Bosch Motronic ME9 OBD System Strategy

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.01.00.00 Catalyst Monitoring

There are two diagnostic functions which are used for monitoring of the catalyst efficiency. Both are based on measure of the Oxygen within the catalyst determined by at least two Oxygen sensors. Each of the functions can be correlated between Oxygen / Hydrocarbon and Oxygen/ Oxides of Nitrogen.

.01.01.00 Passive measurement of amplitude ratio

.01.01.01 General description

The method compares the signal amplitudes obtained from the downstream sensor to the modelled signal amplitudes. The modelled signal amplitudes are derived from a borderline catalyst. The data for borderline catalysts are taken from measurement results on real life deteriorated catalysts. In case the measured amplitudes exceed those of the model, the catalyst is considered defective. This information is evaluated within one single engine load and speed range (detection over full range of engine load versus speed).

According to the described operating principle the following main parts can be distinguished:

- **Computation of the amplitude of the downstream oxygen sensor:**
  The amplitude of the signal oscillations of oxygen sensor downstream catalyst is calculated. This is accomplished by extracting the oscillating signal component, computing the absolute value and averaging over time.

- **Modelling of a borderline catalyst and of the signal amplitudes of the downstream oxygen sensor:**
  The model is simulating the oxygen storage capability of a borderline catalyst. The signal of the downstream oxygen sensor is simulated in the catalyst model based on real time engine operating data (e.g. A/F ratio and engine load). The amplitude of the modelled signal oscillations is calculated.

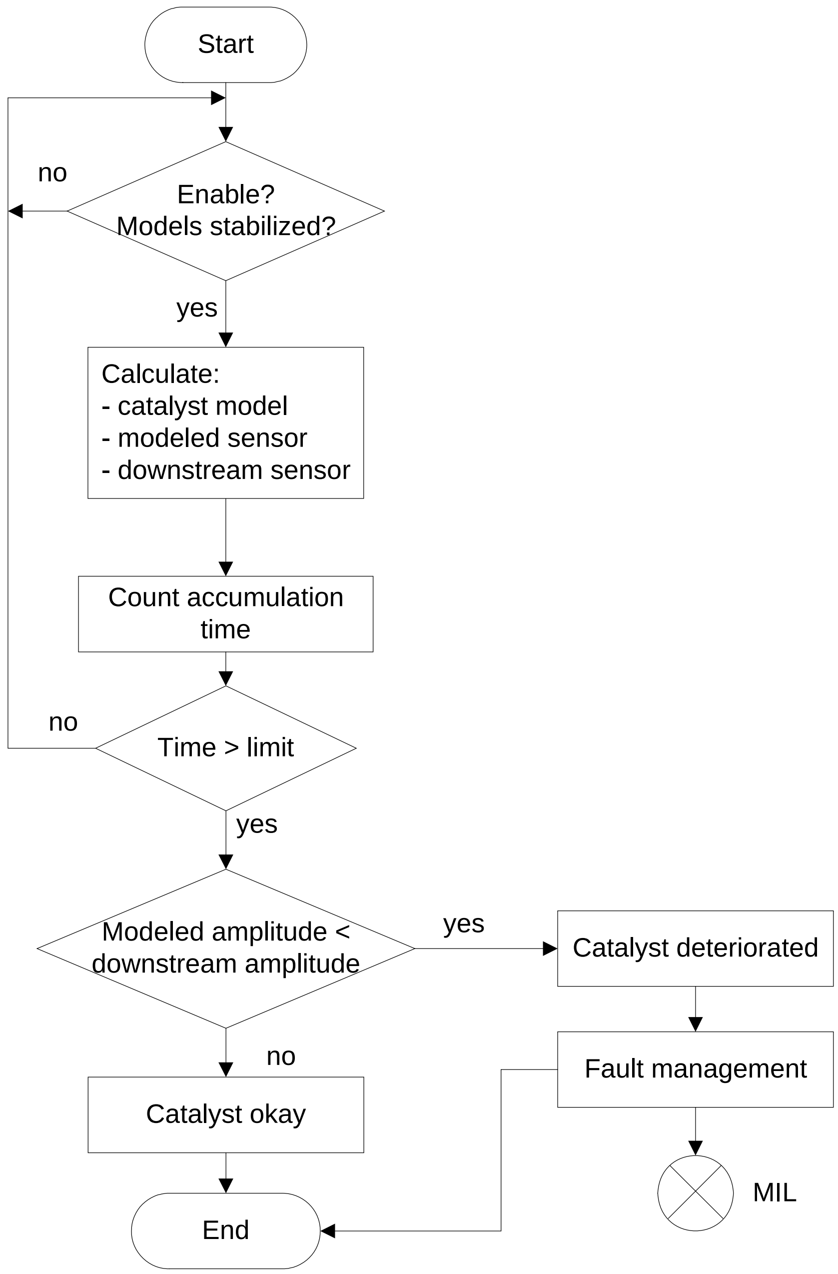
- **Signal and fault evaluation**
  The signal amplitudes of the downstream oxygen sensor are compared with the model for a given time. In case of the signal amplitudes of the downstream sensor exceed the modelled amplitudes, the oxygen storage capability of the catalyst falls short of the borderline catalyst model.

