated threshold
 - > downstream HO2S switches from lean to rich or vice versa

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2. The following conditions are fulfilled:
- desired normalized A/F-ratio set point value lies below calibrated threshold (rich region)
 - closed loop lambda control is active
 - de-bouncing is finished (see the following conditions):
 - > integrated mass airflow exceeds calibrated threshold
 - > downstream HO2S switches from lean to rich or vice versa

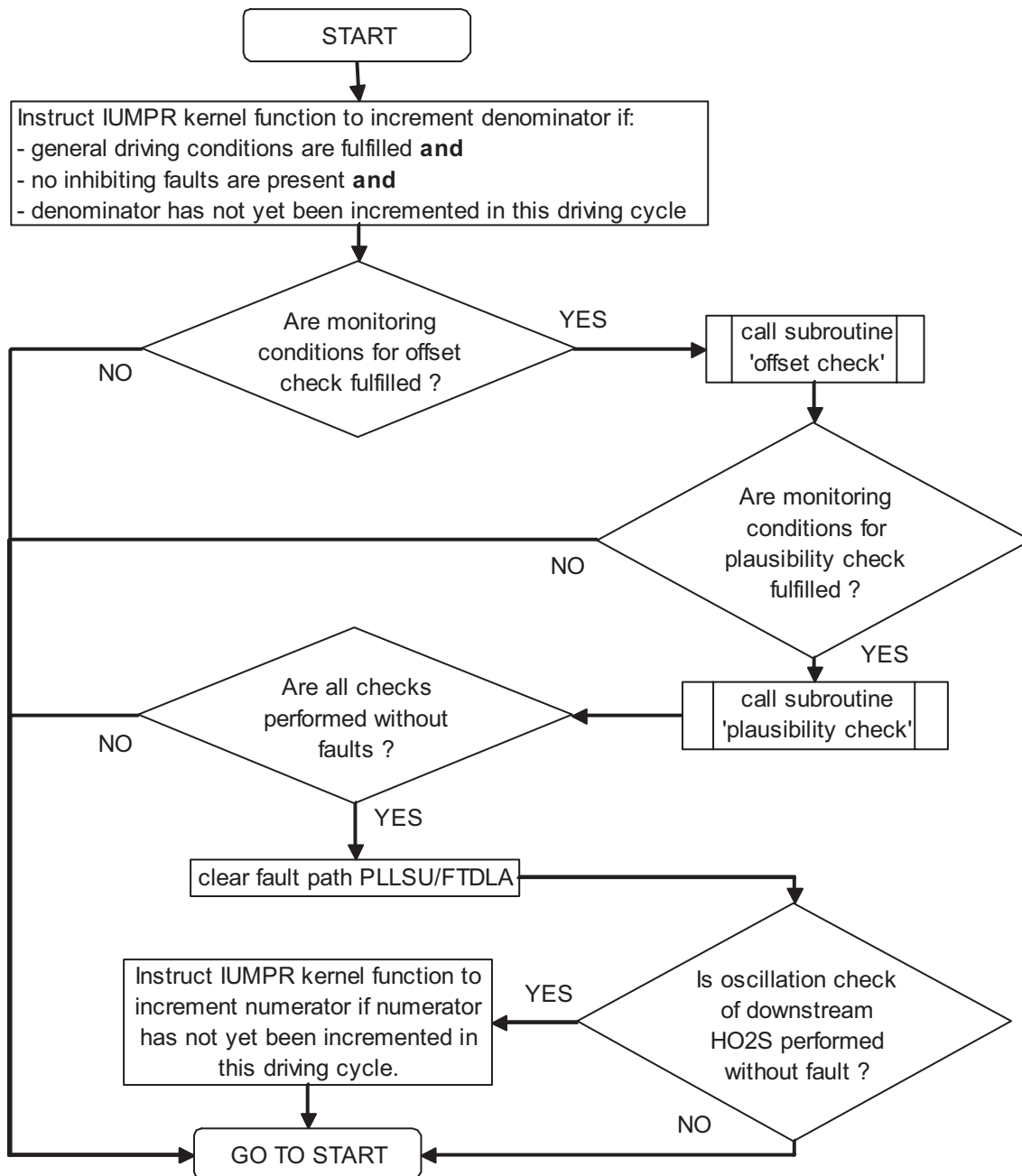


Figure 20: Flow chart Offset check

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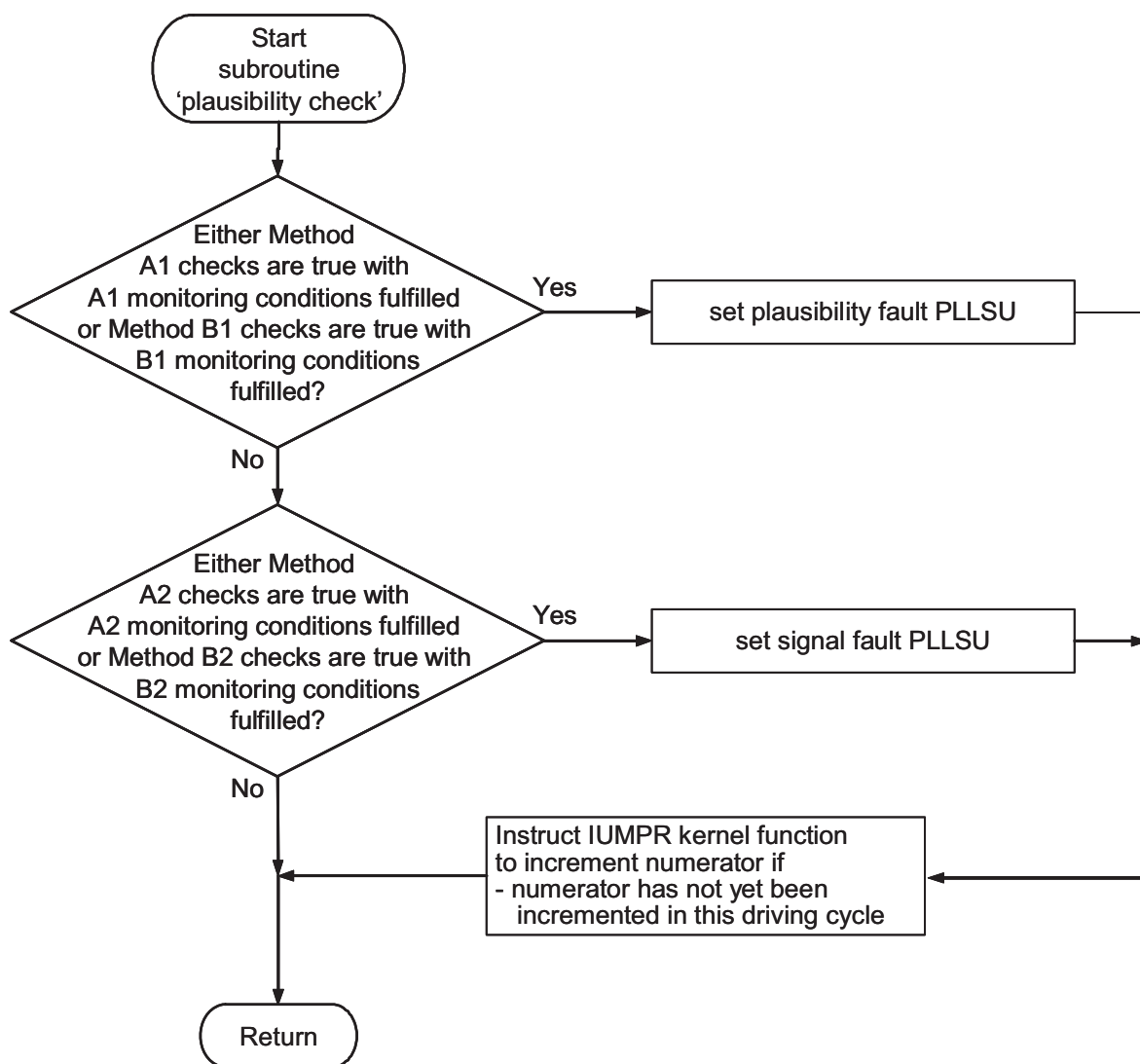


Figure 21: Flow chart Rationality check

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7.1.2.1 Description of slope ratio response rate monitoring strategy

There are different diagnostic strategies available, within Bosch ECM families, for primary oxygen sensor response rate. These are listed, by Test Group, in the VW Group Common OBD Technical Description as Slope Ratio, Area Evaluation and Amplitude Ratio. For the VW Test Groups using the Bosch ME7 ECM, only the Slope Ratio strategy is used. Differences exist with respect to the numerical check of ratio within the slope check algorithm according to Test Group. Refer to the applicability table in section "Description of algorithm for slope check". Figure 25 provides an overview of the slope check where the numerical check is included and Figure 26 where the numerical check is excluded.

7.1.2.1.1 Fault code: P0133 / P0153 (DYLSUmin)

Aging, contamination and improper heating of primary HO₂S slows down the sensor's response rate. A slow response rate can lead to higher emissions. The diagnostic function monitors the HO₂S response rate and is performed multiple each driving cycle.

7.1.2.1.2 General description

Refer to Figure 23. The diagnosis is based on the calculation of a ratio composed of two slopes of the sensor signal. In the lambda control a forced amplitude (square wave signal) is superimposed onto the lambda set-point ($\lambda=1$). This causes a modulated expected signal, which oscillates around lambda $\lambda=1$ value. The maximum and minimum slope, which appears in an established measurement window via the modulation in a half-wave, is compared to the maximum and minimum slope of the measured broadband probe signal. The ratio of the values yields the dynamic value of the probe.

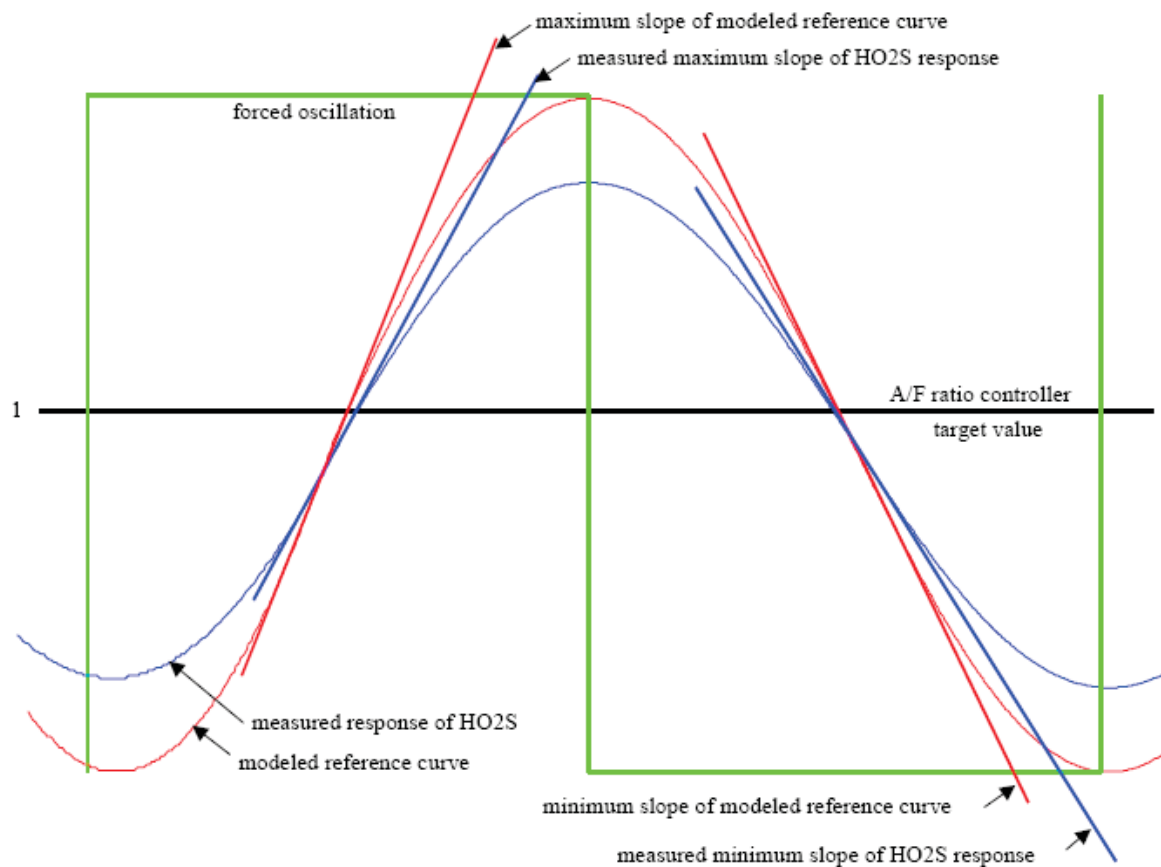


Figure 23: Primary HO₂S – principle of response rate slope calculation

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7.1.2.1.3 Diagnostic enable / disable conditions

Physical parameters:

- Linear lambda sensor is ready for operation
- Linear sensor pumping current open circuit monitor completed without fault
- Forced amplitude is active and exceeds a minimum threshold
- Lambda control value does not stuck at minimum or maximum limit
- Engine coolant temperature is greater than a temperature threshold
- Engine speed is located in a defined speed range
- Engine load is located in a defined load range
- Loading factor of the charcoal canister during evaporation purge is less than a threshold or the evaporation purge is inactive
- All injection valves are actuated and two camshaft rotations occur after cylinder fuel cut off

Signal evaluation / validation:

- The measured lambda signal is within in the defined lambda range
- The gradient of the engine load is below a threshold
- Deviation of ceramic temperature from the set-point temperature of the linear lambda sensor is below a limit, so that the minimum temperature for the operational readiness of the probe is given
- Sensor hexagonal temperature (temperature of the sensor housing) is below a threshold

Disable conditions:

- Enabling the diagnosis system manager, directions: See .DTC Inhibitor List., no faults obstruct the monitor

7.1.2.1.4 Details: Calculation of modelled (expected) and measured lambda

A lambda value is calculated from the signal of the lambda control output over the dead time of control travel and the dead time constants, which are speed and load dependent, as well as from a subsequent low and high pass filtering. This describes the expected lambda at the installation position of the linear O2S in the exhaust system. The measured lambda at this location is likewise filtered by a low and high pass with the same filter constants. The filtering creates a noise and mean value adjusted signal.

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7.1.2.1.5 Description of algorithm for slope check

OBD Group Name	Test group	Engine	Models	Standard	Numerical check of ratio
CVW-W	CBEXV06.0501	6.0 W12T - 2 bank	Continental	LEV II Bin 5	Step 6 excluded (see also Figure 26)

Refer to Figure 24. Steps:

1. All enable criteria must be met.
2. Determination of measurement window:
Starting with the falling edge (plus transport time) of the modulation, two measurement windows (with a max. 500 ms duration) are calculated/commanded within one period of the modulation.
3. Determination of maximum/minimum slopes:
Within the two measurement windows, the maximum and the minimum (negative) slope is selected for both the (filtered) measured and expected lambda-trace.
4. Rationality check expected slope:
Expected slope has to be greater than calibrated value.
5. Calculation of slope ratios:
Rising signal ratio = max. measured / max. expected slope
Falling signal ratio = min. measured / min. expected slope
6. Numerical check of ratio:
Calculation is valid if minimum selection of the two ratios (for rising / falling signal) is greater than 0.01 and smaller than 4.0 and smaller than calibrated threshold.
7. Calculation of mean dynamic value Front O2S:
Mean dynamic-value Front O2S = low pass filtered value (recursive filter) of N samples.
8. Fault determination:
If mean dynamic-value Front O2S < fault threshold and N samples > counter → set fault.

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Additional remarks on steps 4 and 6:

Although steps 4 and 6 serve as secondary parameters, they impact neither the monitoring frequency nor the disablement of the monitor.

Step 4 excludes the evaluation of slopes when the expected slope is getting too small. The calculation of the expected slope is model-based and depends only on engine speed and load. Therefore, expected slope behaves the same on a system with a nominal O2S as on a system with a deteriorated (slow transition, delayed response) O2S.

Step 6 excludes values which are physically not plausible. Values > 4 or < 0.01 would only distort the calculation of the mean dynamic-value.

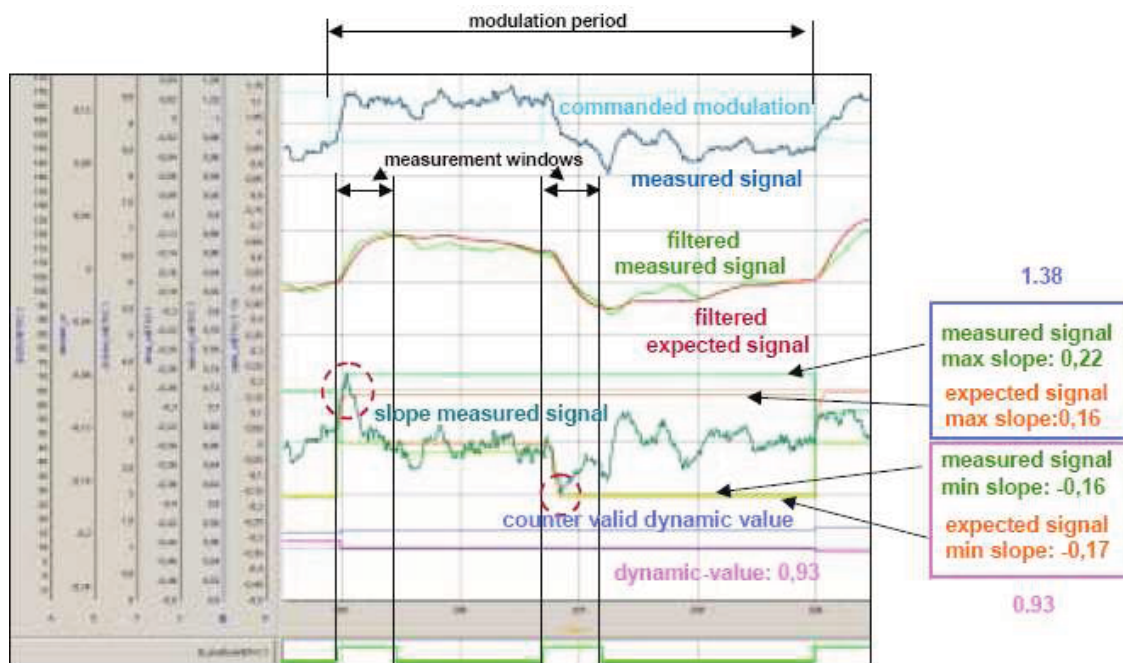


Figure 24: Primary HO2S - measurement window

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7.1.2.1.6 Effect of the delay diagnosis on the formation of the dynamic value of the linear sensor and possible test results

The slope-dynamic monitor of the linear sensor is a multiple running diagnosis. There is a multiple calculation of new dynamic raw values, which are filtered and counted. Thereby, the currently displayed dynamic values are immediately changed across the number of measurement results.

Possible result cases:

Case 1: pass result.

If the counter exceeds a threshold 1 (test complete) and the additional delay monitor is completed, then test complete of the total response rate monitor is set. If the new dynamic value is higher than a fault threshold, an OK result is reported.

Case 2: fail result from transient check.

The current dynamic value causes a fault without the additional delay monitor is completed, if it is less than or equal to the fault threshold. The counter must have again exceeded threshold 1 (test complete).

Case 3: fail result from delay check.

During an identified delay fault from the additional delay monitor, the current dynamic value is immediately replaced by a very low dynamic value (below the fault threshold), regardless of the position of the counter.

Detection of slow response of primary HO2S:

In cases 2 and 3 a dynamic fault is set, because the dynamic value reached or fell below the fault threshold in both cases.

7.1.2.1.7 Effect of fault suspicion from catalyst monitor on the fault threshold of the response rate monitor

A slow sensor response rate causes an insufficiently measured OSC via the catalyst monitor. If the catalyst diagnosis produces a fault suspicion, a higher fault threshold will be switched to. A higher, better dynamic value is therefore required in order to confirm the fault suspicion in the catalyst monitor. The catalyst fault is not confirmed if the dynamic value is below the higher threshold.

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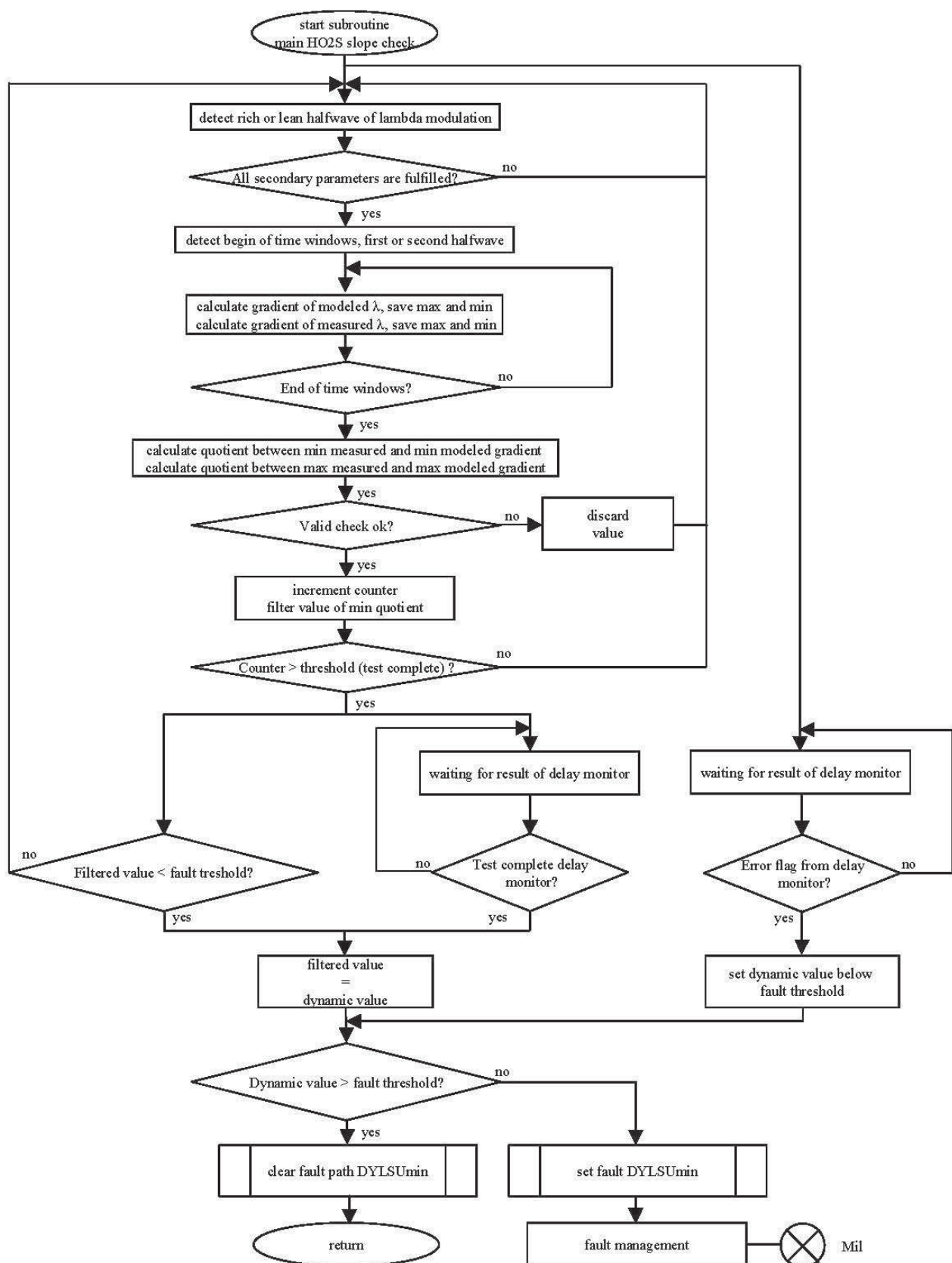


Figure 25: Flow chart: Subroutine main HO2S slope check – numerical check of ratio included

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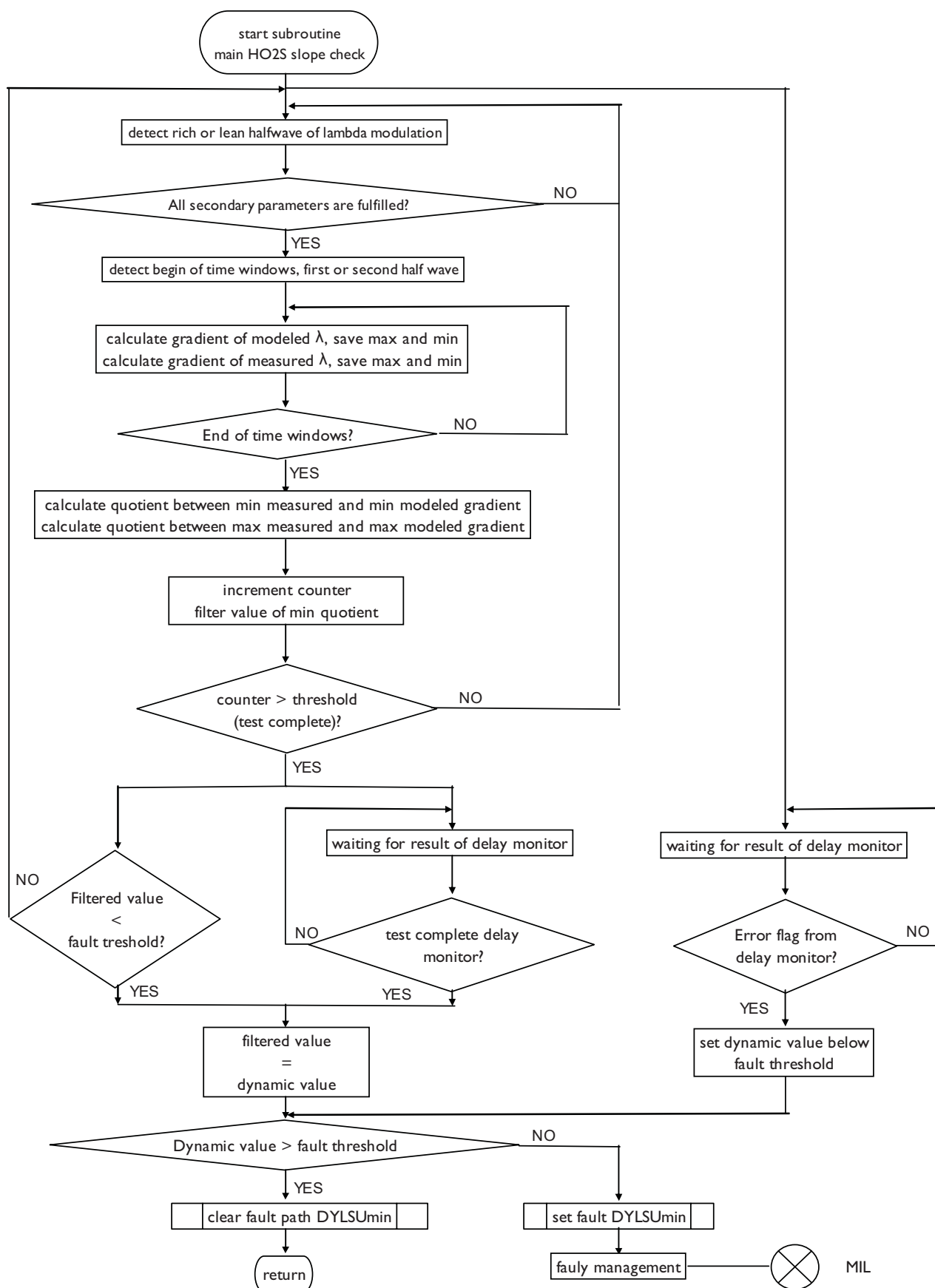


Figure 26: Flow chart: Subroutine main HO2S slope check – numerical check of ratio excluded

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7.1.2.1.8 In Use Monitoring Performance Ratio

The incrementing of the numerator, the denominator and the ratio calculation for the primary HO2S's response rate monitor is executed by the IUMPR kernel function. Like all monitors for which a standardized track and report of the in-use performance is required, the HO2S's response rate monitor reports to the IUMPR kernel function via status flags.

Conditions for incrementing the numerator:

The numerator is incremented, once per driving cycle in the event that a dynamic fault is detected or if the validated measurements counter exceeds a calibrated value and test complete delay detection.

Conditions for incrementing the denominator:

The denominator is incremented if the standardised conditions are met within the actual driving cycle and the monitor is not inhibited due to previously stored faults or faults are detected on the sensors necessary to determine the denominator itself.

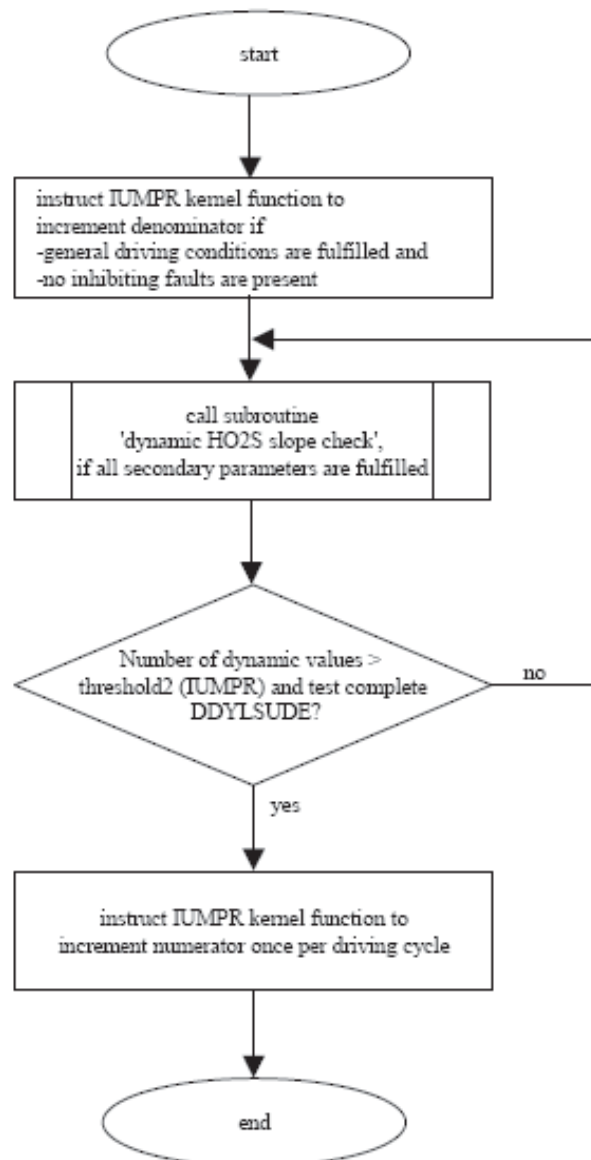


Figure 27: Flow chart: Main HO2S check

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7.1.2.2 Description of delayed response monitoring strategy

System documentation reference: P0133 (DYLSUmin). The following description applies to single bank and multiple bank concepts.

7.1.2.2.1 General information

Pure delay is not known as a fault mode of a wideband O2S, but the detection of a pure delay is required by regulation. A delayed response could affect the catalyst diagnostic and lead to higher emissions. Therefore this additional function monitors the HO2S Response. The monitor is performed once per driving cycle as long as the enable conditions are met and consists of two monitor parts, see Figure 28:

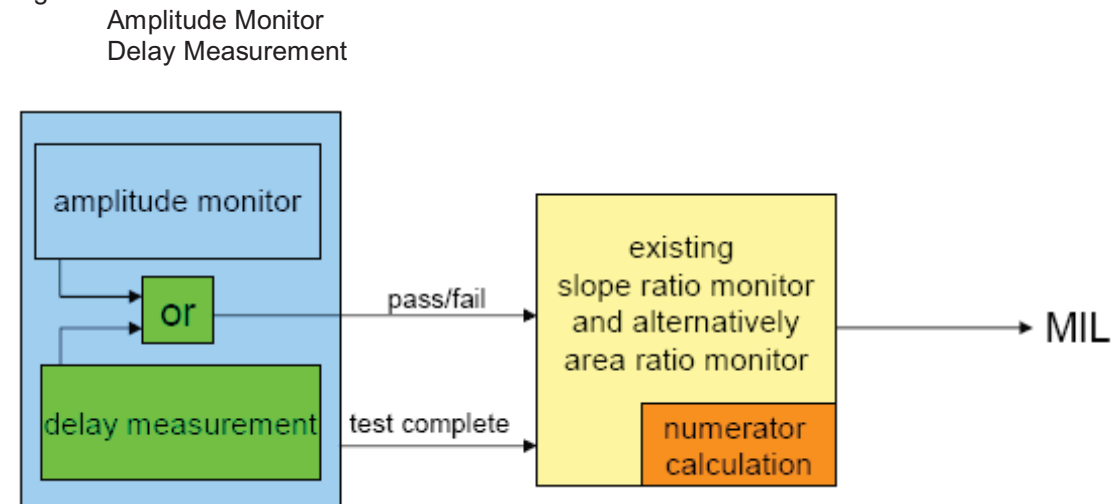


Figure 28: Monitoring principle block diagram

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These partial functions of the Response Rate Monitor are designed strictly for symmetrical delay recognition (both slopes rich-to-lean and lean-to-rich are influenced), see Figure 29.

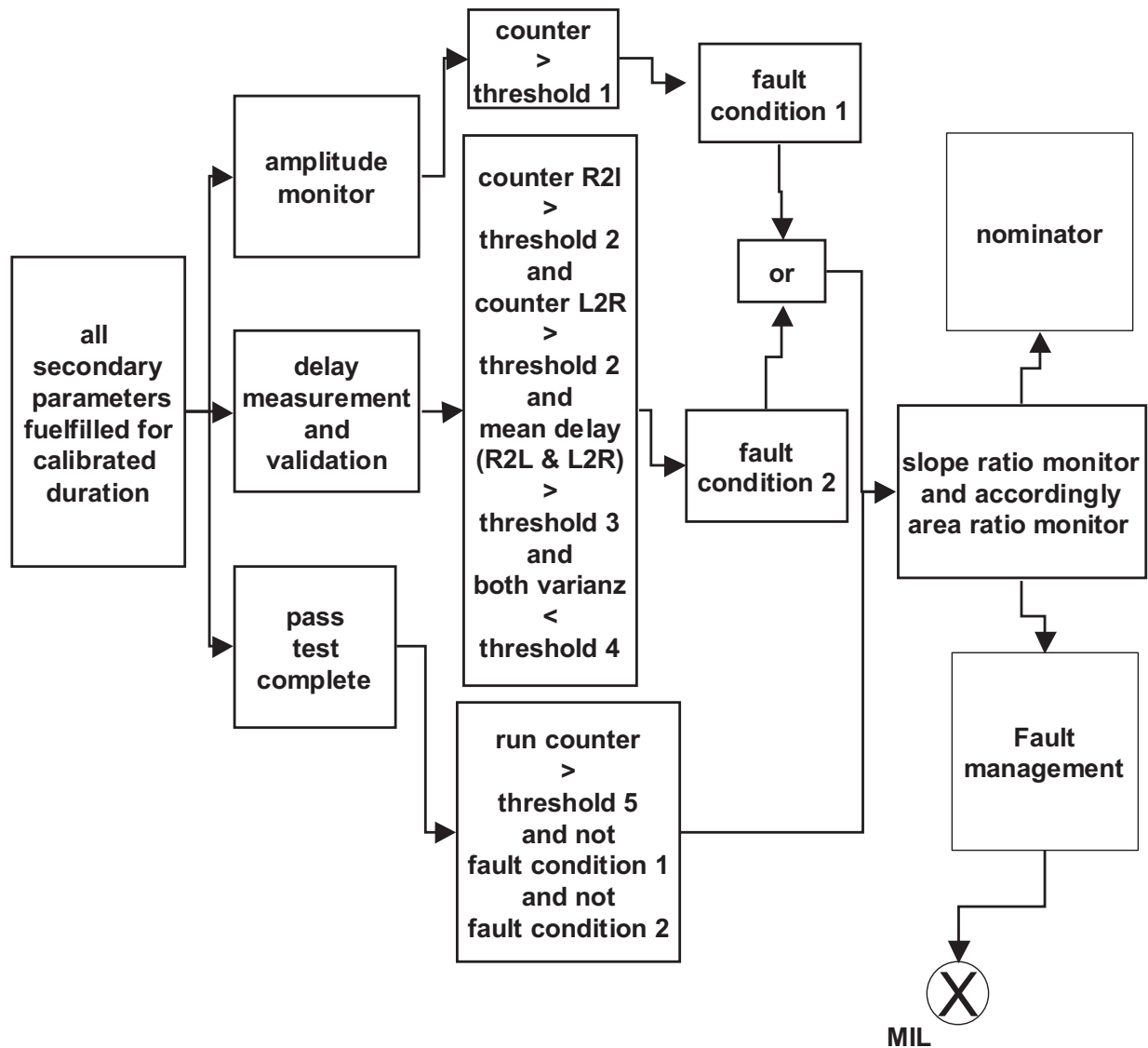


Figure 29: Functional Schematic Diagram

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The diagnostic function is executed when the lambda control is in closed loop operation and enable conditions are met.

The engagement of the lambda control causes, during delayed reaction of the Front O2S, greater lambda deviations in rich and also in lean direction, see Figure 30. This causes higher emissions and an increased load on the catalyst. The extent of the controller oscillations depends on the type of lambda control strategy (refer to “**Fuel System Monitoring Description**”) and the calibration of the controller parameters (Proportional and Integral- Portion). In both diagnostic paths, the oscillation of the lambda control is observed and evaluated. The results of this monitor are read and further processed in the slope ratio or area ratio monitor.

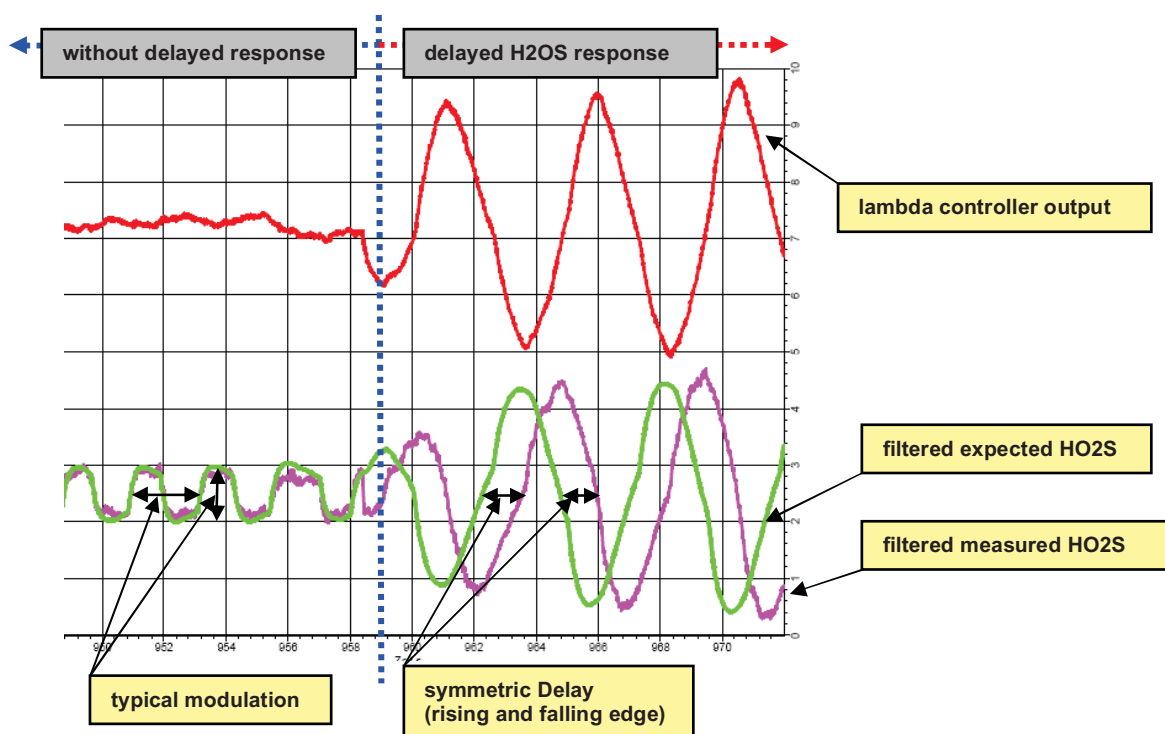


Figure 30: Lambda controller reaction

7.1.2.2.2 Diagnostic Enable Conditions

Enable Parameters:

- Linear HO2S ready for operation
- Linear sensor pumping current open circuit monitor completed without fault
- Primary control loop status: closed loop
- Set point of primary control loop: $\lambda = 1$
- Engine speed is within a calibrated range (typical range: ~1200-5000 rpm)
- Engine load is within a calibrated range (typical range: ~15-80%)
- Slope of engine load is less than a calibrated threshold (typical value: ~3% / period of time)
- Primary HO2S delayed Response monitor is not completed in the actual driving cycle
- Forced lambda modulation is higher than a calibrated threshold (optional parameter) (typical value: 0.01-0.03)
- Nominal time constant of the lambda control is within a calibrated range (typical range: ~0.0-1.5s)
- Primary control loop limits are higher than a calibrated threshold (typical value: ~1±0.15-0.25)
- Canister purge is not active (optional parameter)

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7.1.2.2.3 Signal Evaluation / Validation (applicable only to Delay Measurement)

For a robust monitoring function (Delay Measurement) the HO2S signal needs to meet the following conditions to ensure a certain level of signal quality:

- The measured time delay between target and actual signal is not greater than an applicable time threshold (typical value: ~1-2.5s), see Figure 31.

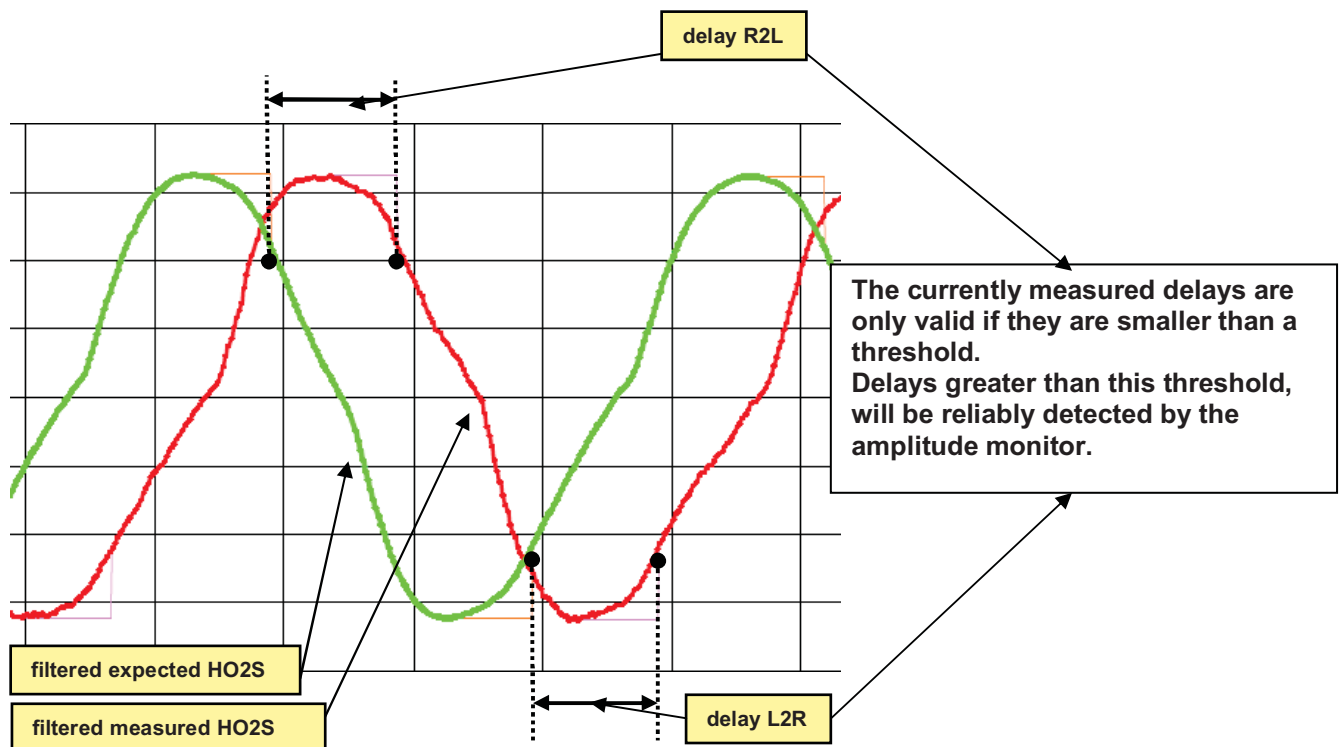


Figure 31: Delay Measurement (1)

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- The time difference between expected and actual signal is greater than an applicable time threshold (typical value: ~0.25-1s), see Figure 32.

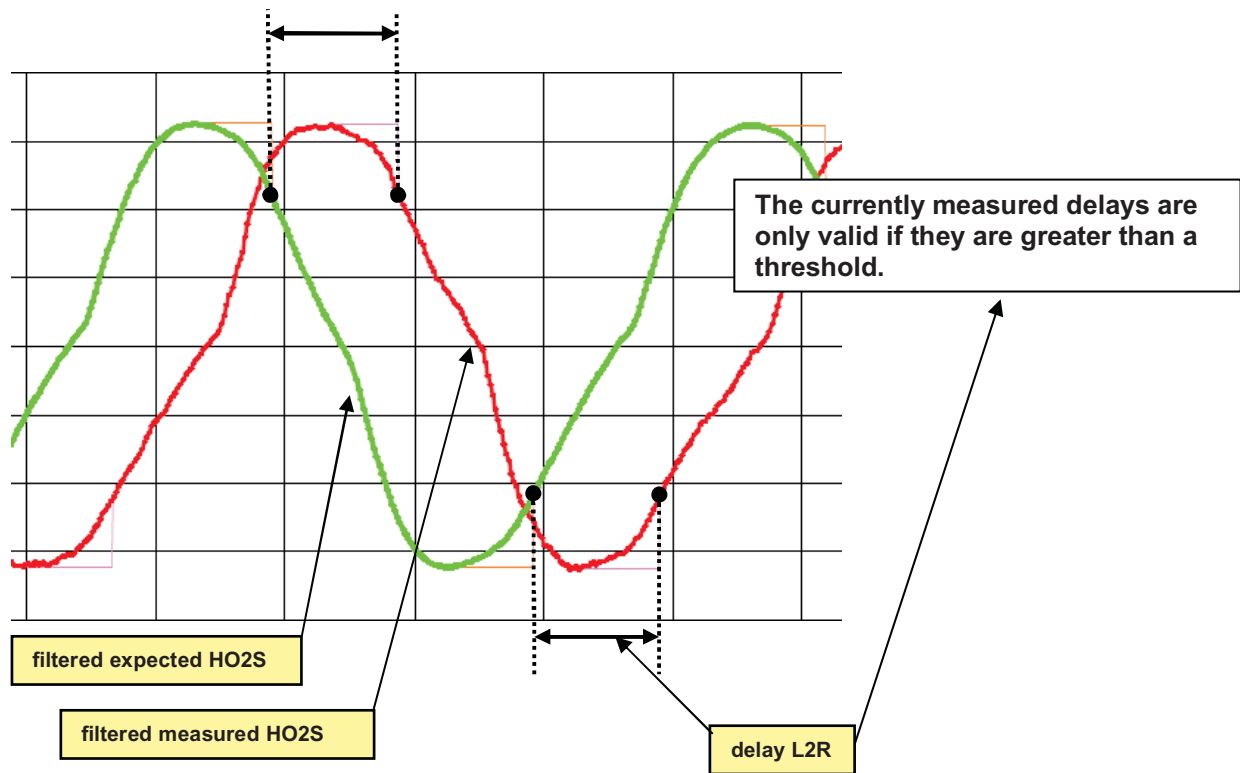


Figure 32: Delay Measurement (2)

- The variance (statistics: relative variance) of every measurement necessary for fault detection is less than a calibrated threshold (typical value: ~0.02-0.1)
- Time period (t1..t4) between recognised maximum or minimum values and their confirmations is within a calibrated range (typical range: ~0.02-2s), see Figure 33.

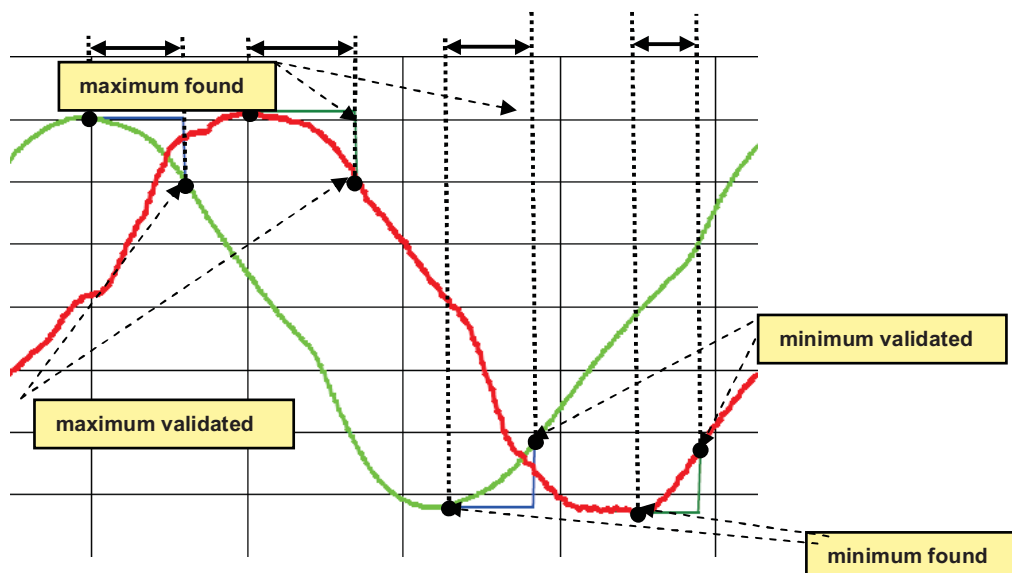


Figure 33: Delay Measurement (3)

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7.1.2.2.4 Monitoring of the controller amplitude

Definition:

The amplitude monitor evaluates the amplitude of the lambda control output. The control oscillation recognition is robust and relatively simple; however, it can only recognise a large time delay, which leads to high oscillations of the lambda control. In order to recognise highly oscillating control, the control value of the lambda control must mutually reach or exceed either the lower and upper limit or the applicable lower and upper thresholds for an applicable time.