- **Check of monitoring conditions**
  It is necessary to check the driving conditions for exceptions where no regular Lambda control is possible, e.g. fuel cut-off. During these exceptions, and for a certain time afterwards, the computation of the amplitude values and the post processing is halted. Thus, a distortion of the monitoring information is avoided.

.01.01.02 Monitoring Structure

The catalyst temperature (model) activates the catalyst monitoring function if the catalyst temperature is above a predetermined value.

.01.01.03 Flow Chart Catalyst Monitoring



.01.02.00 Active measurement of OSC

.01.02.01 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:

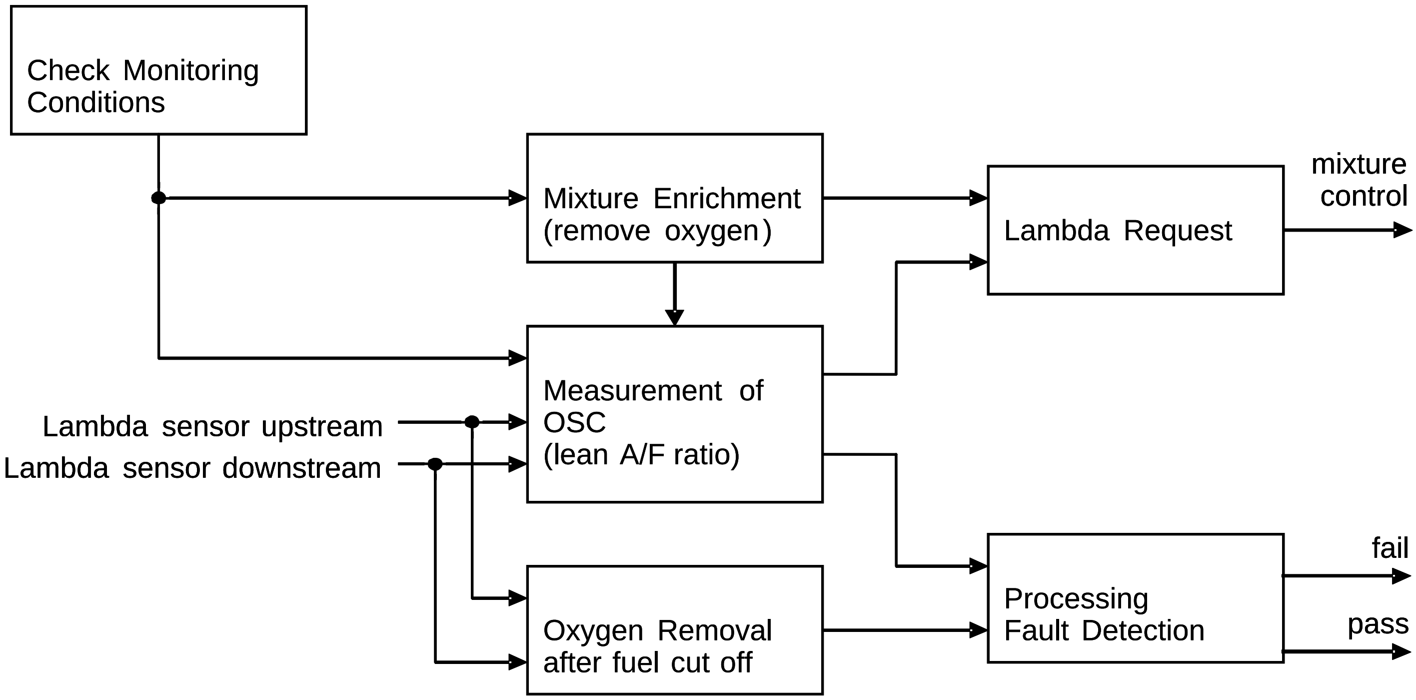
$$OSC = \int \text{air mass flow} * \text{lean mixture } (\lambda-1) * dt$$

- 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.

.01.02.02 Monitoring Structure

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



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 this measuring procedure can be applied to different portions. The different alternatives are shown in the table below.