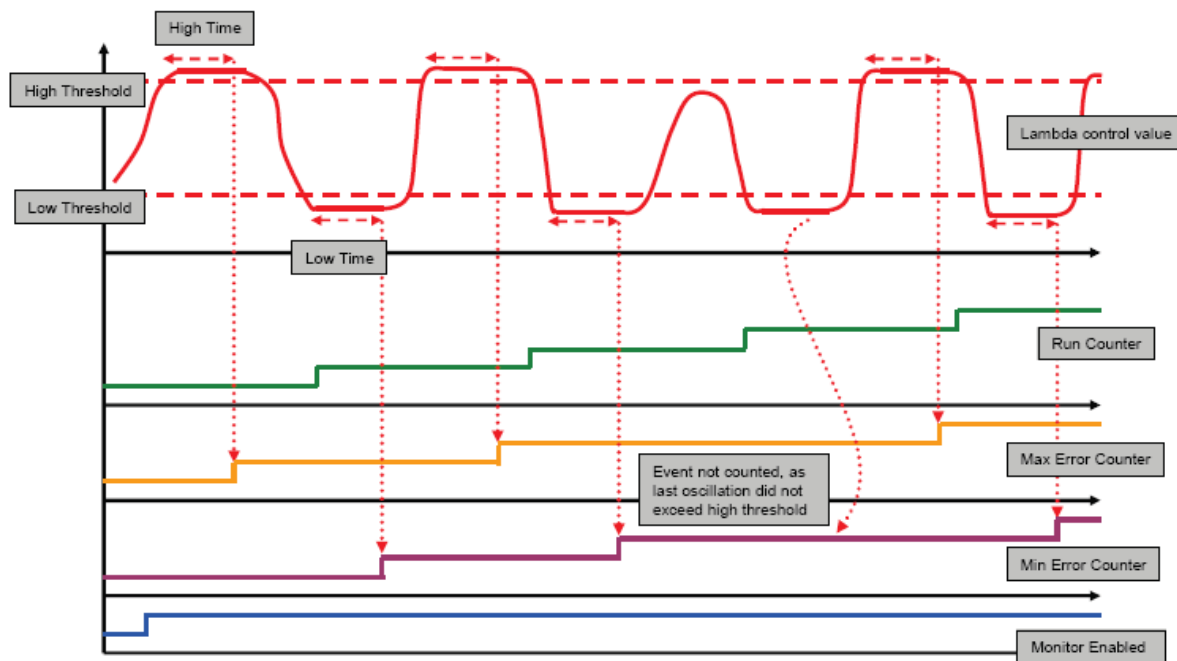


Figure 34: Principle of Amplitude Monitor

Strategy of amplitude monitors: Refer to Figure 34

If the enable conditions are met, the measured value of the amplitude monitor is valid. In order to avoid misdetection from, for example, disturbance by load alternation, the thresholds must be calibrated at a relatively high values (typical value: lean~ 1.18; rich~ 0.82). For this reason robust fault detection below a minimal control deviation is not possible. Furthermore, the time, which stuck the control factor at its limits or over the calibrated thresholds, must be greater than a calibrated time threshold (typical value: ~ 0.1-0.5 s). If the Lambda control output exceeds the threshold in the direction rich to lean or stuck at a limit for the required amount of time, the threshold or the limit must achieve the opposite direction (lean to rich) for the required amount of time. Then an error counter is incremented. The thresholds are expected to always be reciprocally exceeded, which means that if the rich threshold is exceeded, then the lean threshold must be exceeded. Otherwise the rich counter will not be further incremented. If the error counter exceeds a calibrated threshold (typical value: ~ 5-15) a fault will be detected.

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7.1.2.2.5 Delay measurement monitor

7.1.2.2.5.1 Definition

If the enable conditions are met, the measured value of delay measurement is valid. As described above, only greater delays can be recognised by the amplitude monitor, which lead to relatively strong control oscillations. In many concepts, the OBD emissions threshold or disabling of other diagnoses are achieved with considerably lower control oscillations. It is necessary also clearly detect lower signal delays. For this purpose, the time delay between the expected signal and the actual measured signal is evaluated. Refer to Figure 35

This is only feasible when the basic conditions for enabling are further delimited and the actual time delay between the expected and measured sensor signal is precisely enough determined. As with the amplitude monitor, a minimum oscillation of the lambda control is necessary for this monitor. In order to not mistakenly attribute the effects of general driving characteristics (influence of driver behaviour and terrain profiles) and disturbance of the lambda signal, a variance evaluation is required of each measurement value. A delayed signal course will appear in a relatively constant size, therefore, greatly different measurement results are to be considered erroneous measurements.

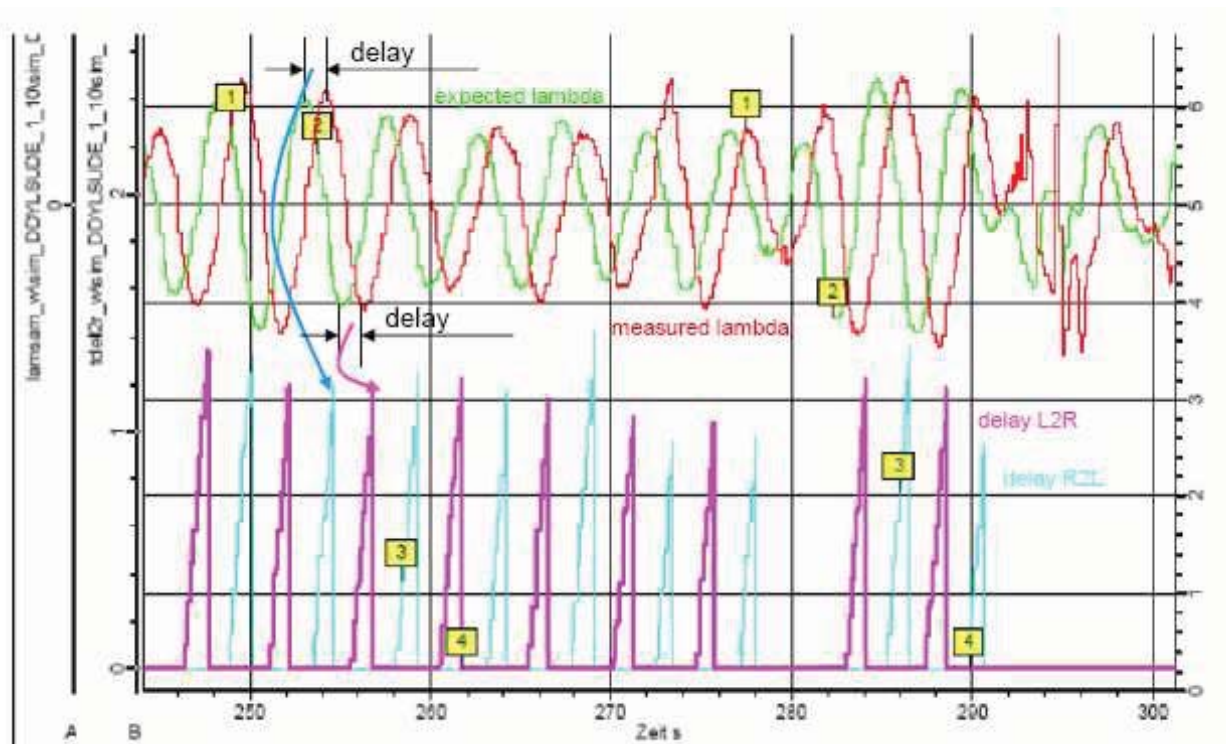


Figure 35: Principle of Delay Measurement

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7.1.2.2.5.2 Strategy of delay measurement

The measured lambda signal is made unbiased with a band pass filtering and released from high-frequency noise. The expected lambda signal is calculated from the position change of the lambda control, therefore, from the value to which the lambda modulation (forced amplitude) is to be added. In accordance with the system model, the control factor of the lambda control is first delayed, and then filtered and inverted via a low pass filter with time constants. In order to ensure the comparability between expected and measured lambda signal, the parallel band pass is used on the measured lambda signal. Refer to Figure 36 and Figure 37.

An exact measurement of the delay time is not always possible, it is recommended to first evaluate it from an applicable minimum amplitude (typical value: ~0.03-0.08) of the filtered measured and expected signal. If the threshold value is exceeded, a time measurement begins and the corresponding maxima (rich) or minima (lean) is determined for the expected and measured signal. The time measurement is triggered after the maxima or minima of the expected and measured signal is reliably recognised. A minimal signal change in the opposite direction is required (secure recognition of the turning points in the signal courses).

Based on the difference between measured and expected maxima or minima, the current minimum or maximum delay time is calculated. After validation (see validation) of both delay times has been carried out, a counter is incremented for each time delay. If the required minimum number of individual measurements is reached, then the variance of every measurement is checked.

7.1.2.2.5.3 Validation of delay measurement:

After each measurement of the maximum or minimum signal delay, the new measured value is checked for validity. The time between maxima or minima must be greater than an applicable time threshold (typical value: ~ 0.02- 0.05 s) and less than a second, calibrated time threshold (typical value: ~1-2s). The time difference between creation of the expected and measured maxima or minima must be greater than an applicable time threshold (typical value: ~0.5-1.0 s). Additionally, the established delay time may not exceed a maximum applicable threshold (typical value: ~2.5 s). Any delay greater than this threshold will be securely detected by the previously described amplitude monitor.

The measurement of the signal delay between the expected and measured signal can be falsified by the following faults:

- The expected maxima / minima come after the measured maxima / minima. For example, due to inaccuracies or tolerances in the parameters of control travel. The lambda sensor has no delay in this case. However, the time interval between the expected maxima / minima and the subsequent measured maxima / minima across two periods is measured, thus yielding a very high value.
- At the moment that the measured lambda signal would have a maxima / minima, a disturbance occurs according to lean / rich, which allows the lambda signal to further rise / fall and thus moves the maxima / minima back. The measured time delay is then too great.
- A disturbance causes the maxima / minima in the measured lambda signal to be deleted. The time difference is then incorrectly turned into the following (actually next but one) measured lambda signal and the measured time delay is too great.
- In a system with a delay fault of the front linear O2S, a disturbance occurs in the measured lambda signal shortly after an expected maxima / minima, causing a small local maximum or minimum. The measured time delay is then too small.
- The signal course has no distinct maxima (for example, plateau in the signal course), therefore, the time mark and, thus, the measured time delay will be relatively random.

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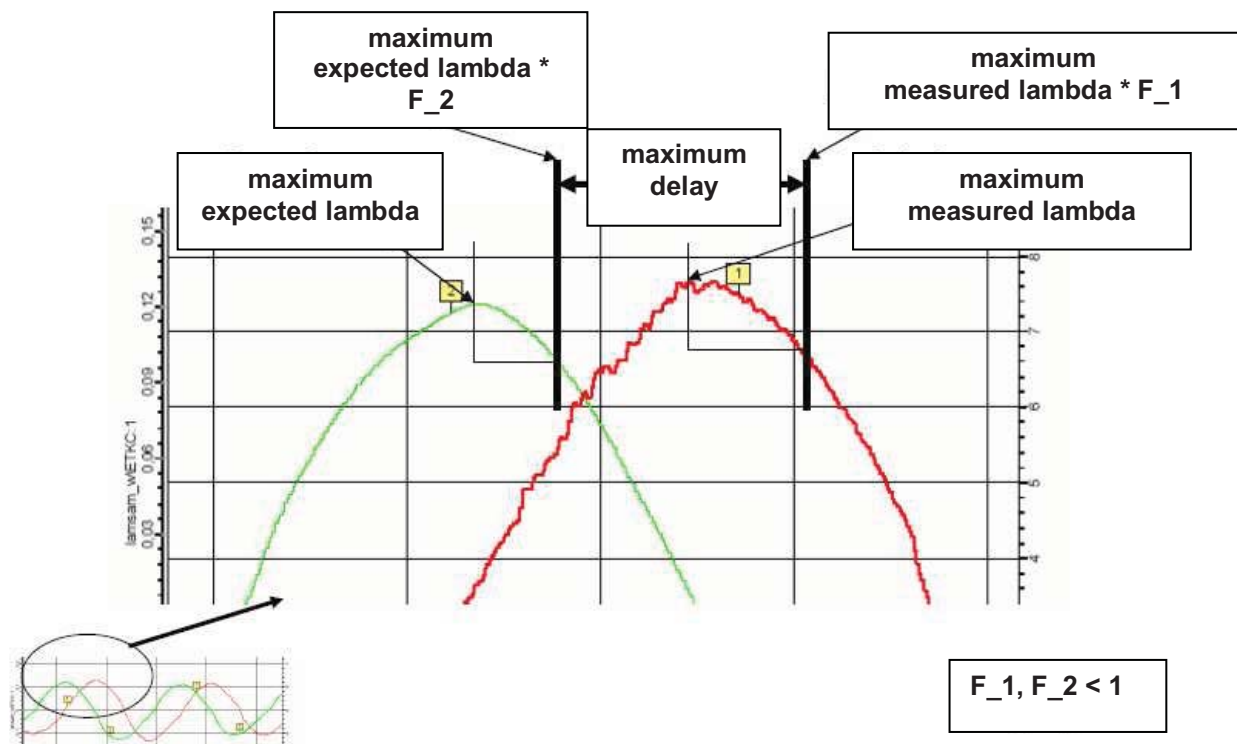


Figure 36: Delay Measurement: lean to rich

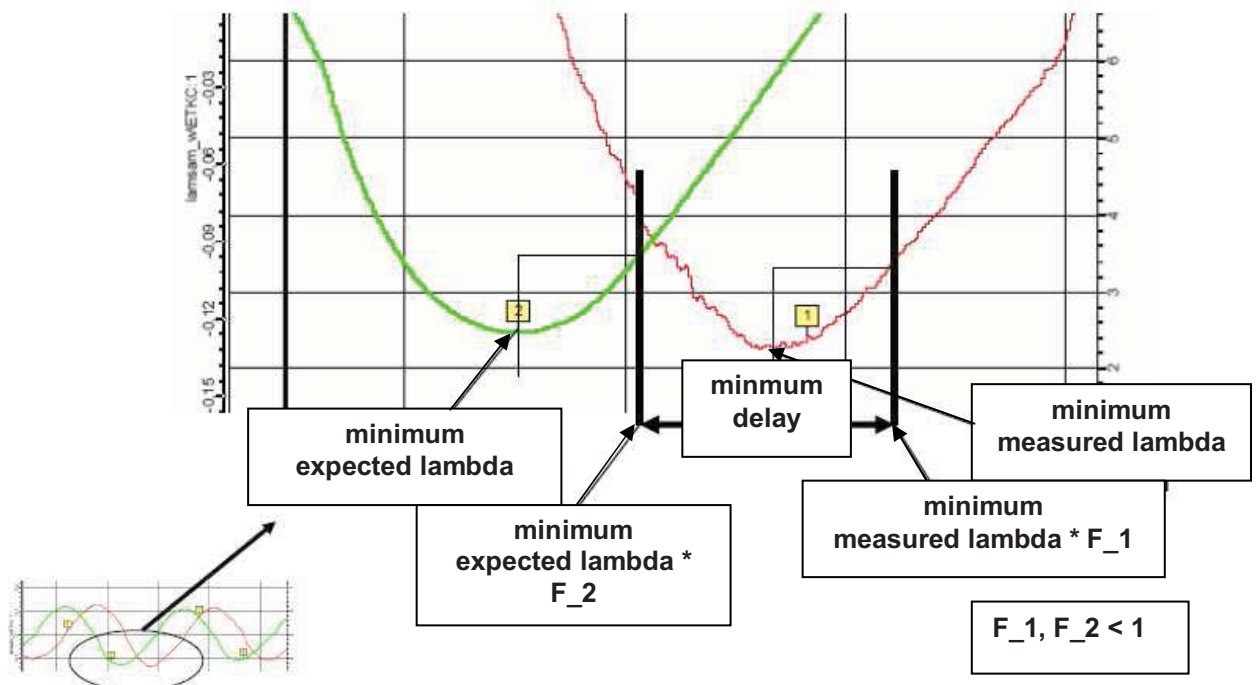


Figure 37: Delay Measurement: rich to lean

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7.1.2.2.6 Conditions for test complete:

IF all secondary parameters > cal. time (typical time: ~ 1-10s) are met.
AND supplementary modulation active and above cal. threshold (optional parameter)
AND supplementary lambda control within limits (optional parameter)
THEN increment run counter
IF number of run counter > cal. threshold (typical value: ~ 10-25)
THEN test complete (no further delay check in actual DC)

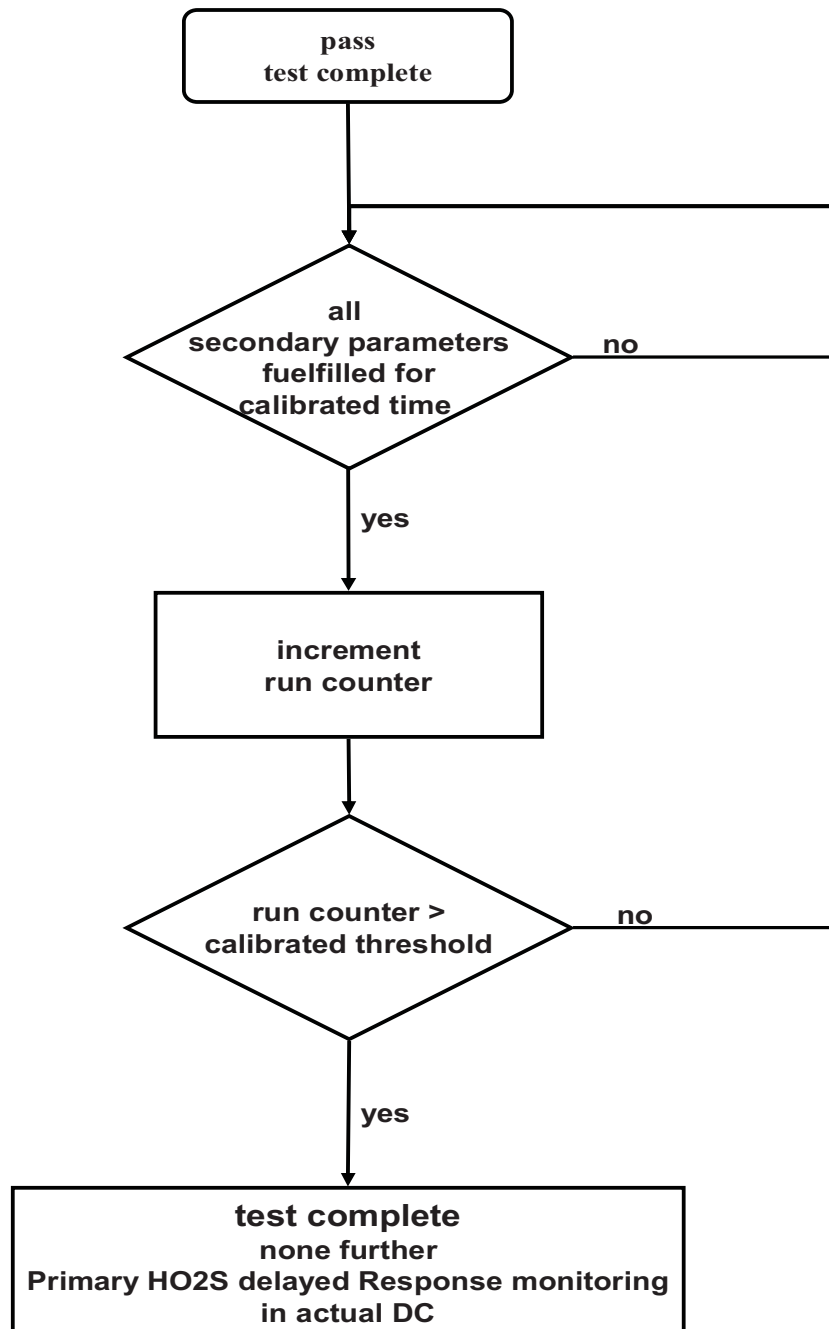


Figure 38: Flow chart: Conditions for Test Complete

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7.1.2.2.7 Fault determination:

IF number of collected lean to rich amplitude > cal. fault threshold
 AND number of collected rich to lean (R2L) amplitude > cal. fault threshold
OR
 AND mean value delay lean to rich > fault threshold
 AND relative variance of mean value lean to rich < cal. Threshold
 AND number of collected lean to rich delays > cal. threshold
 AND mean value delay rich to lean (R2L) > fault threshold
 AND relative variance of mean value rich to lean (R2L) < cal. Threshold
 AND number of collected rich to lean (R2L) delays > cal. threshold
THEN **set fault**
MIL ON is set in second DC

Refer to Figure 39 and Figure 40.

7.1.2.2.8 Conditions for Incrementing the Numerator

The calculation of numerator complete is performed by slope ratio monitor or area ratio monitor (see slope ratio monitor and corresponding area ratio monitor description).

7.1.2.2.9 Conditions for Incrementing the Denominator

The denominator is incremented if the standardized conditions are met within the actual driving cycle and the monitor is not inhibited due to previously stored faults or faults detected on the sensors necessary to determine the denominator itself.

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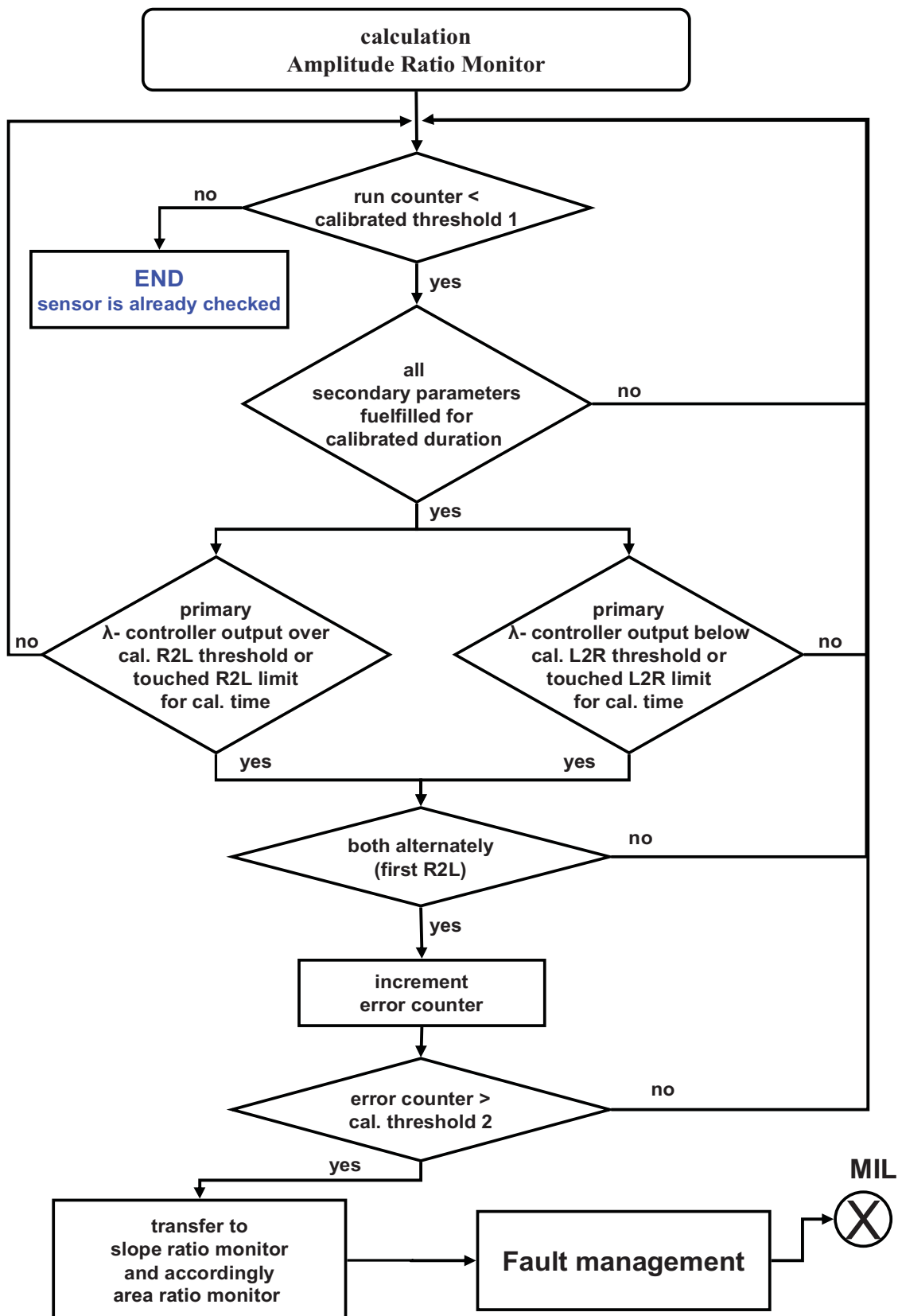


Figure 39: Flow chart: Amplitude Ratio Monitor

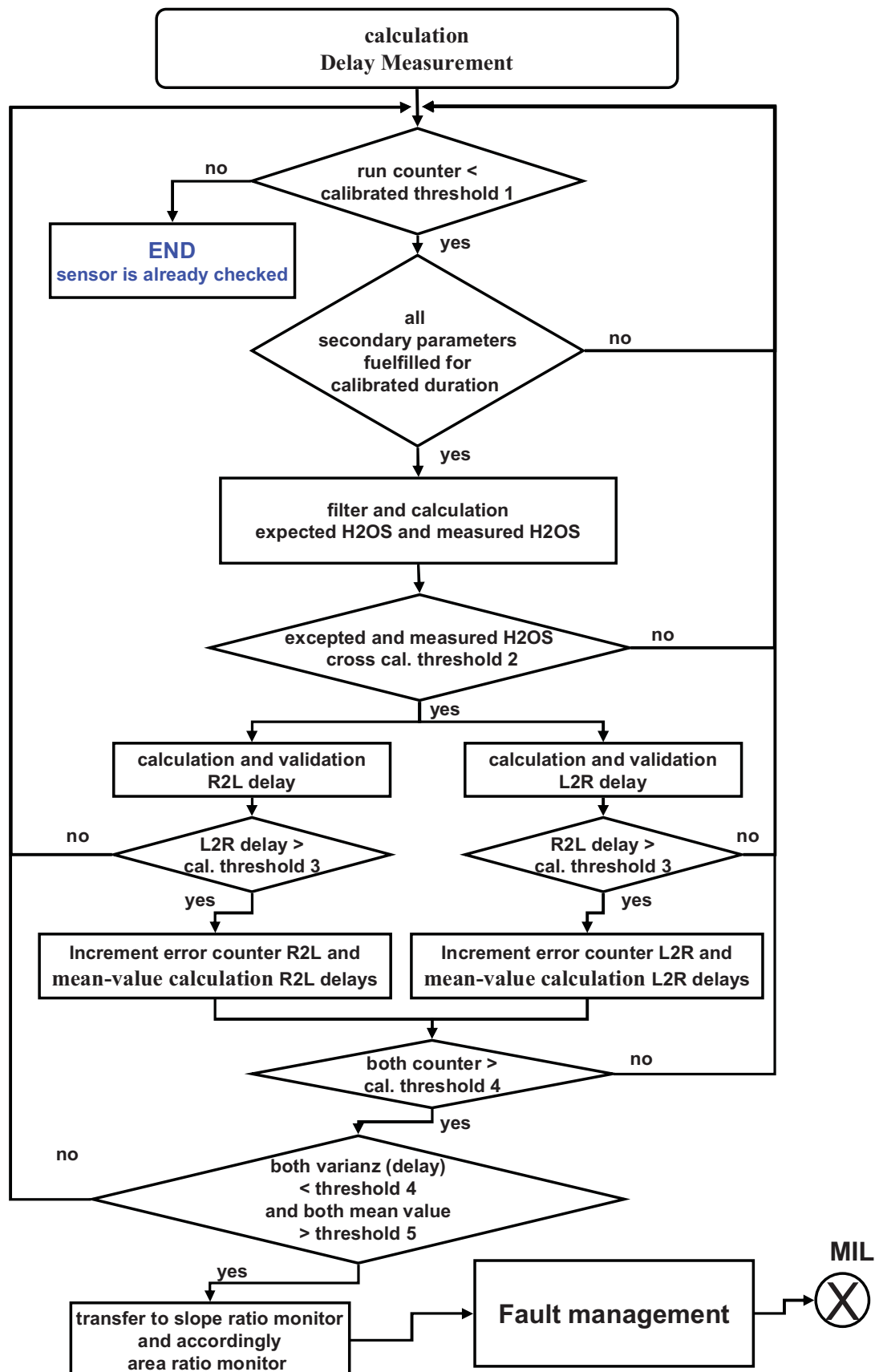


Figure 40: Flow chart: Delay Measurement

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7.1.3 Diagnosis of Evaluation IC of the upstream HO2S

This document describes the sum of all possible evaluation IC checks of the upstream HO2S. Depending on the exact system configuration only a subset of the described checks, monitoring conditions and flowcharts might be performed.

The Diagnosis of the evaluation IC (CJ125) of the heated upstream oxygen sensor (HO2S) detects electrical faults of the UN (Nernst voltage), VM (virtual ground), IA (compensation) and IP (pump) signal lines - see Figure 41. These electrical faults could result from short circuits to battery, or ground and signal interruptions. Short circuits are detected by a self-diagnosis of the CJ125. Line interruptions are identified by observing the system. The diagnosis monitors communication between the CJ125 IC and the electronic control unit and also performs a rationality check of the supply voltage as well as the adaptation values of the IC's electrical compensations. The evaluation IC's diagnosis runs continuously.

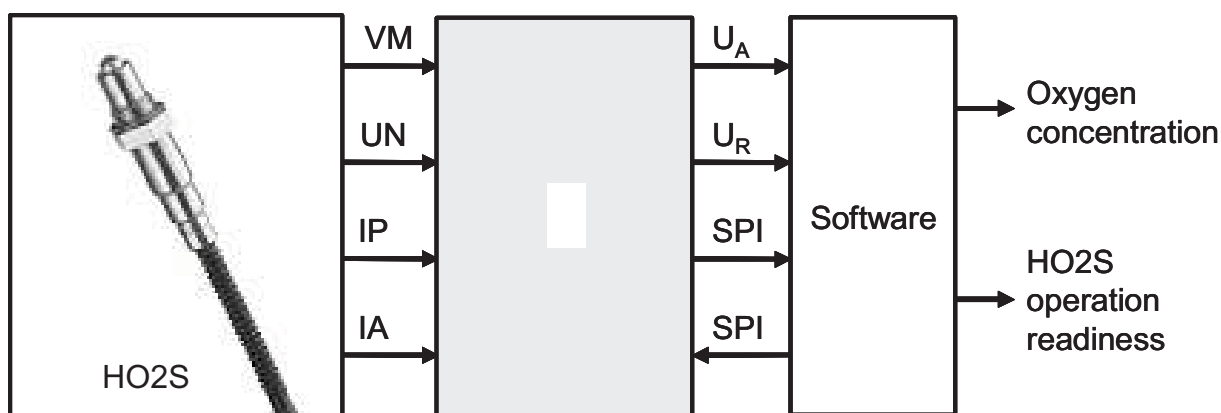


Figure 41: Signal lines between the CJ125IC and the HO2S.

General Monitoring conditions:

- Engine start has finished.
- Battery voltage is in diagnostic range.
- Engine speed has exceeded the calibrated minimum threshold.

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7.1.3.1 Open Circuit - VM (virtual ground) line interruption

7.1.3.1.1 VM line interruption due to internal resistance of Nernst cell check

Refer to Figure 42.

This check is performed for the HO2S type LSU.

The pump- or limit-current of the Nernst cell no longer flows when there is a VM line interruption. This results in an extremely high resistance which remains even when the O2 sensor is sufficiently hot. The O2 sensor's ceramic temperature doesn't rise although the system reacts by increasing the heating power. A malfunction is detected and a signal fault LSUVM is set when the internal resistance of the galvanic (or Nernst) cell exceeds a calibrated threshold after a calibrated period of time.

Monitoring conditions - VM line interruption:

- All general monitoring conditions are fulfilled.
- Offset corrected voltage of the upstream HO2S respectively lies above and below the lower and upper plausible output voltage U_A of the CJ125 IC required for detecting a VM line interruption.
- Internal resistance of the galvanic (or Nernst) cell of the HO2S lies above a calibrated threshold after a calibrated period of time.
- The exhaust gas temperature at the upstream HO2S' vicinity lies below the calibrated permissible maximum for detecting a VM line interruption.
- The upstream HO2S's heater power stage toggles on and off.
- The HO2S' pump voltage has not been switched-off.
- Heater control active for a calibrated period of time.
- No upstream HO2S power stage error.
- The following conditions have to be fulfilled altogether for a calibrated period of time:
 - Heater enabled
 - Engine is running
 - Heater control is switched-on
 - No fuel cut-off lasting longer than a calibrated period of time
 - Battery voltage exceeds calibration

7.1.3.2 Open Circuit - UN (Nernst voltage) line interruption

A UN line interruption leads to an irrationally high U_R signal as well as an undefined output voltage U_A - see Figure 43. A signal fault LSUUN is set when the offset corrected voltage of the upstream HO2S lies above the upper (or below the lower) plausible output voltage U_A of the CJ125 IC required for detecting a UM line interruption.

Monitoring conditions - UN line interruption:

- All general monitoring conditions are fulfilled.
- No power stage error of the upstream HO2S' heater.
- HO2S' pump voltage has not been switched-off.
- Internal resistance of the HO2S Nernst cell exceeds calibrated threshold (after enough time has been allowed for all transient events, induced during the determination of the HO2S' internal resistance, to settle down).
- Heater control active for a calibrated period of time.

7.1.3.3 Open Circuit - IA (compensation) line interruption

An IA line interruption leads to a non-plausible large oxygen sensor voltage signal in a fuel cut off condition. A signal fault LSUIA is set after a calibrated delay time, if the oxygen sensor's voltage is greater than or equal to a calibrated threshold. The fault is set after an additional calibrated time if the fuel tank is empty or in an unknown state. (Refer to Figure 44)

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Monitoring conditions - IA line interruption:

- All general monitoring conditions are fulfilled.
- Fuel cut off condition exist.
- Modeled exhaust gas temperature at the upstream side of the main catalyst is less than a calibrated value.
- HO2S' pump voltage has not been switched-off.
- Oxygen sensor has reached its operating temperature.

7.1.3.4 Open Circuit - IP (pump) line interruption

The pump current of the HO2S, which flows through the IP line, is equivalent to the oxygen concentration in the exhaust gas. An IP line interruption means the pump current will be permanently equal to zero. The output voltage UA of the CJ125 IC will remain constant and corresponds to the normalized A/F ratio of one ($\lambda=1$). UA no longer varies with the oxygen concentration in the exhaust gas.

An IP line interruption is detectable via three methods:

- detection during fuel cut-off condition (λ must be $\neq 1$)
- detection by closed-loop control to a nominal A/F value that differs from one (λ must be $\neq 1$)

7.1.3.4.1 Detection during fuel cut off condition

Refer to Figure 45.

The fuel cut off condition is an operating mode with a nominal A/F ratio $\neq 1$. A rationality fault LSUIP is set when during fuel cut-off condition; the value of the oxygen sensor's voltage is less than a calibrated threshold for a calibrated period of time.

Monitoring conditions for detection during fuel cut-off:

- All general monitoring conditions are fulfilled.
- HO2S has reached its operating temperature.
- Fuel cut-off condition existed for at least 3 seconds.
- HO2S' pump voltage has not been switched-off.
- Canister purge system diagnosis has been performed and no faults were detected.
- All monitoring conditions have been fulfilled for a period of time that is at least equal to a calibration.

7.1.3.4.2 Detection by closed-loop control to a nominal A/F value that differs from one

Refer to Figure 46.

A signal fault LSUIP is set when the normalized nominal A/F ratio (λ) differs from one (lies beyond a calibrated range) and the oxygen sensor's voltage lies within a calibrated range during the time required for the integrated exhaust gas mass flow to exceed a calibrated threshold.

Monitoring conditions for detection by closed-loop control to a nominal A/F value that differs from one:

- All general monitoring conditions are fulfilled.
- Lambda (A/F ratio) closed-loop control is activated.
- Oxygen sensor has reached its operating temperature.
- The heater of the HO2S on the upstream side of the catalyst has no faults.
- HO2S response rate diagnosis did not detect a fault.
- HO2S' pump voltage has not been switched-off.
- Electrical trimming of the HO2S is inactive.

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7.1.3.5 Short circuits to ground or to battery voltage

Refer to Figure 47 and Figure 48.

Short circuits are detected by a self diagnosis of the CJ125 IC. An integrated voltage comparator at each and every pin of the HO2S' CJ125 IC, detects and sets a maximum or a minimum fault LSUKS if the voltage at that pin respectively lies above a calibrated maximum or below a calibrated minimum for a calibrated period of time.

a) Explicitly, a maximum fault LSUKS is set either when

- the HO2S' voltage at the VM pin exceeds a calibrated plausible maximum **or**
- the HO2S' voltage at the UN pin exceeds a calibrated plausible maximum **or**
- the HO2S' voltage at the IA or IP pin exceeds a calibrated plausible maximum

b) Likewise, a minimum fault LSUKS is set either when

- the HO2S' voltage at the VM pin lies below a calibrated plausible minimum **or**
- the HO2S' voltage at the UN pin lies below a calibrated plausible minimum **or**
- the HO2S' voltage at the IA or IP pin lies below a calibrated plausible minimum

7.1.3.6 Monitoring of the communication between the Evaluation-IC CJ125 and the Micro-controller of the ECM

7.1.3.6.1 Non-plausible commands counter

Refer to Figure 49.

The CJ125 evaluation IC communicates with the main processor of the PCM via a serial port interface. They both send data to each other. Interference on the SPI bus leads to non-plausible signals. These non-plausible signals, which persist even when the data is re-transmitted, are tracked by incrementing an internal error counter. A signal fault ICLSU is set when the counter exceeds a calibrated threshold.

7.1.3.6.2 Comparison of initialization and mirror register

Refer to Figure 50.

A further communication monitor compares the old value of the initialization register, which is backed up in a mirror register, with its current value after a rewrite. A rationality fault ICLSU is set after a calibrated period of time, if the current value of the initialization register isn't equal to that of its mirror register.

7.1.3.7 Low supply voltage of the CJ125 IC

Refer to Figure 51.

The CJ125 IC is specified for supply voltages > 9V. It possesses a supply voltage detection module. Low supply voltages lead to faulty diagnosis at the voltage comparators. A minimum fault ICLSU is set when the supply voltage drops below 9V. The supply voltage monitor is aborted if the monitoring conditions are not fulfilled.

Monitoring conditions for the CJ125 IC's supply voltage:

- the battery's voltage must be greater than 10.7V

7.1.3.8 Electrical trimming

Electrical trimming of the oxygen sensor is performed in order to determine and store the difference between the expected and the actual pump-current-proportional output voltage. This difference stems from hardware tolerances. Electrical trimming is carried out once after engine start and once in the idle mode during a calibrated period of time. A maximum fault ICLSU is set when after electrical trimming the adaptation value for the corresponding curve (normal and rich) exceeds a calibrated maximum. Refer to Figure 52.

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Monitoring conditions for electrical trimming:

- Engine start has finished.
- Engine is in idle mode.

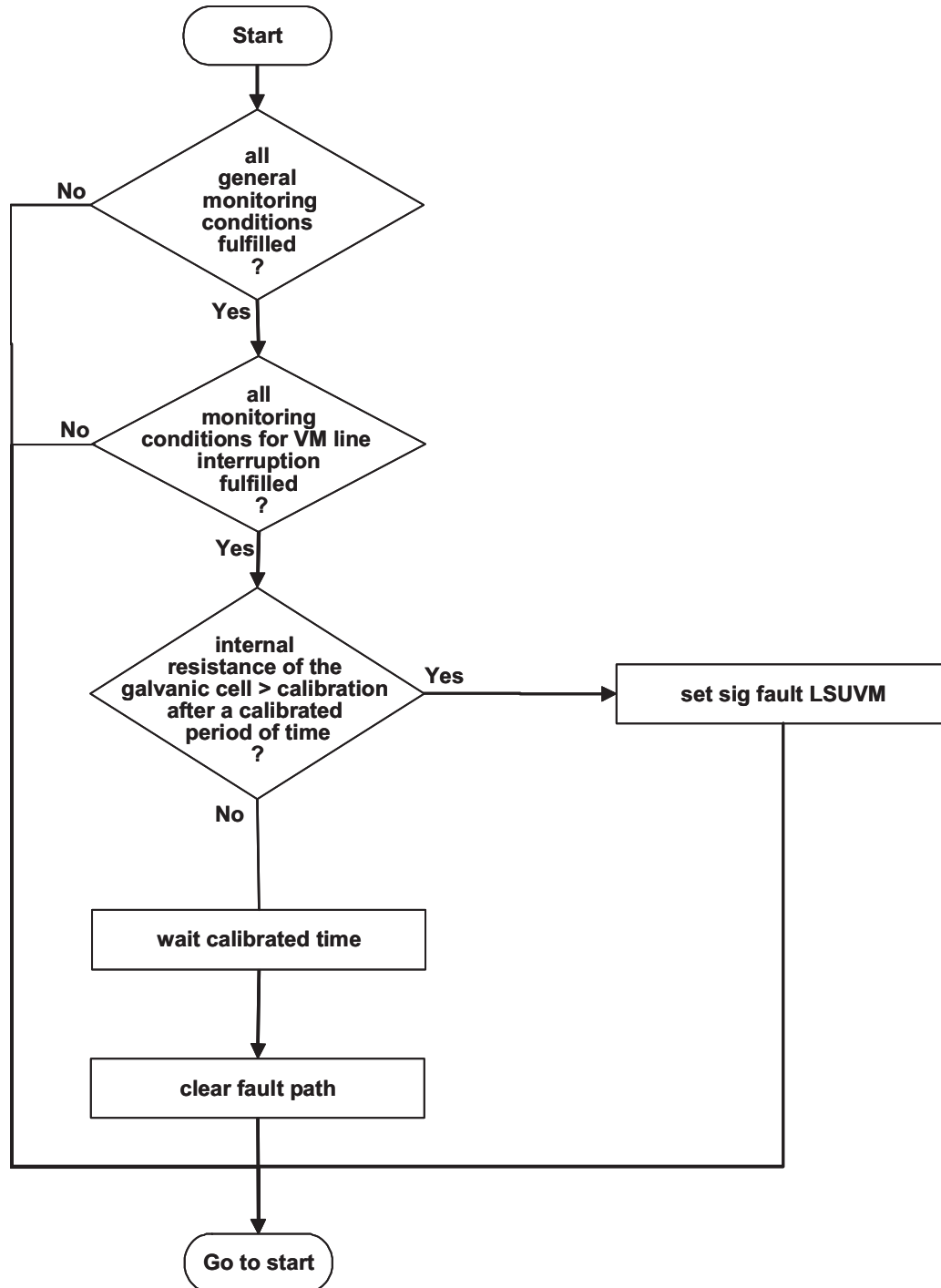


Figure 42: Flow chart: VM line interruption due to internal resistance of Nernst cell check

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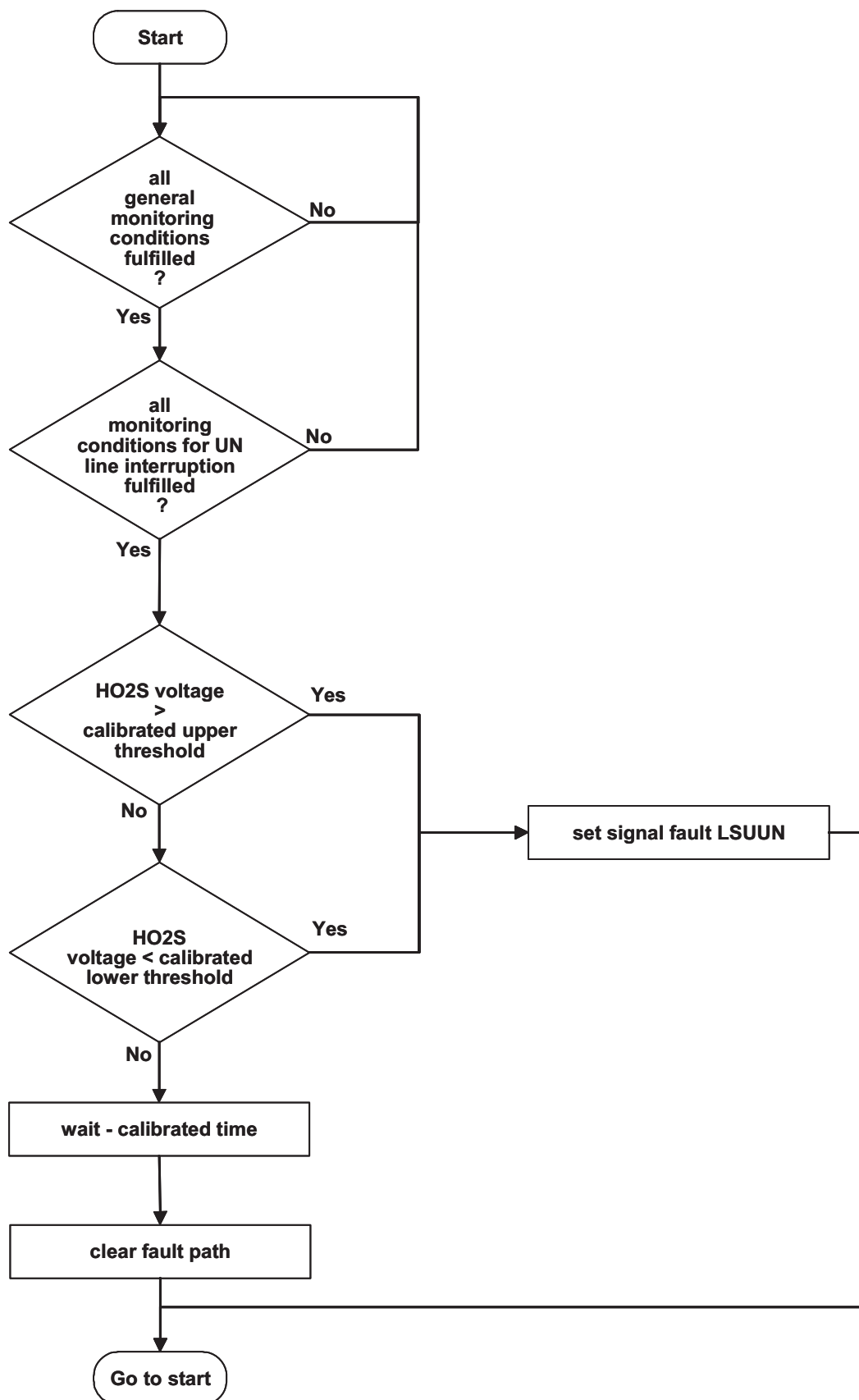


Figure 43: Flow chart: Open Circuit - UN line Interruption Monitoring

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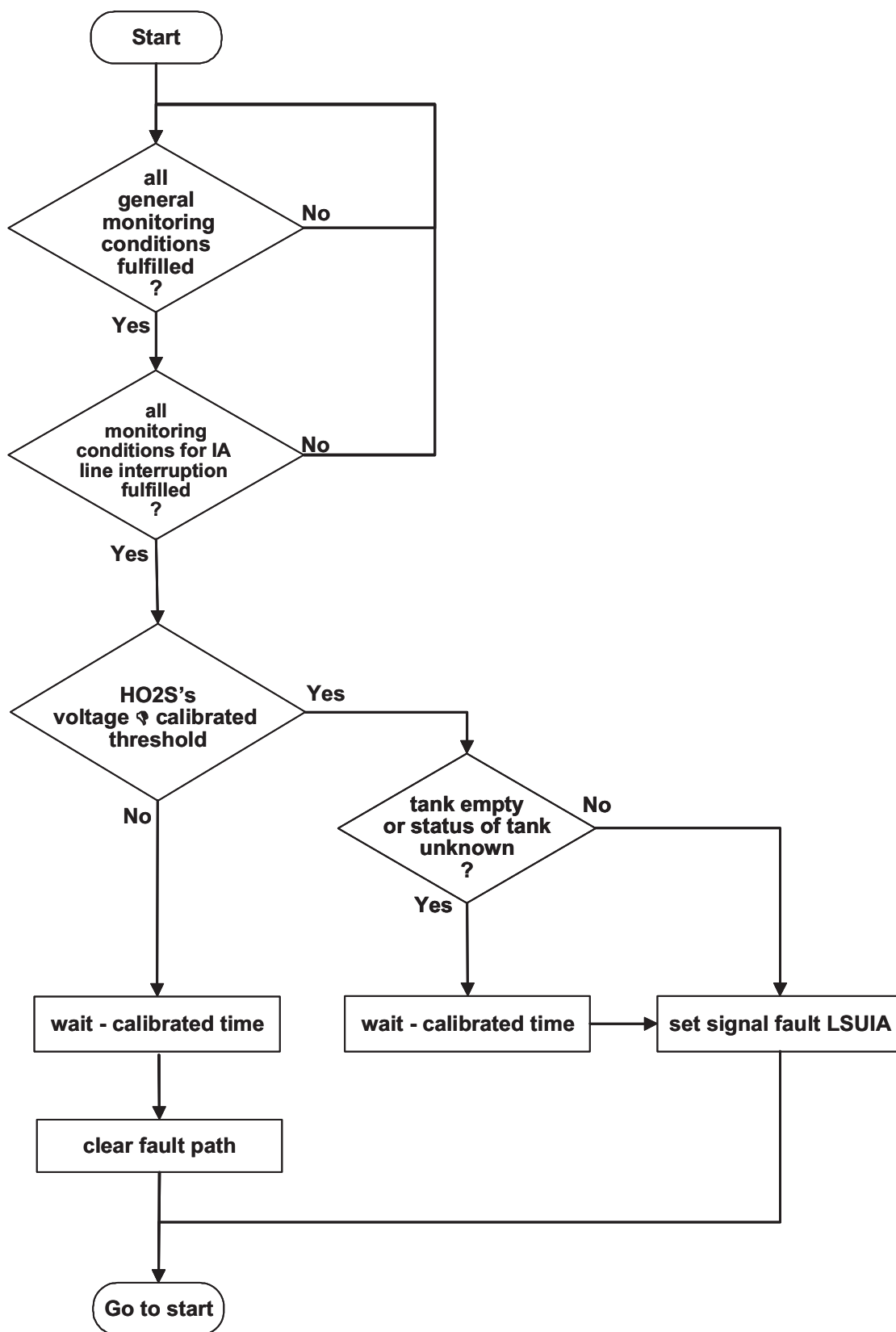


Figure 44: Flow chart: Open Circuit - IA line Interruption Monitoring

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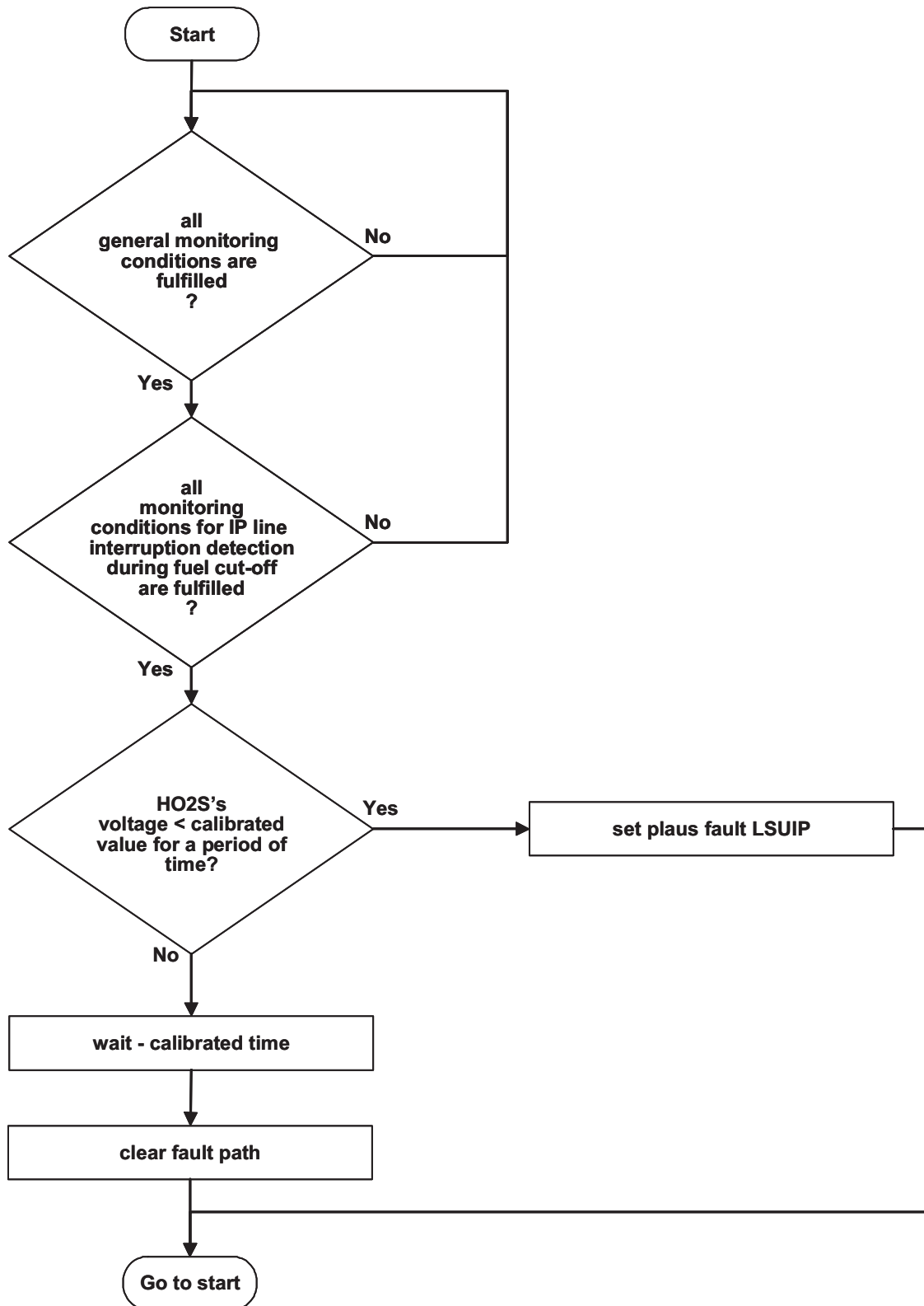


Figure 45: Flow chart: IP Line Interruption detection during fuel cut off condition

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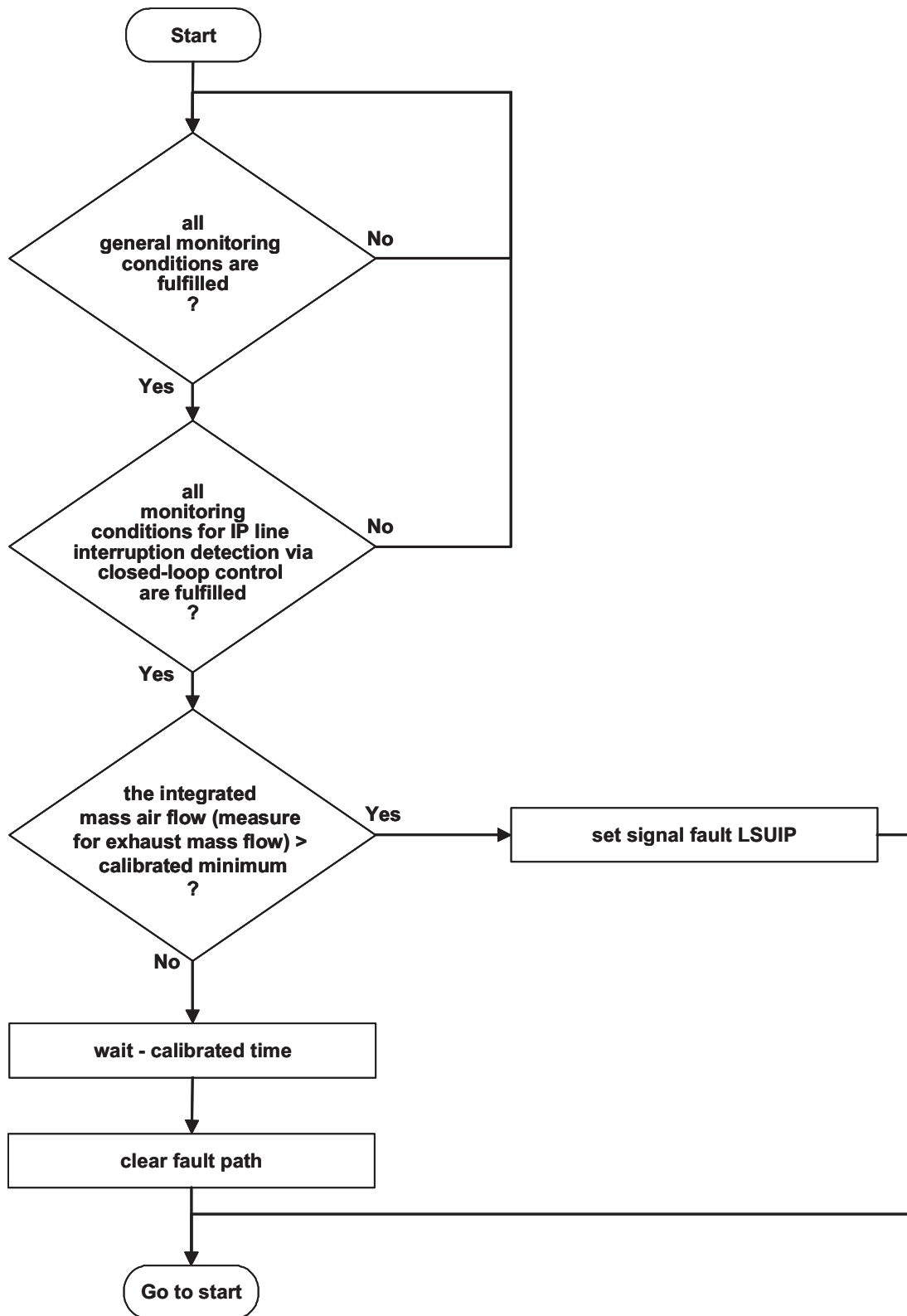


Figure 46: Flow chart: IP Line Interruption detection by closed-loop control to a nominal air / fuel ratio that differs from one

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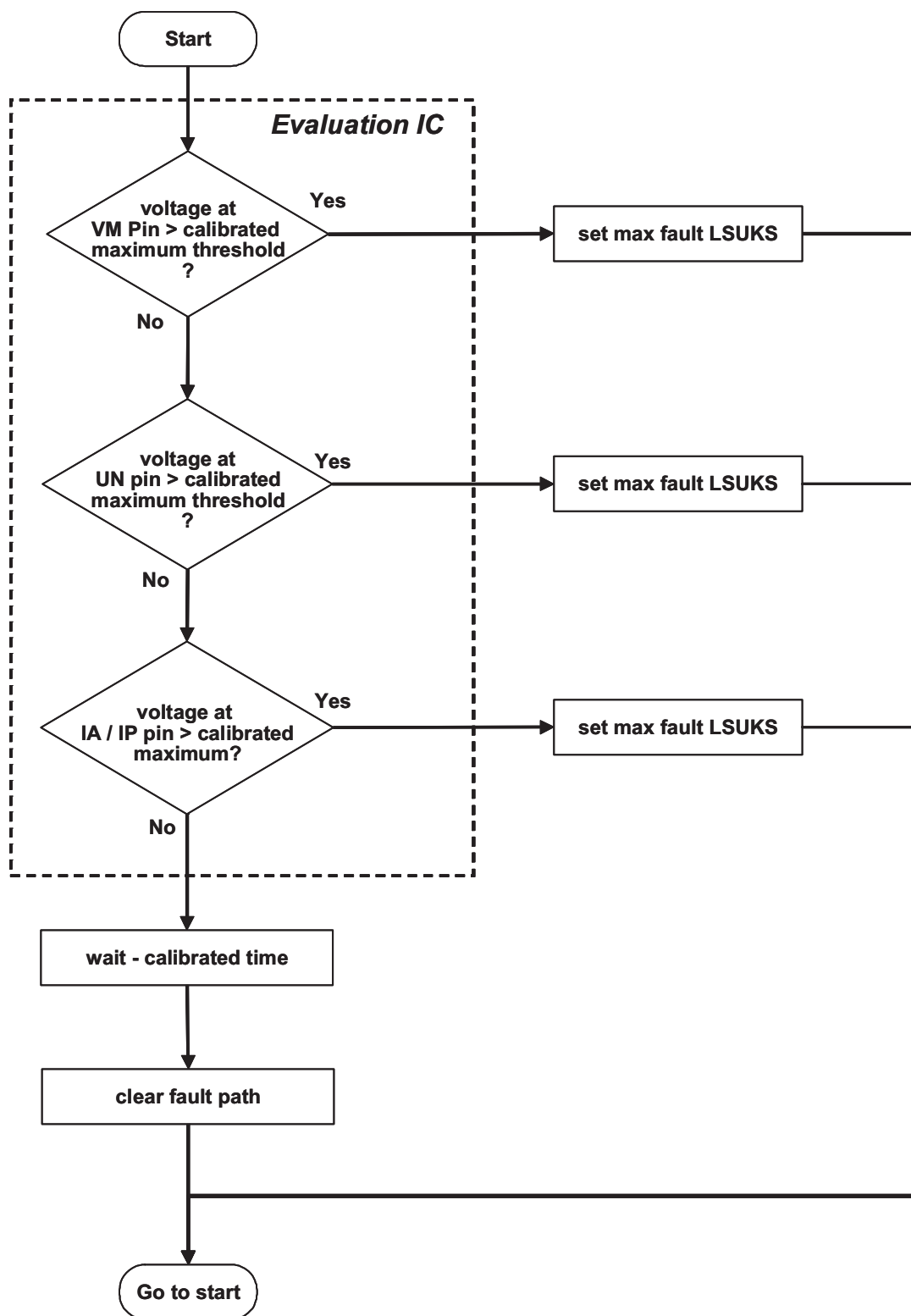


Figure 47: Flow chart: Short circuits to battery

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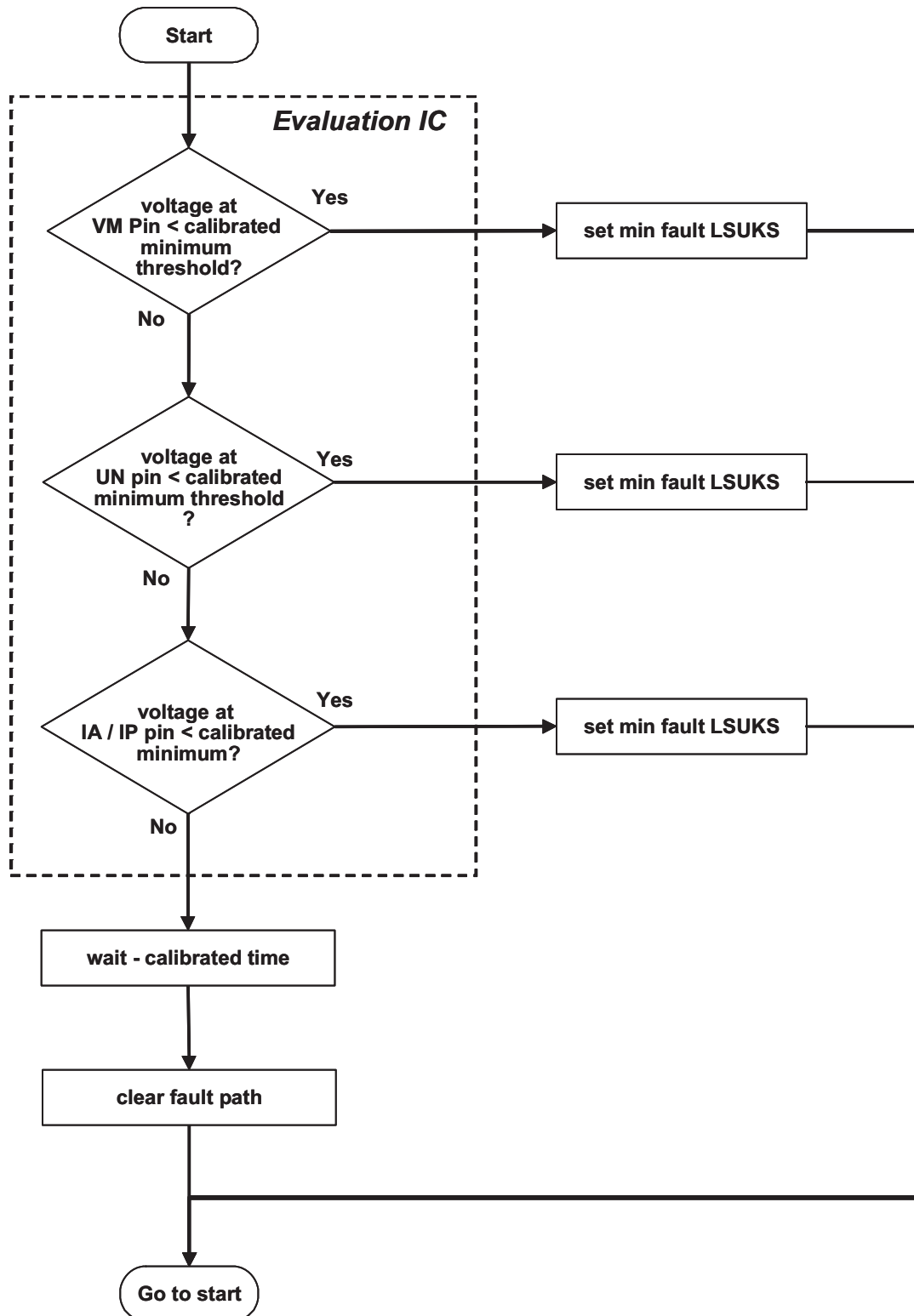


Figure 48: Flow chart: Short circuits to ground

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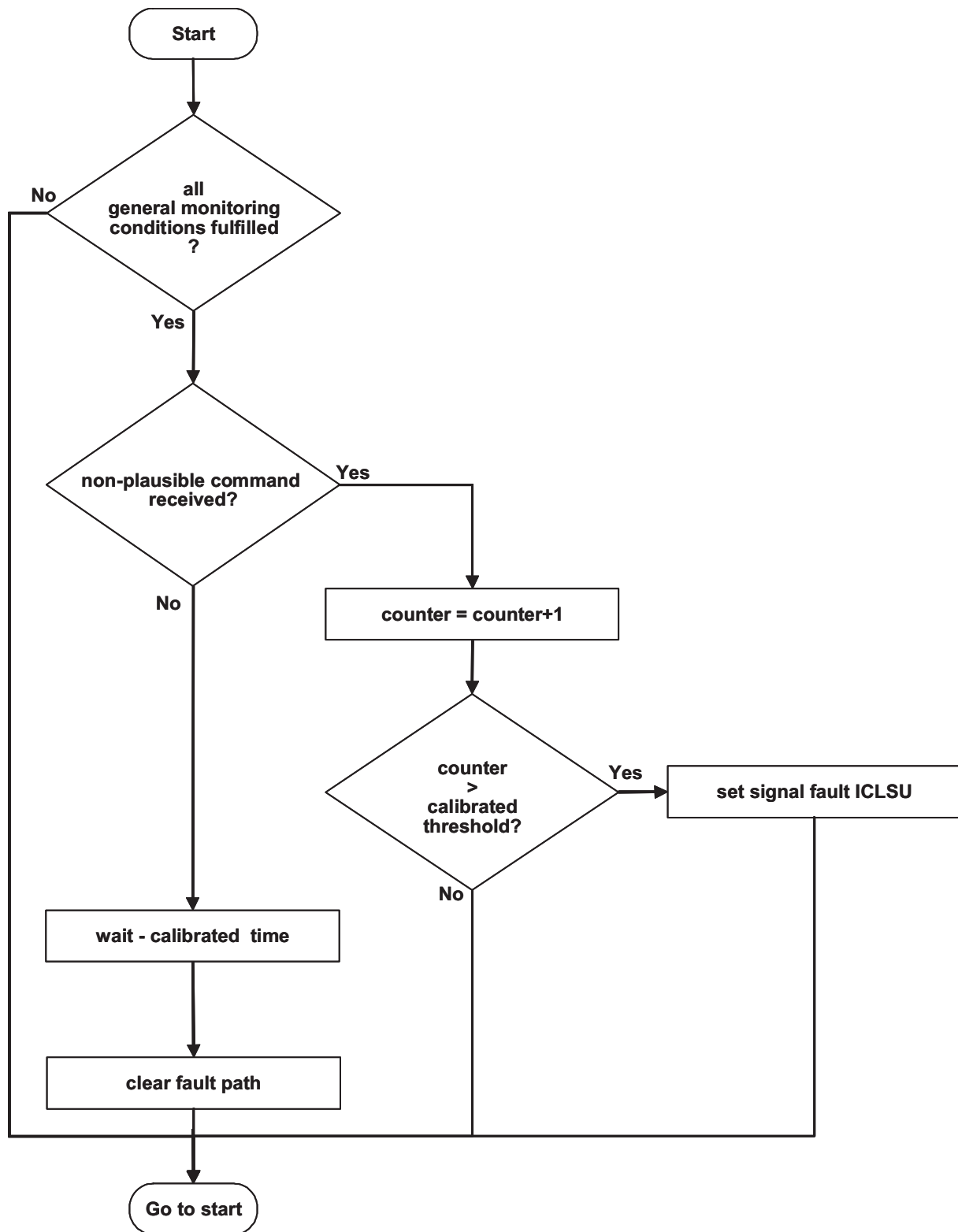


Figure 49: Flow chart: Non-plausible commands counter

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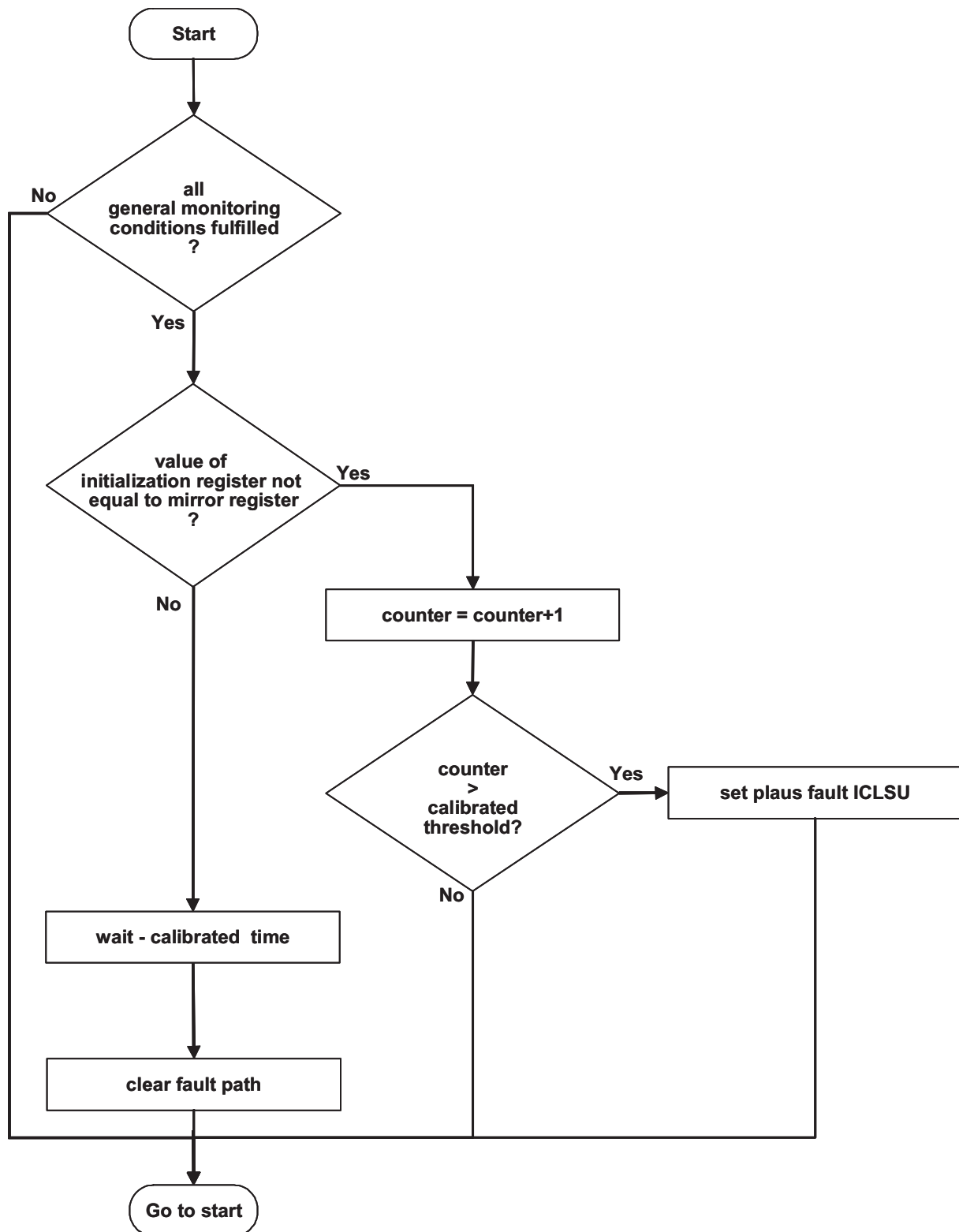


Figure 50: Flow chart: Comparison of the initialization registers with its mirror register

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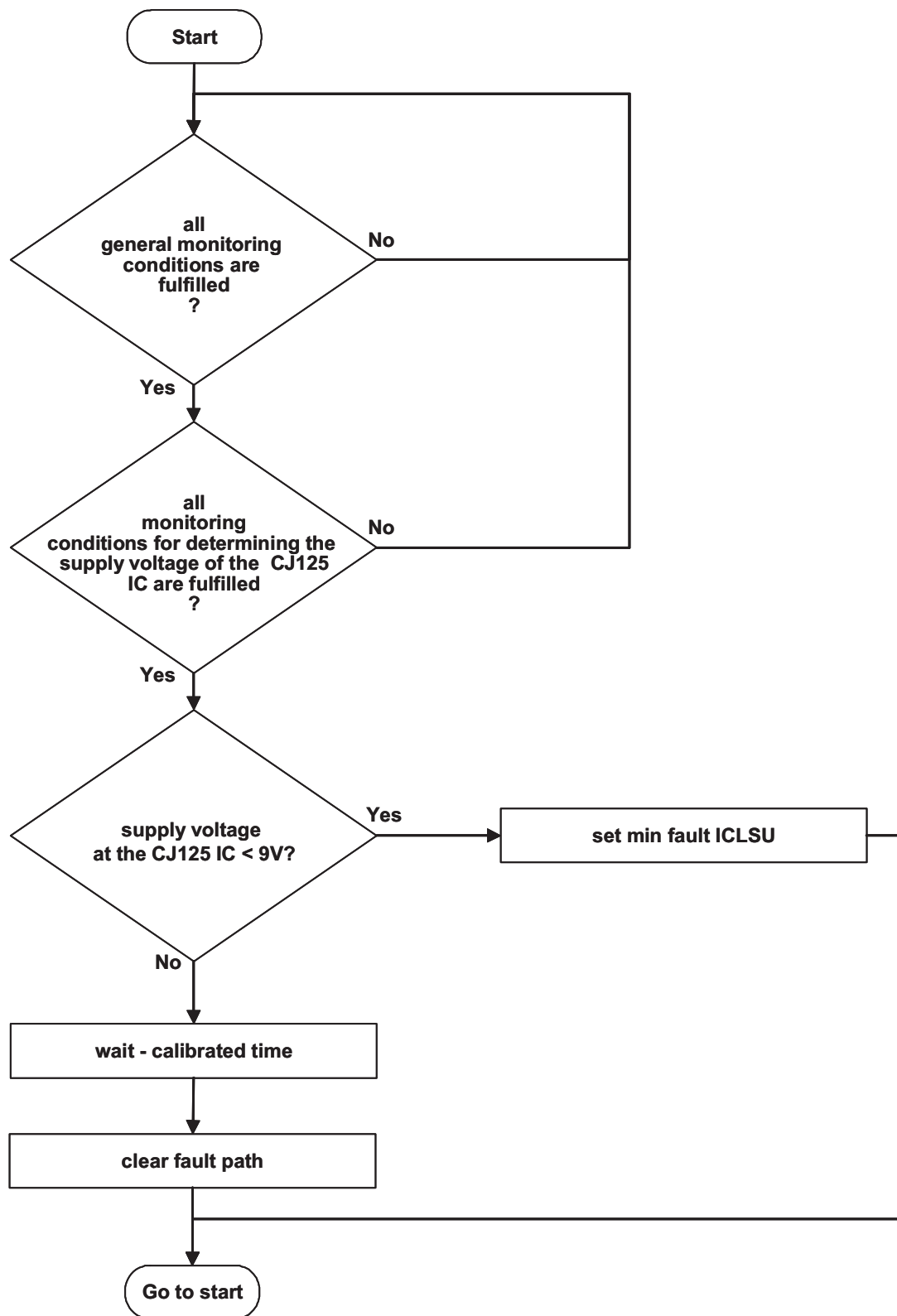


Figure 51: Flow chart: Low supply voltage of the CJ125 IC

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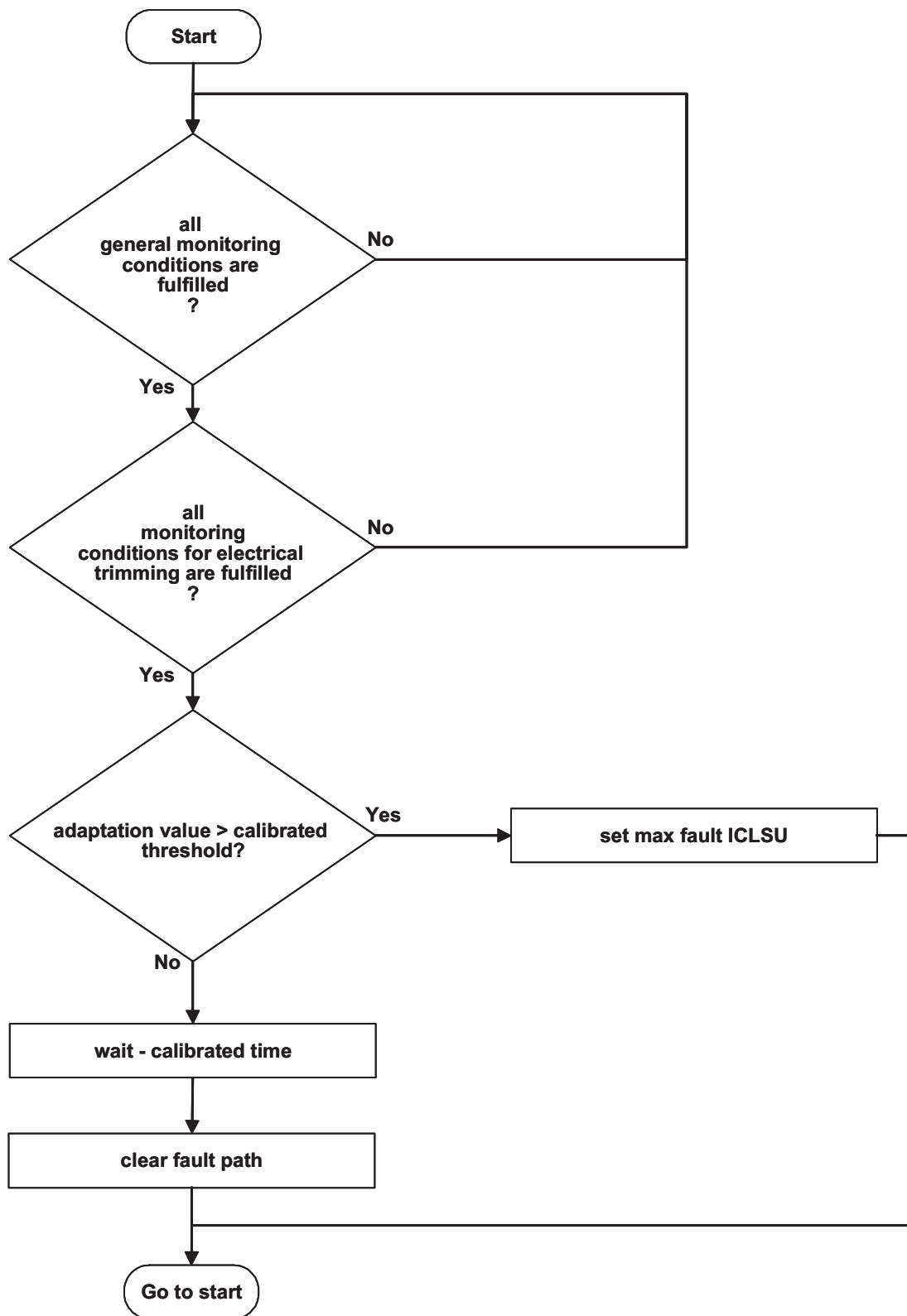


Figure 52: Flow chart: Electrical trimming

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7.1.4 Diagnosis of Electrical Faults at the upstream HO2S

Refer to Figure 53.

Lambda control can be disabled only when at least a pending fault code (service \$07) has been entered in the fault code memory. Several operating conditions do exist, under which faulty components can be pinpointed only after a time delay. Lambda control must however be disabled when fault symptoms are detected.

This diagnostic function detects and sets a general electrical fault. The actual fault which is accompanied by a second entry into the fault code memory is then pinpointed afterwards by the appropriate diagnostic function. This second fault entry could either be a sensor line error or a heater fault of the upstream O2 sensor. In order to ensure timely MIL illumination (two-in-a-row principle) the general electrical fault is also set when a sensor line error or a heater fault of the upstream O2 sensor is set.

A general electrical fault of the upstream heated oxygen sensor will be set either:

- When the internal resistance of the O2 sensor's Nernst cell is implausibly high or the ceramic temperature of the upstream HO2S is implausibly low. All of the following monitoring conditions must be fulfilled in both cases:
 - the exhaust gas temperature model is valid
 - the modeled exhaust gas temperature at the upstream O2 sensor's location lies above a calibrated minimum
 - the upstream O2 sensor's heater is enabled/switched on and throttle fuel cut-off condition doesn't exist
 - the upstream O2 sensor's heater diagnostic has not been inhibited (battery voltage supply)
 - no errors from the upstream O2 sensor's heater power stage
 - no faults of the upstream O2 sensor's evaluation IC
 - no short circuits of the upstream O2 sensor
- or when the upstream O2 sensor's IC Nernst voltage line diagnostic is performed via its IC diagnostic and an interruption of this line is detected.
- or when the upstream O2 sensor's virtual ground line diagnostic has been performed via its IC diagnostic and an interruption of this line is detected
- or when the upstream O2 sensor's heater circuit diagnostic is performed and a heater fault is detected.

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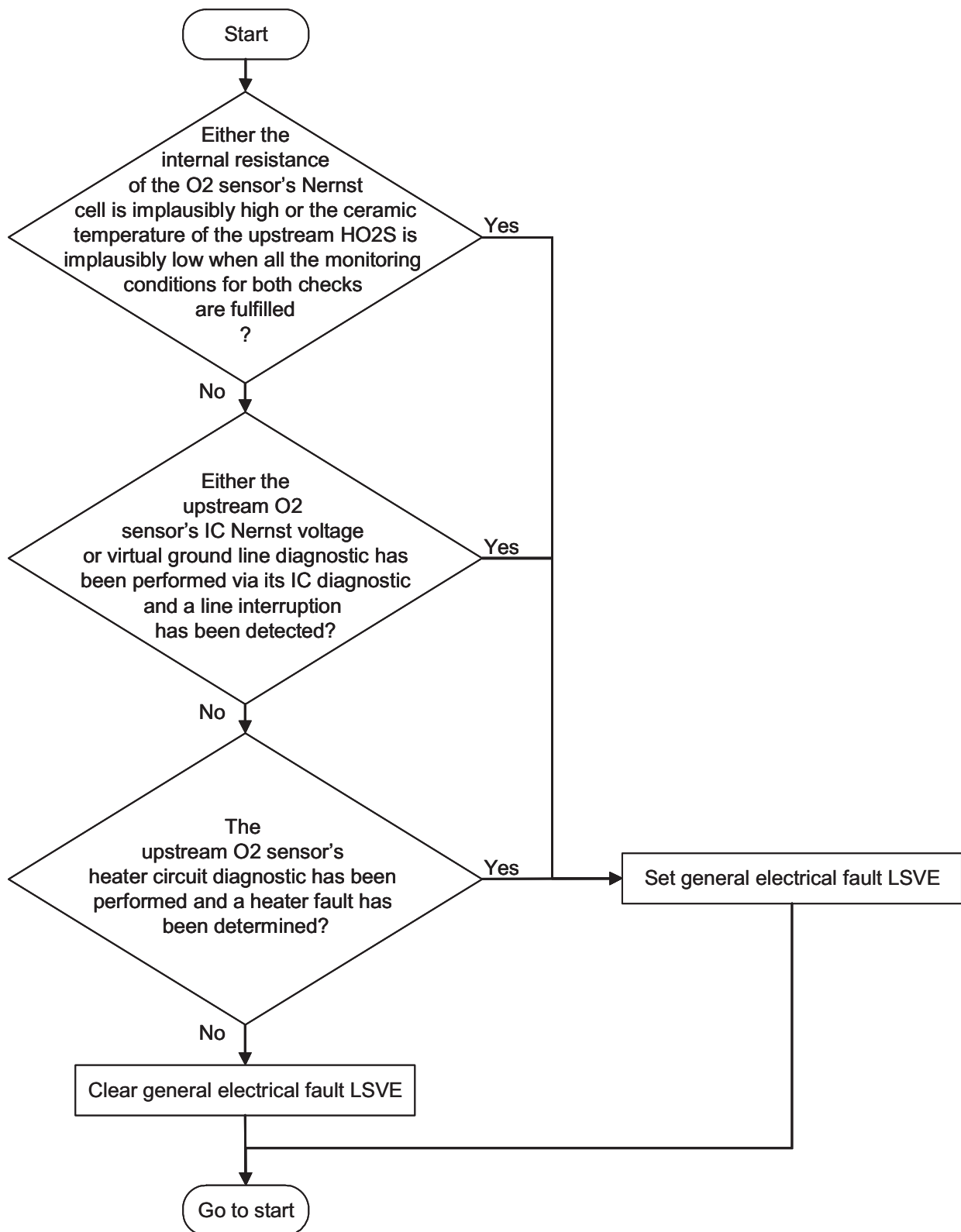


Figure 53: Flow chart: Diagnosis of electrical faults

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7.1.5 Diagnosis of LSU Voltage

Refer to Figure 54 and Figure 55.

This section describes the sum of all possible LSU voltage checks of the upstream HO2S. Depending on the exact system configuration only a subset of the described checks, monitoring conditions, IUMPR functions and flowcharts might be performed.

The diagnosis performs a range check of the voltage V_A of the output signal of the heated wide band upstream oxygen sensor (LSU) after amplification by the CJ125 integrated circuit – see fig.1 below. V_A depends on the characteristics of the oxygen sensor itself and those of the peripheral circuitry of CJ125.

Generally, in homogenous or homogenous-lean engine operation the measured output voltage V_A lies clearly below the voltage read when the oxygen sensor lies in ambient air. If the measured Voltage V_A exceeds the calibrated ambient air voltage but lies below a calibrated maximum voltage, all for a calibrated period of time, a malfunction is detected and a rationality fault ULSU is set. .

A fault could be triggered if an electrically connected oxygen sensor is not properly mounted in the exhaust system.

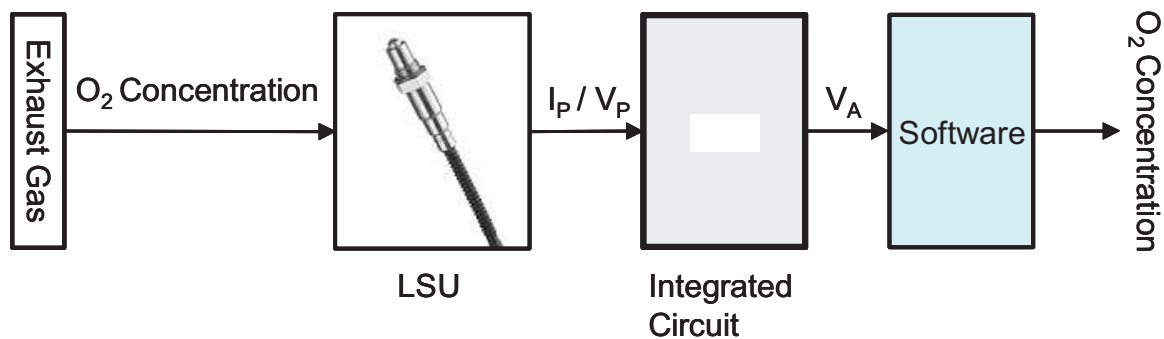


Figure 54: Voltage diagnosis of the wide band upstream oxygen sensor

Monitoring conditions:

- all injection valves are active
- engine start is finished
- upstream oxygen sensor has reached operating temperature
- upstream oxygen sensor is ready for operation
- set point value of normalized air-fuel ratio lies below threshold value
- no lean shift fault in last driving cycle without cooled off sensor
- fuel tank level has been validated
- AIR injection not active
- no fault of crankshaft ventilation diagnosis
- diagnosis of 'evaluation IC of the upstream HO2S' performed without faults
- enabled by the diagnostic scheduler

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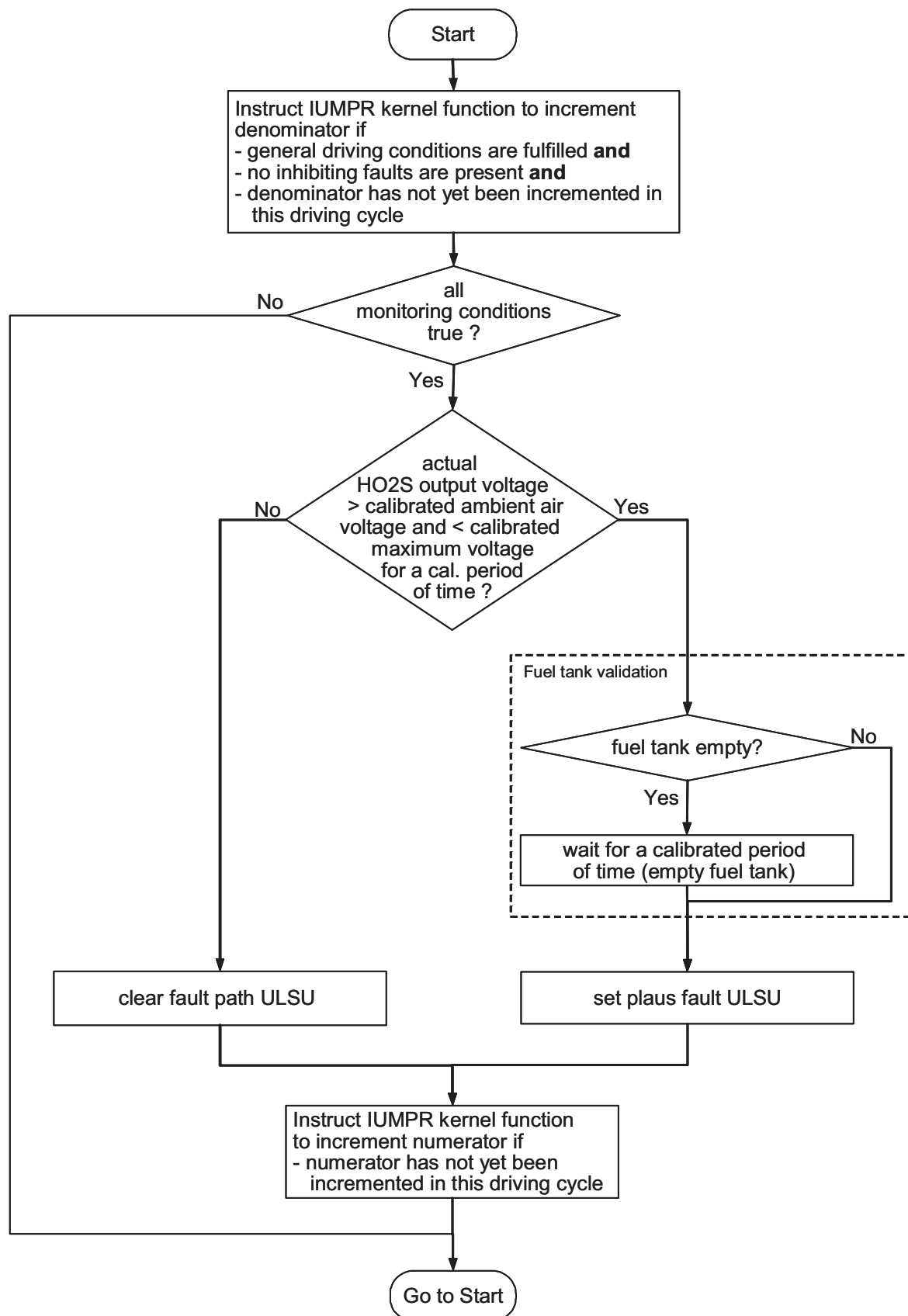


Figure 55: Flow chart: Diagnosis of LSU Voltage

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7.1.6 Diagnosis of readiness of downstream HO2S

This section describes the sum of all possible readiness checks of the downstream HO2S. Depending on the exact system configuration only a subset of the described checks, monitoring conditions and flowcharts might be performed.

The operation readiness diagnostic of the downstream heated oxygen sensor (HO2S) runs continuously and can detect faulty electrical connections of the HO2S. Heater circuit faults are monitored separately.

Most of the checks use the measured voltage of the downstream HO2S as an input for diagnosis. The following figure shows the areas where a malfunction is detected.

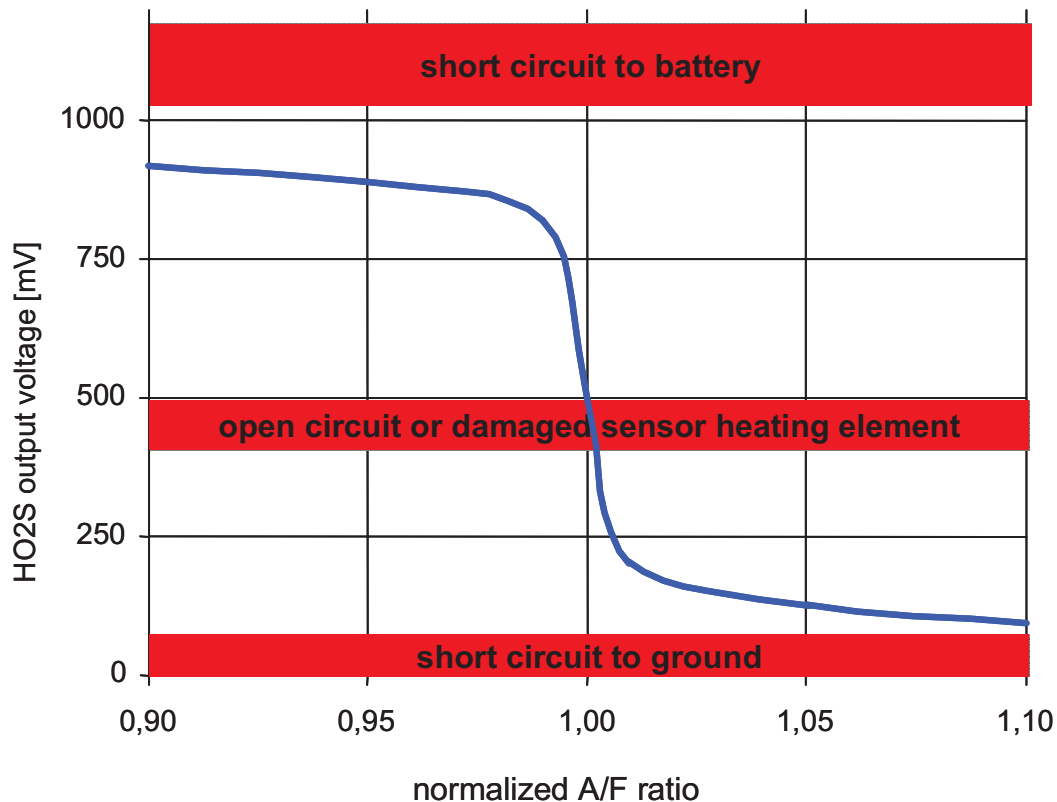


Figure 56: Illustration of HO2S output voltage characteristic and malfunction detection areas

7.1.6.1 Detection of short circuit to battery

Refer to Figure 57.

A short circuit to battery of the sensor's signal wire can be detected by monitoring the voltage of the downstream HO2S.

If the measured voltage of the downstream HO2S exceeds permanently the upper calibration limit for a calibrated period of time, a malfunction is detected and a maximum fault LSH is set.

Monitoring conditions – short circuit to battery:

- modelled exhaust gas temperature at the downstream HO2S' vicinity lies within calibrated range
- heating of the downstream oxygen sensor is active (without interruptions) for at least a calibrated period of time
- battery voltage exceeds calibrated threshold
- engine is running

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7.1.6.2 Detection of short circuit to ground

Refer to Figure 57.

A wire-to-wire short circuit between sensor signal and sensor ground or a short circuit between sensor signal and car body ground can be detected by monitoring the voltage of the downstream HO2S. If the measured voltage of the downstream HO2S lies below the lower calibration limit for a calibrated period of time and the HO2S is cold, a malfunction is detected and a minimum fault LSH is set. The fault is set after an additional calibrated time if the fuel tank is empty.

Monitoring conditions - short circuit to ground:

- modelled exhaust gas temperature at the downstream HO2S' vicinity lies within calibrated range
- heating of the downstream oxygen sensor is active (without interruptions) for at least a calibrated period of time
- battery voltage exceeds calibrated threshold
- engine is running
- cold HO2S. Conditions for a cold HO2S are:
 - no fault of engine coolant temperature sensor
 - engine coolant temperature at last engine stop exceeds calibrated threshold
 - current engine coolant temperature lies below calibrated threshold
 - calibrated time since engine start not elapsed

7.1.6.3 Detection of open circuit or damaged sensor heating element

Refer to Figure 58. Depending on the exact system configuration the open circuit check consists of

- ((either variant 1a or variant 1b) and always variant 2)

OBD Group Name	Test group	Engine	Models	Standard	Damaged sensor heating element variant
CVW-W	CBEXV06.0501	6.0 W12T - 2 bank	Continental	LEV II Bin 5	1b & 2

Variant 1a) Detection of open circuit or damaged sensor heating element

A wire interruption of the sensor's signal or sensor's ground or a damaged sensor heating element can be detected by monitoring the voltage of the downstream HO2S.

If the measured voltage of the downstream HO2S lies within a calibrated range for a calibrated period of time, a malfunction is detected and a signal fault LSH is set.

Monitoring conditions - open circuit or damaged sensor heating element:

- modelled exhaust gas temperature at the downstream HO2S' vicinity lies within calibrated range
- heating of the downstream oxygen sensor is active (without interruptions) for at least a calibrated period of time
- battery voltage exceeds calibrated threshold
- engine is running
- engine start is finished

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Variant 1b) Detection of open circuit or damaged sensor heating element

A wire interruption of the sensor's signal or sensor's ground or a damaged sensor heating element can be detected by monitoring the voltage of the downstream HO2S.

If the measured voltage of the downstream HO2S lies within a calibrated range for a calibrated period of time, a malfunction is expected and an additional test function is started. The additional test function is described in the aging diagnosis of the downstream HO2S (oscillation check).

If after completion of the additional test function the measured voltage of the downstream HO2S still lies within the calibrated range, a signal fault LSH is set.

Monitoring conditions - open circuit or damaged sensor heating element:

- modelled exhaust gas temperature at the downstream HO2S' vicinity lies within calibrated range
- heating of the downstream oxygen sensor is active (without interruptions) for at least a calibrated period of time
- battery voltage exceeds calibrated threshold
- engine is running
- engine start is finished

Variant 2) Detection of open circuit or damaged sensor heating element

A wire interruption of the sensor's signal or sensor's ground or a damaged sensor heating element can be detected by monitoring the internal resistance of the Nernst cell of the downstream HO2S.

If the measured internal resistance of the Nernst cell and the modelled exhaust gas temperature at the vicinity of the downstream HO2S exceed their calibrated thresholds, a malfunction is detected and a signal fault LSH is set.

Monitoring conditions - open circuit or damaged sensor heating element:

- modelled exhaust gas temperature at the downstream HO2S' vicinity lies within calibrated range
- heating of the downstream oxygen sensor is active (without interruptions) for at least a calibrated period of time
- battery voltage exceeds calibrated threshold
- engine is running

Heater coupling check

Heater noise couplings into the HO2S signal are detectable only when the heater is being switched off (falling edge). A heater-off-counter is incremented every time the HO2S' heater is switched off (falling edge). Likewise a coupling-detection-counter is incremented when the switching off of the heater (falling edge) is accompanied by an HO2S voltage gradient that exceeds a calibrated threshold for a calibrated period of time.