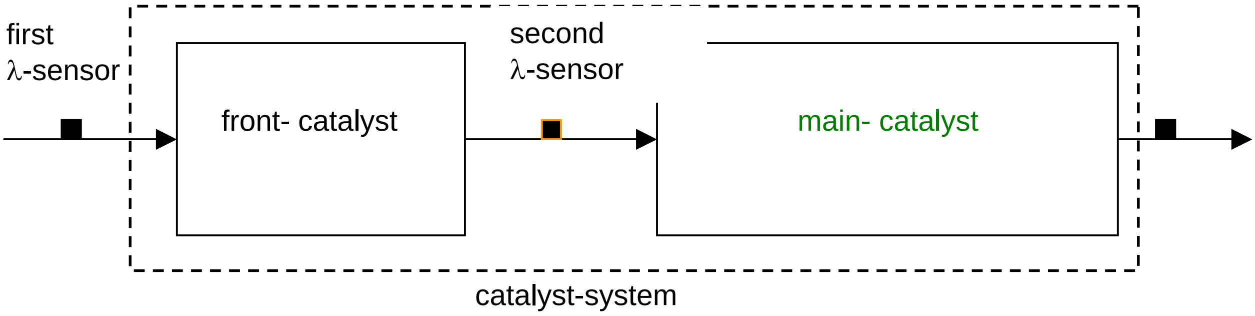


Table 1: Necessary conditions to check the different catalyst volume

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

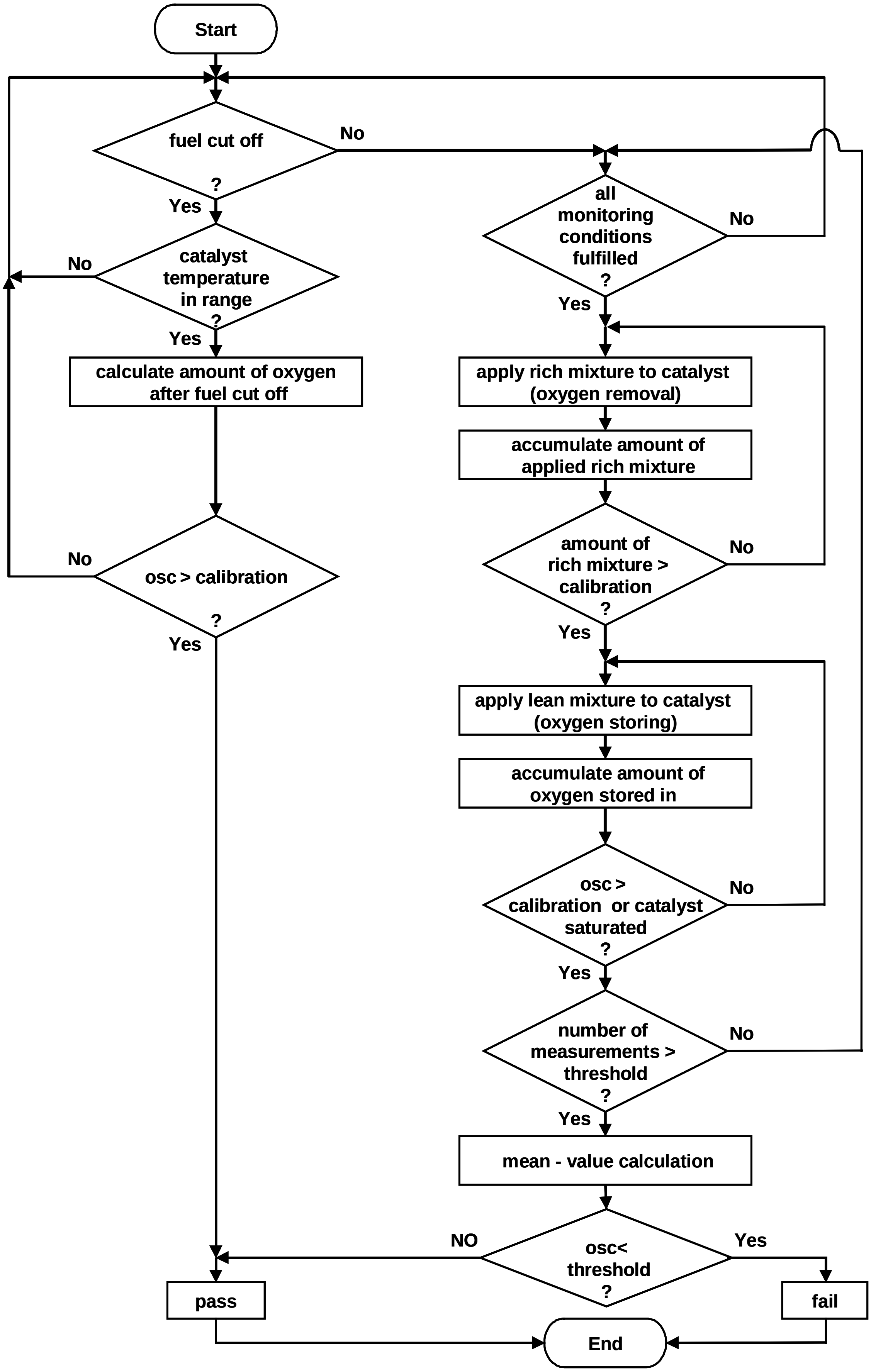
If the secondary parameters for the different catalyst portions are met at the same time, the diagnostic functions can run simultaneously.

According to table 1 the following result combinations are described in table 2.

Table 2: Results which can be obtained after the diagnosis of the different catalyst volumes

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

.01.02.03 Flow Chart Catalyst Monitoring



.02.00.00 Heated Catalyst Monitoring

Not applicable

.03.00.00 Misfire Monitoring

.03.00.01 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

.03.01.02 Monitoring function description

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.

Detecting 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).

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.