If the heater-off-counter reaches a calibrated threshold and at the same time the coupling-detection-counter exceeds a calibrated threshold, a malfunction is detected and a rationality fault LSH is set.

Monitoring conditions - heater coupling check:

- modelled exhaust gas temperature at the downstream HO2S' vicinity lies within calibrated range
- heating of the downstream oxygen sensor is active (without interruptions) for at least a calibrated period of time
- battery voltage exceeds calibrated threshold
- engine is running
- temperature downstream catalyst exceeds dew-point for a calibrated period of time
- heater power stage of downstream HO2S is active

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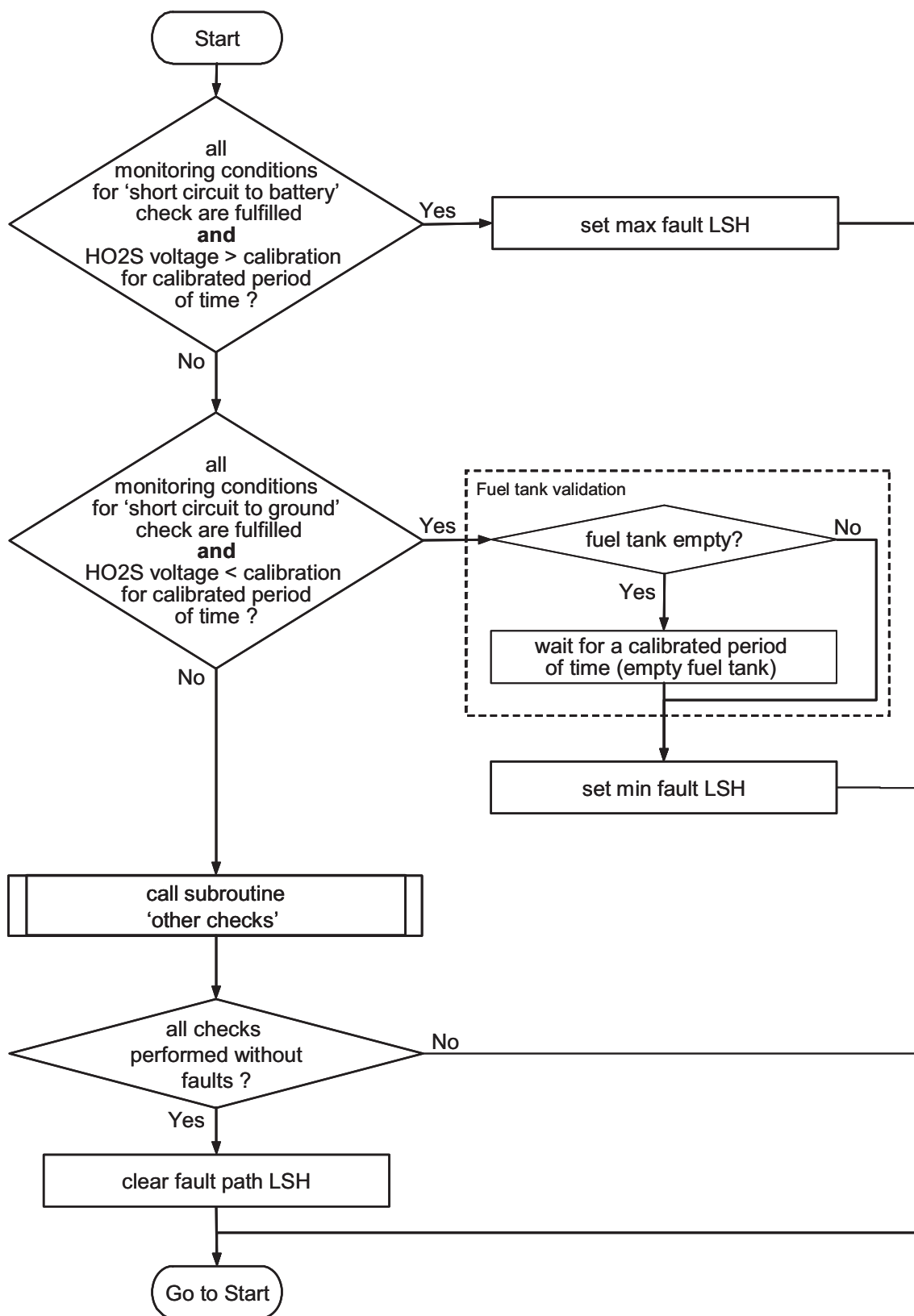
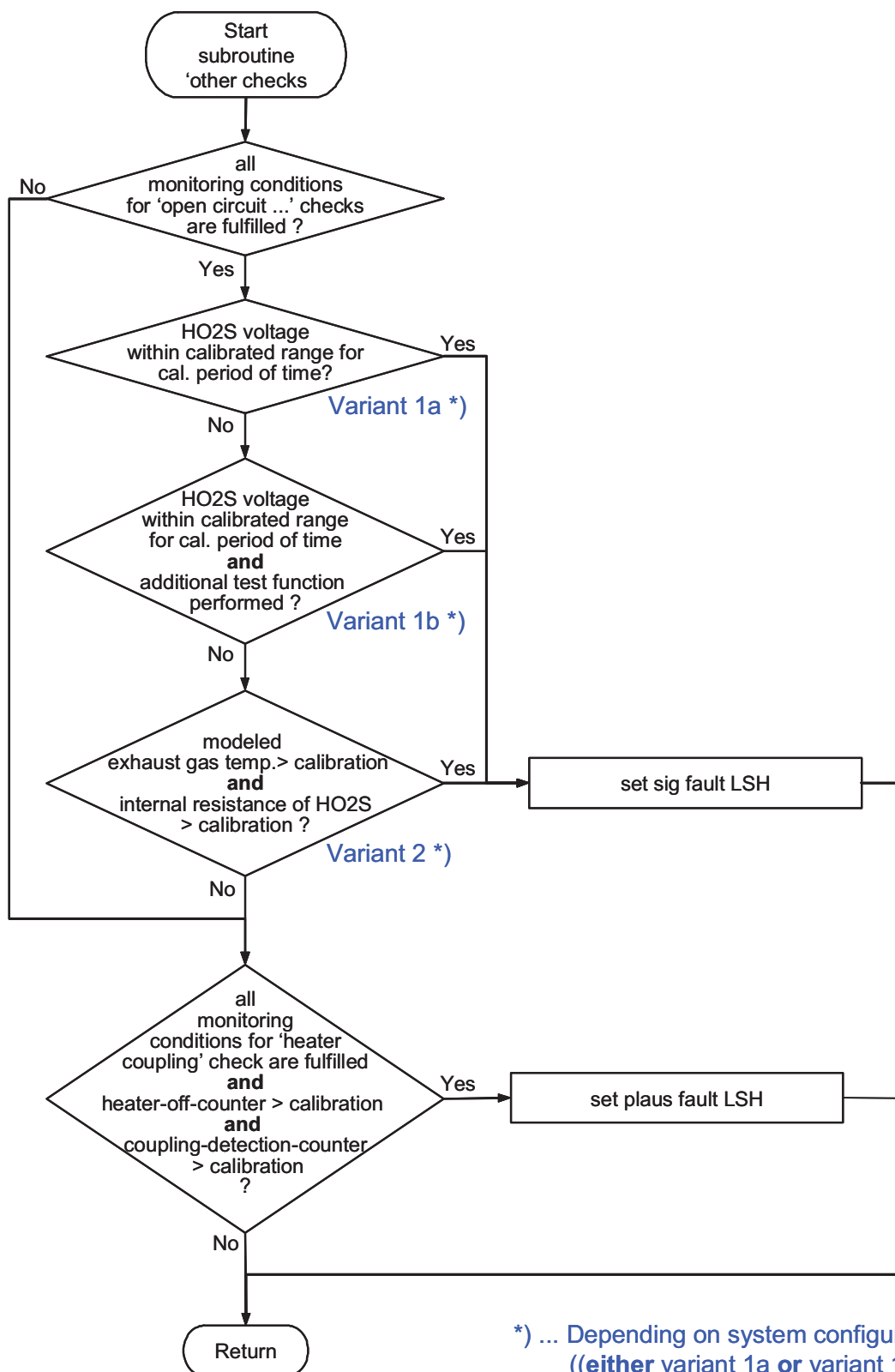


Figure 57: Flow chart: Readiness of downstream HO2S (short circuit detection)

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*) ... Depending on system configuration ((either variant 1a or variant 1b) and always variant 2) is performed

Figure 58: Flow chart: Detection of open circuit or damaged sensor heating element

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7.1.7 Diagnosis of aging of downstream HO2S-Oscillation check

The diagnosis of the aging of the downstream HO2S consists of an oscillation check and a threshold check during fuel cut-off. It analyzes the fault paths of up to 2 banks. The faults paths of bank1 are identical to those of bank2 and the fault paths of each bank are handled separately using the same procedure. The diagnosis runs continuously.

General Monitoring Conditions:

- the canister purge system diagnosis has detected no faults
- no faults of the canister purge valve's power stage diagnosis
- no battery voltage faults
- the downstream oxygen sensor connectors are correctly matched with their corresponding banks (only for 2 bank systems)

7.1.7.1 Oscillation Check

Refer to Figure 59.

During normal engine operation the normalized A/F ratio and hence the voltage of the HO2S oscillates about the set point value. The oscillation check triggers a test function if the measured voltage of the HO2S' signal permanently lies below or above the set point value for a calibrated period of time. The test function applies a rich A/F mixture if the voltage is below the set point value or a lean A/F mixture if the voltage is above the set point value.

If the voltage doesn't cross the set point value in the expected direction after applying a lean or rich A/F mixture, a malfunction is detected and a minimum or maximum fault LASH will be respectively set.

Monitoring Conditions for Oscillation Check:

- all general monitoring conditions have been fulfilled
- the proportional part of the mixture control system on the downstream side of the main catalyst has been activated
- the mass airflow is greater than calibration
- the canister purge valve is inactive
- fuel control error threshold has not been exceeded
- no critical misfiring rate.

7.1.7.2 Threshold Check during trailing throttle Fuel Cut-off

This check determines whether the voltage of the HO2S' signal exceeds a calibrated threshold for a calibrated period of time during fuel cut-off. A malfunction is detected and a signal fault LASH is set if this is true.

Monitoring Conditions - Threshold Check during trailing throttle Fuel Cutoff:

- all general monitoring conditions are fulfilled
- fuel cut-off for a calibrated period of time
- the required mass airflow for response rate determination has been reached
- no electrical faults of the downstream HO2S
- no electrical fault of the downstream HO2S' heater
- no electrical fault of the downstream HO2S heater's power stage
- the modeled exhaust gas temperature on the downstream side of the catalyst is above a calibrated threshold
- the downstream HO2S has been sufficiently heated up
- the dew-point temperature on the downstream side of the catalyst has been exceeded.

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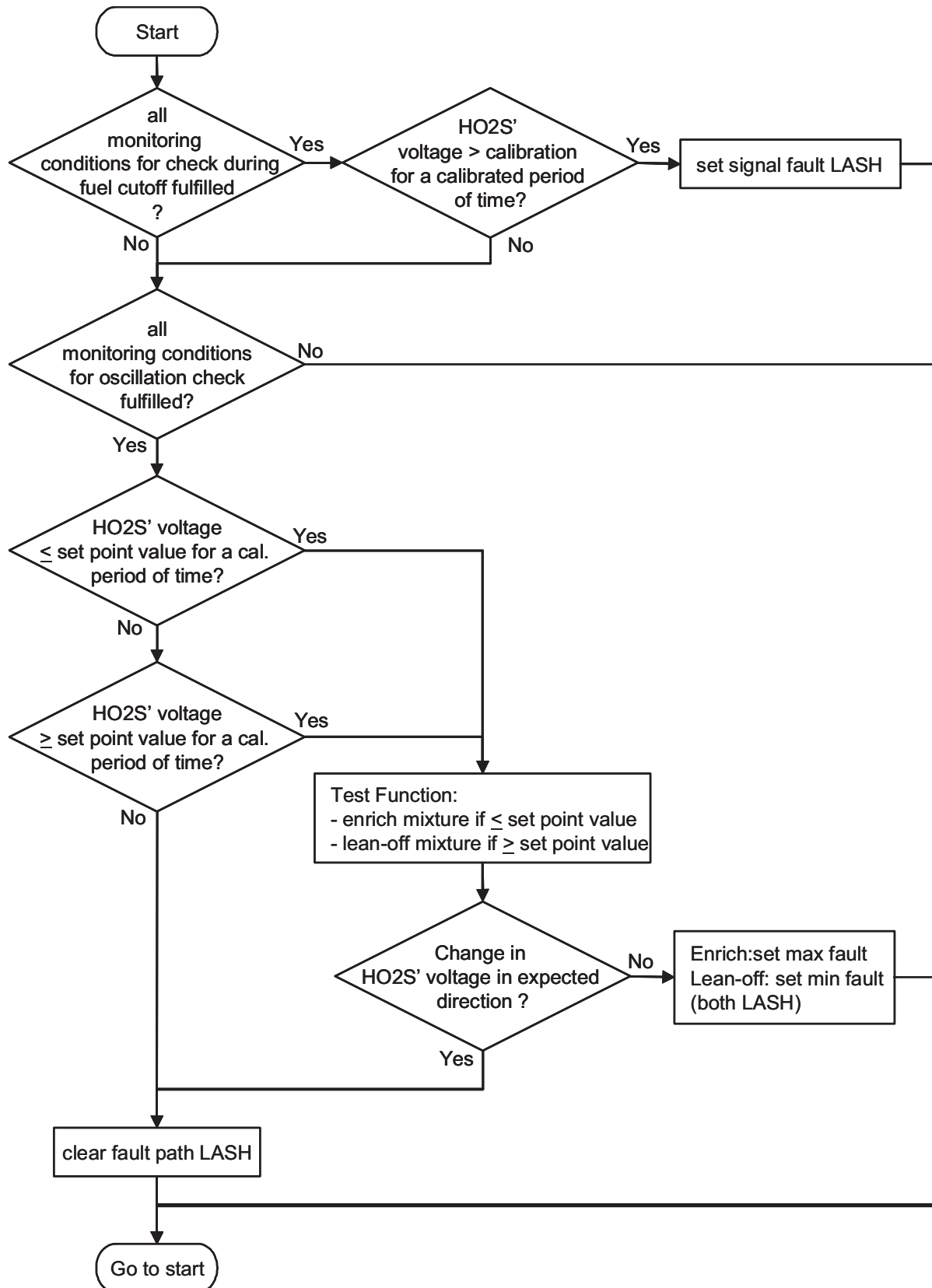


Figure 59: Flow chart: Oscillation check

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7.1.8 Secondary HO2S response time and transition time monitoring

Applicability of response time and transition time monitoring is indicated in the table:

OBD Group Name	Test group	Engine	Models	Standard	OBD II Monitoring Strategy
CVW-W	CBEXV06.0501	6.0 W12T - 2 bank	Continental	LEV II Bin 5	Response Time

7.1.8.1 Second and Third HO2S Response Rate Diagnostic

System documentation reference: (DYLSFsig; DDYLSHsig; DDYLSFmax)

Aging, contamination or insufficient heating of the secondary (third) HO2S may slow down the sensor's response rate. A slow response rate could influence the catalyst diagnostic and can lead to higher emissions. Therefore this diagnostic function monitors the HO2S Response Rate. The monitor is designed to be executed repeatedly (multiple times) within the same driving cycle as long as the enable conditions are fulfilled or fulfilled again and consist of two monitoring functions. The Response Rate and the Transition Time monitoring function.

The diagnostic function is executed while fuel cut-off during coast down driving condition is present. The diagnostic results are updated depending on the driving profile and the length of the fuel cut-off period. Typical monitoring frequency during a FTP72 is at minimum one to two events, during the Unified Cycle approximately 5 events and during normal driving on road in customer's hand the typical frequency is 10 to 15 events (based on engineering evaluation of road-data). Refer to Figure 60.

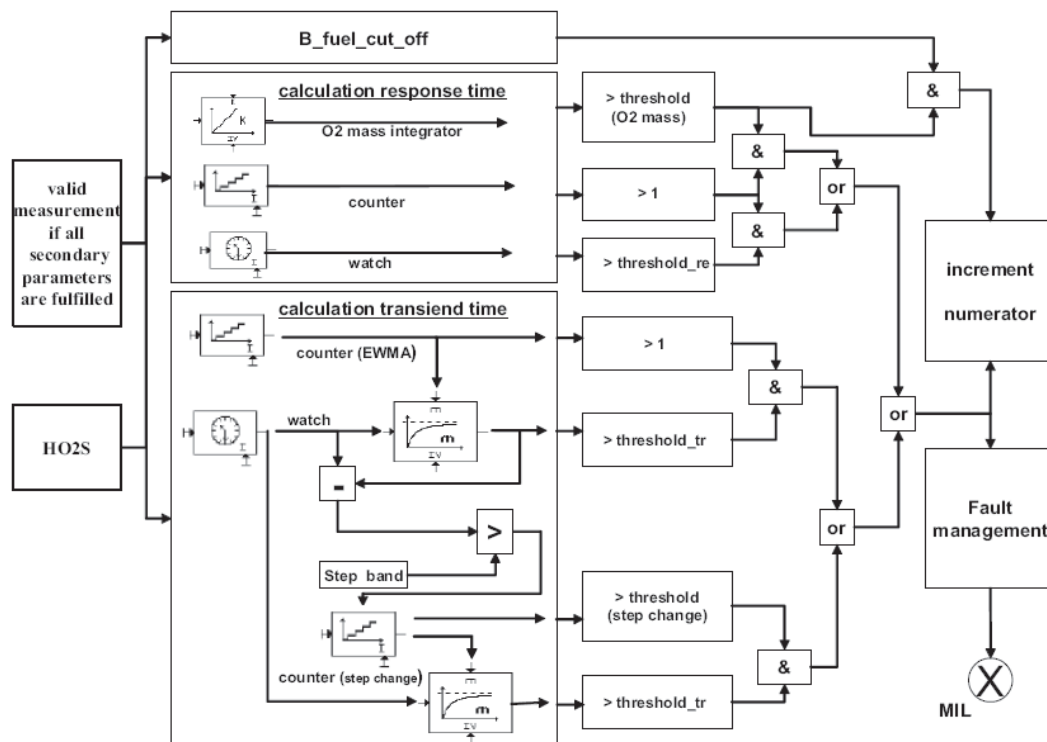


Figure 60: Second (Third) HO2S – Functional Schematic Diagram

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Diagnostic Enable / Disable Conditions

Physical Parameters:

- HO2S ready
- Exhaust temperature post catalyst above an applicable level (typical value: 500°C) (dew point exceeded; to ensure homogeneous temperature distribution in the catalyst)
- Internal resistance of the HO2S is less than an applicable value
- HO2S voltage able to cross control level (typical value: 0.6-0.65V) of fuel trim (optional parameter)
- Exhaust mass flow exceeds an applicable value (typical value: ~15-25 kg/h)
- Slope of exhaust mass flow post catalyst is less than an applicable value ((typical value: Delta mass flow of ~10 kg/h)

Disable Conditions:

- Cycle flag of aging diagnostic HO2S post catalyst (lash) not set or failure(s) detected
- Cycle flag of EVAP purge diagnostic not set or failure(s) detected
- Cycle flag HO2S front catalyst not set or failure(s) detected
- No failures detected on final stage for O2S heater

Signal Evaluation / Validation:

For a robust monitoring function the HO2S signal needs to fulfill the following conditions ensuring a certain level of signal quality:

- HO2S voltage post catalyst exceeds a certain level (typical value: ~0.55-0.6V) before fuel cut-off occurs
- Fuel cut-off is present (Bit for this condition is set)
- HO2S in front of the catalyst is ready and shows definitely "lean" (e.g. Lambda is equal or greater than 10). The front HO2S signal range maximum value is equivalent to a Lambda of 16!
- The signal of the HO2S is monotone decreasing (outlier detection)*
- No HO2S faults detected by the dynamic diagnostic within the actual driving cycle

Outlier Detection

The outlier detection is necessary to exclude interferences of the catalyst during fuel cut-off conditions on the HO2S signal.

The rich-to-lean dynamic diagnostic of the HO2S post catalyst is based on the physical / chemical effect that during fuel cut-off the Lambda value changes in a step response from Lambda equal one to a Lambda equal or greater than 10 indicating the Oxygen storage capability (OSC) of the catalyst is exceeded. In reality the signal behavior of the rear O2S shows occasionally during fuel cut-off a first decrease of sensor voltage to approximately 0.4 Volts, remains at that voltage level for a certain time and then falls again to a voltage of 0.1 Volts. In this specific case the measured transition time is above the fault threshold of the diagnostic but can not be counted as a O2S failure because the event is based on chemical reaction within the catalyst.

Explanation of chemical effect:

At the beginning of the fuel cut-off the CO post catalyst reaches a minimum level because of the increase of Oxygen available in the catalyst allowing an increase in CO-conversion rate into CO₂, the O2S voltage decreases to approximately 0.4 Volts and stays at that level until the OSC of the catalyst is exceeded and the Oxygen level post catalyst increases causing another O2S voltage drop to approximately 0.1 Volts. This interference of the catalyst on the O2S voltage must be excluded from further evaluation by the monitor to prevent false failure detection by the response time diagnostic.

The described physical / chemical effect on the rear O2S signal is shown in Figure 61 below.

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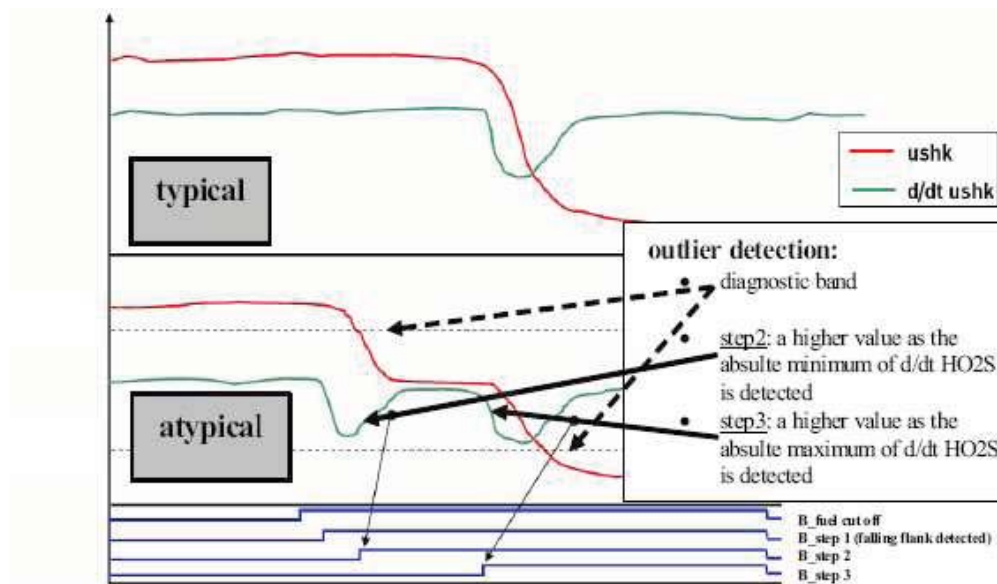


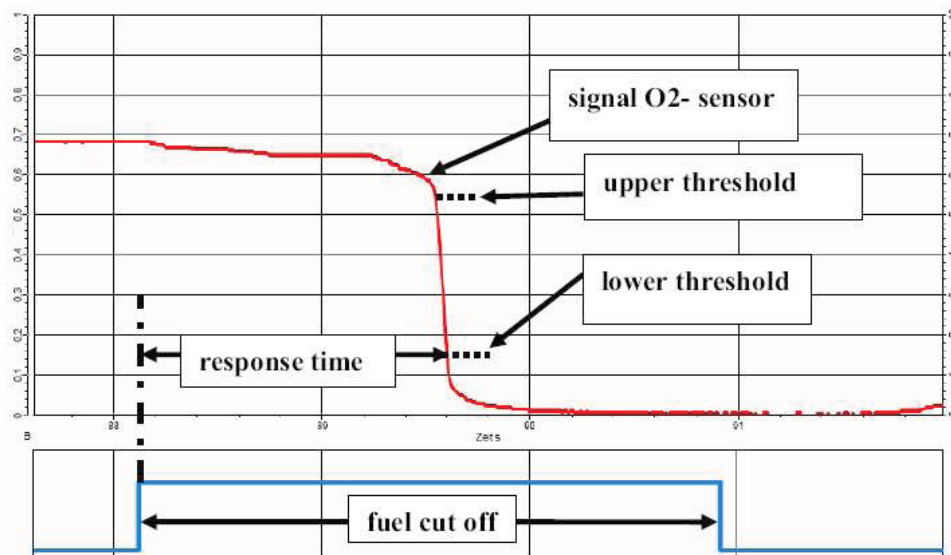
Figure 61: Second (Third) HO2S – Outlier Detection Chart

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7.1.8.2 Monitoring of the Response Time

Definition

Once fuel cut-off is present, the response time is defined as the O2S signal time needed to fall below a certain voltage level (typical value: ~0.15V). (Figure 62) This part of the diagnostic replaces the former diagnostic of the O2S aging-monitor (DLSAHK) conducted during fuel cut-off.



Second (Third) HO2S – 'Response Time'

Figure 62: Monitoring of response time

Application of Response Time Diagnostic

Refer to Figure 63.

The main factors influencing the response time diagnostic are the exhaust mass flow, engine operating condition and the aging level of the catalyst. The maximum time allowed needs to be determined on the catalyst with the highest OSC value (e.g. new catalyst). The evaluation of the response time therefore is a measure whether the O2S signal is capable to show a voltage drop below a certain level within a certain time.

If the enable conditions are fulfilled and the O2S signal falls below an applicable voltage level (typical value: ~0.15 Volts) or the mass of Oxygen lead into the catalyst is above an applicable value (typical value: ~ 2.5 g O₂) the measured value of response time is valid. Every valid value is evaluated and counted. The memory of response time and counted events will be cleared with power fail or with the OBD fault memory deleted by use of a Generic Scan Tool (GST).

If the event counter exceeds an applicable level the cycle flag can be set or in case of a response time measured exceeding the applicable fault threshold the diagnostic trouble code (DTC) is stored.

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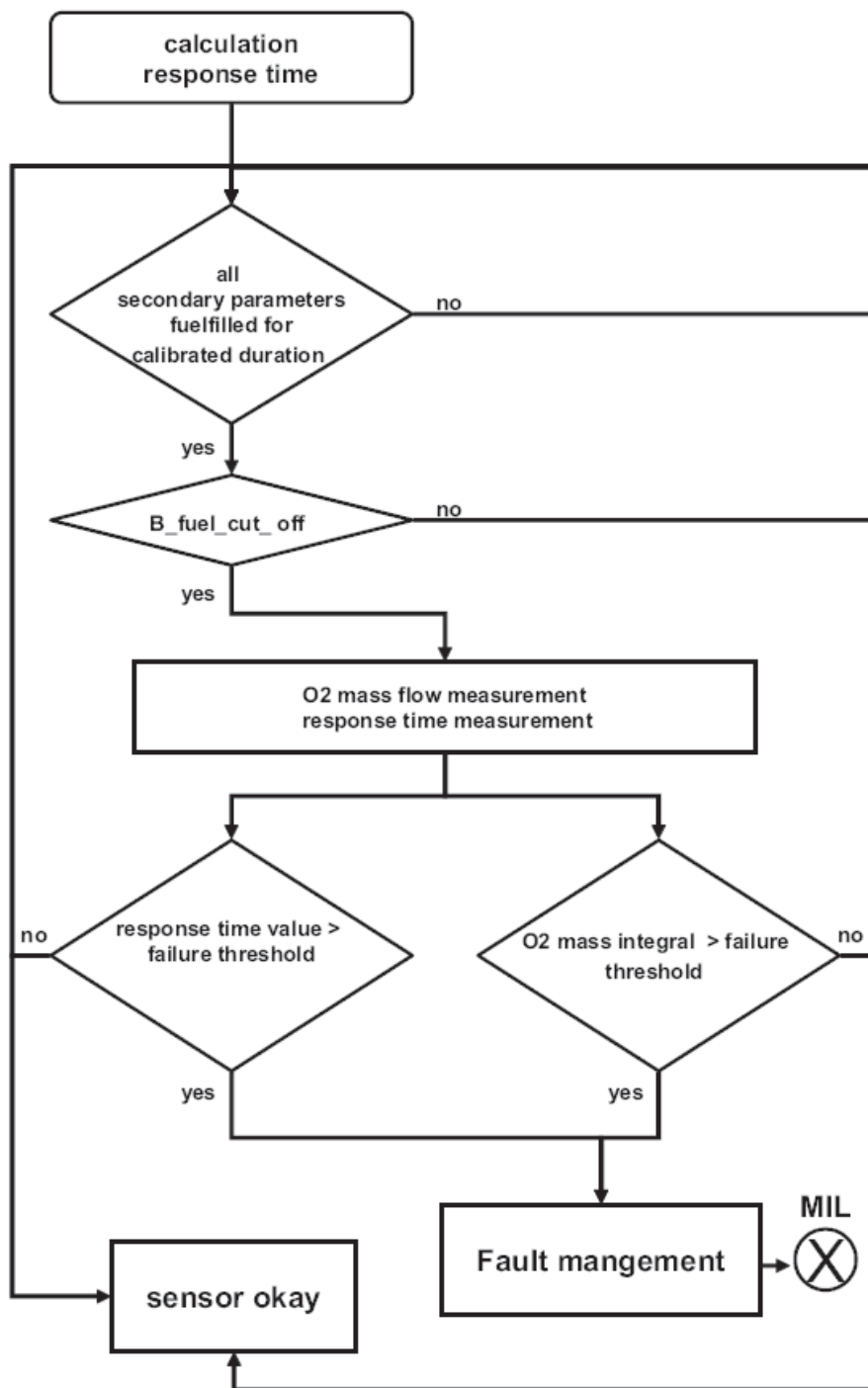


Figure 63: Second (Third) HO2S – Calculation HO2S response time check

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7.1.8.3 Monitoring of Transition Time

Definition:

The transition time is defined as the time the O₂S signal needs to pass-through an applicable voltage band (typical range: ~0.4-0.2V). This diagnostic function shall ensure that the reduced O₂S signal dynamic (e.g. due to aging) exceeds a specified time threshold. This function is also used to improve the monitoring capability by minimizing the theoretical possibility of “false passes” of an aged catalyst caused by reduced HO₂S dynamic. See Figure 64.

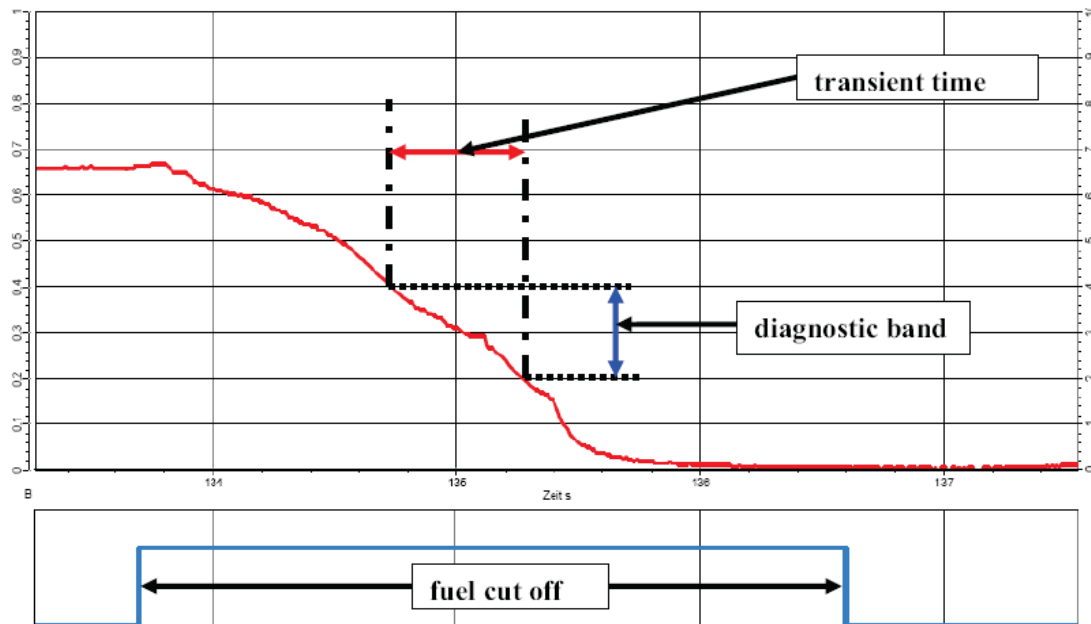


Figure 64: Second (Third) HO₂S – Transition time

Application of Transition Time Diagnostic

If all enable conditions are fulfilled and the difference between actual and stored transition time value is less than a calibrated value (typical value: ~0.3V) the valid measured value is filtered (moving average) and an event counter is increased. The filter features a “step change” capability in case of difference between actual measured transition time and previously stored transition time is greater than a calibrated value (typical value: ~0.3V) a second filter (arithmetic mean value) and a second event counter is used. This ensures an adequate system reaction in cases of suddenly occurrence of great deterioration in O₂S dynamic by storing a diagnostic trouble code in a shorter time. The memory of transition time and counted events will be cleared with power fail or with the OBD fault memory deleted by use of a Generic Scan Tool (GST).

If the event counter exceeds an applicable level the cycle flag can be set or in case of the filtered transition time exceeding the applicable fault threshold the diagnostic trouble code (DTC) is stored.

The following schematic shows the principle of the diagnostics in Figure 65.

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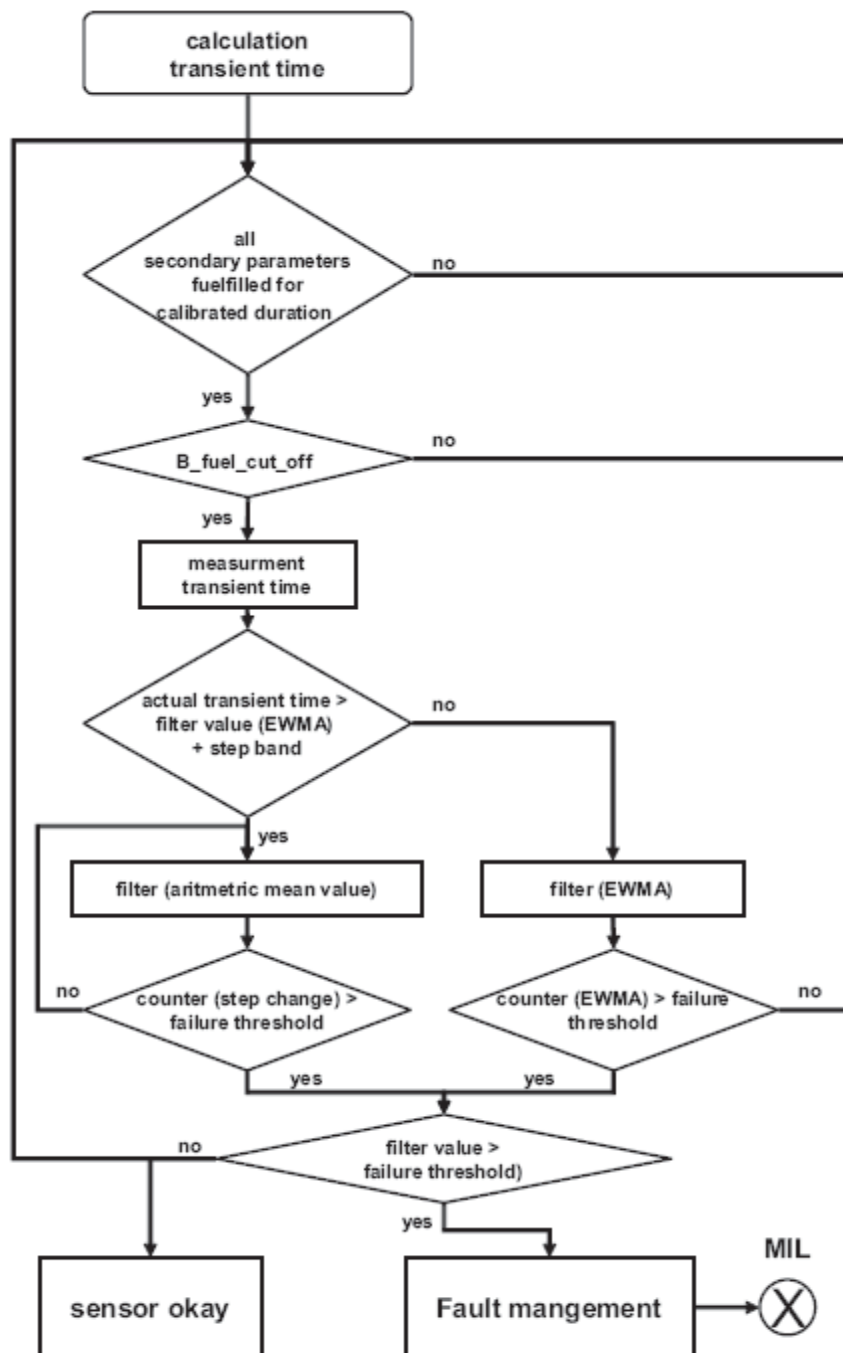


Figure 65: Second (Third) HO2S – Calculation HO2S transition time check

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7.1.8.4 In Use Performance Ratio for HO2S Response Rate Monitor

Refer Figure 66.

OBD Group Name	Test group	Engine	Models	Standard	Monitor Reporting
CVW-W	CBEXV06.0501	6.0 W12T - 2 bank	Continental	LEV II Bin 5	YES

The incrementing of the numerator, the denominator and the ratio calculation for the HO2S "Response Rate" monitor is executed by the "IUMPR-Kernel" as a subroutine. Like all monitors for which a standardized tracking and reporting of the in-use performance is required, the HO2S "Response Rate" monitor reports to the "IUMPR Kernel"-function via status flags.

Conditions for Incrementing the Numerator

The numerator is incremented, once per driving cycle in case of a fault is detected or if the Oxygen mass flow integral exceeds an calibrated value (typical value: ~2.5 – 3.5 g O₂) and a certain number of valid measurements has been conducted (typical value: ~1 - 3 measurements).

Conditions for Incrementing the Denominator

The denominator is incremented if the standardized conditions are fulfilled within the actual driving cycle and the monitor is not inhibited due to already stored faults or faults detected on the sensors necessary to determine the denominator itself.

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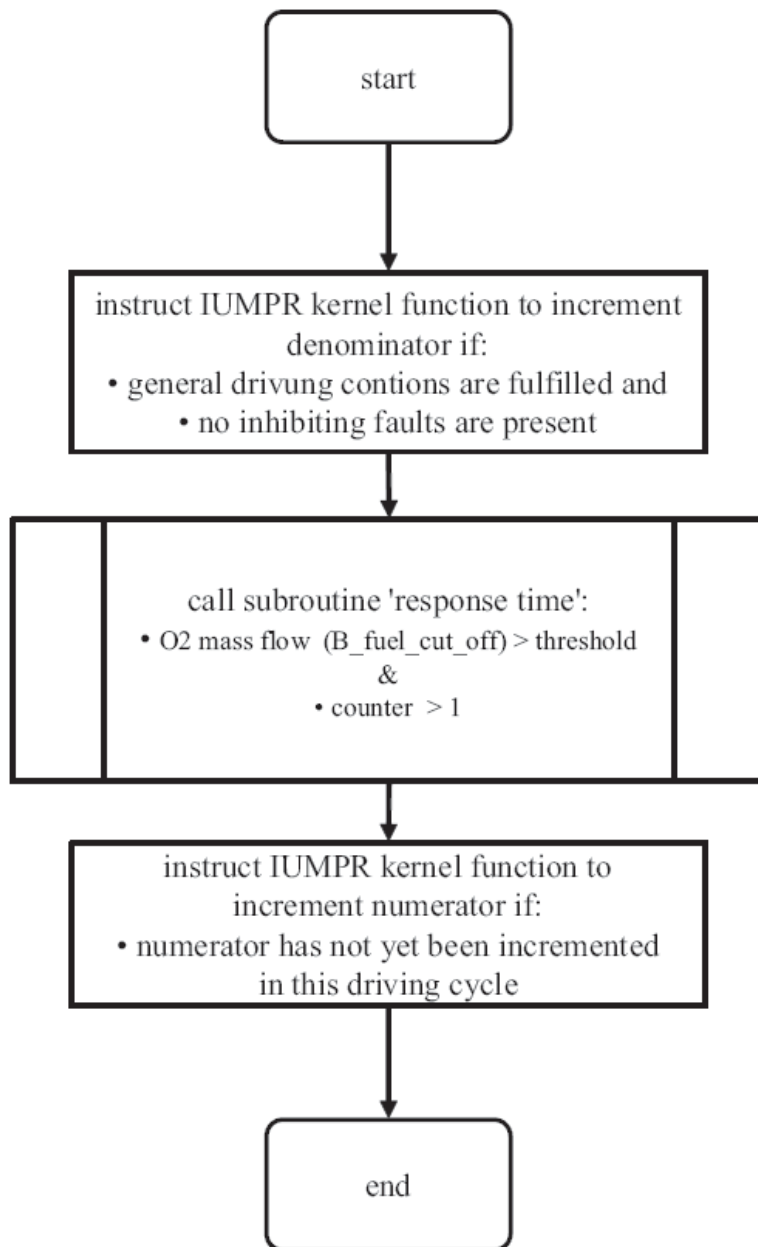


Figure 66: Second (Third) HO2S – main HO2S check

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7.1.8.5 EWMA filter for Second and Third HO2S “Response Rate” Monitoring

General Description

If all enable conditions are fulfilled the actual transition time is measured. The single raw values are feed into a filter (EWMA).

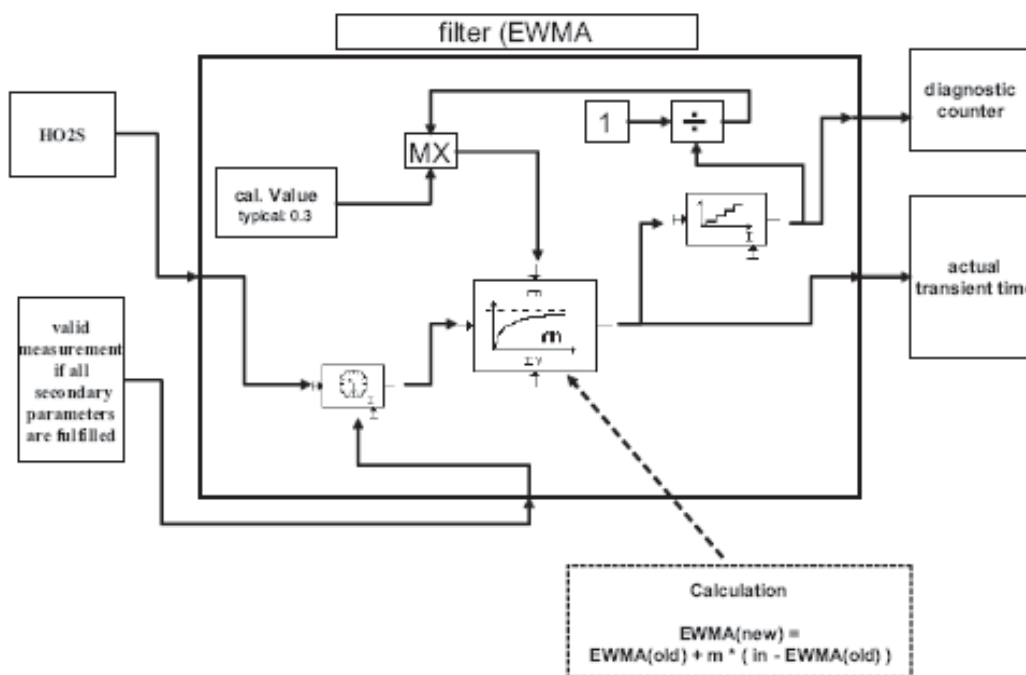


Figure 67: Block Diagram of EWMA Filter

The EWMA filter is being calculated / updated with each valid measured transition time.

- During a stabilization phase the filter is filled with single valid measured values of transition time.
- After the stabilization phase an actual and valid measured value is necessary.
- If the current transition raw value deviates by a certain amount from the stored EWMA filter value, a malfunction is suspected (step change suspicion). The criteria for “step change suspicion” is not depending on the “MIL on” threshold. Typically an error decision (“MIL on”) is achieved within the same driving cycle.

There are three different stages for the EWMA filter possible:

1. Stabilized State (EWMA filter is filled with sufficient single measured values)
2. Step Change triggered (Difference of raw value from the EWMA value exceeds a certain amount)
3. Fast Initialization (After the EWMA filter is deleted due to power fail or the use of a GST)

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7.1.8.5.1 Stabilized State of EWMA Filter

Refer to Figure 68 and Figure 69.

- Standard condition of the EWMA filter during normal aging of second (third) HO2S over time.
- Calculation of each measured data sample during each driving cycle.
- Numerator incremented after first sample "O2 mass integral is greater than a calibrated level" while response rate diagnostic is enabled.
- Test failed (malfunction of HO2S "Response Rate" and "MIL on" is set immediately after EWMA filter value exceeds the malfunction threshold value.

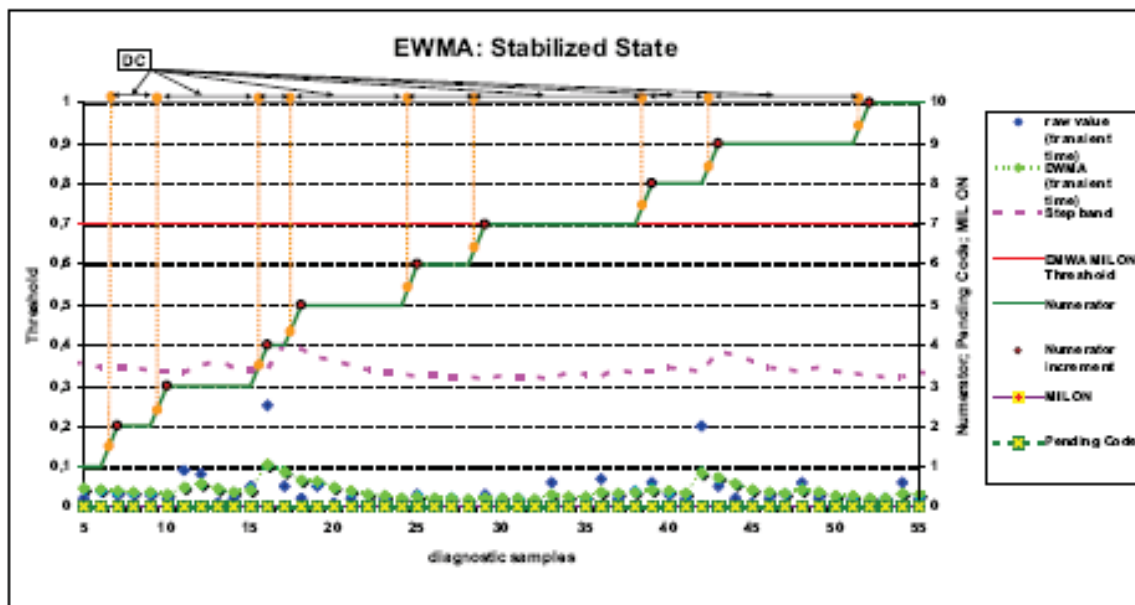


Figure 68: EWMA: Stabilized State

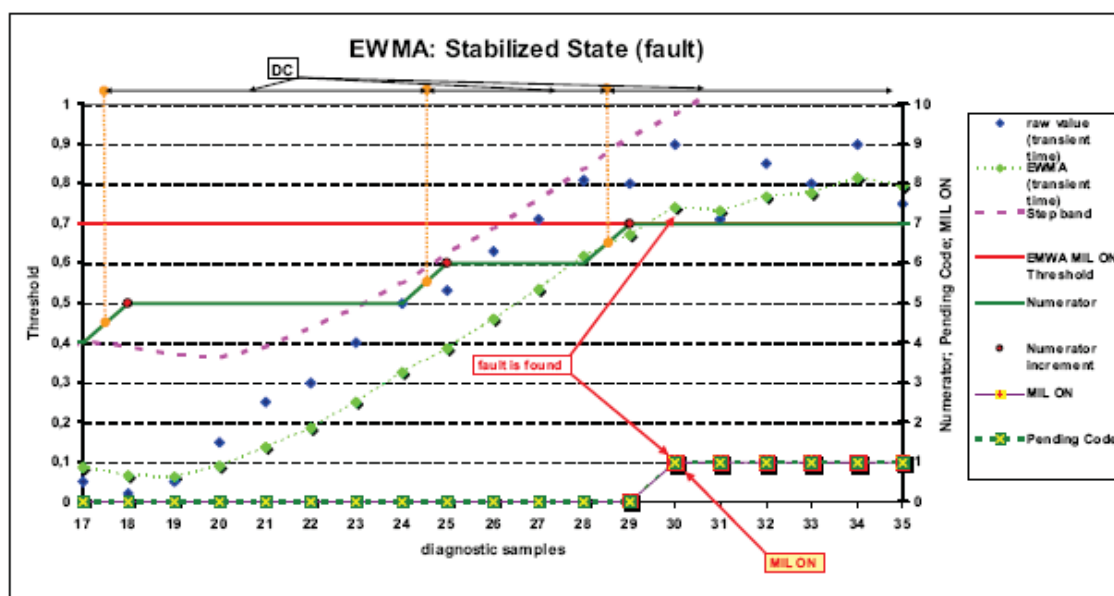


Figure 69: Stabilized state of EWMA filter with fault detected

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7.1.8.5.2 Step Change of EWMA Filter

Refer Figure 70.

The Step Change function account for suddenly occurrence of events where the actual measured transition time value differs significantly from the EWMA filter value.

- If actual transition raw value falls below the “step band” a “step change” is suspected.
- Step change suspicion triggers up to a calibrated sample. Calculation of an arithmetical mean value for a total of calibrated samples.
- Numerator increments after sample “O2 mass integral exceeds a calibrated value” and crossing maximum error sample (response time; transition time) or fault is detected.
- If difference between EWMA filter value and mean value is greater than a certain amount, the EWMA value is set to the mean value. The step change is confirmed.
- Test failed (e.g. malfunction HO2S transition time) and “MIL on” is set immediately after EWMA filter value exceeds the malfunction threshold.