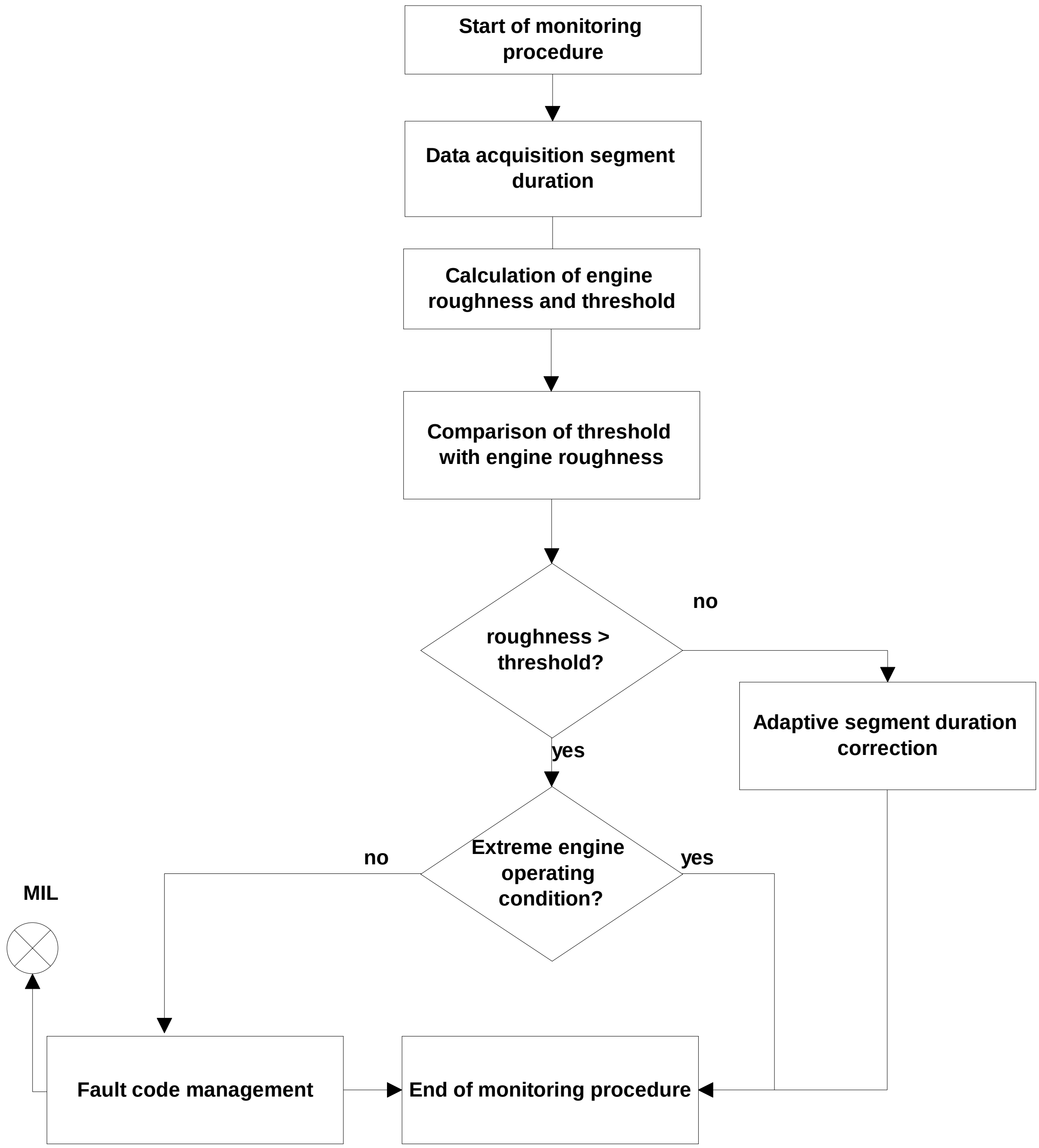
Statistics, Fault processing:
Within an interval of 1,000 crankshaft revolutions, the detected number of misfiring events is totalled for each cylinder. If the sum of cylinder fault counters exceeds a predetermined value, a fault code for emission relevant misfiring is preliminary stored after completion 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 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.

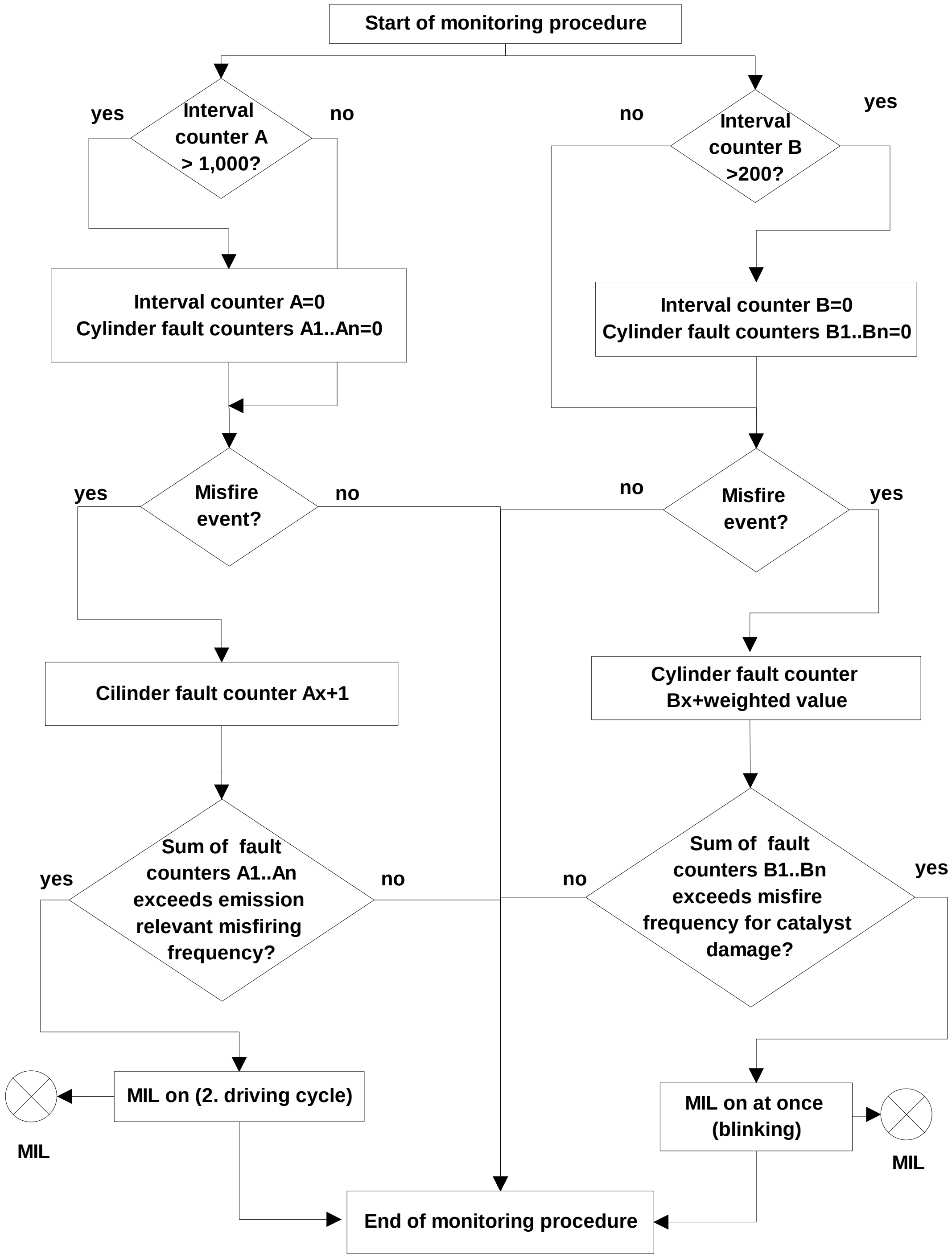
In the case of catalyst related misfire, the Lambda closed loop system is switched to open-loop condition according to the basic air/fuel ratio calculation (Lambda=1).

All misfire counters are reset after each interval.

.03.00.03 Chart(s) and Flow Chart(s)



Paths for misfire and catalyst damaging misfire rate



.04.00.00 Evaporative System Diagnosis

.04.01.00 Leakage Check

.04.01.01 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.