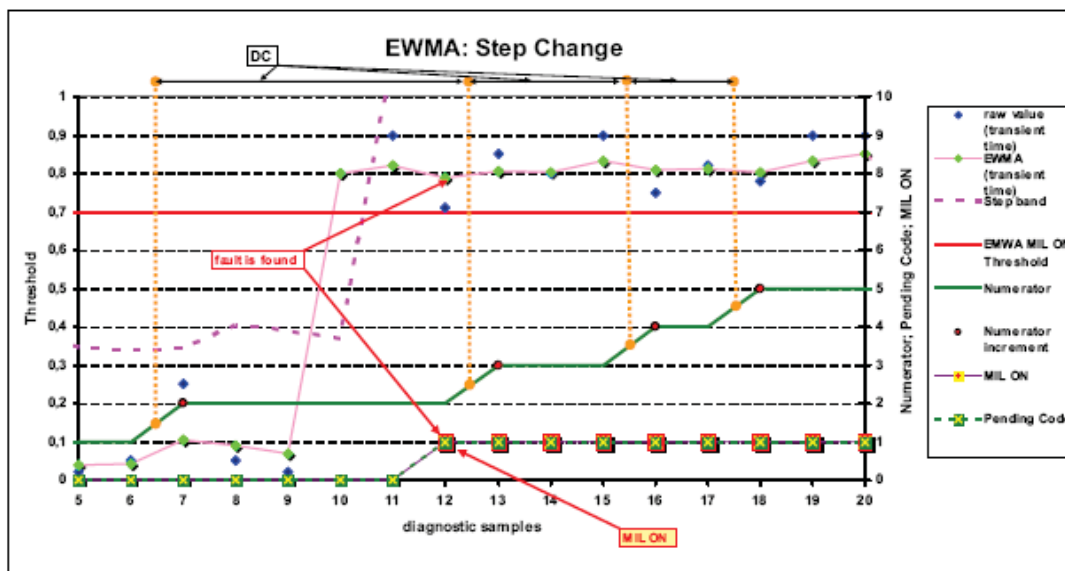


Figure 70: EWMA: Step change

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7.1.8.5.3 Fast Initialization

Refer Figure 71.

- EWMA filter is initialized with calibration value (typical value: ~0.05 - 0.15).
- During the state of “fast initialization” a calibrated number of samples is collected. Calculation of an arithmetical mean value for a total number of calibrated values (typical value: 3).
- The IUMPR numerator starts incrementing after the same calibrated number of samples.
- If the difference between EWMA filter value and mean value is bigger than a certain amount, the EWMA value is set to the mean value. A “step change” is detected.
- Test failed (malfunction in HO2S transition time) and “MIL on” is set immediately after the EWMA filter value exceeds the malfunction threshold.

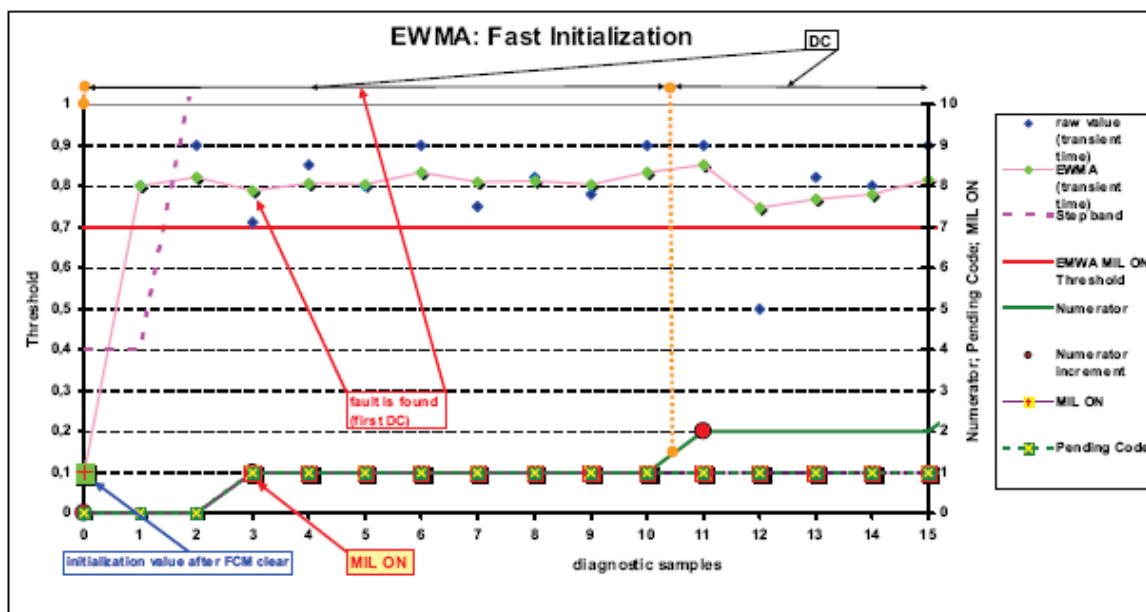


Figure 71: EWMA: Fast initialization

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7.2 Oxygen Sensor Heater Monitoring

7.2.1 Diagnosis of upstream HO2S' heater

This document describes the sum of all possible heater checks of the upstream HO2S. Depending on the exact system configuration only a subset of the described checks, monitoring conditions and flowcharts might be performed.

The operating temperature of the HO2S depends on the type used. Internal heating is required when the heat dissipated from the exhaust gas isn't sufficient to maintain the HO2S at its operating temperature. The extra power required for heating depends on the deviation from the operating temperature. It can be controlled by varying the duty cycle factor of the heater - see Figure 72.

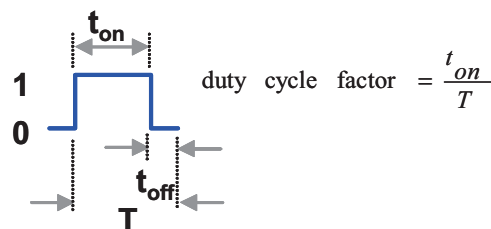


Figure 72: Duty cycle factor of the heater

The HO2S' heater diagnosis consists of the following checks.
Refer to Figure 73.

7.2.1.1 Calibration resistor check

A reliable Nernst cell temperature determination is ascertained by referencing a calibration resistor. The resistance of this calibration resistor mounted in the PCM is constant.

If the difference between its nominal and measured value exceeds a calibrated threshold for a calibrated period of time, a malfunction is detected and a signal fault HSV is set.

If the signal fault HSV is present, a proper Nernst cell temperature determination will be impossible.

Monitoring conditions for calibration resistor check:

- battery's voltage lies within calibrated range
- engine start has finished
- engine is running
- temperature upstream catalyst exceeds dew-point
- heater of upstream oxygen sensor is ready for operation
- no faults of diagnosis of 'Evaluation IC of the upstream HO2S'

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7.2.1.2 Temperature check of Nernst cell after engine start

The oxygen sensor's ceramic temperature is determined by measuring the internal resistance of its Nernst cell. If the ceramic temperature of the sensor lies below a calibrated minimum after a calibrated period of time, a malfunction is detected and a rationality fault is set.

Monitoring conditions for temperature check after engine start:

- the heater control is active
- all injection valves are activated
- internal resistance calculation (with respect to heater control) is possible
- no faults of diagnosis of 'Evaluation IC of the upstream HO2S'
- no HO2S power stage faults
- battery's voltage lies within calibrated range
- engine start has finished
- engine is running
- temperature upstream catalyst exceeds dew-point
- no fault of calibration resistor check
- engine soak time exceeds calibrated threshold
- engine start temperature exceeds calibrated threshold
- enabled by the diagnostic scheduler
- diagnosis enabled time for 'temperature check of Nernst cell after engine start' not elapsed

7.2.1.3 Maximum heater output check

If the target temperature of the oxygen sensor's ceramic isn't reached during controlled operation, the duty cycle factor of the output function will converge towards one. A duty-cycle factor equal to one for a long period of time is implausible and prohibited.

If, with maximum heater output, the temperature of the oxygen sensor's ceramic lies below a calibrated threshold for a calibrated period of time, a malfunction is detected and a maximum fault HSV is set

Monitoring conditions for maximum heater output check:

- battery's voltage lies within calibrated range
- diagnosis of 'Evaluation IC of the upstream HO2S' performed without faults
- the heater control is active
- calculated model of exhaust gas temperature is valid
- modeled exhaust gas temperature exceeds calibrated threshold
- no fuel cut-off
- engine start has finished
- engine is running
- temperature upstream catalyst exceeds dew-point
- no reduced heating power active
- no fault of power stage of upstream oxygen sensor heater
- enabled by the diagnostic scheduler

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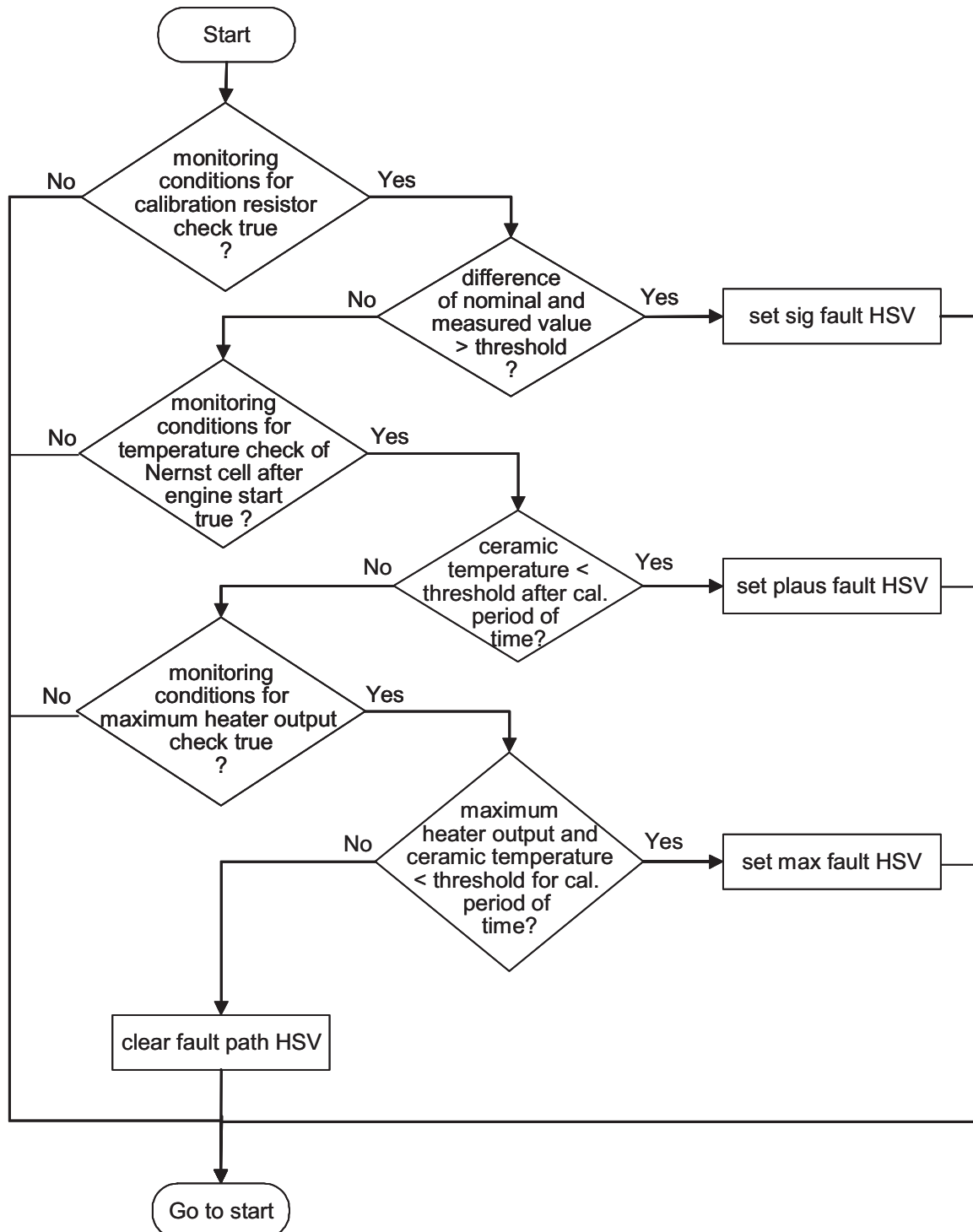


Figure 73: Flow chart: Diagnosis of upstream HO2S heater

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7.2.2 Diagnosis of heater of downstream HO2S

Refer to Figure 74.

This document describes the sum of all possible heater checks of the downstream HO2S. Depending on the exact system configuration only a subset of the described checks, monitoring conditions and flowcharts might be performed.

The diagnosis of the heater of the downstream HO2S monitors the internal resistance of the Nernst cell. The internal resistance of the Nernst cell depends on both the electrical power of the heater and the exhaust gas temperature.

The resistance of the Nernst cell is measured and compared with the calculated temperature-dependant reference value. If the measured resistance exceeds the calculated reference value for a calibrated period of time, a malfunction is detected and a rationality fault HSH is set.

Monitoring Conditions:

- no faults of power stage of downstream HO2S heater
- no faults of downstream HO2S
- modeled exhaust gas temperature at the vicinity of the downstream front catalyst HO2S lies within calibrated range
- engine soak time exceeds calibrated threshold
- intake air temperature exceeds calibrated threshold
- battery's voltage lies within calibrated range
- engine is running
- engine start is finished
- voltage supply for heater of oxygen sensor is active
- measuring of internal resistance is active
- no signal interruption of downstream HO2S's ground
- no fuel cut-off
- enabled by the diagnostic scheduler

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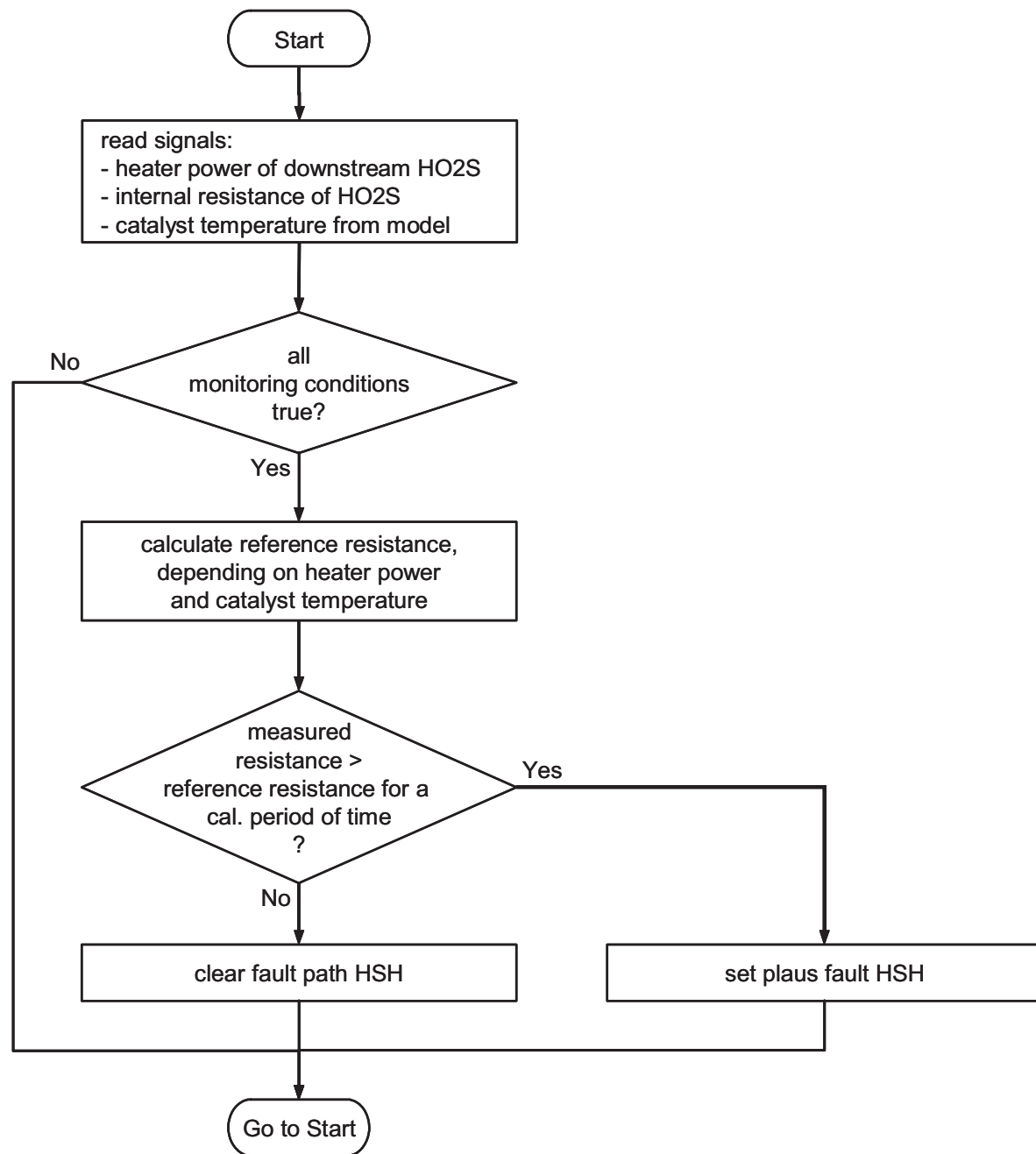


Figure 74: Flow chart: Diagnosis of downstream HO2S heater

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8 EGR MONITORING

Not applicable.

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9 PCV MONITORING

9.1 PCV Monitoring for 6.0l W12 engine

Applicable only to OBD group:

OBD Group Name	Test group	Engine	Models	Standard	Controller / OBD II strategy
CVW-W	CBEXV06.0501	6.0 W12T - 2 bank	Continental	LEV II Bin 5	Bosch ME7.1.1 VW-W

9.1.1 General Description

The crankcase ventilation system on the turbocharged W12 engine was designed according to the regulatory requirements of positive crankcase ventilation (Section (e)(9) of OBD II Regulation) in combination with a monitoring function indicating any disconnection or open hose via fuel system monitoring.

The W12 engine is configured in two banks of six cylinders and each bank has an independent positive crankcase ventilation (PCV) system. Whilst detail differences in design exist between the two banks, the system configuration and principles of design and monitoring are common to both banks. The following description relates to a single bank but can be taken to apply to both banks.

The hose connected to the cylinder head camshaft cover lead the crankcase gases, via a pre-separator, to the input line of the main oil separator. The separator ensures that only the gaseous phase is drawn through the output line of the separator, PCV valve and one way valves to the intake manifold or turbocharger inlet duct (depending on off- or on-boost operation), respectively. The separated liquid phase, from both pre- and main separators, is led back to the oil sump. The return lines from the separator to the oil sump do not lead gaseous phase. Figure 75 shows the general system configuration.

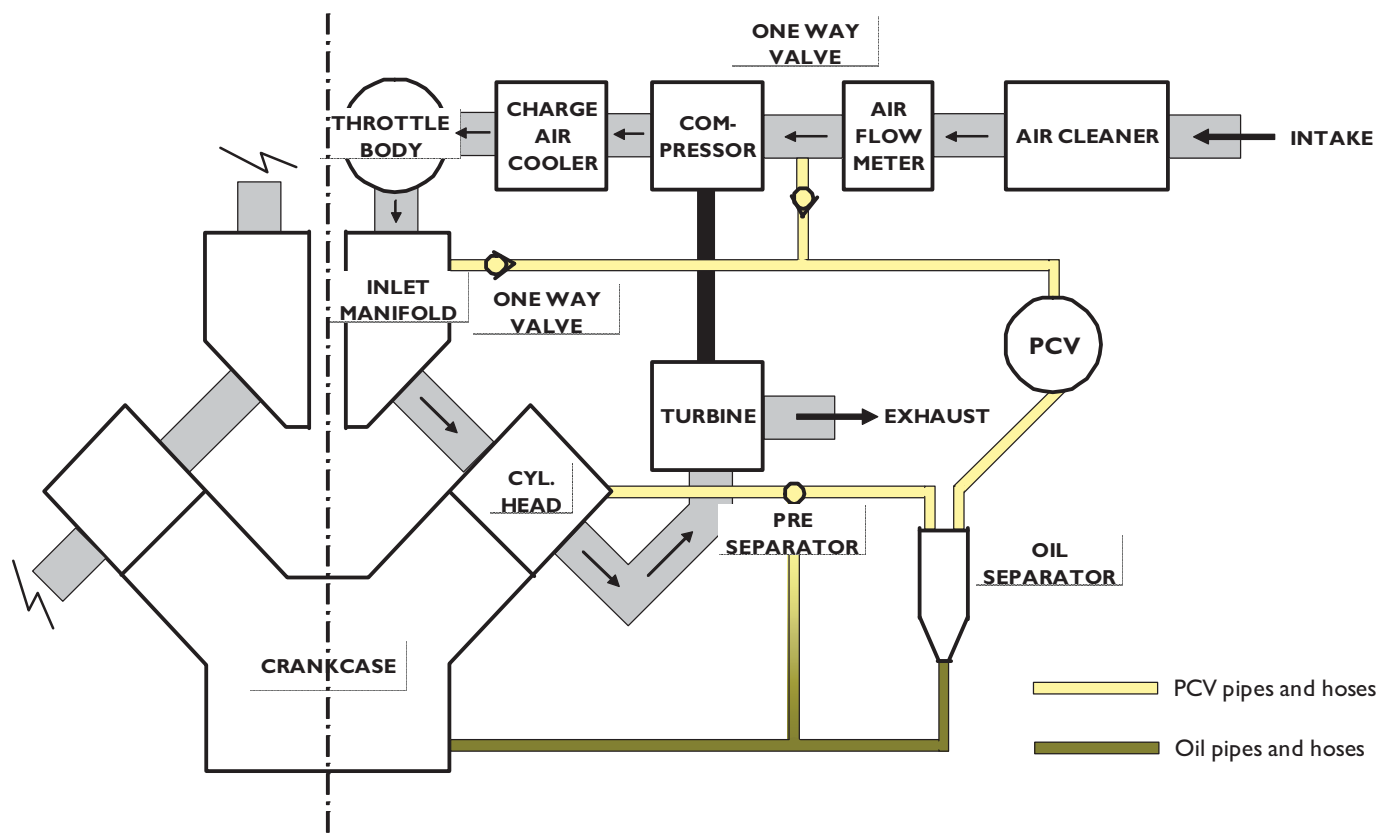


Figure 75: General configuration of PCV system W12T

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The operation of the circuit under part load (off-boost) and high load (on-boost) conditions is illustrated in Figure 76 and Figure 77, respectively.

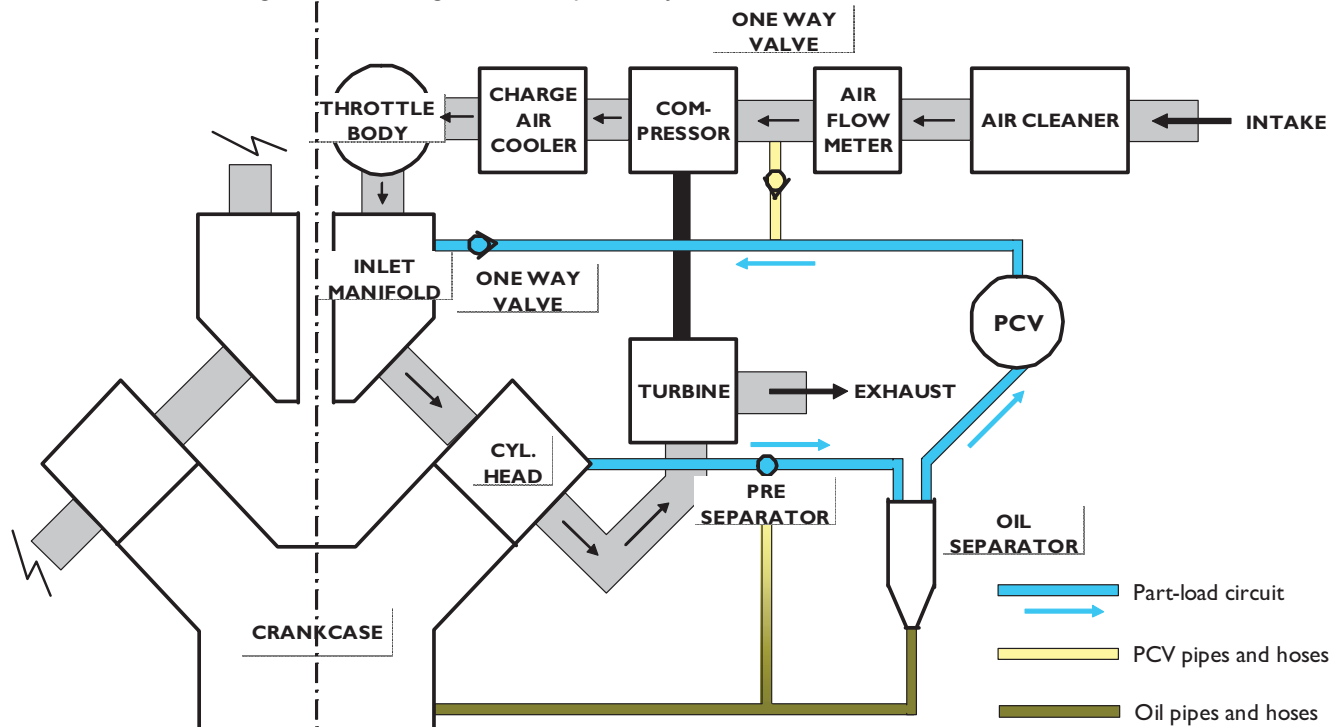


Figure 76: Operation of PCV circuit under part load conditions.

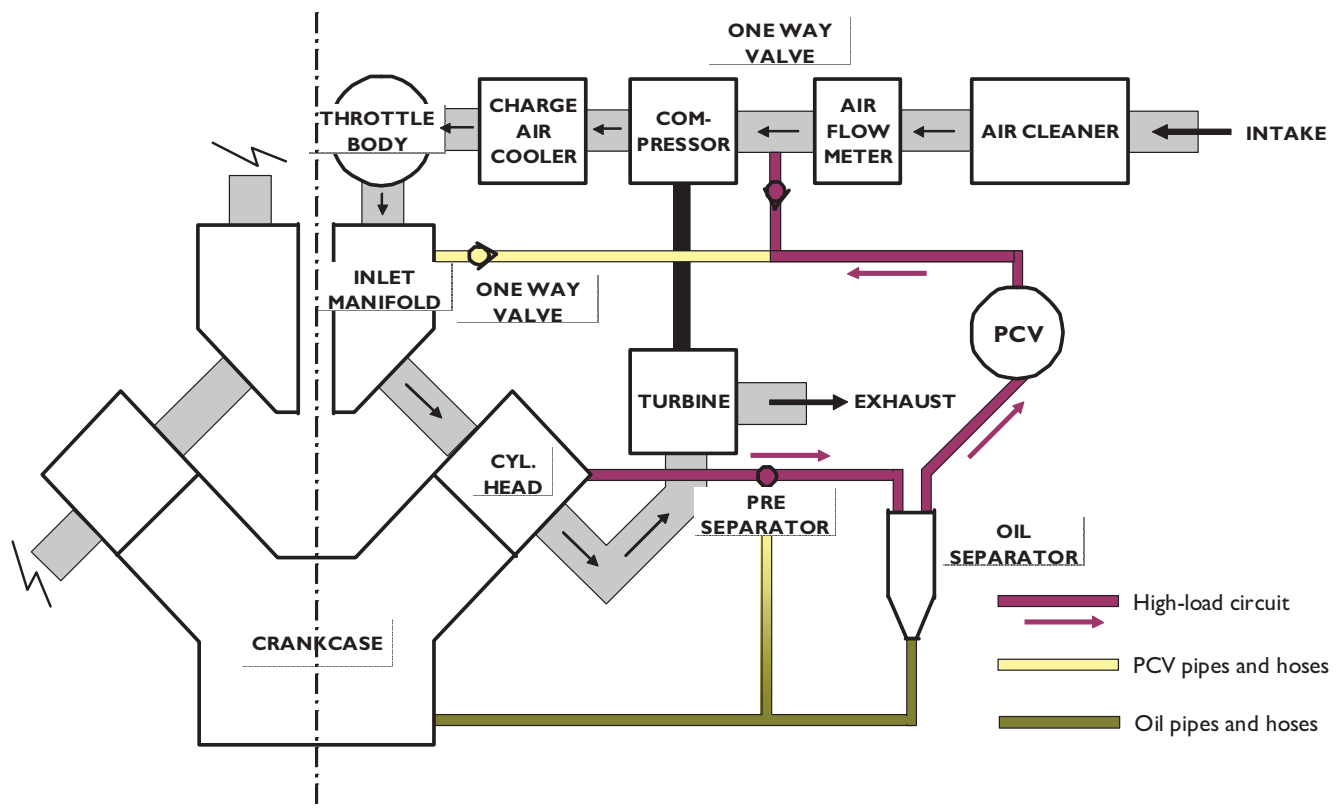


Figure 77: Operation of PCV circuit under high load conditions.

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9.1.2 Monitoring concept

The system has been designed such that most disconnections result in an air leak at the inlet manifold that can be detected by the fuel system monitor.

The part of the system, between one way valve and turbocharger compressor inlet housing, is not accessible. This part of the system is located in the engine bay such that it cannot be accessed either from above or from below. It does not need to be disconnected for any routine servicing. Any repairs necessitating disassembly (e.g. turbocharger replacement) would require engine removal.

An open connection between either of the oil separators and the oil sump will cause loss of oil from the engine.

Figure 78 identifies the different portions of the PCV system, described above.

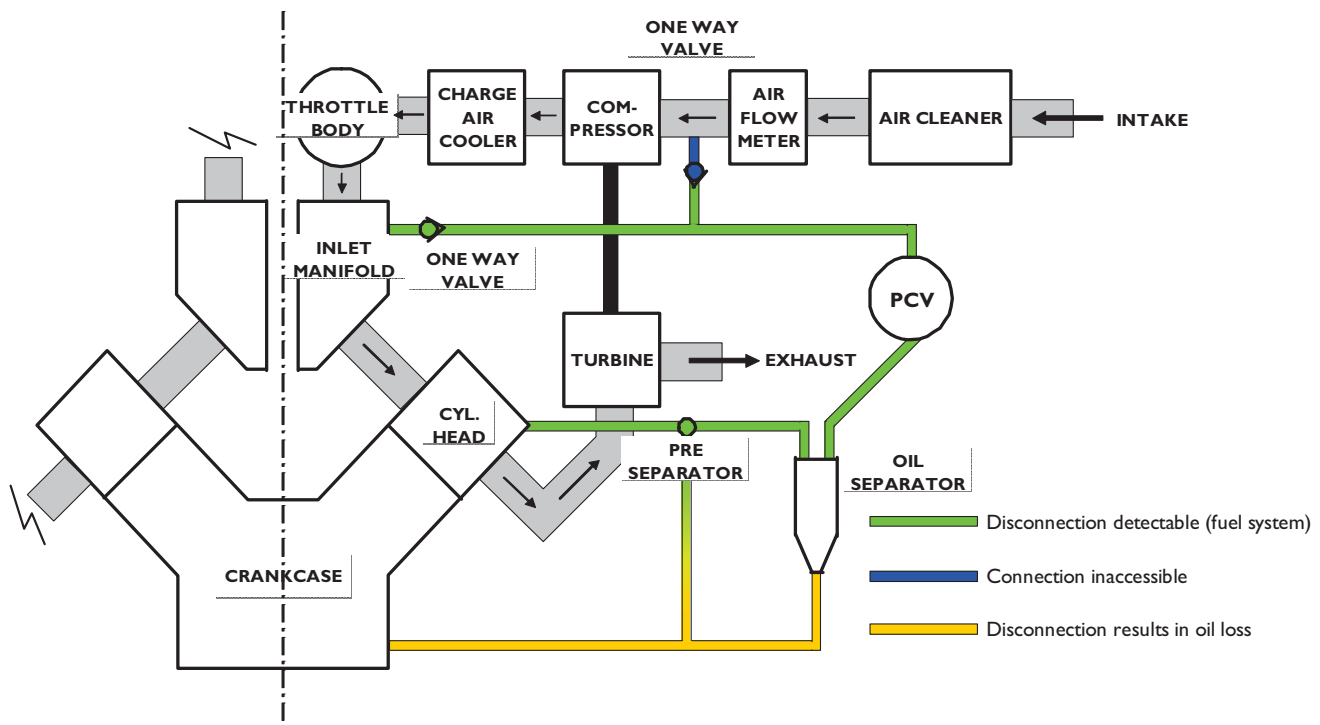


Figure 78: Effect of disconnection of different portions of the PCV system.

9.1.3 Materials

There are no new materials used for the design of the crankcase ventilation system. All materials are already proved in several test procedures of the development and within the ADP cycle. Therefore all materials show durability equal to, or in excess of, 120 000 miles.

The crankcase ventilation hose and connectors are made PA 12 GF 20 or PA 12 GF 30 which shows the same durability. The oil separator is made from PA6-GF25 and the return line is AEM. The lower portion of the line is made from steel with a surface protection.

Refer to Figure 79 for a simplified representation of the physical hardware of the PCV system.

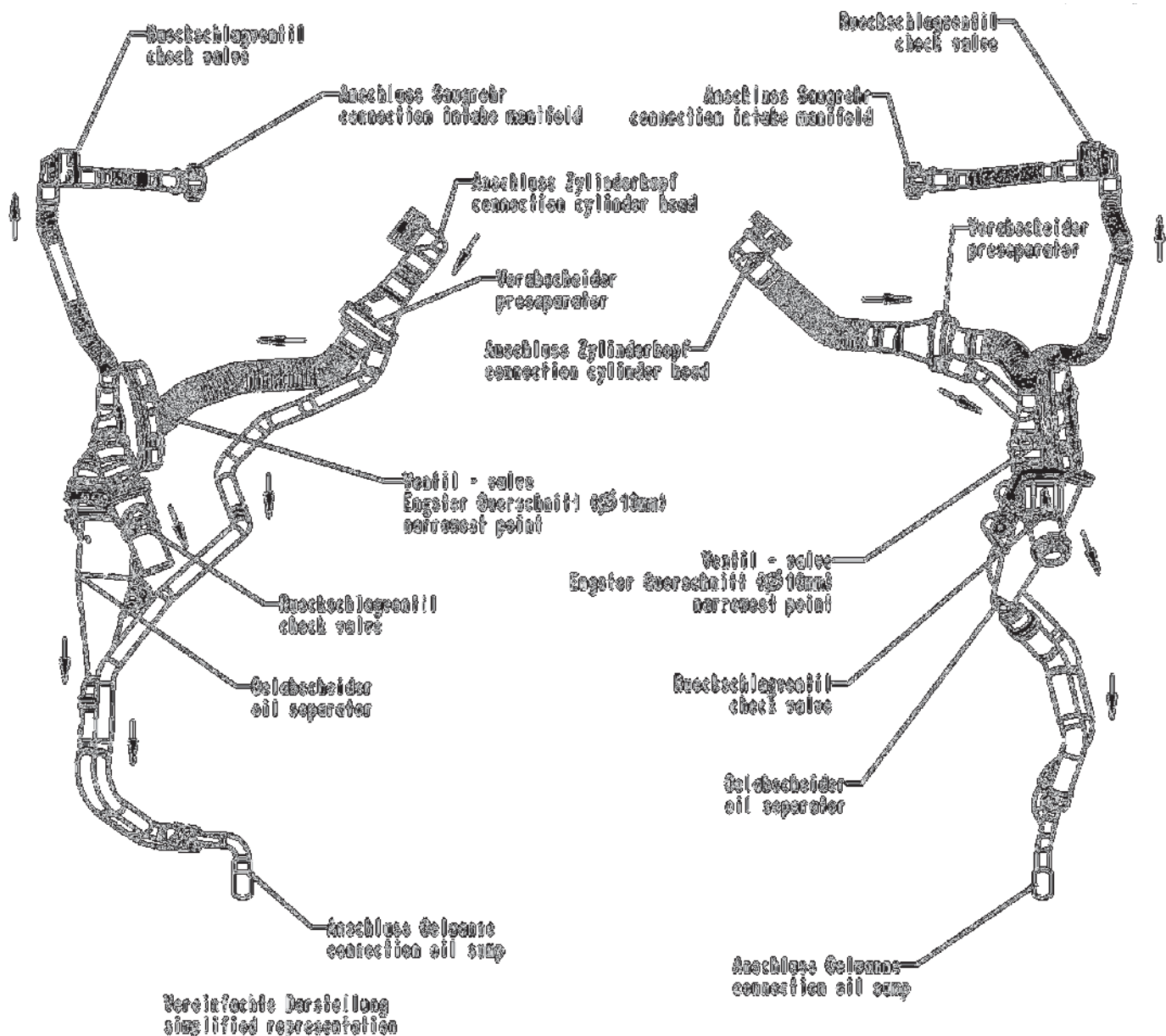


Figure 79: Simplified representation of the physical hardware of the PCV system.

9.1.4 Maintenance and Repair:

The crankcase ventilation system is free of any scheduled maintenance. In case of repair necessary to the Air Flow Meter or to the Throttle Body there is no need to unplug or disconnect the crankcase ventilation hose. In case of any repair necessary to the cylinder head or where the intake manifold has to be removed the crankcase ventilation hoses will be disconnected either at the inlet manifold, the camshaft cover on the cylinder head or at the main oil separator.

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10 ENGINE COOLING SYSTEM MONITORING

10.1 General Description

The engine cooling system consists of the following main parts, see Figure 80:

- Radiator
- Engine Coolant Temperature Sensor
- Thermostat
- Bypass Cooling Circuit
- Main Cooling Circuit
- Radiator Temperature Sensor (certain OBD groups only)

During warm-up of the engine, the coolant flows first inside the bypass cooling circuit. After the coolant reaches a sufficient temperature the thermostat opens the main cooling circuit to integrate the engine coolant radiator.

The engine coolant temperature sensor measures a mixed temperature between the coolant coming from the bypass and main cooling circuits.

On some concepts, a radiator temperature sensor is used to measure the temperature at the inlet (OBD group ABE-V) of the radiator.

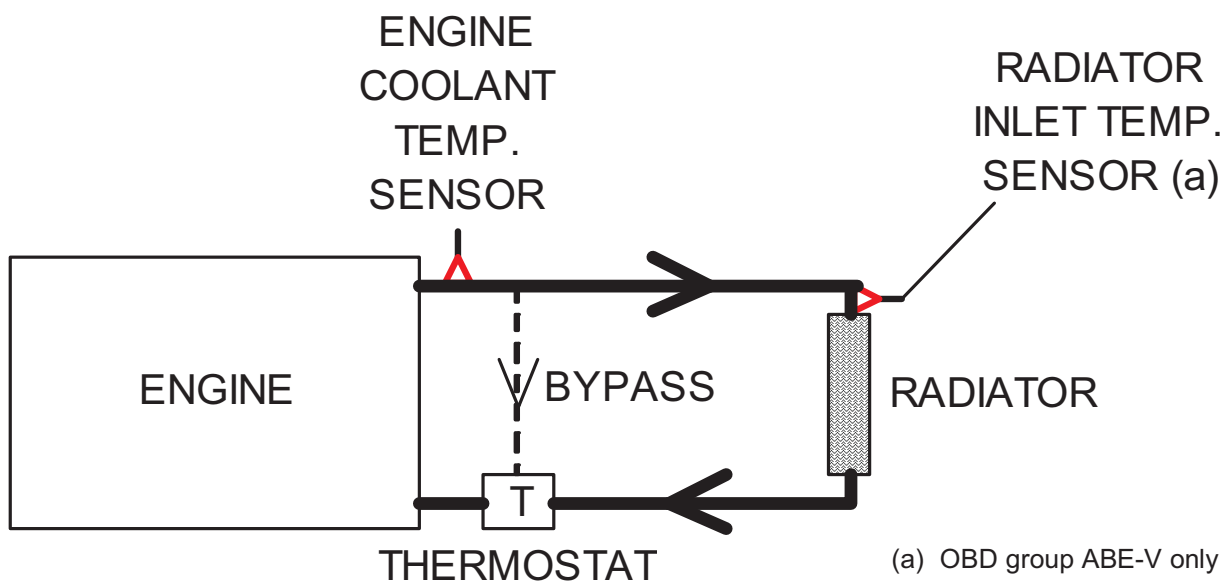


Figure 80: Main elements of engine cooling system

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10.2 Concepts without radiator temperature sensor

Applicable to OBD Groups:

OBd Group Name	Test group	Engine	Models	Standard	Controller / OBd II strategy
CVW-W	CBEXV06.0501	6.0 W12T - 2 bank	Continental	LEV II Bin 5	Bosch ME7.1.1 VW-W

10.2.1 Monitor Functional Description

The engine cooling system monitoring strategy consists of two main diagnostic parts, shown in Figure 81.

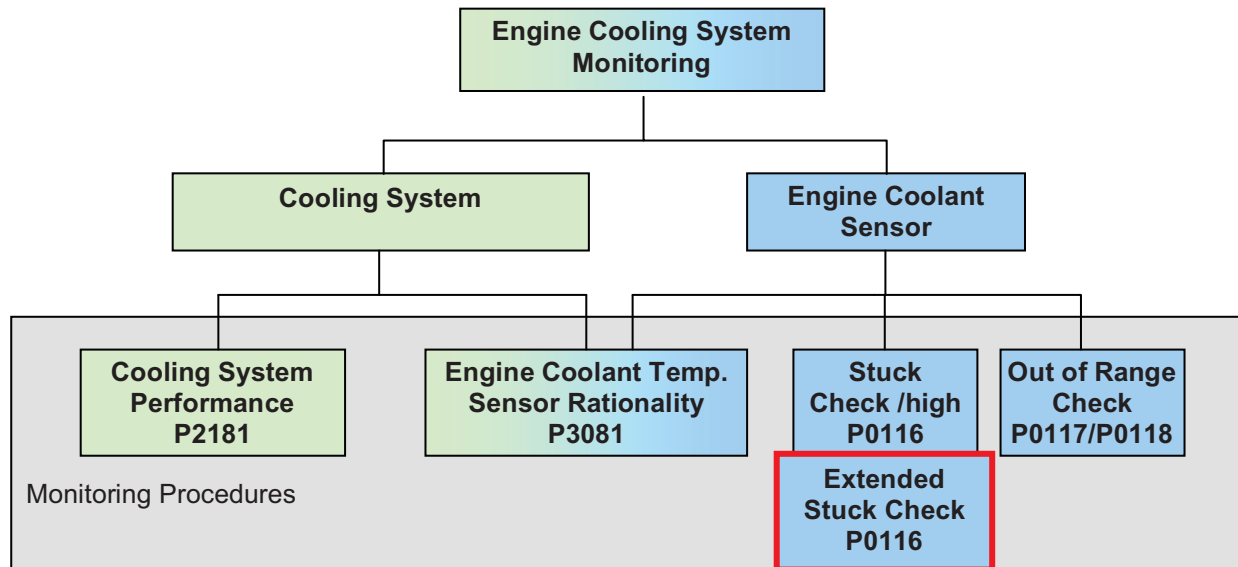


Figure 81: Engine cooling system monitoring strategy

Each engine cooling monitoring function has its own specific engine temperature range in which it will be enabled. Refer to Figure 82.

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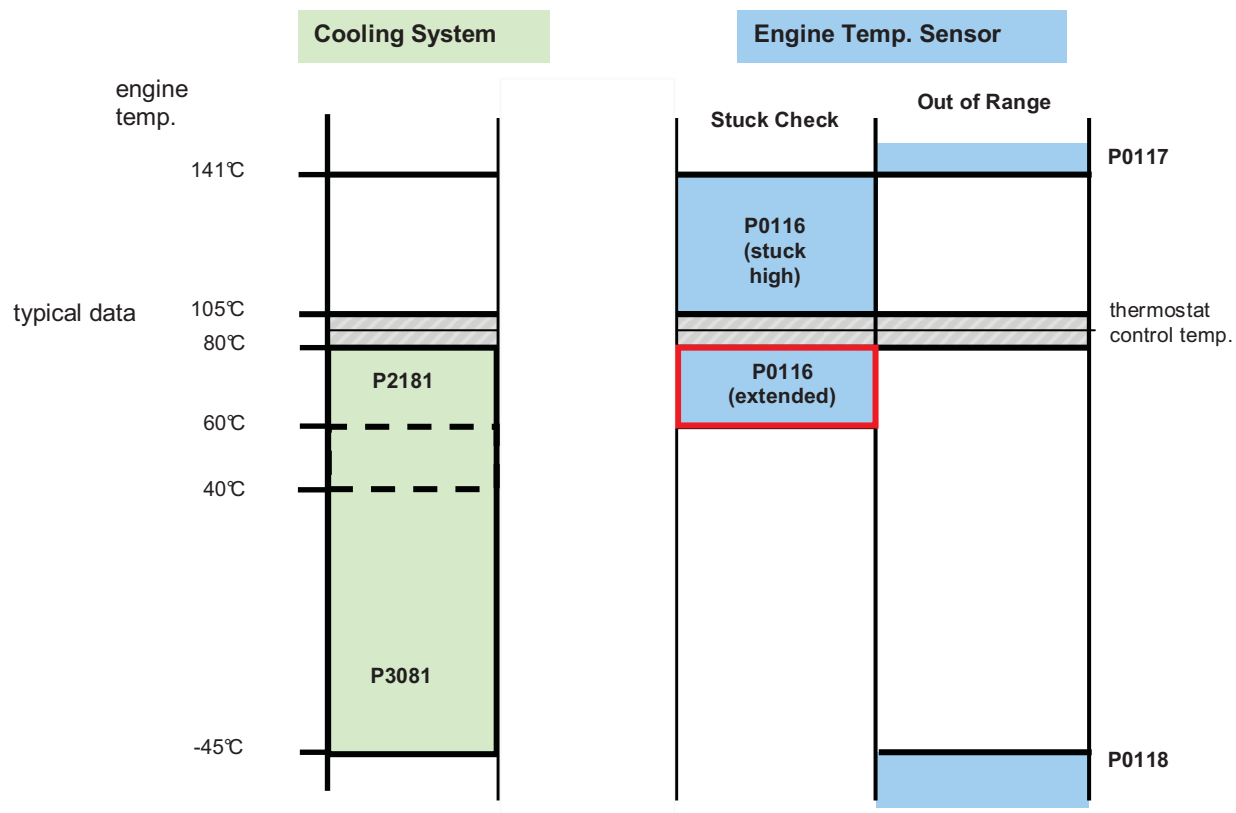


Figure 82: Engine temperature range

10.2.2 Cooling System Performance (P2181)

In case that the engine coolant temperature does not reach a certain value after a sufficient mass air flow under normal driving conditions, the cooling system performance is considered to be reduced. Refer to Figure 83 and Figure 84.

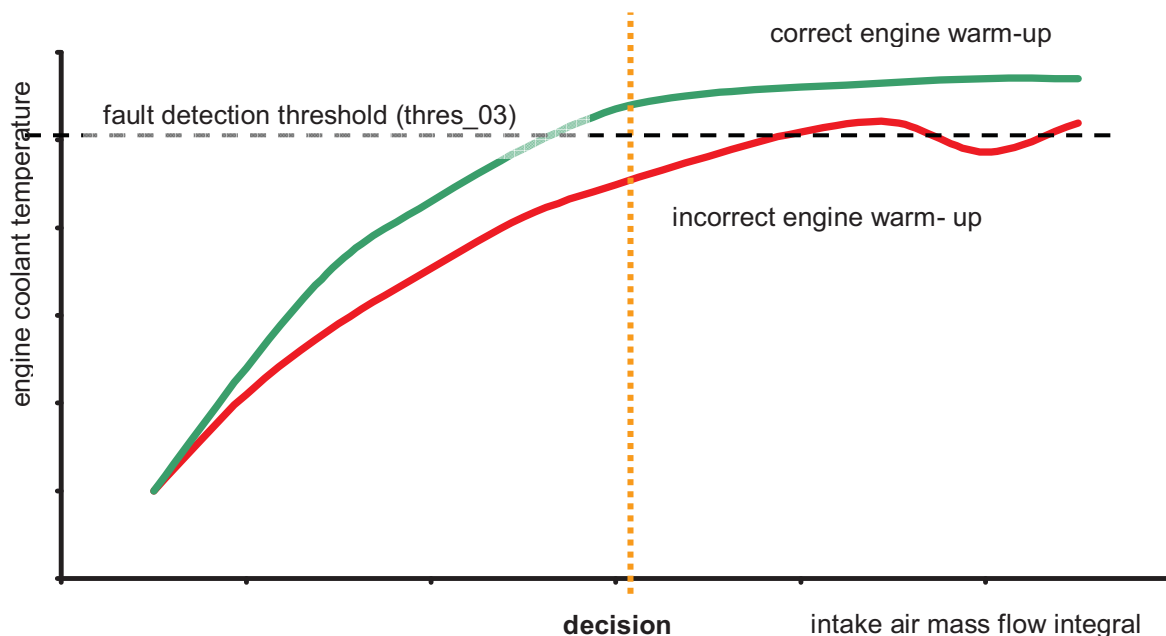


Figure 83: Cooling system performance chart

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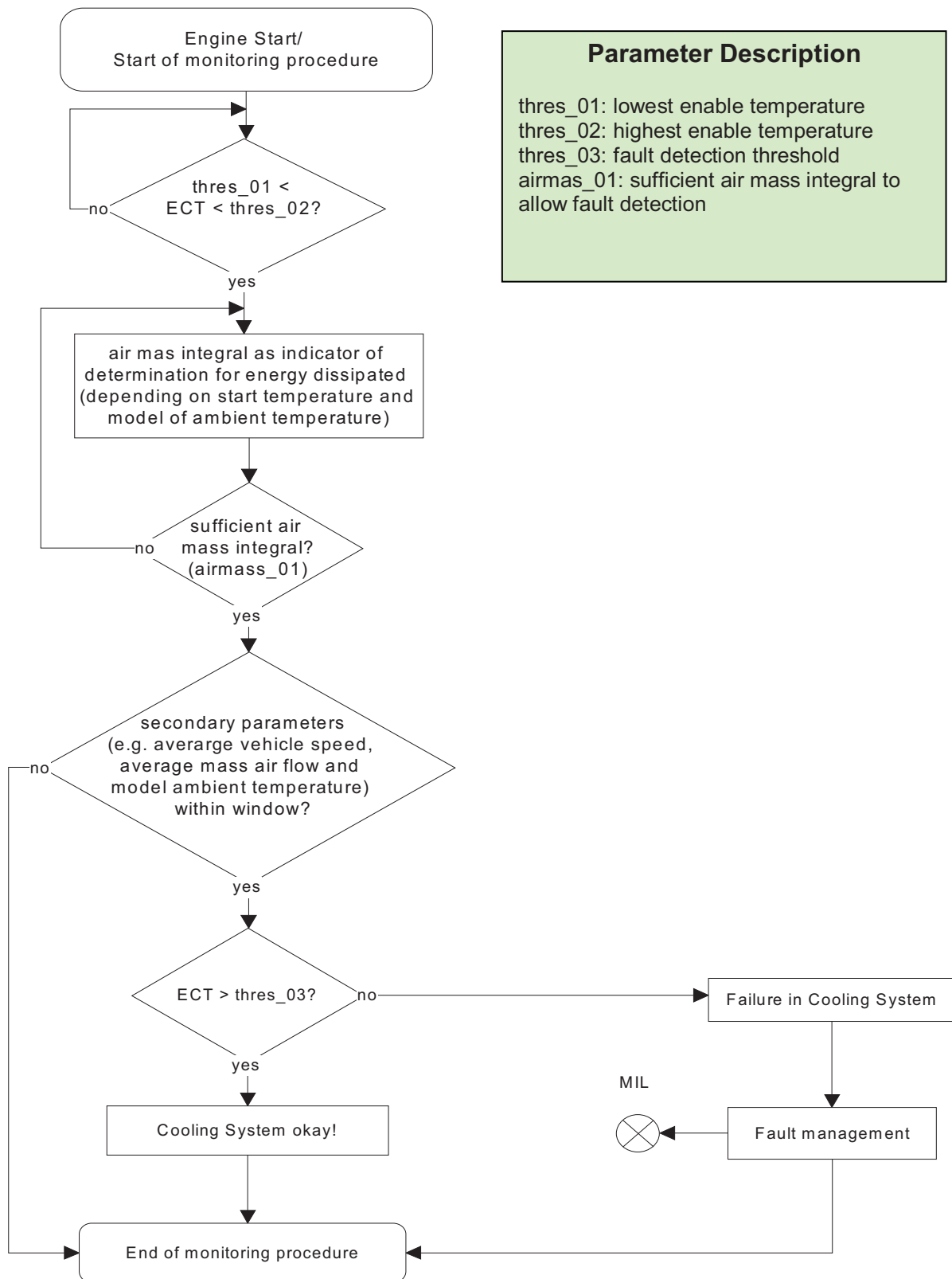


Figure 84: Flow Chart: cooling system performance monitoring

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10.2.3 Engine Coolant Temperature Sensor Rationality (P3081)

In case that the engine coolant temperature does not fit to a reference model temperature in a certain range, the cooling system is defective or the sensor is not in a plausible range. Refer to Figure 85 and Figure 86.