.04.01.02 Monitoring function description

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

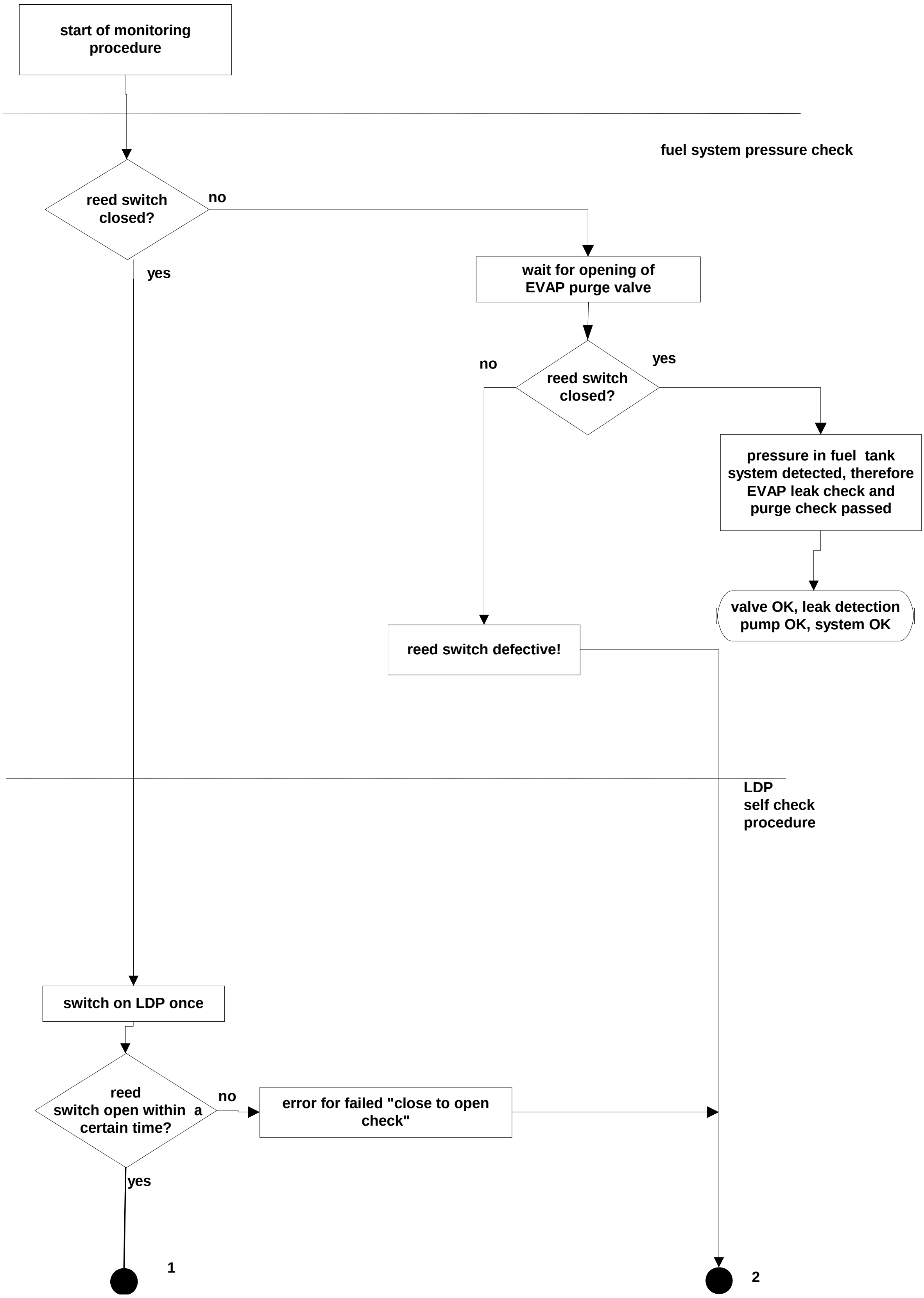
Fast pulse

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.

.04.01.03 Chart(s) and flow chart(s)



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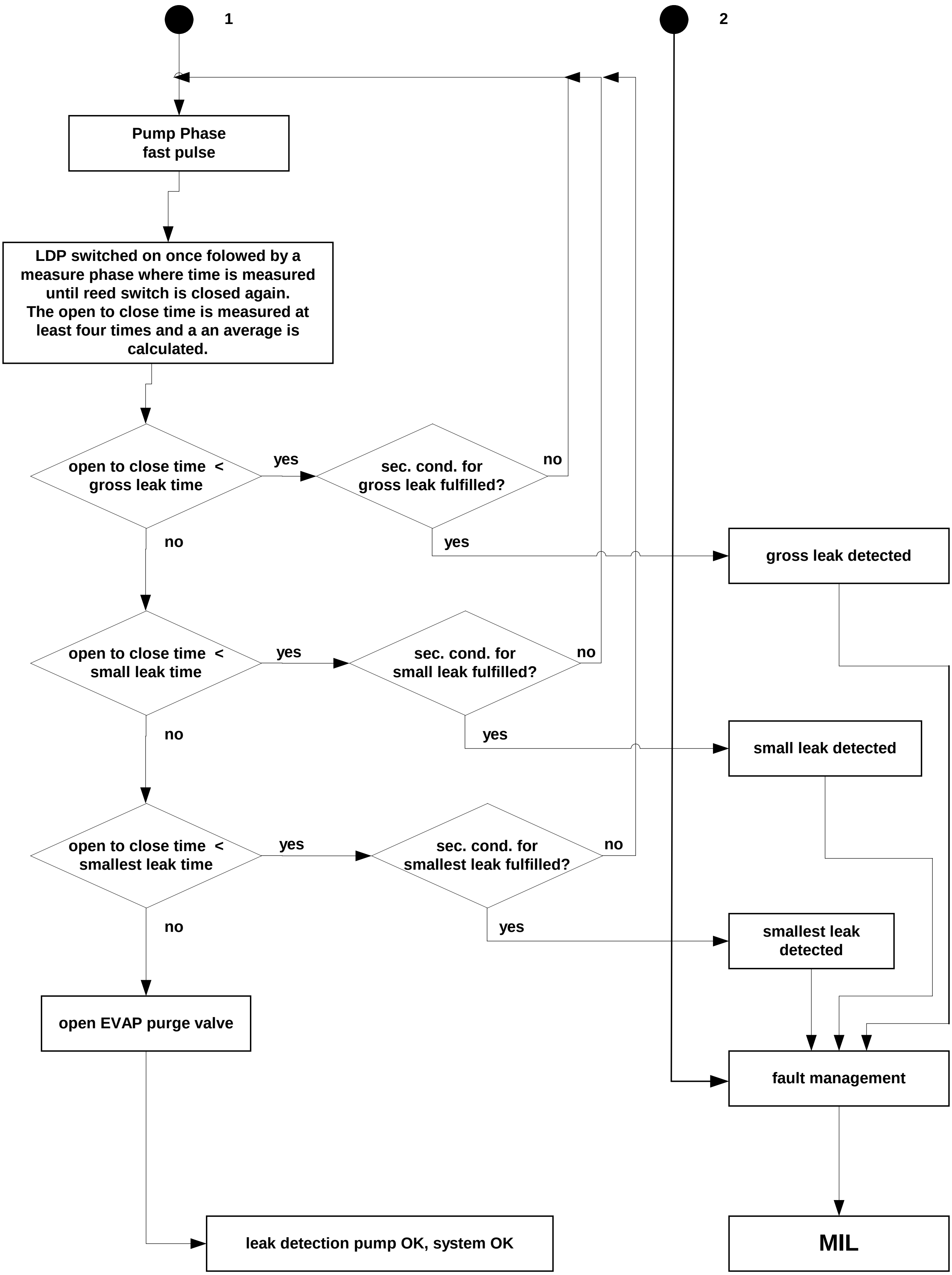