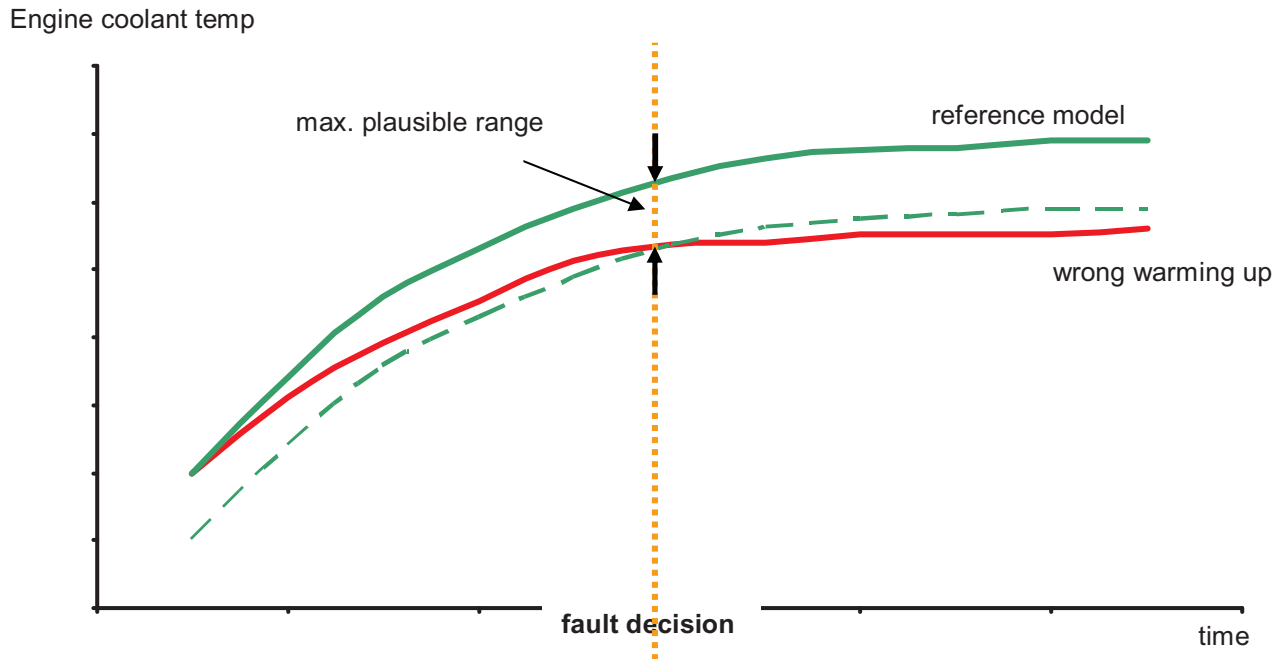


Figure 85: Coolant temperature Sensor Rationality Overview

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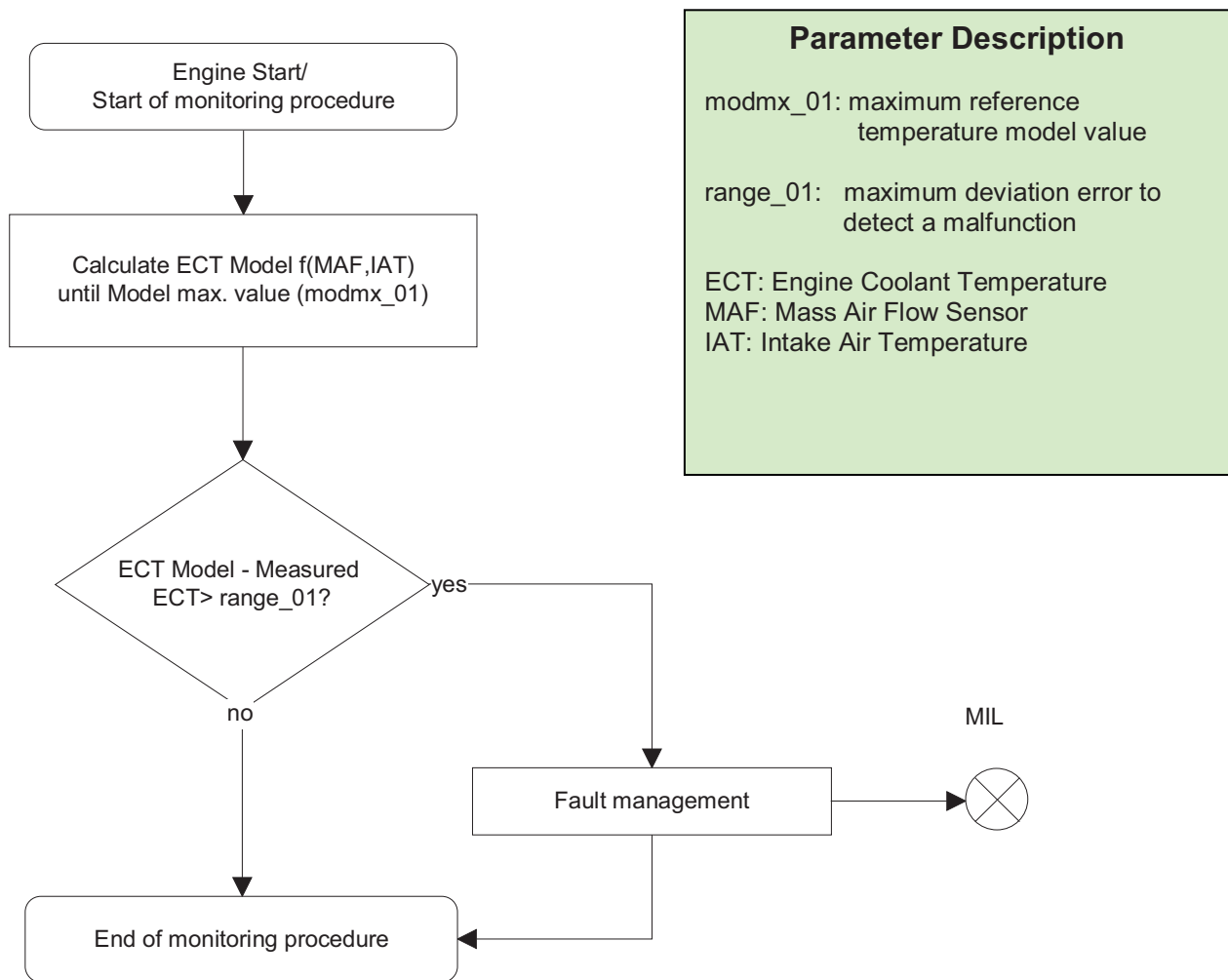


Figure 86: Flow Chart Coolant Temperature Sensor Rationality (P3081)

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10.2.4 Engine Coolant Temperature Sensor Stuck (P0116)

After engine start the system stores continuously the lowest and highest ECT above the thermostat control temperature for a driving cycle. In case that after several driving conditions the difference between ECT max and ECT min is lower than the threshold the sensor is stuck at a high (Figure 87) or low (Figure 88) value, depending on start temperature, respectively. Figure 89 is a flow chart of the function.

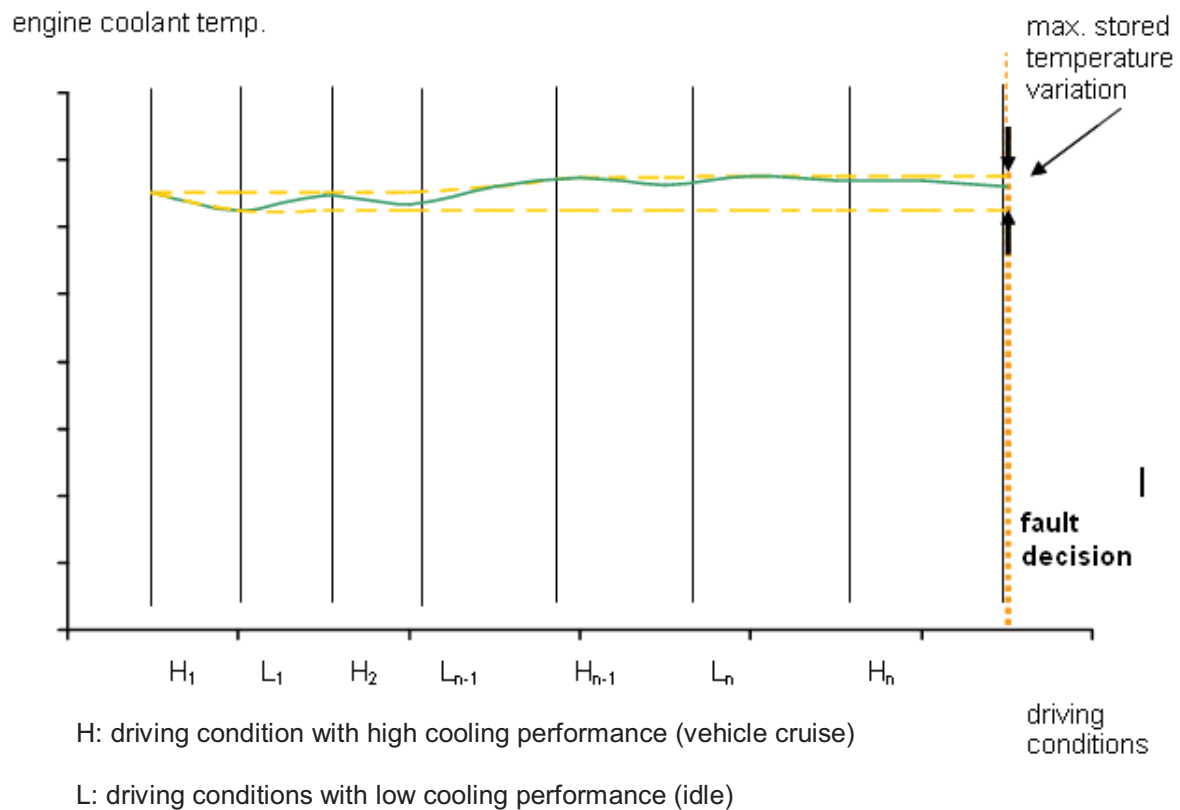
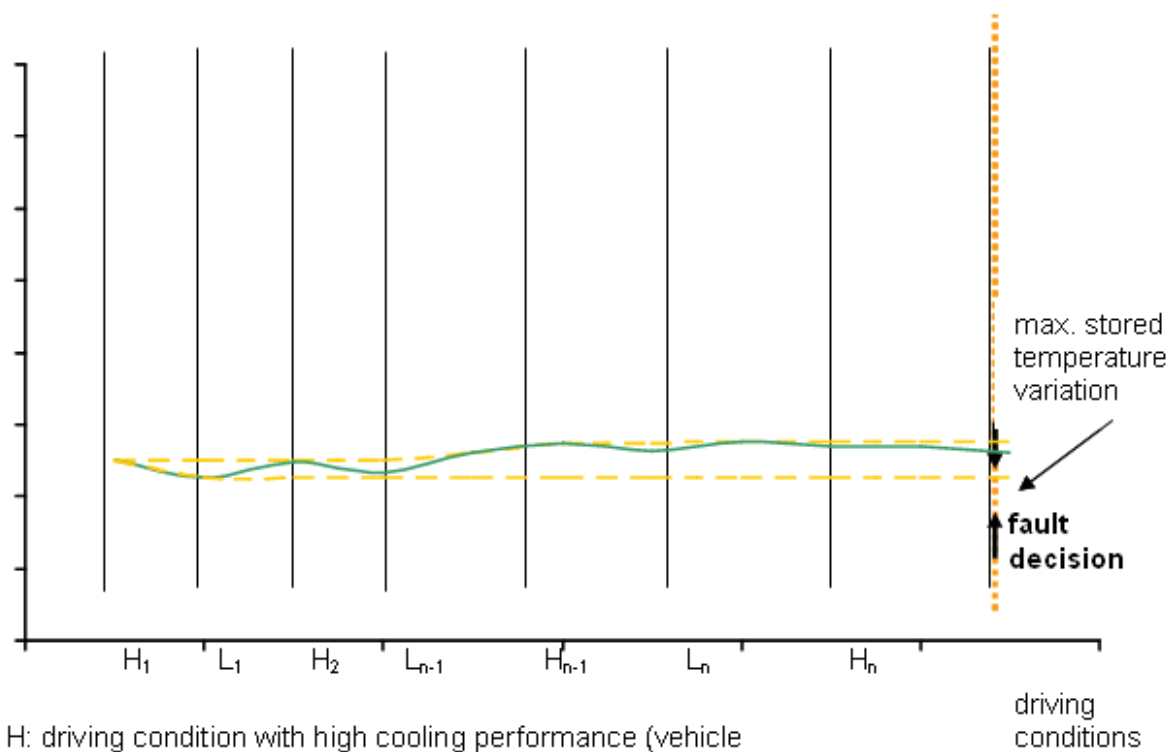


Figure 87: Coolant temperature Sensor Stuck High Overview

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engine coolant temp.



H: driving condition with high cooling performance (vehicle cruise)

L: driving conditions with low cooling performance (idle)

Figure 88: Coolant temperature Sensor Stuck Low Overview

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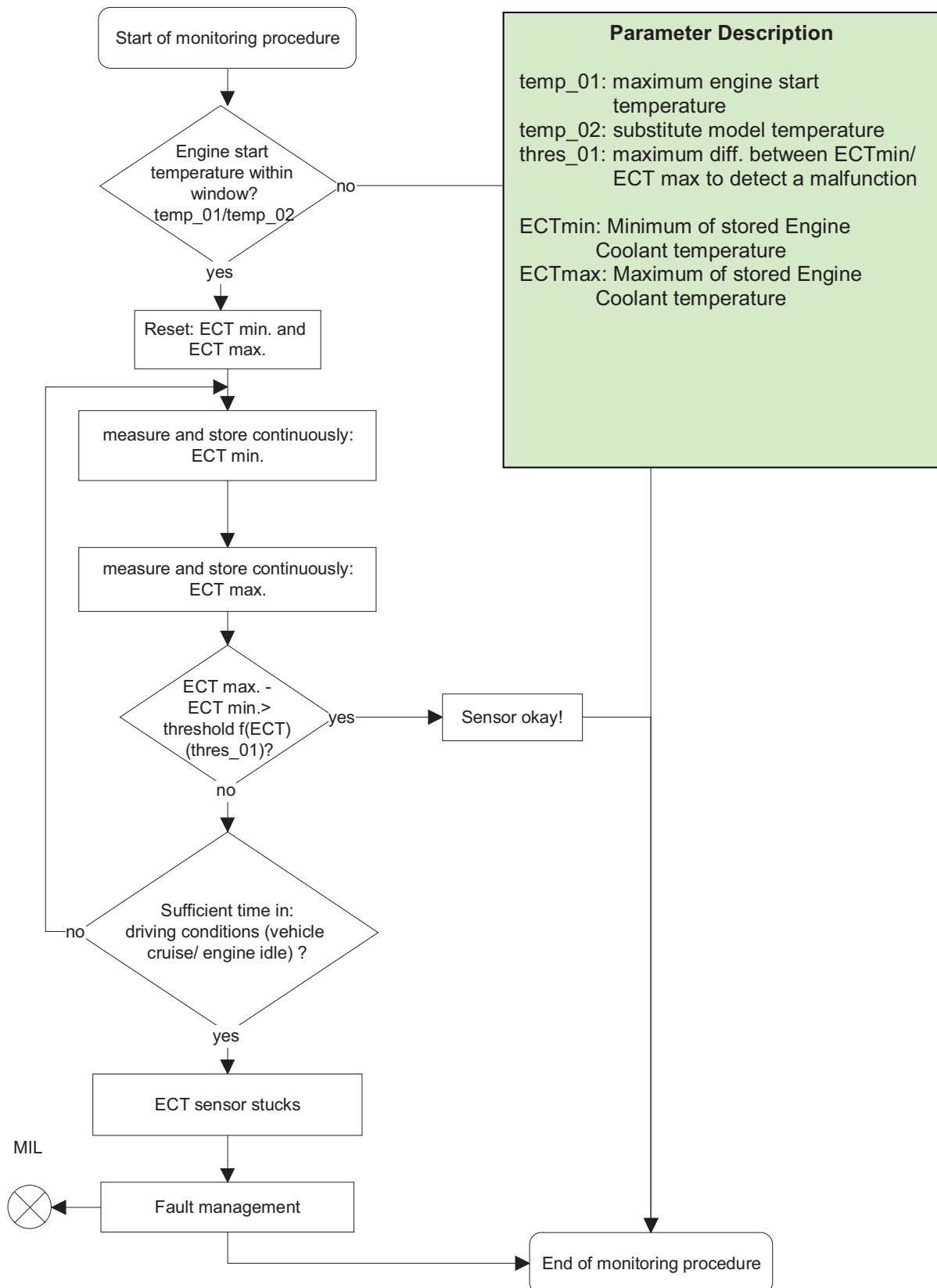


Figure 89: Flow Chart Engine Coolant Temperature Sensor Stuck (P0116)

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10.2.5 Engine Coolant Temperature Sensor Out of Range Check (P0118 / P0117)

The signal of Engine Coolant Temperature Sensor is evaluated and considered to be electrically out of range if either the upper or the lower thresholds is exceeded.

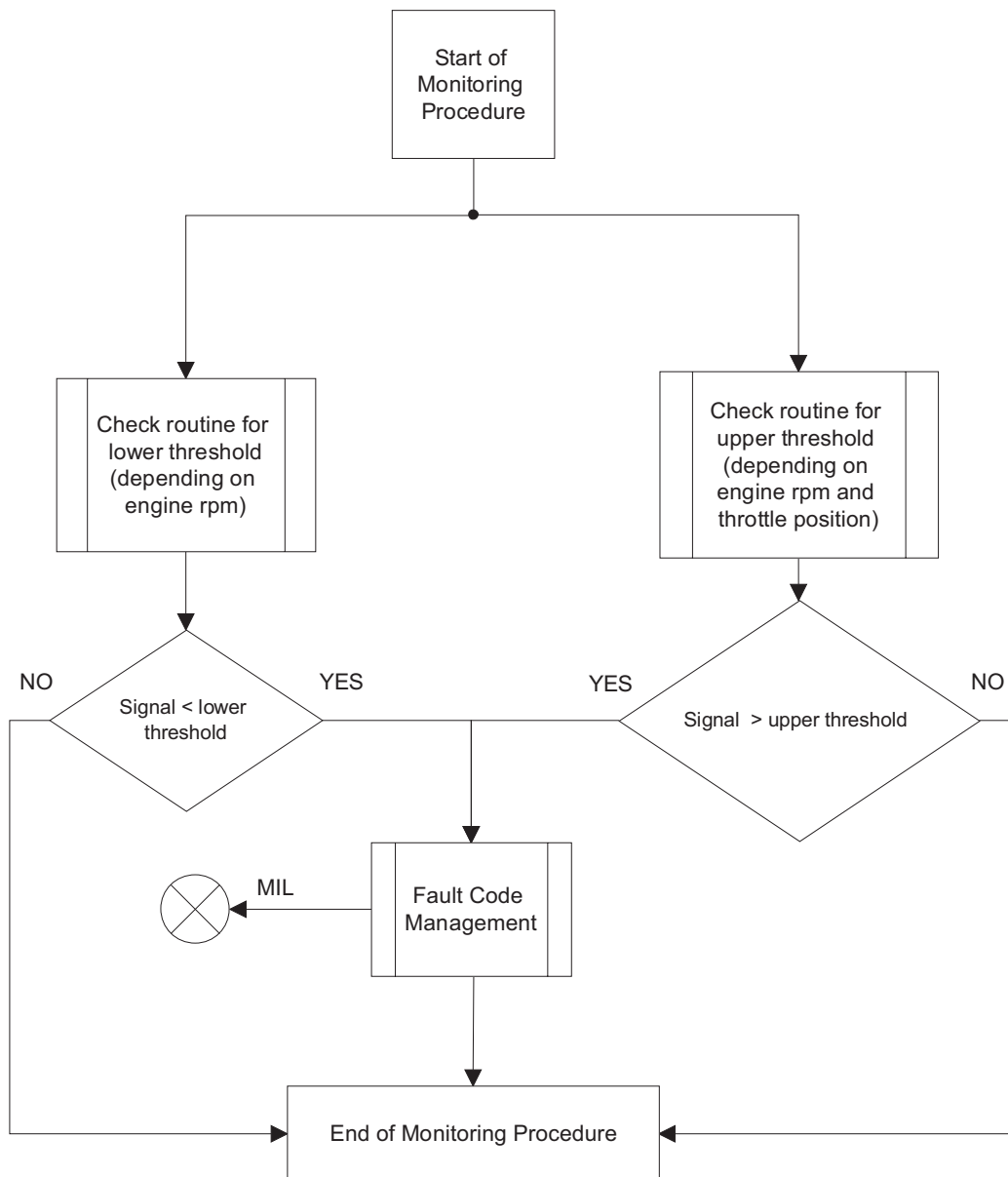


Figure 90: Flow Chart ECT Sensor Out of Range Check (P0118 / P0117)

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10.2.6 Monitoring of ECT during driving and after engine shut off

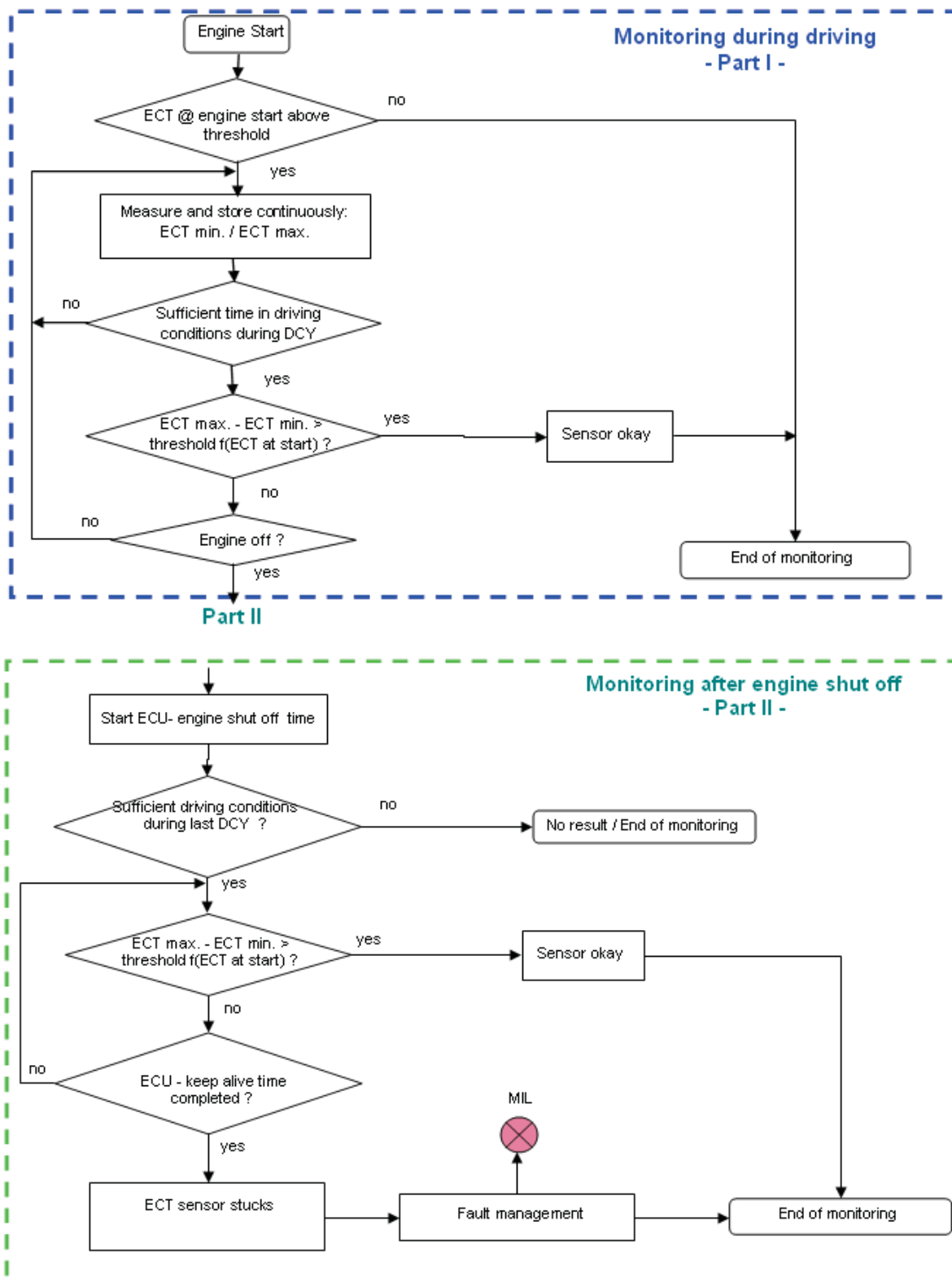


Figure 91: Monitoring of engine temperature during driving and after engine shut off (P0116)

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11 COLD START EMISSION REDUCTION STRATEGY MONITORING

11.1 Monitoring Concept

Cold start emission reduction strategy (CSERS) monitoring is achieved by monitoring those components that influence the key parameters used for catalyst heating. In this way, rather than storing a specific fault code for a CSERS malfunction, the fault code relating to the component causing the CSERS malfunction will be stored. This approach is in accordance with section (e)(11.2.1) of the OBD II Regulation.

11.2 Key Parameters and Monitored Components

The key parameters in the cold start emission reduction strategy (CSERS) are controlled by components which are included in and covered by the OBD II system. Any malfunction of one of these components would be indicated by the MIL without regard to its usage in the CSERS.

11.1.1 Key Parameters

The key parameters used for the quick catalyst heat-up during the first portion of a cold started driving cycle are as follows:

1. Engine speed
Catalyst heat-up strategy is most effective and, therefore, active during idle operation. The strategy involves use of an elevated target idle speed compared to that used in "warmed-up" conditions. An advanced idle control monitor verifies that the target engine speed is achieved.
2. Fuel mixture (engine Lambda)
Fuel control during catalyst heat-up is pre-controlled (open loop) to a target lambda in the order of 1.1. It becomes closed loop controlled if the primary oxygen sensor is active, depending on engine specific model-based dew point calculation.
3. Ignition timing
The strategy applies application-specific ignition retard, fixed within a range, relative to that used during "warmed-up" operation. Catalyst heat-up ignition retard takes priority over any other requests to vary the ignition timing (e.g. the application of ignition advance for combustion stability). The transition from heat-up strategy ignition timing to warmed-up timing is controlled by an air mass integral depending on engine coolant temperature at engine start exceeding a threshold.
4. Camshaft position
On OBD Groups with Variable Valve Timing, the heat-up strategy uses a different camshaft position relative to that used during "warmed-up" operation. That position does not vary during heat-up strategy operation.

The implemented component monitors, see below, will detect malfunctions before exceeding 1.5 times the applicable standard. Monitoring conditions include engine warm-up period.

The misfire monitor verifies the occurrence of combustion, it cannot verify that the correct ignition timing is achieved.

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11.1.2 Monitored Components

The key parameters are achieved in their ranges by the engine management system based on components which are already monitored by the OBD system. The attached table, Figure 92, shows the influence of components on the key parameters and identifies the monitoring functions running during cold start as well as under the condition of a warmed-up engine.

The components with influence on the key parameters for the warm-up strategy are as follows:

1. Injection valves
2. Throttle unit
3. Air flow meter
4. Intake manifold pressure sensor
5. Ambient pressure sensor
6. Intake air temperature sensor
7. Ignition coils
8. Variable valve timing system
9. Camshaft/crankshaft alignment
10. Phase sensor
11. Engine speed sensor

The above list includes all the possible components influencing the key parameters for OBD Groups using the ME7 ECM. For specific applicability for each OBD Group, please refer to Figure 92.

The calibration of the monitors used during cold start is the same as used later on a warmed-up engine. All of the components listed above are monitored by the OBD system during cold start at least for circuit continuity.

The components with influence on injection and ignition are also monitored by the misfire diagnostic function during the cold start. There is no reduction of ignition retard allowed as long as cold start conditions are present.

Under closed loop condition monitoring is additionally supported by rationality functions using the signal of the oxygen sensor (e.g. injection valves monitored by the fuel system, rationality checks for throttle unit, ambient pressure sensor and intake air temperature are performed in comparison to the mass air flow meter).

Specifically, for OBD Group AVW-I5, instead of using the MAF signal, the fuel system controls the cold start of the engine based on throttle angle and engine speed. The throttle angle during cold start is adjusted based on the signals from intake manifold pressure sensor, ambient pressure sensor and intake air temperature. Later, if the secondary injection has been finished, the fuel system is based on the MAF sensor signal.

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Component	Monitor	Diagnostic	Key Parameter				OBD Group Applicability
		During and after cold start strategy	Engine speed	Ignition angle	Injection / engine Lambda	Camshaft Position (N/A to ABE-V)	
Injection Valves	Circuit continuity	yes	X	X	X	-	All
	Misfire Monitor						
Throttle Unit	Circuit continuity	yes	X	X	-	-	All
	Rationality Check						
Air flow meter	Circuit continuity	yes	X	X	X	-	AVW-W & ABE-V
	Rationality Check						
Intake manifold pressure sensor	Circuit continuity	yes	X	X	X	-	AVW-I5 only
	Rationality Check						
Ambient Pressure sensor	Circuit continuity	yes	X	X	X	-	All
	Rationality Check						
Intake Air Temperature Sensor	Circuit continuity	yes	X	X	X	-	All
Ignition Coils	Circuit continuity	yes	X	X	-	-	All
	Misfire Monitor						
Variable valve timing system	Circuit continuity	yes	-	-	-	X	AVW-I5 & AVW-W
	VVT-Monitor	yes					
Camshaft / crankshaft alignment	Rationality check	yes	-	X	-	X	All
Phase sensor	Circuit continuity	yes	-	X	-	X	All
Engine Speed sensor	Circuit continuity	yes	X	-	-	-	All
	Rationality Check						

Figure 92: Table of key-parameters and components

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12 AIR CONDITIONING (A/C) SYSTEM COMPONENT MONITORING

12.1 General Description

The engine control module recognises the air conditioning status (on or off) as a torque request and compensates the engine torque demand accordingly.

The status of the air conditioning system does not result in use of a different strategy regarding ignition or fuel injection.

The components of the air conditioning system are not used for OBD functions and can not disable monitors. This applies to both separate and integrated climatic control modules. Integrated climatic control modules may be a separated part of the ECM as "box in a box" unit.

12.2 Monitoring Concept

The air conditioning system is not monitored by the OBD II system for the following reasons:

- Sensors of the air conditioning system are not used within OBD as an input signal.
- Actuators of the air conditioning system are not used as an OBD output component.
- Air conditioning system components can not disable any of the OBD monitors.
- Any failure mode of the air conditioning system does not cause exhaust emissions to exceed 1.5 times the applicable standard.
- For the exhaust emissions Volkswagen has evaluated failure modes over the FTP cycle on different engine concepts (e.g. 4.2l V8, 1.8l ULEVII, 2.0l TFSI and 2.5l PZEV).
- Possible failures of the air conditioning system may result in reduction or loss of cooling efficiency during SC03. In this case the vehicle runs with lower load and the emission would not increase.

Based on the engineering evaluation and the presented emission results the AC-system is exempt from the requirements of Title 13 CCR Section 1968.2.

13 VARIABLE VALVE TIMING (VVT) AND CONTROL SYSTEM MONITORING

This description applies to the following OBD groups:

OBD Group Name	Test group	Engine	Models	Standard	Controller / OBD II strategy
CVW-W	CBEXV06.0501	6.0 W12T - 2 bank	Continental	LEV II Bin 5	Bosch ME7.1.1 VW-W

The VVT diagnosis analyses the actual movement of the camshaft(s) according to the predicted target angle using information from the camshaft position sensor. It recognises "target error" as less movement or "slow response" as delayed or insufficient movement of the camshaft(s).

13.1 General Description

The method watches the predicted target angle(s) of the camshaft(s) for rapid movement requests. In the moment a movement request greater than a specified minimum angle occurs, the actual angle is stored and a predicted time to reach the target angle is calculated. After this time plus a calibrated minimum delay time the actual camshaft angle is compared to the start angle and to the target angle.

- If the actual angle is in range of the target angle the test passed
- If the actual angle is in range of the start angle, the test failed with a target error
- If the movement was not sufficient to reach the target range the test failed with a delay error

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The monitor evaluates a predetermined number of test results for final fault determination.

Refer to Figure 93 for graphical description of strategy for emission related VVT failures.

Refer to Figure 94 for graphical description of strategy for flowchart of VVT monitoring function.

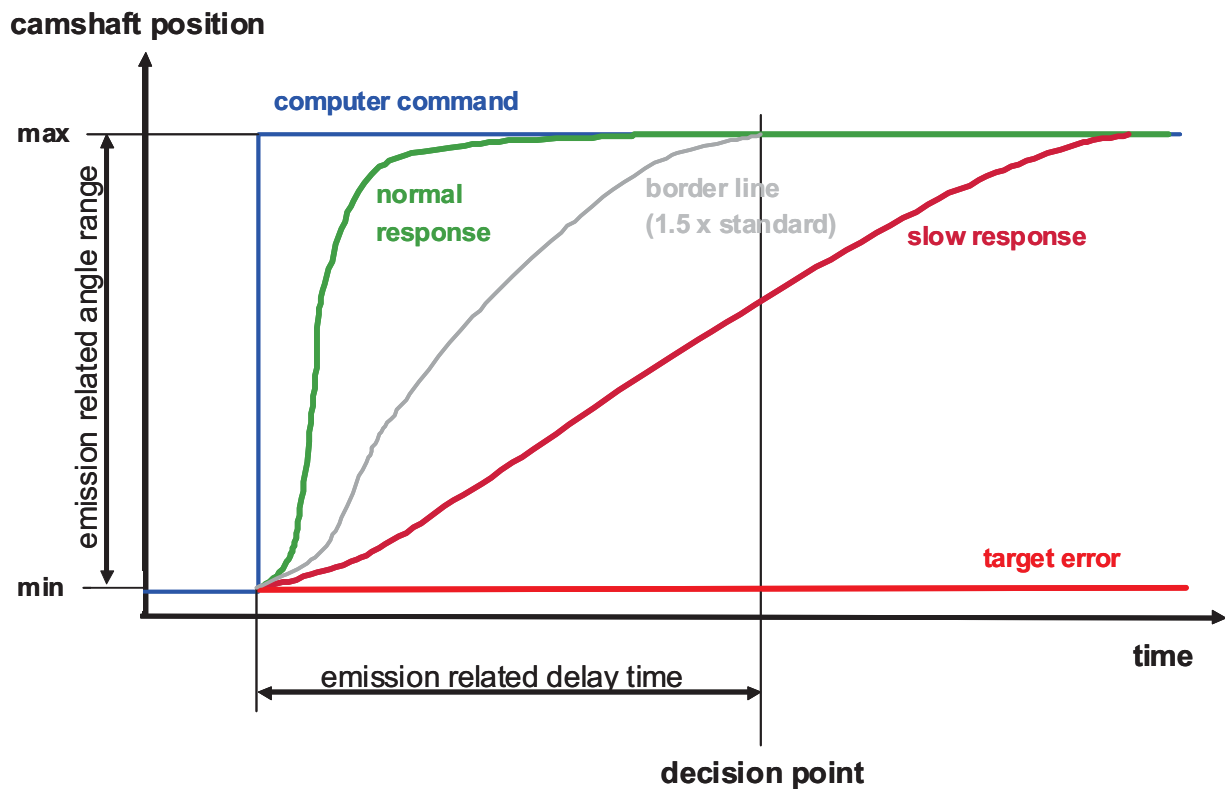


Figure 93: Strategy for emission related VVT failures

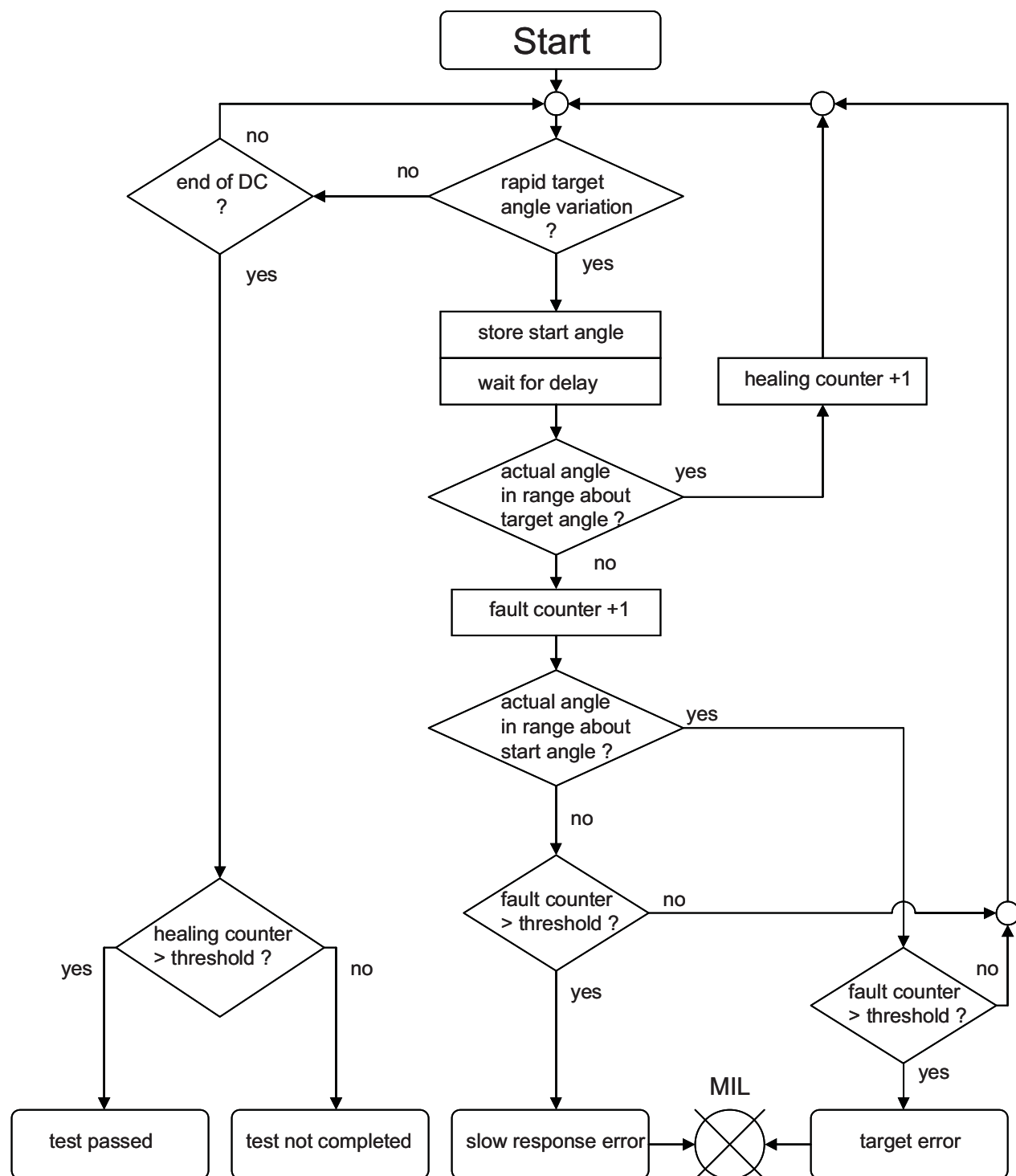


Figure 94: Flowchart of VVT monitoring function

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14 DIRECT OZONE REDUCTION (DOR) SYSTEM MONITORING

Not applicable

15 COMPREHENSIVE COMPONENTS MONITORING

This section provides flow charts and additional descriptive material for use in conjunction with the summary table.

15.1 Injection Valve

Refer to generic description of comprehensive component "Output Stage Check".

15.2 Fuel Pump Relay

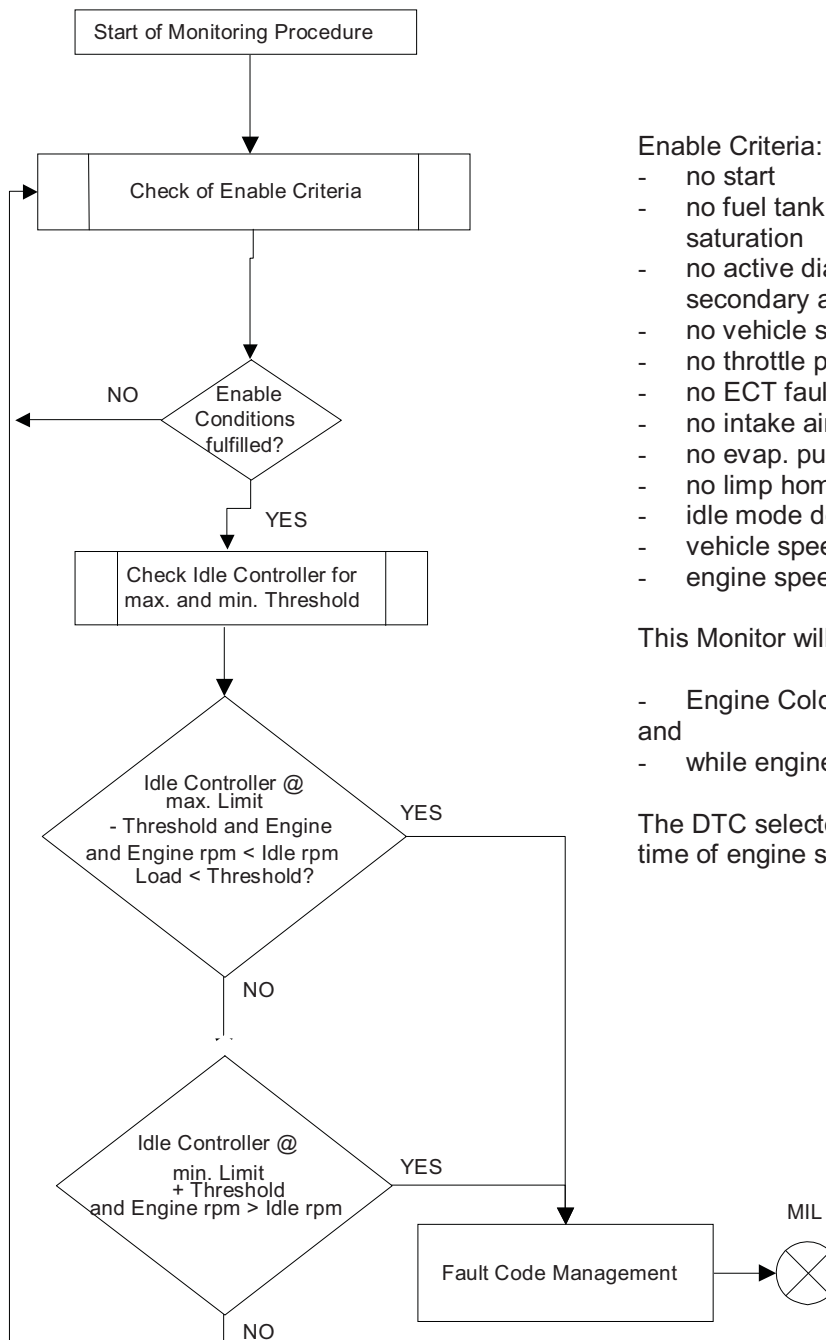
Refer to generic description of comprehensive component "Output Stage Check".

15.3 Ignition Coil

Refer to generic description of comprehensive component "Output Stage Check".

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15.4 Idle Speed Controller



Enable Criteria:

- no start
- no fuel tank ventilation with high degree of saturation
- no active diagnosis of EVAP system and secondary air
- no vehicle speed fault
- no throttle position fault
- no ECT fault
- no intake air temperature fault
- no evap. purge valve fault
- no limp home of engine speed sensor
- idle mode detected
- vehicle speed = 0 mph
- engine speed @ idle

This Monitor will be conducted during

- Engine Cold Start with Catalyst Heating active and
- while engine is in warmed-up condition.

The DTC selected will be based on ECT at the time of engine start.

Figure 95: Flow Chart Idle controller monitoring

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15.5 Engine Speed Sensor

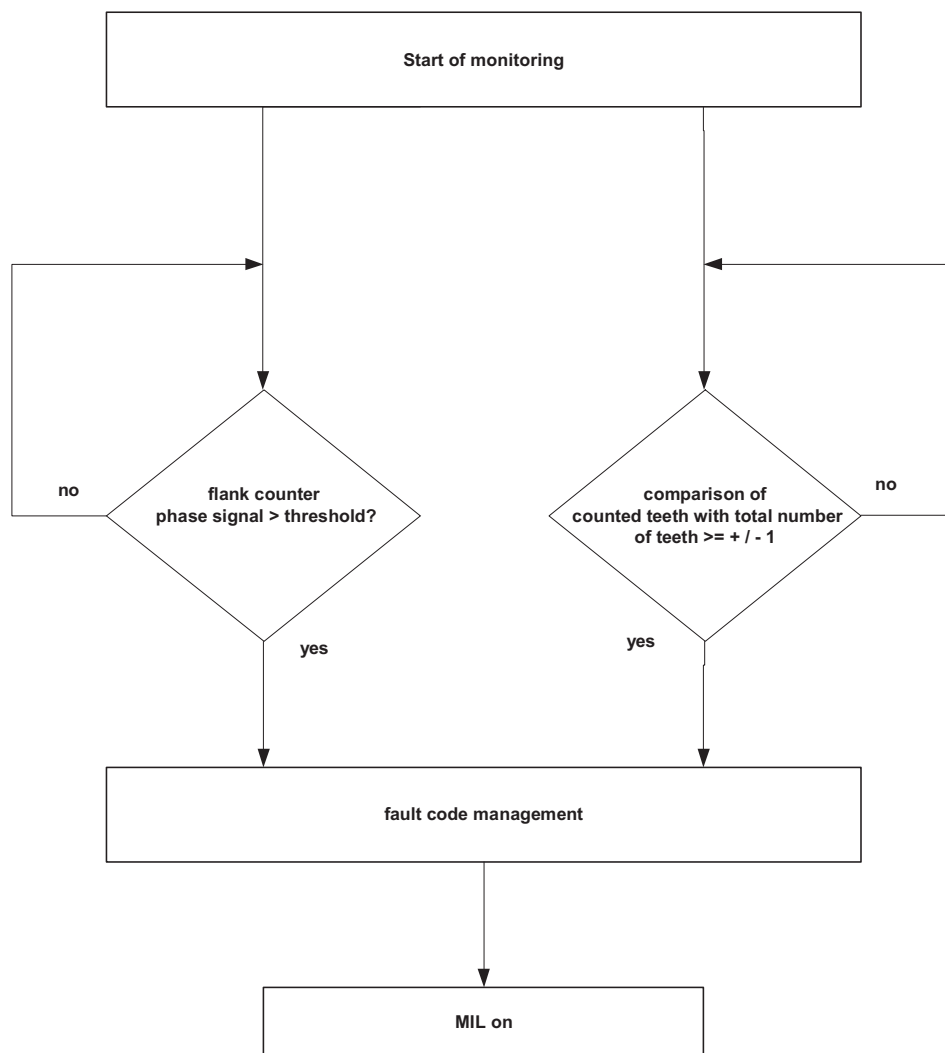


Figure 96: Engine Speed Sensor monitoring

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15.6 Generic Signal Range Check for Input Sensor

Refer to input / output table in applicable OBD Group submission for list of input sensors. This monitor is conducted continuously by the OBD system.

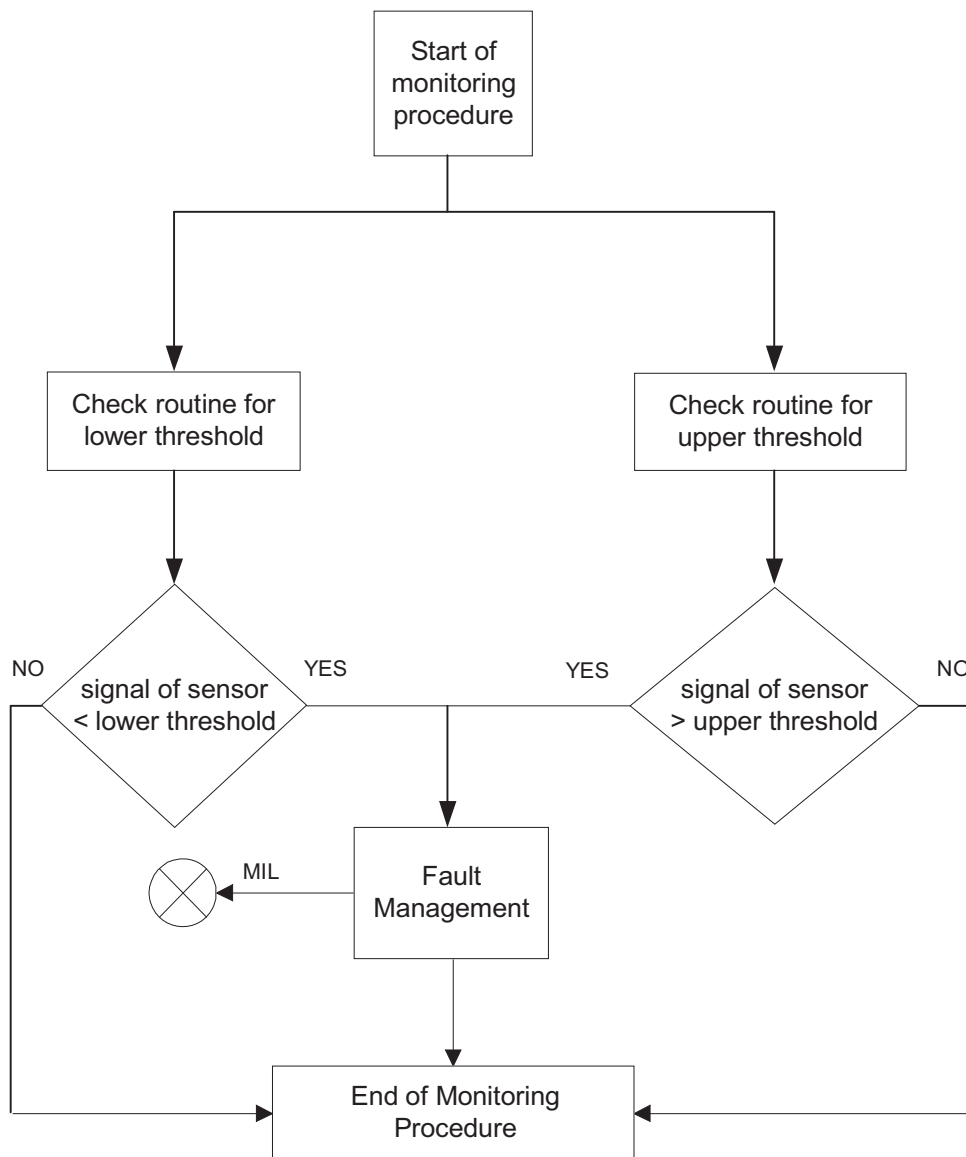


Figure 97: Flow Chart Signal Range check for input sensor

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15.7 Rationality Mass Air Flow Sensor (MAF)

15.7.1 Twin MAF Sensor System

Applicable to OBD groups:

OBD Group Name	Test group	Engine	Models	Standard	Controller / OBD II strategy
CVW-W	CBEXV06.0501	6.0 W12T - 2 bank	Continental	LEV II Bin 5	Bosch ME7.1.1 VW-W

15.7.1.1 Monitoring Concept

The flowchart (Figure 98) outlines the monitoring concept used.

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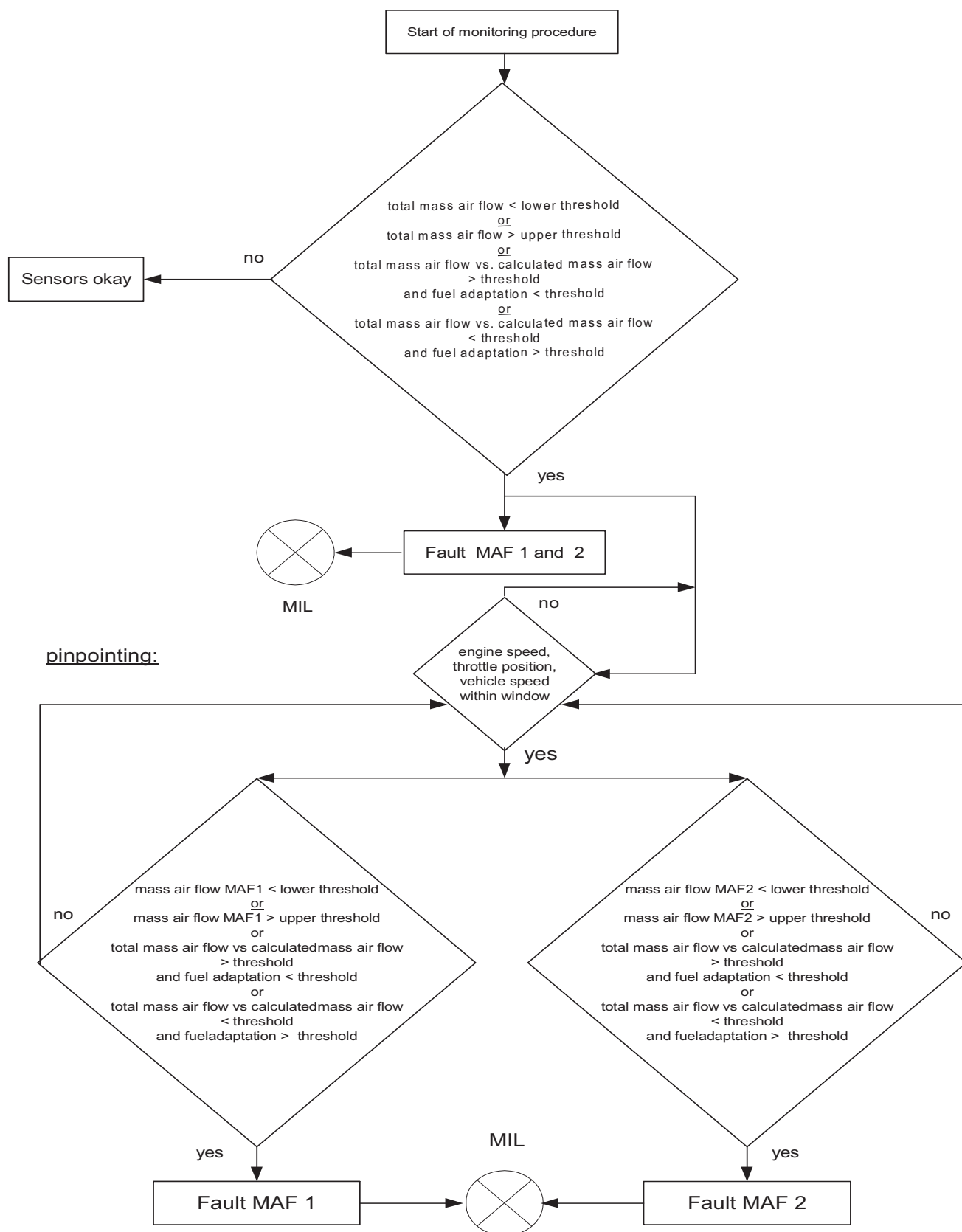


Figure 98: Flow Chart MAF rationality monitoring

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15.8 Vehicle Speed Sensor (VSS)

Refer to Figure 99.

15.8.1 Diagnosis of vehicle speed

The diagnosis of the vehicle speed consists of a CAN wheel speed message check, a range check and rationality checks. The wheel speed information from the CAN message can directly be calculated into the vehicle speed.

15.8.1.1 CAN wheel speed message check

The CAN wheel speed message check reads and analyses the wheel speed CAN message and determines whether the CAN message is corrupt or missing.

If the CAN wheel speed message is corrupt or missing, a malfunction is detected and a signal fault VFZE is set.

15.8.1.2 Range check

Taking into account the engine design it is possible to determine a maximum valid drivable vehicle speed.

If the vehicle speed exceeds the valid calibrated maximum threshold for a calibrated period of time, a malfunction is detected and a maximum fault VFZE is set.

15.8.1.3 Rationality check

The first rationality check (stuck check) evaluates the change of vehicle speed within a calibrated time. During normal driving conditions a vehicle speed change must occur since it is not possible to drive absolutely steady.

If no change of the vehicle speed within a calibrated time for a calibrated period of time occurs, a malfunction is detected and a minimum fault VFZE is set.

The second rationality check (fuel cut-off check) evaluates the vehicle speed during fuel cut-off condition. It is assumed that the vehicle moves during this condition. To cover the special fuel cut-off case when the driver has revved-up the engine at standstill the check must be debounced for a calibrated time.

If the vehicle is in fuel cut-off condition and the vehicle speed lies below a calibrated threshold for a calibrated period of time, a malfunction is detected and a minimum fault VFZNP is set.

The third rationality check (high load check) assumes that the vehicle speed at a certain load at driving state (automatic gear box) has to exceed a calibrated vehicle speed. If the vehicle speed is below this calibrated threshold for a calibrated period of time, a malfunction is detected and a maximum fault VFZNP is set.

15.8.1.4 Monitoring conditions for rationality checks

- vehicle speed exceeds calibrated threshold (stuck check)
- fuel cut-off condition active (fuel cut-off check)
- engine speed lies within calibrated range (fuel cut-off check)
- engine coolant temperature exceeds calibrated threshold (fuel cut-off check and high load check)
- no fault of engine coolant temperature sensor (fuel cut-off check and high load check)
- no fault of engine speed sensor (fuel cut-off check and high load check)
- no electrical or range error of vehicle speed (fuel cut-off check and high load check)
- engine speed exceeds calibrated threshold (high load check)
- driving state for automatic gear box is active (high load check)
- load exceeds calibrated threshold (high load speed check)

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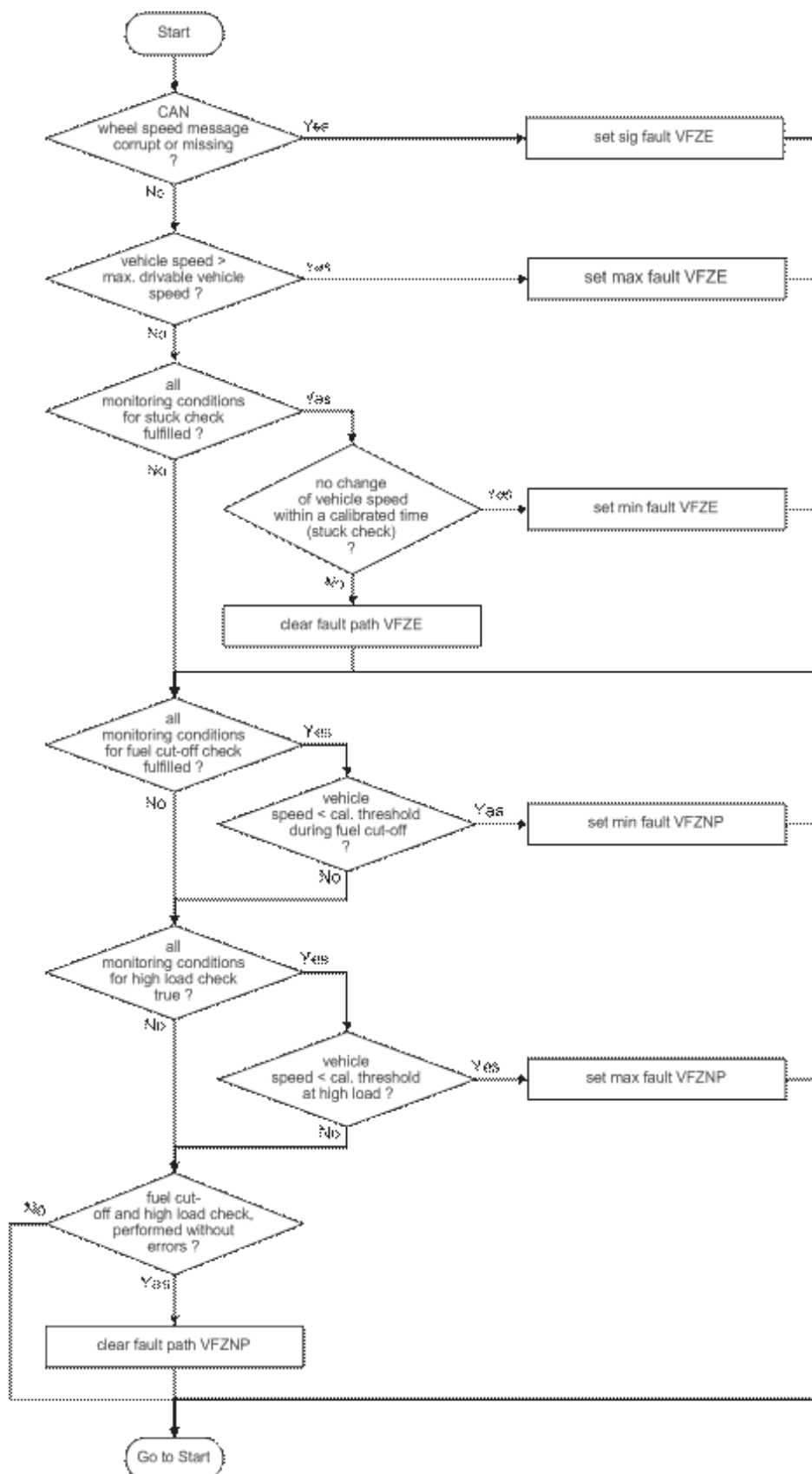


Figure 99: Flow Chart: Vehicle Speed Sensor monitoring

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15.9 Throttle Position Sensor

The throttle body consists of two potentiometers (reversed voltage logic). During the first start, the potentiometer characteristics are adapted and stored. The diagnostic monitors the corrected values of potentiometer 1 and 2. In the case of a higher difference than the threshold values both signals are compared to the engine load to determine and disable the faulty one. A fault code will be stored and the MIL will be illuminated.

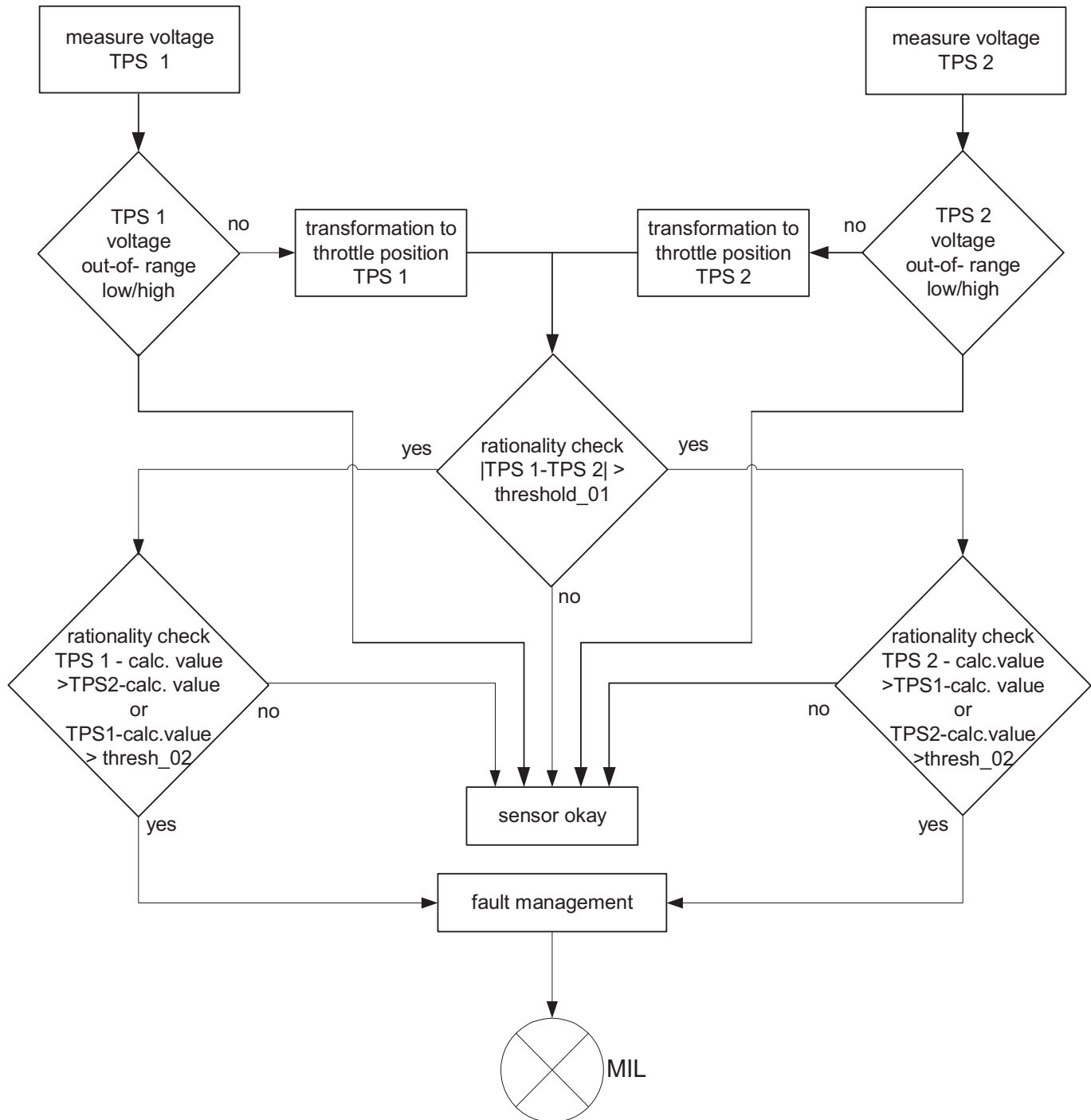


Figure 100: Flow Chart for Throttle position Sensor monitoring

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15.10 Accelerator Pedal Position Sensor (APPS)

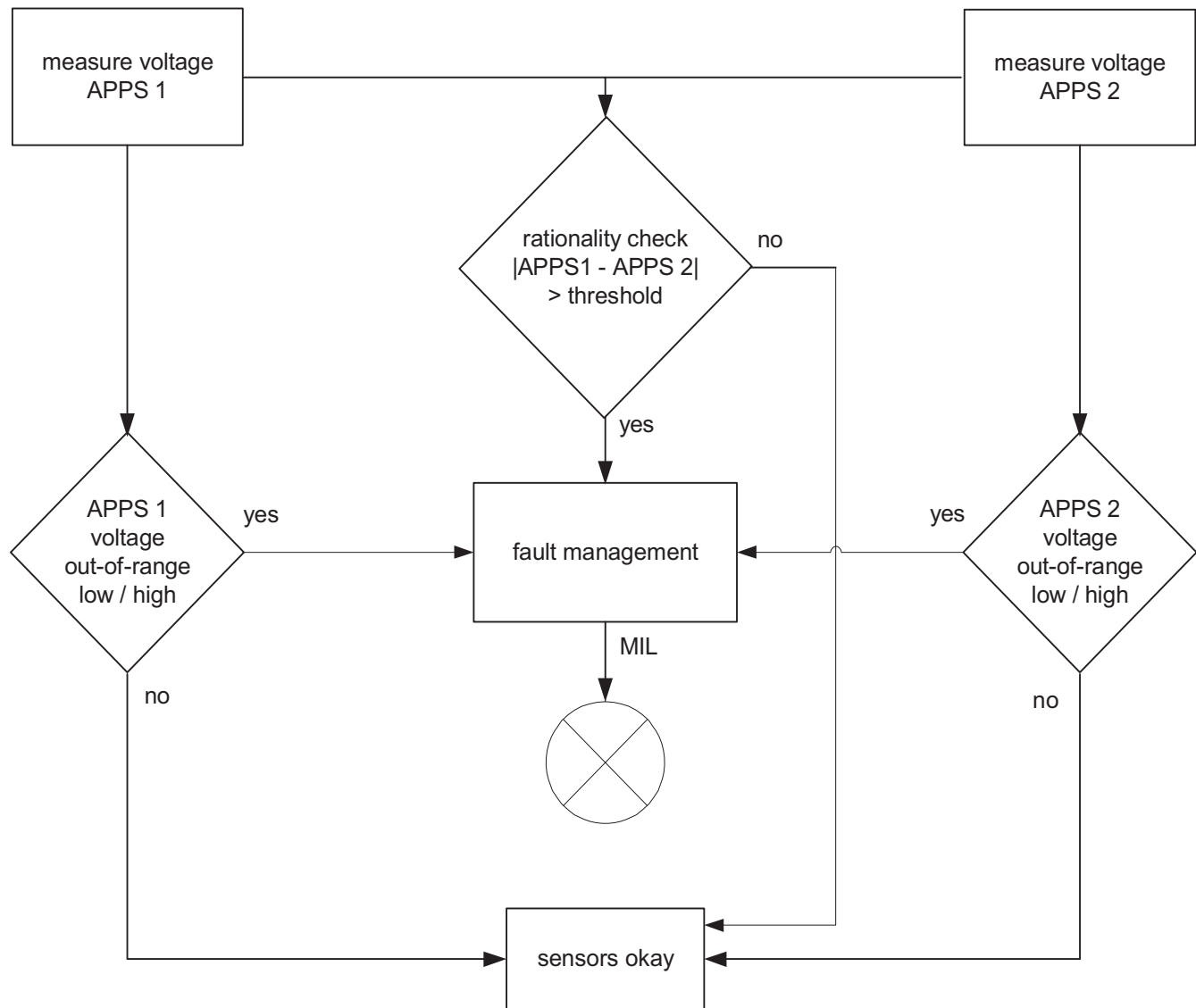


Figure 101: Flow Chart for Accelerator pedal position Sensor monitoring

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15.11 Camshaft Position Sensor

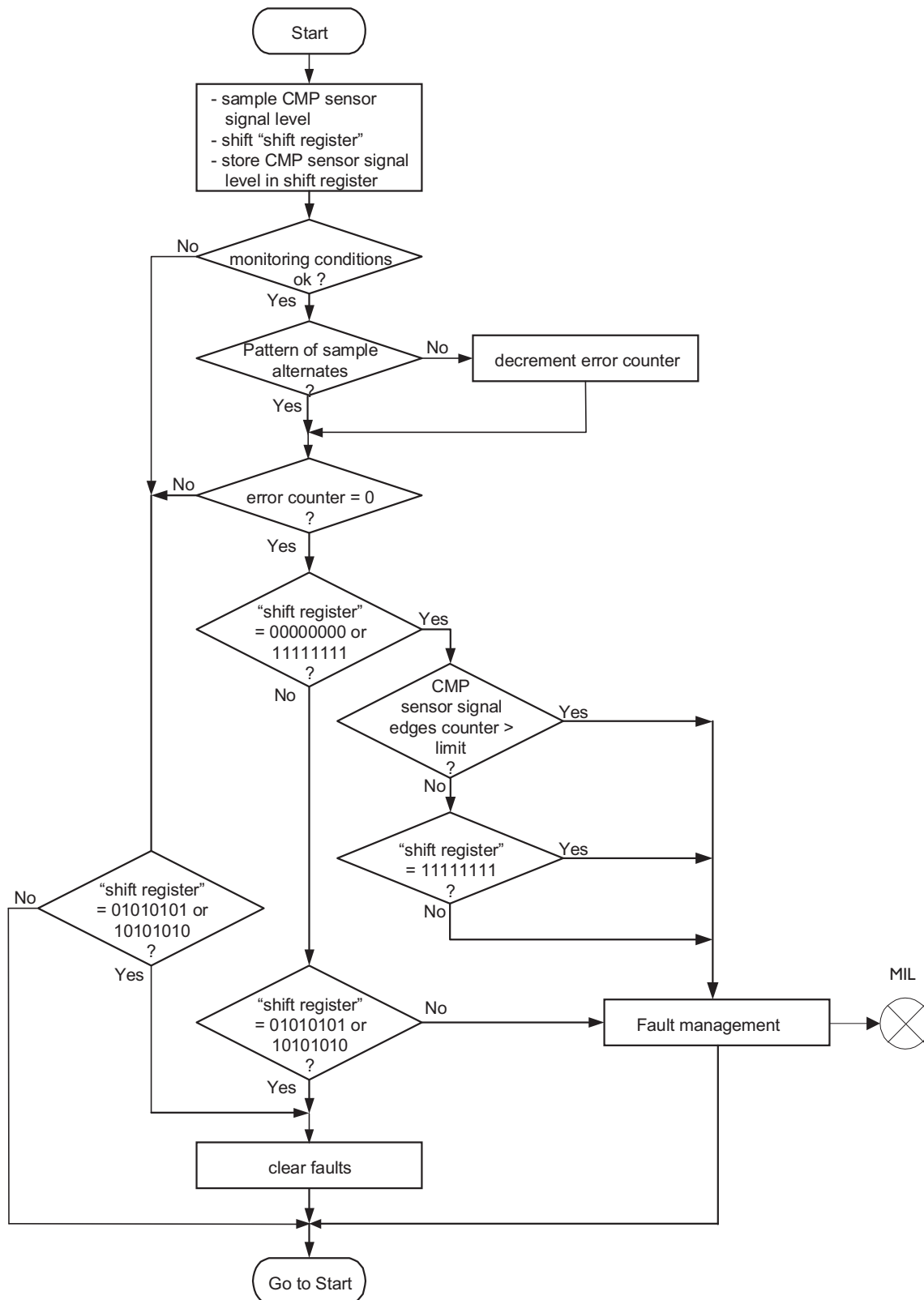


Figure 102: Flow Chart for Camshaft Position Sensor monitoring

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15.12 Boost Pressure Control Valve

Applicable only to OBD groups:

OBD Group Name	Test group	Engine	Models	Standard	Controller / OBD II strategy
CVW-W	CBEXV06.0501	6.0 W12T - 2 bank	Continental	LEV II Bin 5	Bosch ME7.1.1 VW-W

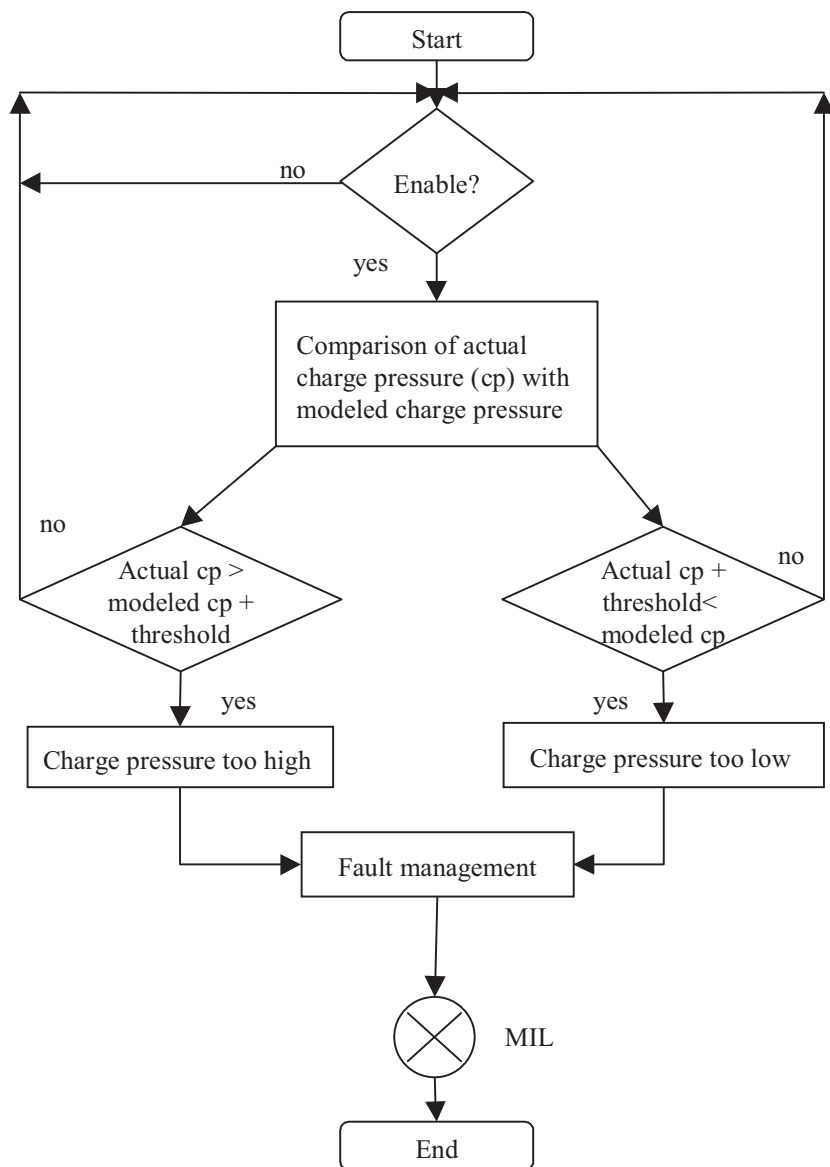


Figure 103: Flow Chart for Boost pressure control valve monitoring

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15.12.1 Intake air system leak detection

The Intake air system leak detection can detect fine or coarse leaks upstream of the throttle. The modelled pressure ratio across the throttle is compared with the actual ratio. If the ratio of modelled to real pressure ratio exceeds different thresholds, fine or coarse leaks are detected. A fine leak is detected if boost control is active and the ratio of the pressure ratios exceeds a limit after a calibrated time, and an Intake Air System Leak fault is set. A coarse leak is detected if a fine leak is already detected and the ratio of pressure ratio remains below a threshold whilst the engine is idling, and an Intake Air System Leak fault is set. Refer to Figure 104.

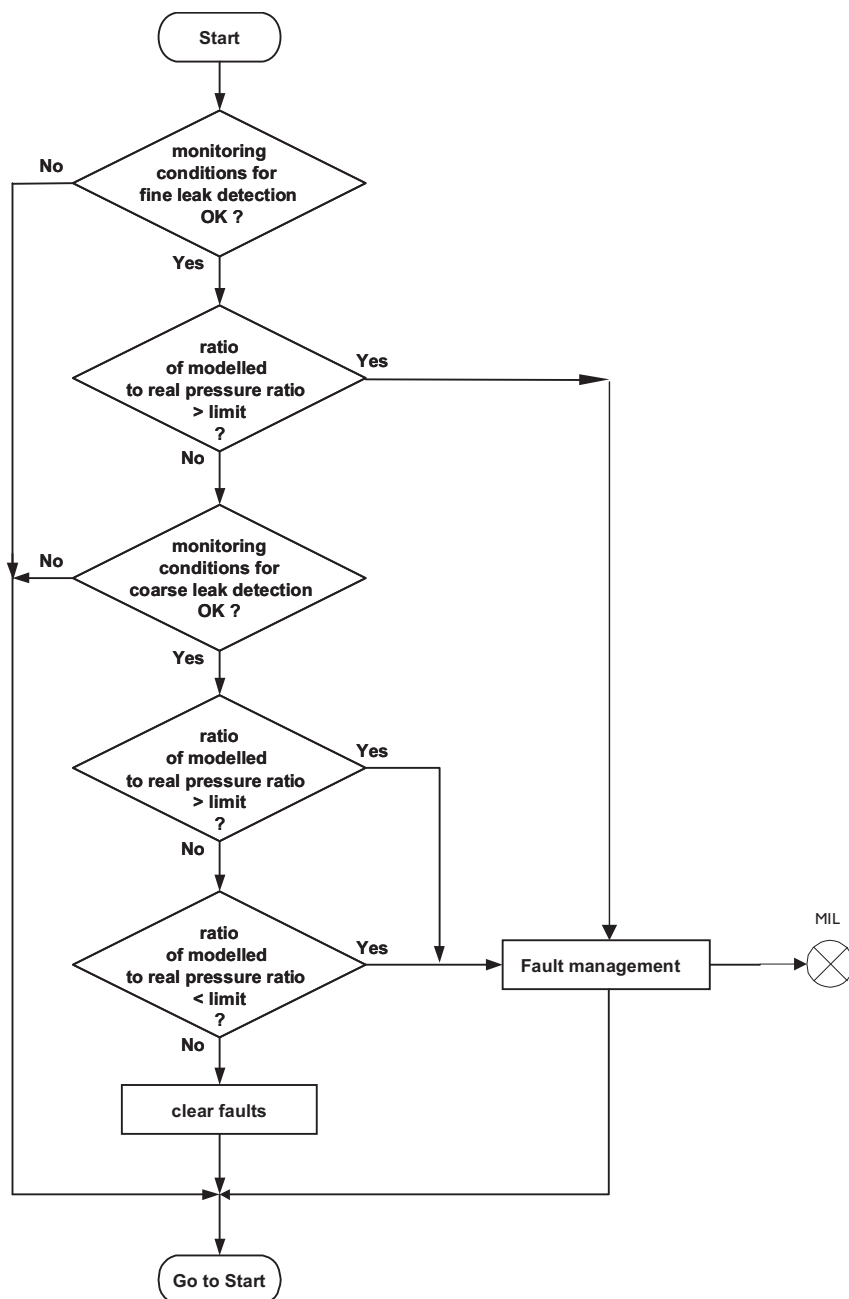


Figure 104: Flow Chart: Intake air system leak detection

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15.13 Boost Pressure Sensor

Applicable to OBD groups:

OBD Group Name	Test group	Engine	Models	Standard	Controller / OBD II strategy
CVW-W	CBEXV06.0501	6.0 W12T - 2 bank	Continental	LEV II Bin 5	Bosch ME7.1.1 VW-W

15.13.1 General Description

The Boost Pressure Sensor monitor checks for electrical circuit continuity, out of range values and irrational values.

15.13.2 Monitoring Structure

Refer to Figure 105.

Circuit continuity:

If the boost pressure lies below the lower limit for too long, a short circuit to battery or open circuit is detected and a Turbocharger/Supercharger Boost Sensor "A" Circuit Low fault is set.

If the boost pressure lies above the upper limit for too long, a short circuit to ground is detected and a Turbocharger/Supercharger Boost Sensor "A" Circuit High fault is set.

Range check:

If the boost pressure lies below the lower limit or above the upper limit for too long, an out of range low fault is detected and a Turbocharger/Supercharger Boost Sensor "A" Circuit Range/Performance fault is set.

Rationality check:

A modeled minimum boost pressure is calculated from atmospheric pressure and the pressure loss across the air filter, and a modeled maximum boost pressure is calculated from a factor dependant on engine speed. If the boost pressure lies outside of these limits for too long, a Turbocharger/Supercharger Boost Sensor "A" Circuit Range/Performance fault is set.

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15.13.3 Boost Pressure Sensor Monitoring

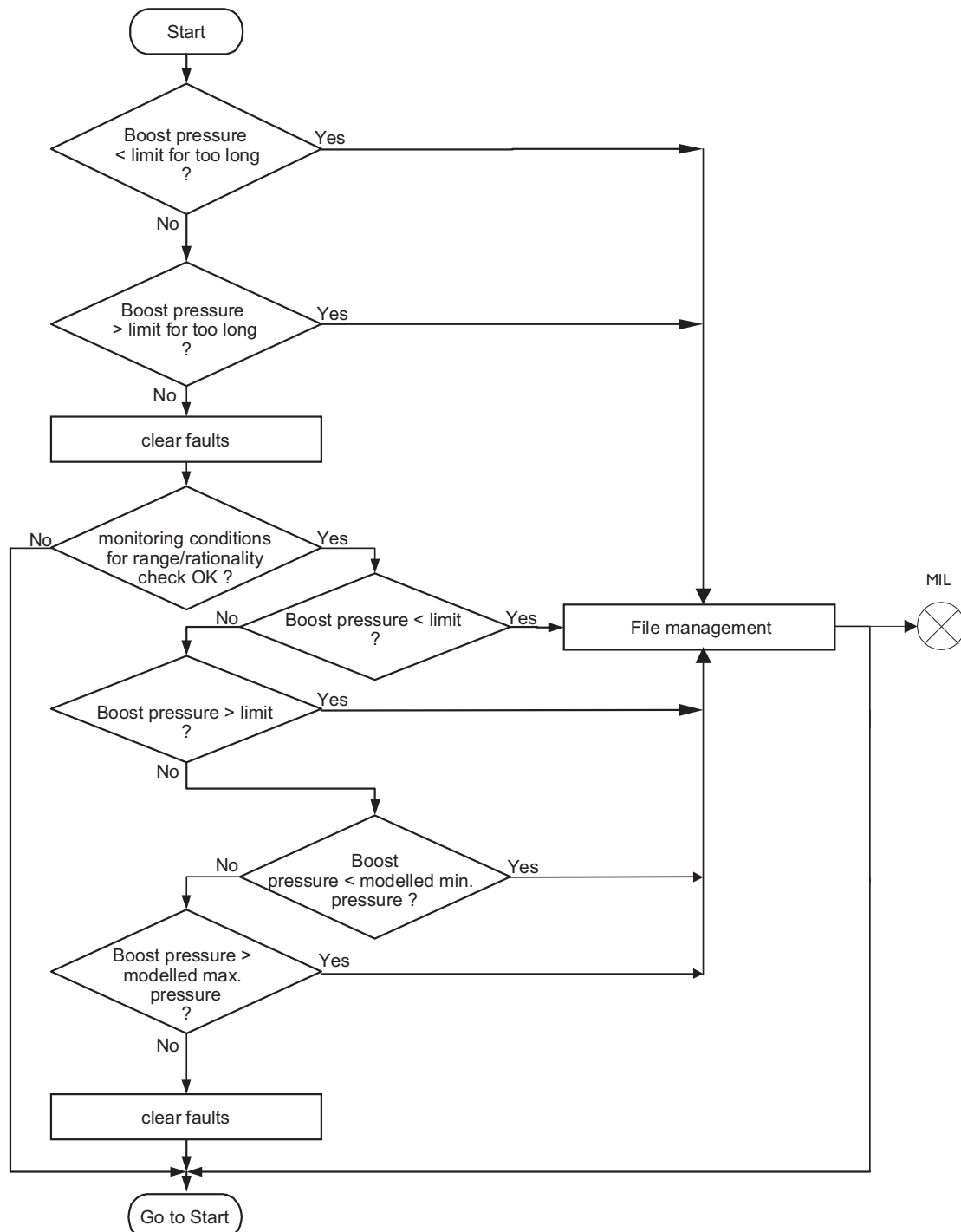


Figure 105: Flow Chart for Boost Pressure Sensor monitoring

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15.14 Atmospheric Pressure Sensor

15.14.1 General Description

The atmospheric pressure sensor monitor checks for circuit continuity, out of range signals and rationality check.

15.14.2 Monitoring Structure

Refer to Figure 106 and Figure 107.

Circuit Continuity

If the atmospheric pressure exceeds an upper limit for too long, a short circuit to battery is detected and a Atmospheric Pressure Circuit High fault is set.

If the atmospheric pressure stays below a lower limit for too long, a short circuit to ground is detected and a Atmospheric Pressure Circuit Low fault is set.

Range Check

If the atmospheric pressure exceeds an upper limit for too long, out of range high is detected, and an Atmospheric Pressure Circuit fault is set.

If the atmospheric pressure stays below a lower limit for too long, out of range low is detected, and an Atmospheric Pressure Circuit fault is set.

Driving Check

The driving check monitors the change of atmospheric pressure during normal driving. If the atmospheric pressure changes by more than a threshold during a period of time, an Atmospheric Pressure Circuit Range/Performance fault is set.

Key On, Engine Off (KOEO) Check

The KOEO check compares the atmospheric pressure at KOEO with the value stored at the last engine shut down. If this is not the same, and the atmospheric pressure is not similar to the upstream throttle pressure at KOEO, a Atmospheric Pressure Circuit Range/Performance fault is set.

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15.14.3 Atmospheric Sensor Monitoring

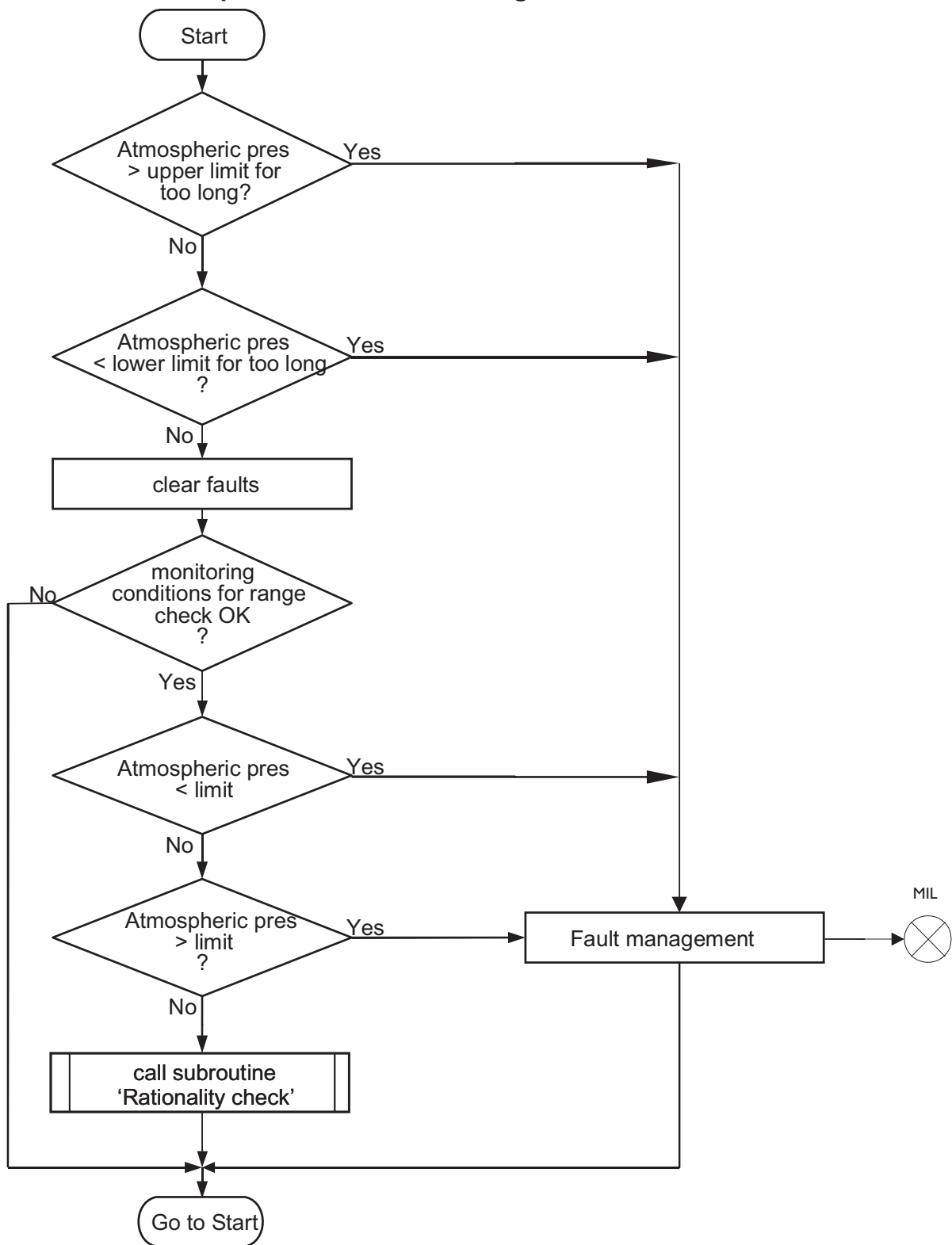


Figure 106: Flow Chart for Atmospheric Sensor lower monitoring

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15.14.4 Atmospheric Sensor Monitoring - Sub-routine “Rationality Check”

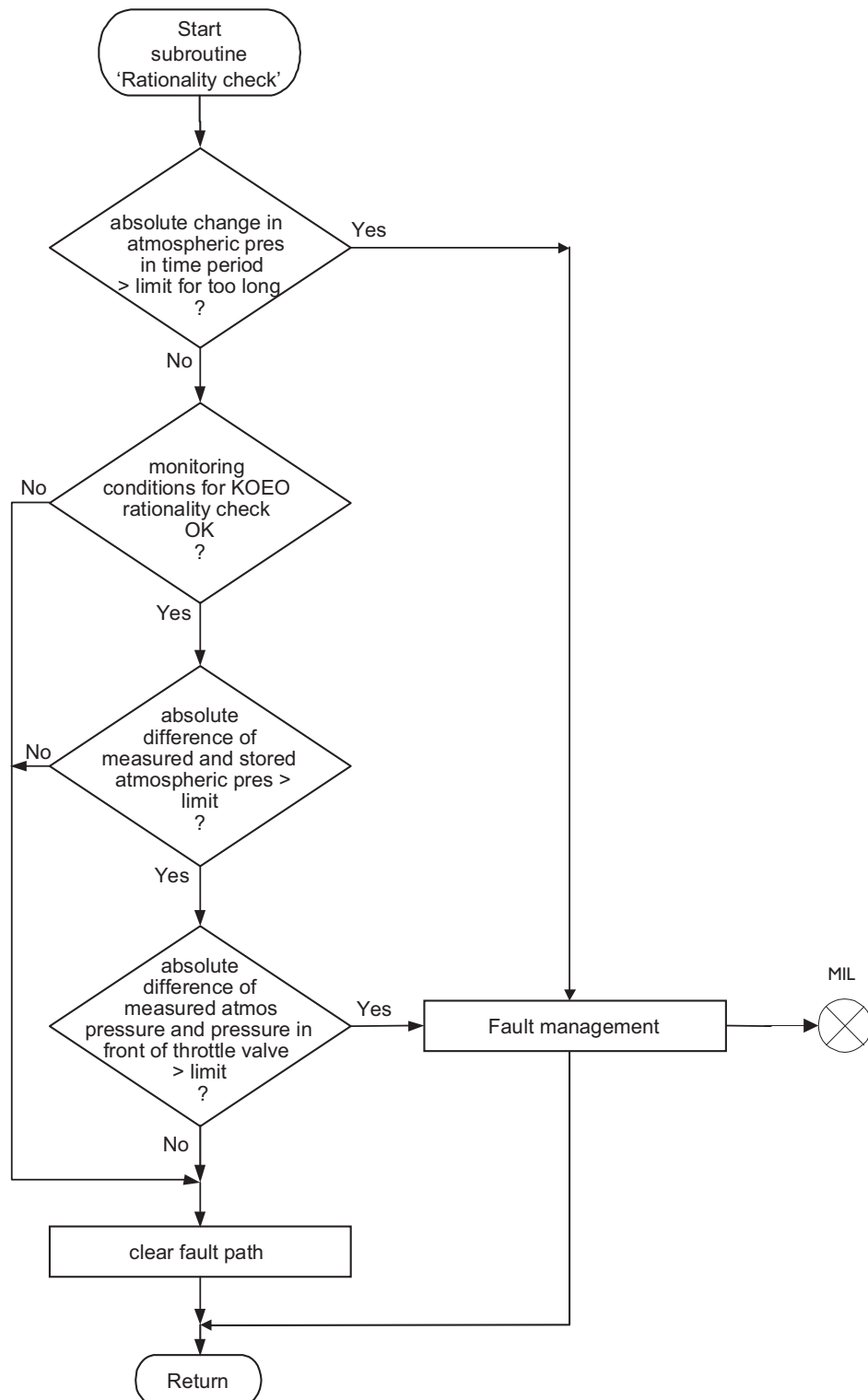


Figure 107: Flow Chart for Atmospheric Sensor Monitoring - Sub-routine “Rationality Check”

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15.15 Knock Sensor

15.15.1 General Description

The knock sensor signals are evaluated and processed in a custom integrated circuit (IC). This IC is controlled by the ECM microprocessor and the processed signals from the knock IC are sent to the microprocessor for knock control and diagnosis.

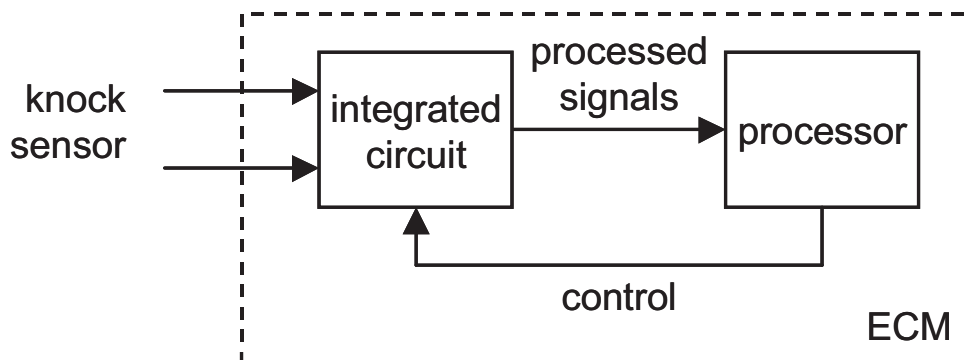


Figure 108: Knock Sensor Circuit

The knock sensor (KS) monitors checks for electrical circuit faults and signal rationality. In some cases, it can also detect excessive engine noise due to (for example) piston or valve gear problems.

15.15.2 Monitoring Structure Zero Test

Refer to

Figure **109**. For monitoring purposes the knock sensor signals can be switched off and the integrated circuit is operated with a “zero signal” as input. The zero signal is integrated in the circuit and the integrator output at the beginning (int_beg) and at the end (int_end) of a monitoring window is used for diagnostics.

Integrator check

The first part monitors the integrator value at the beginning of the measuring window, which is typically about 715 mV. If the absolute value of the difference between integrator and 715 mV exceeds a limit on a number of occasions, a Knock Control System Error fault is set.

Integrator gradient check

A second check is performed by monitoring the gradient of the integrator. The difference in the integrator output between the end and beginning of the measuring window is compared against a limit. If the absolute value of this difference exceeds the limit on a number of occasions, a Knock Control System Error fault is set.