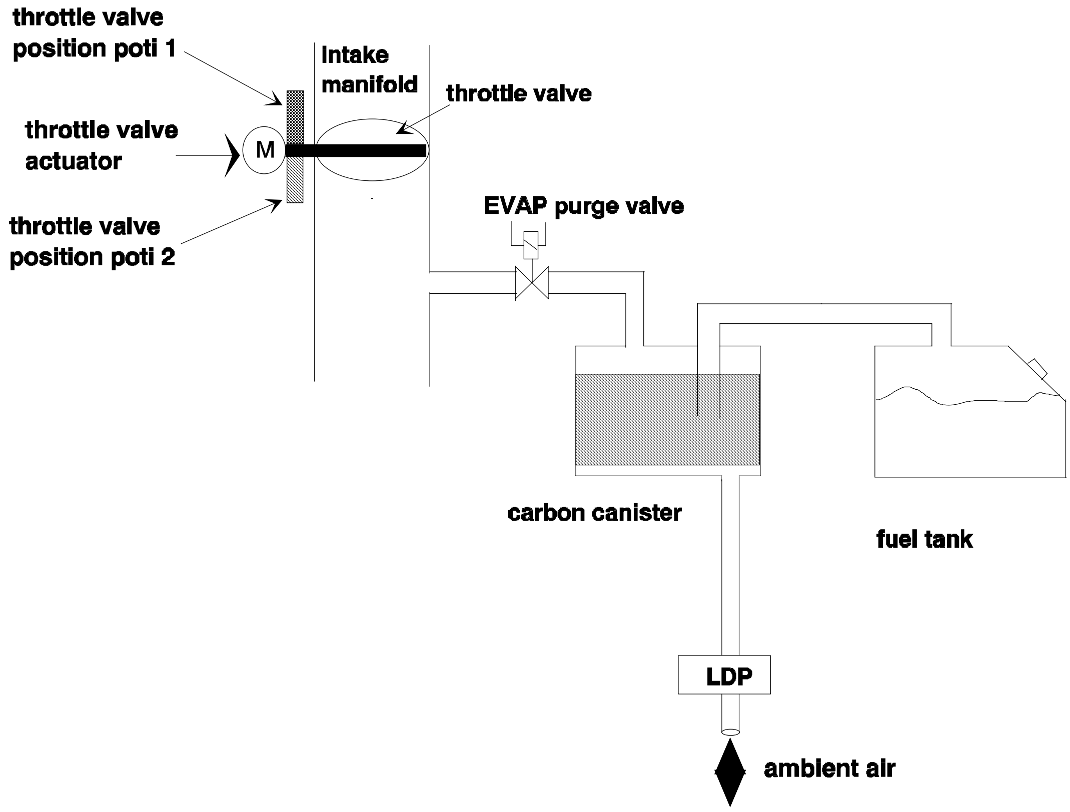
.04.02.00 Purge Check

.04.02.01 General description

The purge flow through the EVAP Purge Valve 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.