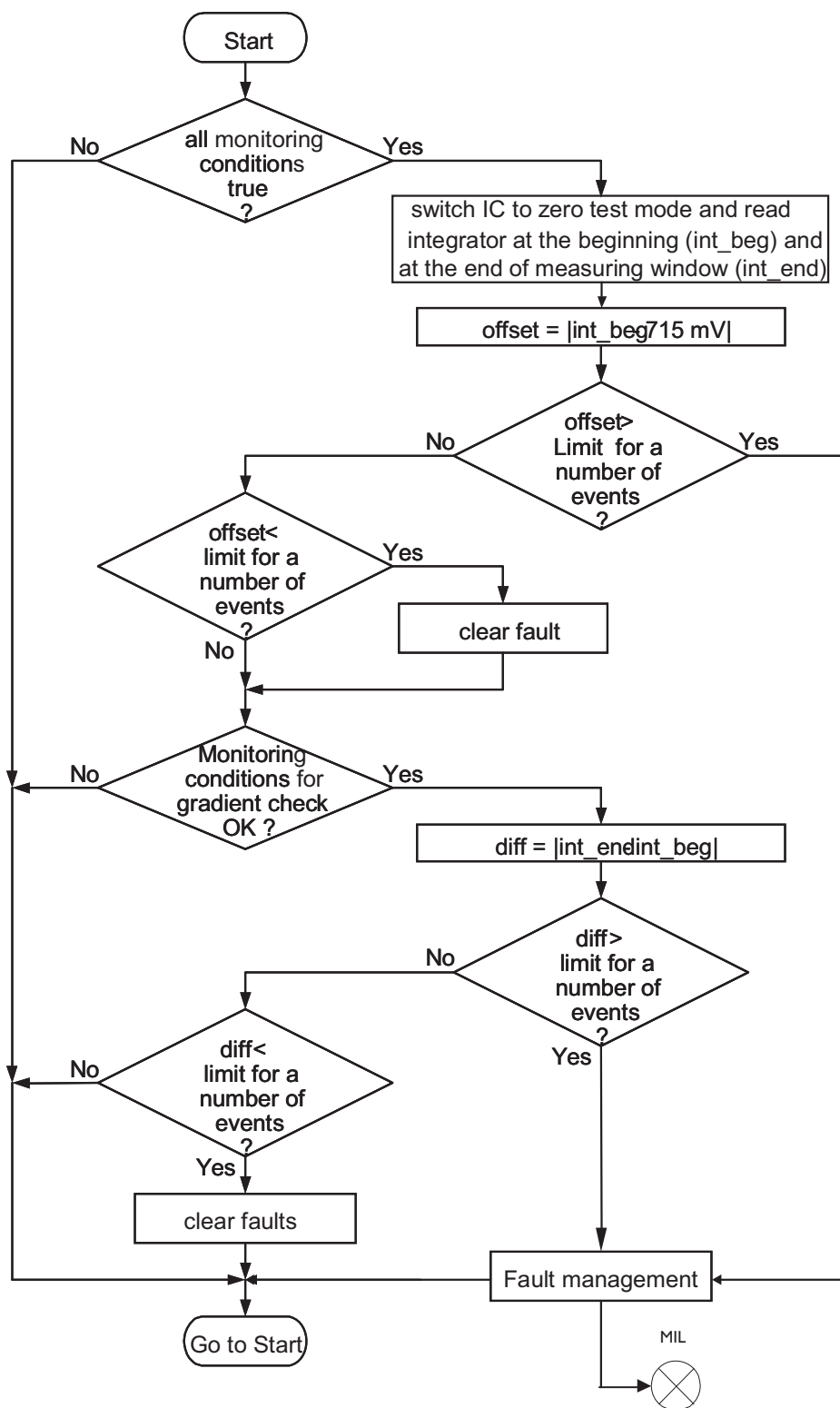


Figure 109: Flow Chart for Knock Control “Zero Test” Monitoring

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15.15.3 Monitoring Structure Pulse Test

Refer to Figure 110. For monitoring purposes the knock sensor signals can be switched off and the integrated circuit is operated with a “test pulse” as input.

For an advanced diagnosis a test pulse can be generated at the input of the knock control circuit. In this mode, the test pulse signal is integrated instead of the signal from the knock sensors.

The integral of the test pulse is calculated in a monitoring window. The test pulse signal is integrated in the circuit and the integrator output at the beginning (int_beg) and at the end (int_end) of a monitoring window is used for diagnostics.

Therefore the content of the signal integrator at the beginning of the measuring window is subtracted from its content at the end of the window. If the difference is below a limit for a number of samples, a Knock Control System Error fault is set.

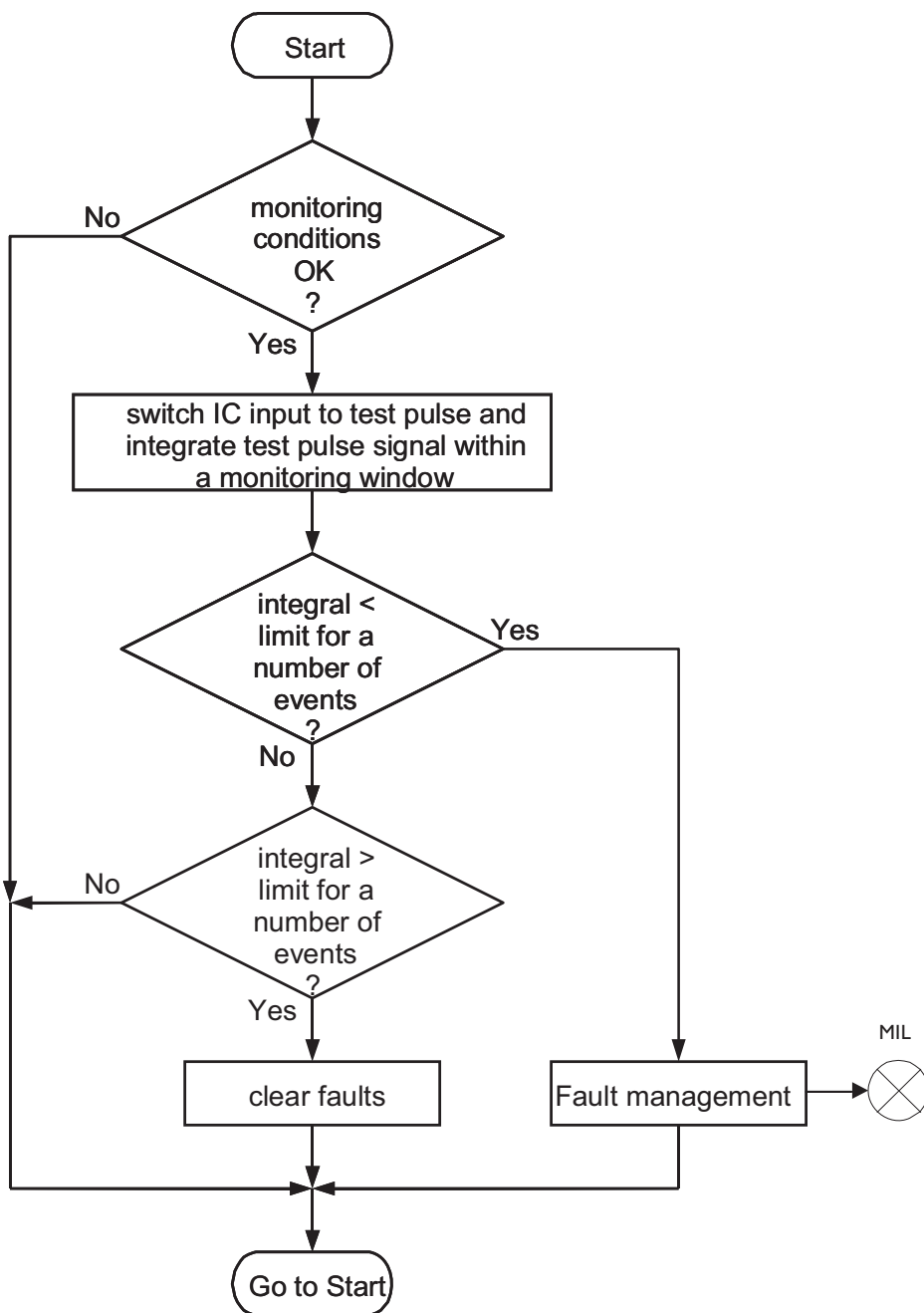


Figure 110: Flow Chart for Knock Control (Pulse test) Monitoring

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15.15.4 Monitoring Structure Knock Sensor Monitor

15.15.4.1 Concepts with knock sensor circuit high and low fault paths active

Applicable to OBD Groups:

OBD Group Name	Test group	Engine	Models	Standard	Controller / OBD II strategy
CVW-W	CBEXV06.0501	6.0 W12T - 2 bank	Continental	LEV II Bin 5	Bosch ME7.1.1 VW-W

Refer to Figure 111. A reference signal (U_{REF}) is calculated based on the knock sensor signal. This reference value represents the basic noise of the current cylinder being monitored.

If U_{REF} exceeds the upper limit for a number of samples, a Knock Sensor Circuit High fault is set.

If U_{REF} stays below the lower limit for a number of samples, a Knock Sensor Circuit Low fault is set.

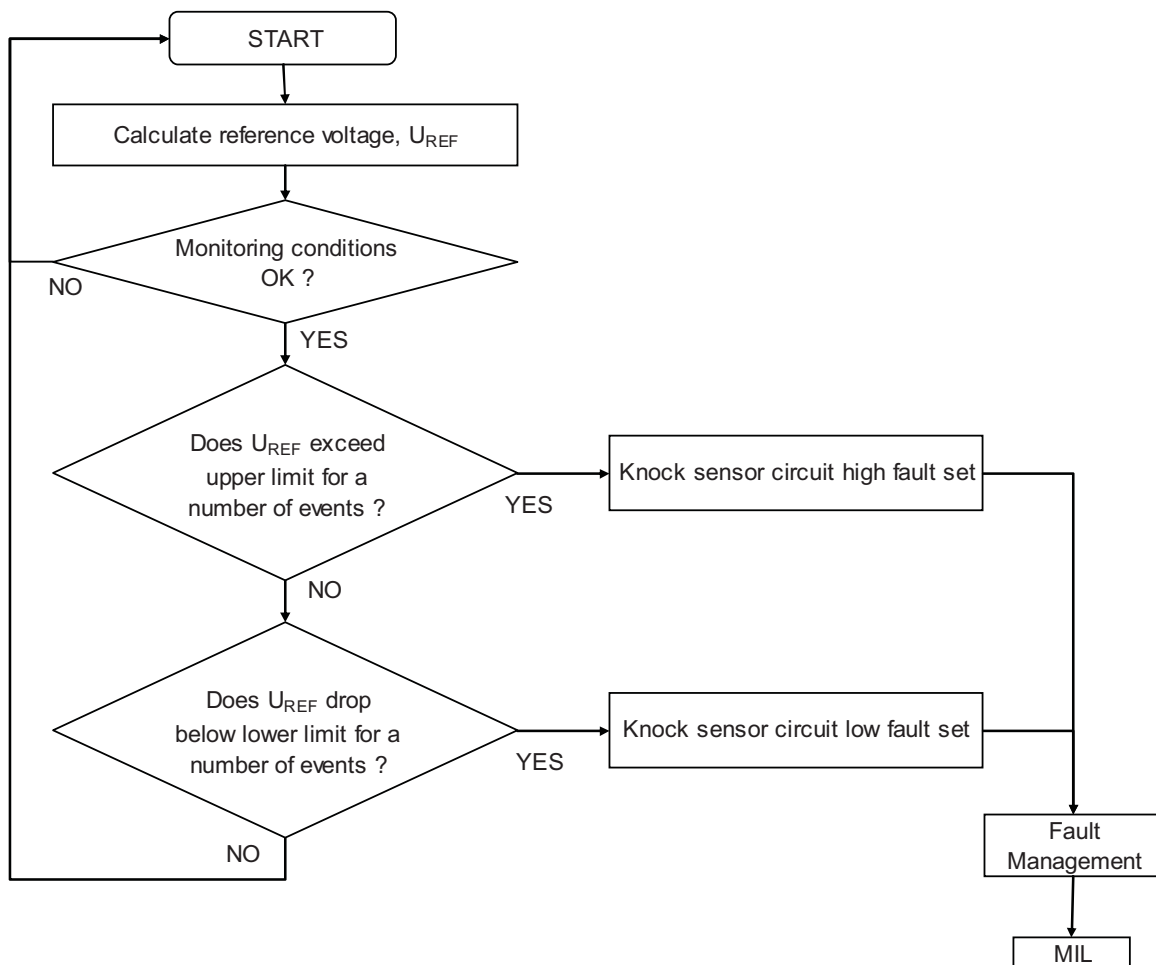


Figure 111: Flow Chart for Knock Control Circuit High & Low Monitoring

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15.16 Camshaft to Crankshaft Alignment Monitor

15.16.1 Concepts with Variable Valve Timing (VVT)

Applicable to OBD Groups:

OBD Group Name	Test group	Engine	Models	Standard	Controller / OBD II strategy
CVW-W	CBEXV06.0501	6.0 W12T - 2 bank	Continental	LEV II Bin 5	Bosch ME7.1.1 VW-W

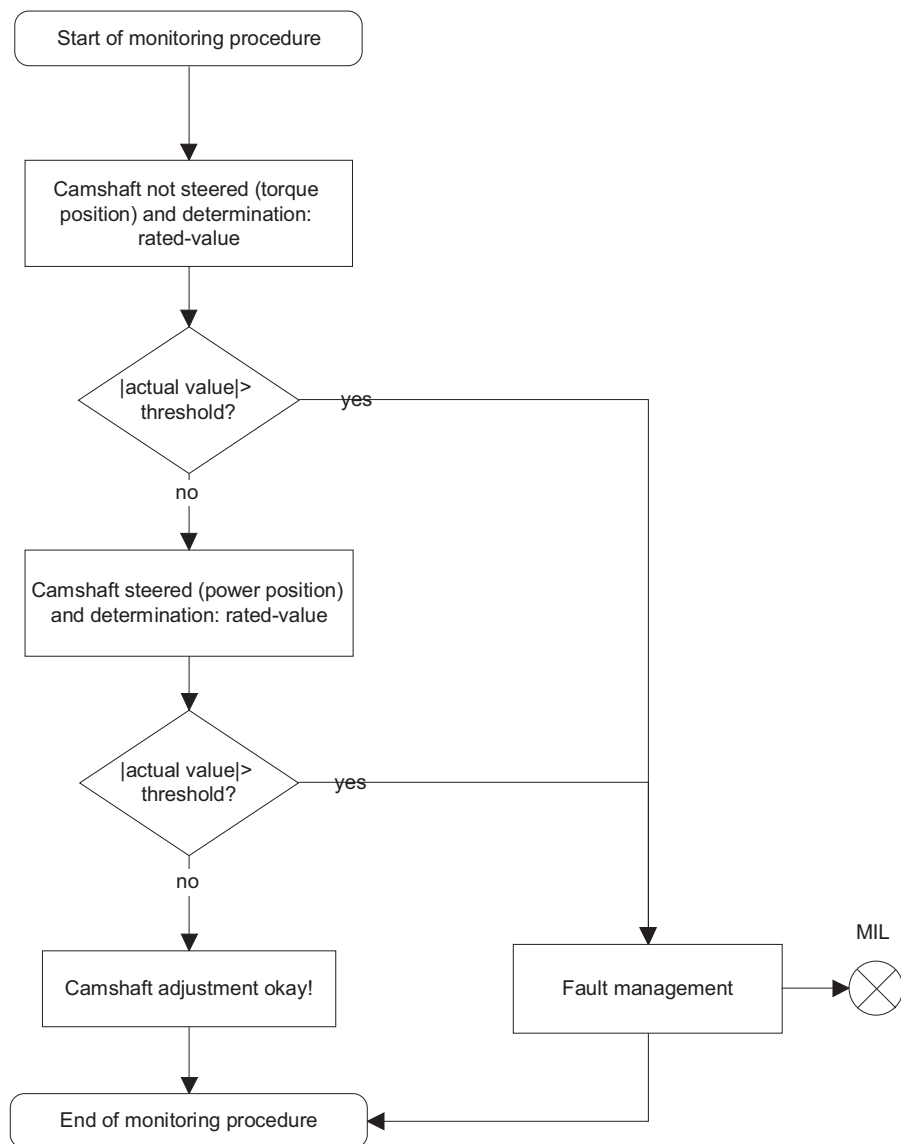


Figure 112: Flow Chart for Camshaft position Sensor monitoring (Concepts with VVT)

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15.17 Transmission Monitoring

VW Group has different basic transmission systems incorporating electronic controls. For each of these systems, representative OBD II summary tables are provided as part of each OBD Group's specific technical documentation.

In addition, the Common VW Group OBD Description includes a TCM Groups Chart showing the references between transmission type and OBD / Test groups.

15.18 Generic Output Stage Check

The output stages are integrated in manufacturer specific integrated circuits.

The integrated circuit (IC) has a binary diagnostic line (e.g. SJ401).

If the control line of one stage has a different signal than the output line, the logic circuit inside the IC detects a malfunction. The logic circuit within the IC can separate the type of fault to a short circuit to minus, an open line, or a short circuit to plus. The check result will be sent to the ECM via diagnosis line.

U_{batt}=16V	normal working situations	short circuit to ground	Short circuit to battery	wiring defective
U_{in}	low high	high	low	high
U_{out} / I_{out}	low high	<0.25-0.37 U _{Batt}	>2.2-3.0A	<0.65-0.84 U _{Batt}
Fault detection	no fault	fault	fault	fault

U_{batt}=8V	normal working situations	short circuit to ground	Short circuit to battery	wiring defective
U_{in}	low high	high	low	high
U_{out} / I_{out}	low high	<0.22-0.4 U _{Batt}	>2.2-3.0A	<0.54-0.78 U _{Batt}
Fault detection	no fault	fault	fault	fault

U_{in} input voltage
U_{out} output voltage
I_{out} output current

To identify which components use the output stage check please refer to the respective OBD Group summary table.

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15.19 Ethanol Sensor Monitoring

15.19.1 General Description

For "FlexFuel" concepts the combustion engine can be operated with gasoline or a mixture of ethanol and gasoline containing up to 85 % of ethanol. For this reason, the ethanol content has to be determined in order to adjust the amount of fuel injected and the ignition time. The ethanol content is determined by measuring the dielectric conductivity. The permittivity of ethanol is temperature-dependent. To measure the temperature of the fuel, a temperature sensor is installed in the ethanol sensor module in addition to the ethanol sensor. Besides the following monitors that are executed by the ECM, the ethanol sensor module runs internal self tests and sends a fixed frequency signal to the ECM. The fixed frequency signal sent to the ECM is outside of the measurement range in which the ethanol content can be determined. This signal is detected by the ECM as a fault.

15.19.2 Ethanol sensor signal out of range, P0177

- **Monitoring Strategy**

The measured value of the sensor is compared to a lower and an upper threshold value.

- **Typical Enable Conditions (Details see Summary Table)**

Ignition on

- **Malfunction Criteria**

If the measured value of the sensor is less than a lower threshold value or greater than an upper threshold value for a defined time period, the fault "Ethanol sensor signal out of range" is detected.

If, after exceeding the upper threshold value, the measured value falls below the upper threshold value and exceeds it again within a defined time period, the event is counted. If the number of events exceeds a threshold value, the fault "Ethanol sensor signal out of range" is detected, too.

If, after falling below the lower threshold value, the measured value exceeds the lower threshold value within a defined time period and falls below it again, the event is counted. If the number of events exceeds a threshold value, the fault "Ethanol sensor signal out of range" is detected, too.

If a fault is also detected by the internal fault detection of the sensor module, a fault is registered in the fault code management only once.

This fault symptom is not connected to the disabling matrix.

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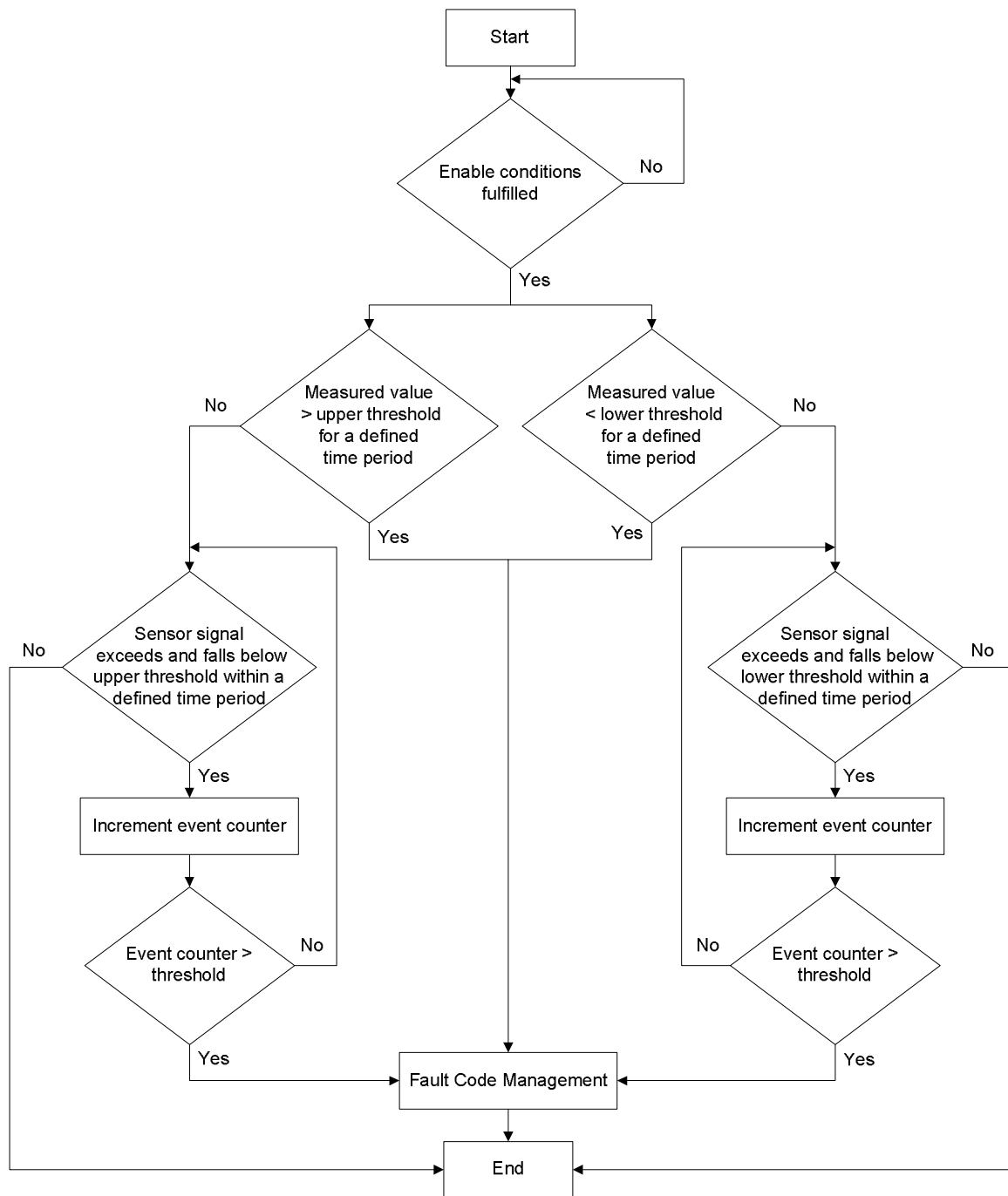


Figure 113: Flow Chart Ethanol sensor signal out of range

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15.19.3 Change of the ethanol sensor signal irrational (gradient check), P0177

- **Monitoring Strategy**

The change of the sensor signal is evaluated.

- **Typical Enable Conditions (Details see Summary Table)**

Ignition on

- **Malfunction Criteria**

When the enable conditions are fulfilled, the monitor is started. The gradient is generated from two measured values that are taken with a defined time interval between them. If the gradient is greater than a threshold value, a fault indication is set. If a fuel supply system fault (DKVS system - see description "fuel supply system") is present thereafter, the fault "Change of the ethanol sensor signal irrational" is registered. Taking the fuel supply system fault into account prevents that temporary emission-neutral faults in the determination of the ethanol content by air bubbles or water pockets lead to false fault memory entries. These effects may occur e. g. after a fuel filter replacement.

This fault symptom is not connected to the disabling matrix.

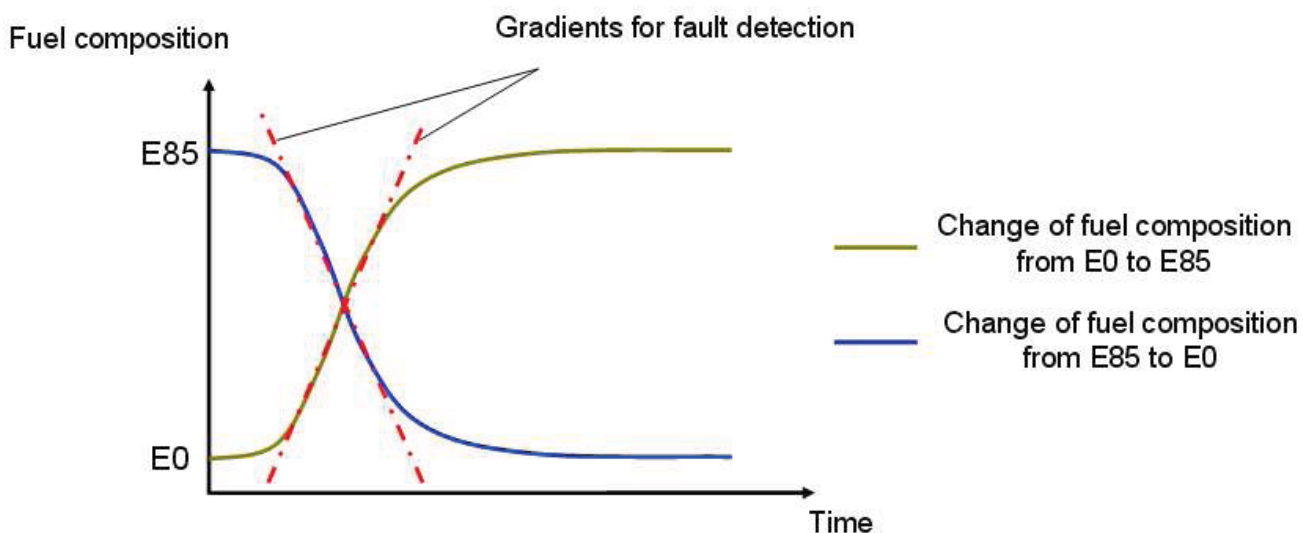


Figure 114: Typical curves for the change of fuel composition in the fault-free case

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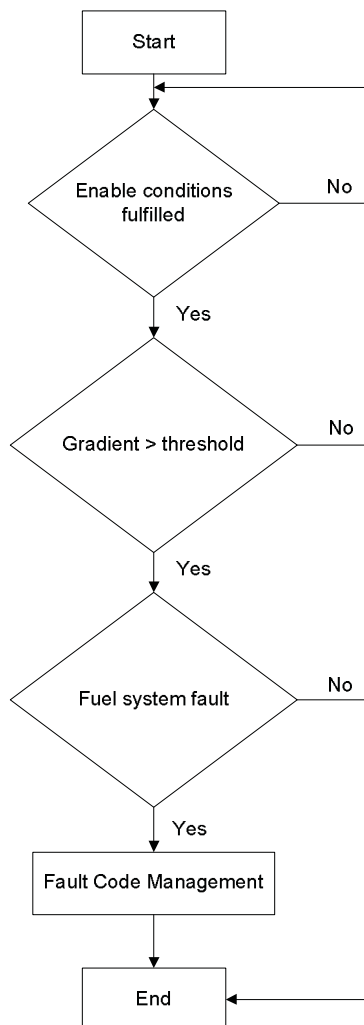


Figure 115: Flow Chart Change of the ethanol sensor signal irrational

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15.19.4 Ethanol sensor signal stuck in operating range (“stuck check”), P0177

- **Monitoring Strategy**

This monitor checks if the sensor signal remains at a constant value when a signal change would be expected due to a change in the fuel composition.

- **Typical Enable Conditions (Details see Summary Table)**

Change of the ethanol sensor signal < threshold value

Vehicle speed = 0 and idle speed for a defined time period

OR

Engine-off time > threshold value

This way it is detected if a fueling event and thus if a change of the fuel composition was possible.

- **Malfunction Criteria**

When the enable conditions are fulfilled, the monitor is started. After a possible fueling event the fuel from the supply line to the injection valves has to be consumed in order to make sure that the changed fuel composition has reached the combustion chambers.

If, in this case, a significant deviation of the lambda control occurs within a range that is determined by the consumption of a defined fuel amount (fuel composition change window), without the ethanol sensor signal changing, a fault indication is set.

An emission-relevant fault in the system is not present as long as the lambda adaptation is capable of compensating for the deviations. If the lambda adaptation factor changes significantly within the fuel composition change window, the fault “Sensor signal stuck within operating range” is detected. This fault is registered when it is confirmed by a fuel supply system fault (DKVS system).

This fault symptom is not connected to the disabling matrix.

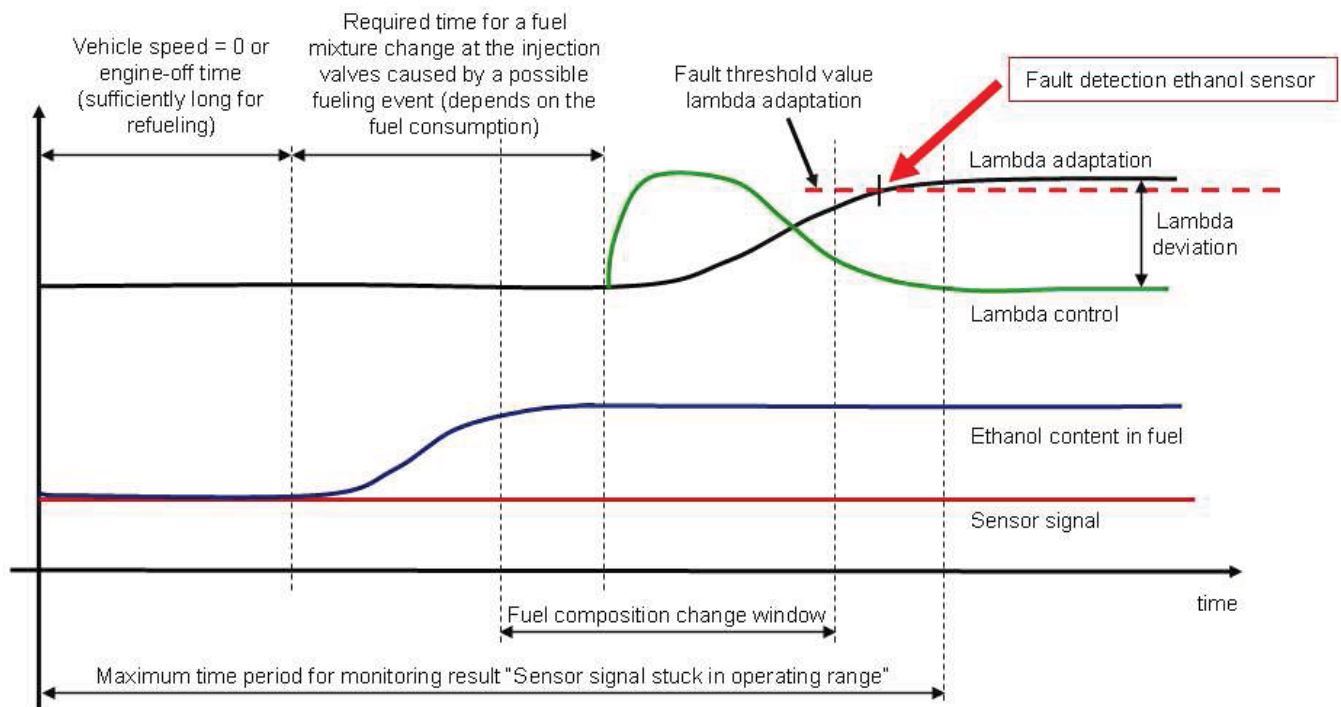


Figure 116: Fault detection “Sensor signal stuck in operating range (stuck check)”

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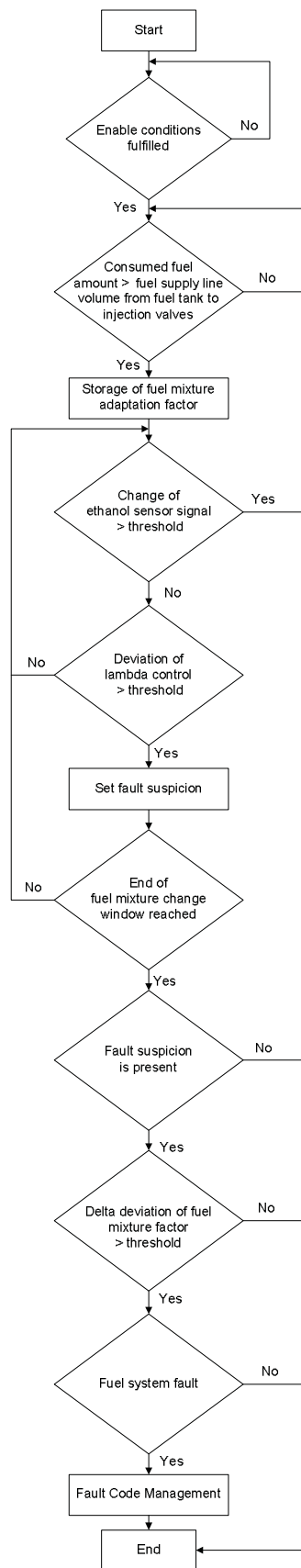


Figure 117: Flow Chart Sensor signal stuck in operating range

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- **In-Use Monitor Performance Ratio**

Incrementing the numerator:

The numerator is incremented if the enable conditions are fulfilled, a fueling event was possible and a sufficient amount of fuel was consumed so that the potentially new fuel composition has reached the injection valves and a sufficient time period for the lambda adaptation has elapsed.

For a PASS result, the longest time period required for a lambda adaptation, is simulated. For this purpose, a time counter is started when the enable conditions for the lambda adaptation are fulfilled. This time counter runs until its value is greater than a threshold value.

Incrementing the denominator:

The denominator is incremented when the conditions for incrementing the general denominator according to CCR (d) (4.3.2) (B) are fulfilled.

15.19.5 Temperature sensor signal irrational, P0177

- **Monitoring Strategy**

If a cold start is detected, the difference between the measured value of the ethanol temperature sensor and the measured value of a temperature sensor which has already been checked for rationality is compared to a threshold value.

- **Typical Enable Conditions (Details see Summary Table)**

- ~ Cold start detected (Engine-off time > threshold value)
- ~ Engine coolant temperature > threshold value

- **Malfunction Criteria**

When the enable conditions are fulfilled, the temperature sensor monitor is started. The measured value of the ethanol temperature sensor is compared to the value of a temperature sensor (engine coolant temperature sensor) that has already been rationalized by another monitor. If the absolute value of the difference between the two values is greater than a threshold value, the fault "Temperature sensor signal irrational" is detected.

This fault symptom is not connected to the disabling matrix.

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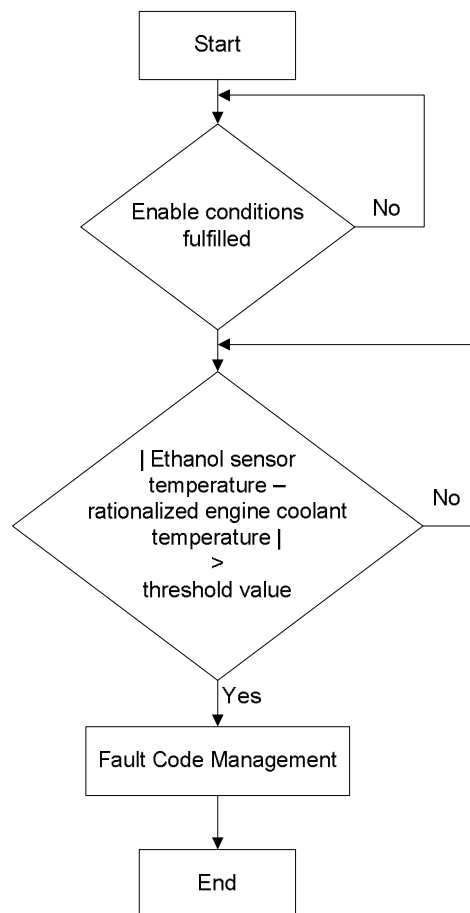


Figure 118: Flow Chart Temperature sensor signal irrational

- **In-Use Monitor Performance Ratio**

- Incrementing the numerator:

The numerator is incremented when the monitor has been completed once.

- Incrementing the denominator:

The denominator is incremented when the conditions for incrementing the general denominator according to CCR (d) (4.3.2) (D) "Evaporative System Denominator" are fulfilled.

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15.19.6 Temperature sensor signal out of range, P0177

- Monitoring Strategy**

The measured value of the sensor is compared to an upper and a lower threshold value.

- Typical Enable Conditions (Details see Summary Table)**

No electrical faults present

Ignition on

- Malfunction Criteria**

When the enable conditions are fulfilled, the monitor is started. If the measured value of the sensor is less than a lower threshold value OR greater than an upper threshold value, the fault "temperature sensor signal out of range" is detected.

This fault symptom is not connected to the disabling matrix.

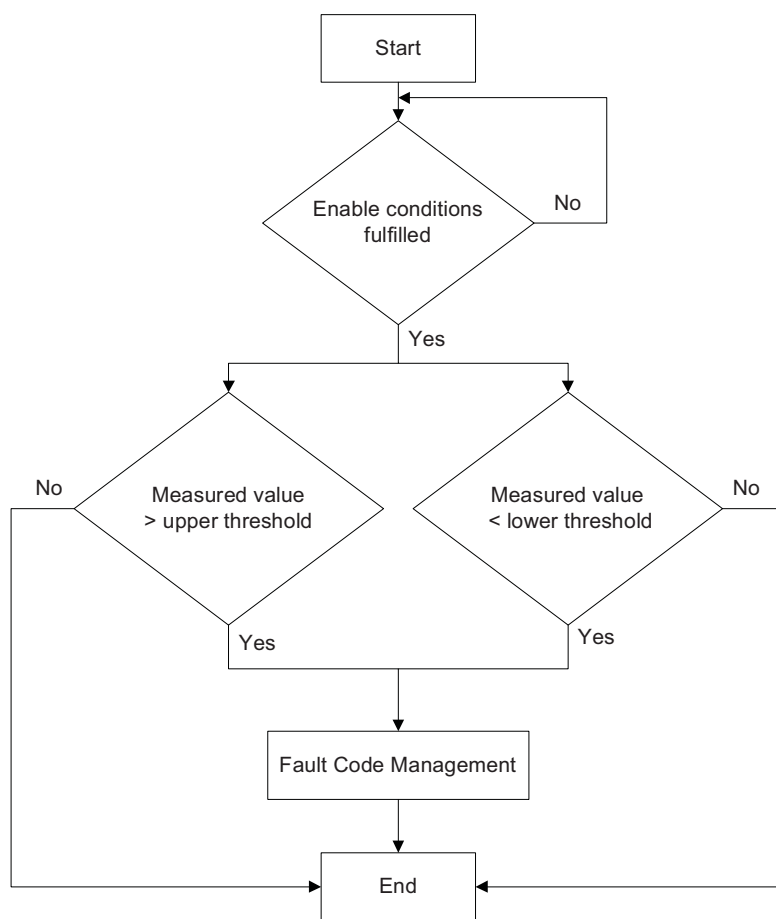


Figure 119: Flow Chart Temperature sensor out of range

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16 OTHER EMISSION CONTROL OR SOURCE SYSTEM MONITORING

Not Applicable

17 EXEMPTIONS TO MONITOR REQUIREMENTS

Not Applicable

18 PARAMETERS AND CONDITIONS FOR CLOSED LOOP OPERATION

18.1 General Description

The highest conversion efficiency of the catalyst is given in a small window of air-fuel mixture close to the ratio of $\Lambda=1$. Therefore a combination of two (or three for SULEV) control loops are used to achieve the conditions for highest conversion capability of the catalyst. The first control loop uses the signal of the first Oxygen sensor (pre catalyst) to correct the air fuel ratio by adjusting the injection time. The second and third control loop uses the signals of the middle (SULEV) and post catalyst Oxygen sensors. These control loops perform a fine tuning of the air / fuel ratio to optimize the catalytic conversion.

The first control loop has a quicker response time than the post control loops which are depending on the death time of the exhaust systems. Therefore the adjustment ranges for the post control loops are restricted and the response time is larger than the one of the first control loop.

18.2 Conditions for closed loop operation of the first control loop

The main condition for closed loop is a proper heated up Oxygen sensor and the dew point must be exceeded. To guaranty the Oxygen sensor readiness the heat-up strategy starts depending on engine temperature first on a low level of heater power. Upon the exhaust temperature reaches a level where no liquid water is expected to be in the exhaust system the heater power is controlled to achieve normal ceramic temperature of the Oxygen sensor. The ceramic temperature has to be $>350^{\circ}\text{C}$ for binary and $>685^{\circ}\text{C}$ linear sensors. Specific temperatures are mentioned in the individual summary tables of the concepts.

Additional heat-up of the Oxygen sensor is caused by the thermal energy of the exhaust gas. The engine management system evaluates permanently engine temperature and thermal energy introduced to calculate the exhaust temperature based on a model. The main value therefore is the integrated air mass after engine start. Upon the integrated air mass exceeds an applicable threshold, depending on engine start temperature, the dew point is exceeded. In that case, the heater power will be increased until the sensor readiness is achieved and sensor is considered to be ready for closed loop control.

The criteria for sensor readiness of a binary sensor are:

- no fault from heater final stage check
- Sensor signal is out of a range $0,4\text{V} < \text{sensor voltage} < 0,5\text{V}$
- heater power $> 50\%$ within a certain time (typically 8-10 s)

The criteria for sensor readiness of the linear are:

- no fault from LSU-Heater, LSU-Signals and LSU-IC
- LSU is heated up to a ceramic-temperature of $> 685^{\circ}\text{C}$ or the internal sensor resistor $R_i < 130\ \Omega$.

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18.2.1 Parameters evaluated to begin closed loop (first control loop)

The target is to begin closed loop operation in a very early state after engine start. However closed loop is delayed if engine is operated according the catalyst heat-up strategy. In the table below the importance parameters are listed.

Parameter / System	Condition/Evaluation	Monitor
Oxygen Sensor	No fault detected in Oxygen sensor, wiring of the sensor or the sensor IC (linear sensors).	Oxygen sensor monitor for the front sensor(s)
Dew Point exceeded	Exhaust Temperature > threshold, calculated based on mass air flow integral.	Monitor of the mass air flow meter (out of range, rationality)
Oxygen Sensor Readiness	Sensor heated up, evaluated based on heater resistance.	Monitored by diagnostic of the heater control.
Mass Air Flow	Integrated air mass > threshold	Out of range / rationality
Oxygen Sensor Heater	OBD evaluation on sensor heater finished without fault	Oxygen sensor heater monitor.
Engine Load	Calculated value based on mass air flow and fuel injection.	Fuel system monitor, mass air flow meter monitor
Engine Temperature	Signal used to trigger the model calculation.	Monitor for engine coolant temperature sensor (out of range, rationality). Monitor of the cooling system (rationality).
Intake Air Temperature	Signal used to trigger the model calculation.	Monitor for the intake air temperature sensor (out of range)
Secondary Air System	No fault in the secondary air system is detected by OBD.	Monitor for the secondary air system.
Fuel injectors	OBD evaluation on injectors finished without fault	Monitor for the fuel injectors (out of range). Fuel system monitor
Ignition system	OBD evaluation on ignition system finished without fault. No misfire detected.	Monitor for the ignition system (out of range). Misfire monitor.

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18.2.2 Continuity of closed loop operation (first control loop)

The closed loop operation is the most dominant operation mode for the fuel system. Despite that fact, there are operating conditions of the engine where closed loop control must be temporary disabled.

Parameter / System	Condition/Evaluation	Monitor
Target Lambda	Control range is within normal values of Lambda ($0.8 < \lambda < 1.5$)	Fuel system monitor, mass air flow meter monitor, oxygen sensor monitor
Engine load	Engine load is too low, to control the exhaust lambda value during SAI (typically relative engine load $< 15\%$)	Fuel system monitor, mass air flow meter monitor, oxygen sensor monitor
Secondary air injection	During the monitor of air injection the target Lambda is commanded to determine deviation cause by air mass.	Fuel system monitor, mass air flow meter monitor
Fuel Injection	Injection time is not at minimum threshold. Injection is not disabled. Fuel cut is not commanded (e.g. coasting)	Monitor for the ignition/injection system (out of range). Misfire monitor. Fuel system monitor

18.2.3 Typical Values

Given a normal cold started FTP (around 20°C) most of the concepts reaches the closed loop condition for the first control loop within 20s to 60s. Additionally closed loop is forced depending on engine start temperature after a maximum time.

Vehicles produced in MY 2004 and MY 2005

Engine Start Temperature	Time, when closed loop is forced
Temperature ≥ 10 °C	120 s
Temperature ≥ -6.7 °C and < 10 °C	300 s

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18.3 Conditions for closed loop operation of the second control loop

Applicable to OBD groups:

OBD Group Name	Test group	Engine	Models	Standard	Controller / OBD II strategy
N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

As already mentioned under "General" the 2nd control loop optimizes the adjustments of the first control loop over a longer time to achieve the maximum conversion of the catalyst in a very small window of air/fuel ratio close to Lambda=1. The second control loop uses a binary Oxygen sensor which is operated at a target value of sensor output voltage. Deviations from the target voltage are corrected by adjusting the air/fuel ratio until the target voltage is achieved again. The controller of the 2nd control loop is a combination of proportional and integral (PI-) controller. The proportional and the integral portion of the controller have individual enable criteria.

18.3.1 Parameters evaluated to begin closed loop (second control loop)

18.3.1.1 Enable criteria for P-portion of the controller

The proportional-portion of the controller corrects short term deviations and achieves the target sensor output voltage.

Parameter / System	Condition/Evaluation	Monitor
Closed loop condition for the first control loop . Minimum of integrated mass air flow passed.	No fault detected in wiring of the sensor or the sensor IC (linear sensors). Fuel control performs normal, no fault is detected and fuel control is not temporarily disabled.	Oxygen sensor monitor for the front sensor(s). Monitor of the mass air flow meter (out of range, rationality). Fuel system monitor
Oxygen Sensor for 2 nd control loop readiness	Sensor heated up, a minimum power was delivered to the heater, sensor voltage has left the voltage range of a cold sensor	Monitored by diagnostic of the heater monitor and sensor wiring monitor.
Catalyst model temperature	Exhaust Temperature > threshold, calculated based on mass air flow integral, ignition timing, lambda value, vehicle speed.	Monitor of the mass air flow meter (out of range, rationality) Fuel system monitor, oxygen sensor monitor, vehicle speed sensor monitor
Variable Valve Timing System (if applicable)	No fault detected	VVT monitor
Secondary Air System	No fault detected	AIR System monitor
EVAP purge System	No fault detected	EVAP purge monitor
Mass Air Flow Meter	No fault detected	Mass Air Flow Meter monitor
Controller range for the first control loop is not at the threshold limit.	Controller for the first control loop not at minimum or maximum threshold	Oxygen sensor monitor

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18.3.1.2 Enable criteria for adaptive I-portion of the controller (additionally)

The integral-portion of the controller corrects permanent deviations / shifts over a longer time by adjusting the adaptation.

Parameter / System	Condition/Evaluation	Monitor
Engine speed/load within a normal operating range	Engine Speed within 1500-4000 rpm Engine Load within 20-60% (Typical values; may differ on individual concepts)	Engine Speed Sensor monitor, Mass Air Flow Meter monitor, fuel system monitor.
Carbon Canister of the EVAP system	High load of carbon canister indicated during EVAP purge.	EVAP purge monitor.
Minimum of integrated mass air flow passed and P-portion of controller achieves target range for Oxygen sensor voltage already.	Oxygen sensor voltage of 2 nd control loop, P-portion of controller for 2 nd control loop	Oxygen sensor monitor for secondary sensor(s). Fuel system monitor

18.3.2 Typical Values (second control loop)

Given a normal cold started FTP (around 20°C) most of the concepts reaches the closed loop condition for the second control loop within 60s to 100s.

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19 DETERMINATION OF CALCULATED LOAD AND FUEL TRIM VALUES

19.1 Calculated Load Values

19.1.1 Spark Ignition, Mass Airflow Sensor, Turbocharged concepts

Applicable to OBD groups:

OBd Group Name	Test group	Engine	Models	Standard	Controller / OBd II strategy
CVW-W	CBEXV06.0501	6.0 W12T - 2 bank	Continental	LEV II Bin 5	Bosch ME7.1.1 VW-W

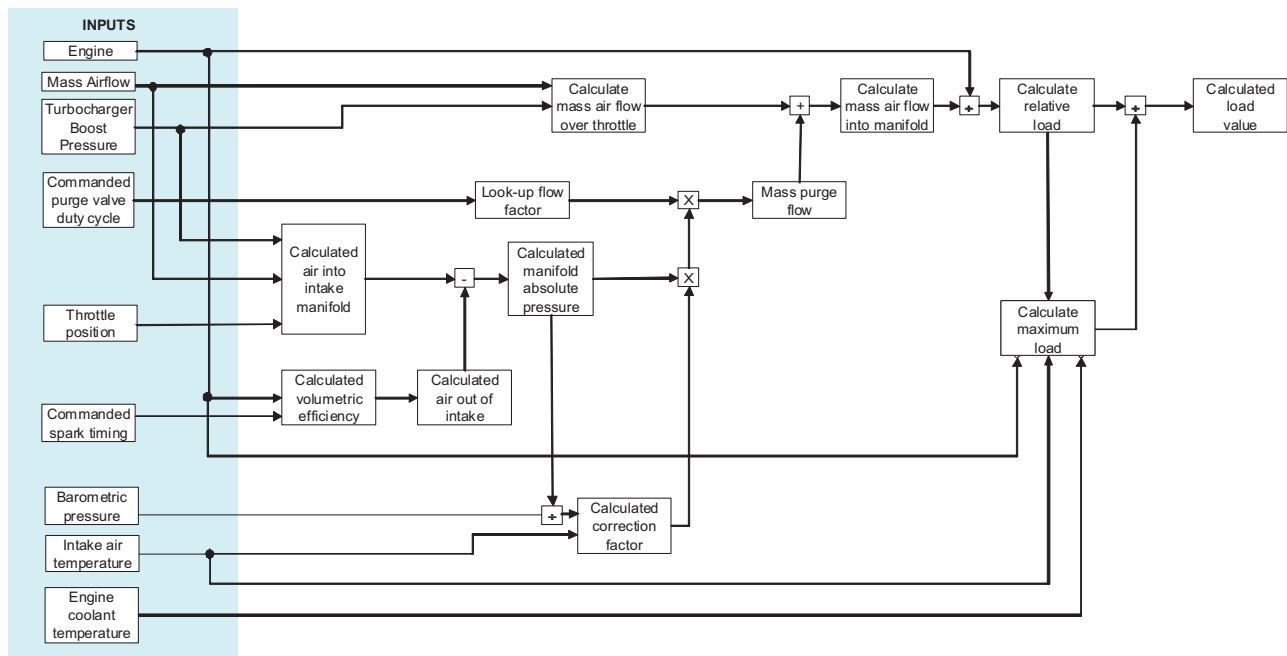


Figure 120: Block Diagram: Calculated Load Value: Spark Ignition, Mass Airflow Sensor, Turbocharged.