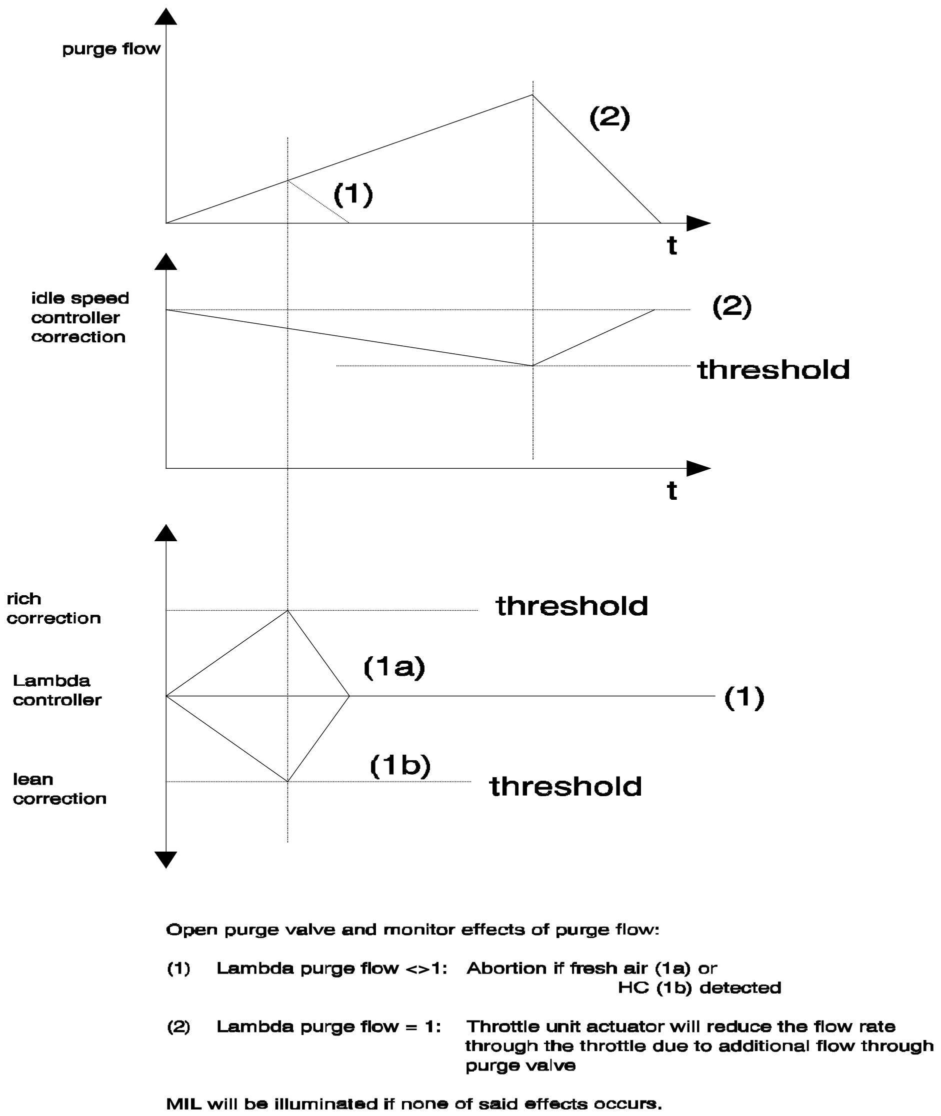


.04.02,02 Monitoring function description

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.

.04.02.03 Chart(s) and flow chart(s)



.05.00.00 Secondary Air System Monitoring

not applicable.

.06.00.00 Fuel System Monitoring

.06.01.00 General Description

Fuel Injection System

In comparison to conventional systems the gasoline is not injected into the intake manifold but directly into the combustion chamber.
Due to the higher pressure level in the combustion chamber, e.g. during the compression stroke, a high pressure fuel injection system is used.

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

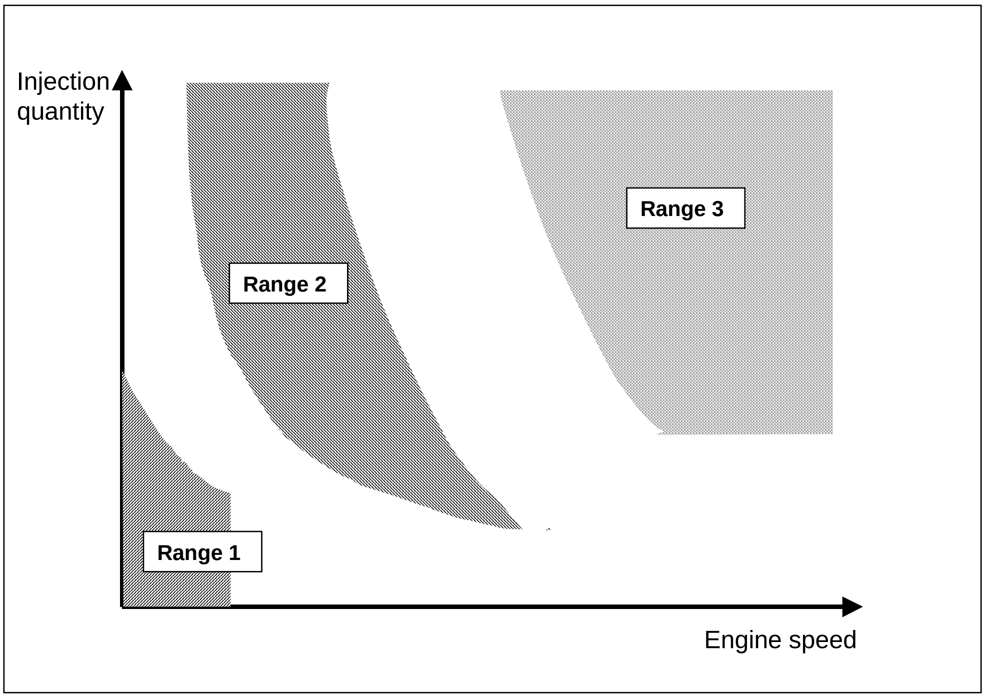
Lambda-controller
The ECM compares the Oxygen sensor signal upstream the catalyst with a reference value and calculates a correction factor for the pilot control.

.06.00.02 Monitoring function description

Adaptive pilot control
Drifts and faults in sensors and actuators of the fuel delivery system as well as unmeasured air leakage influences the pilot control. The controller corrects amplitudes increases. If there are 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.

Fuel trim
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.

.06.00.03 Chart(s) and flow chart(s)



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.

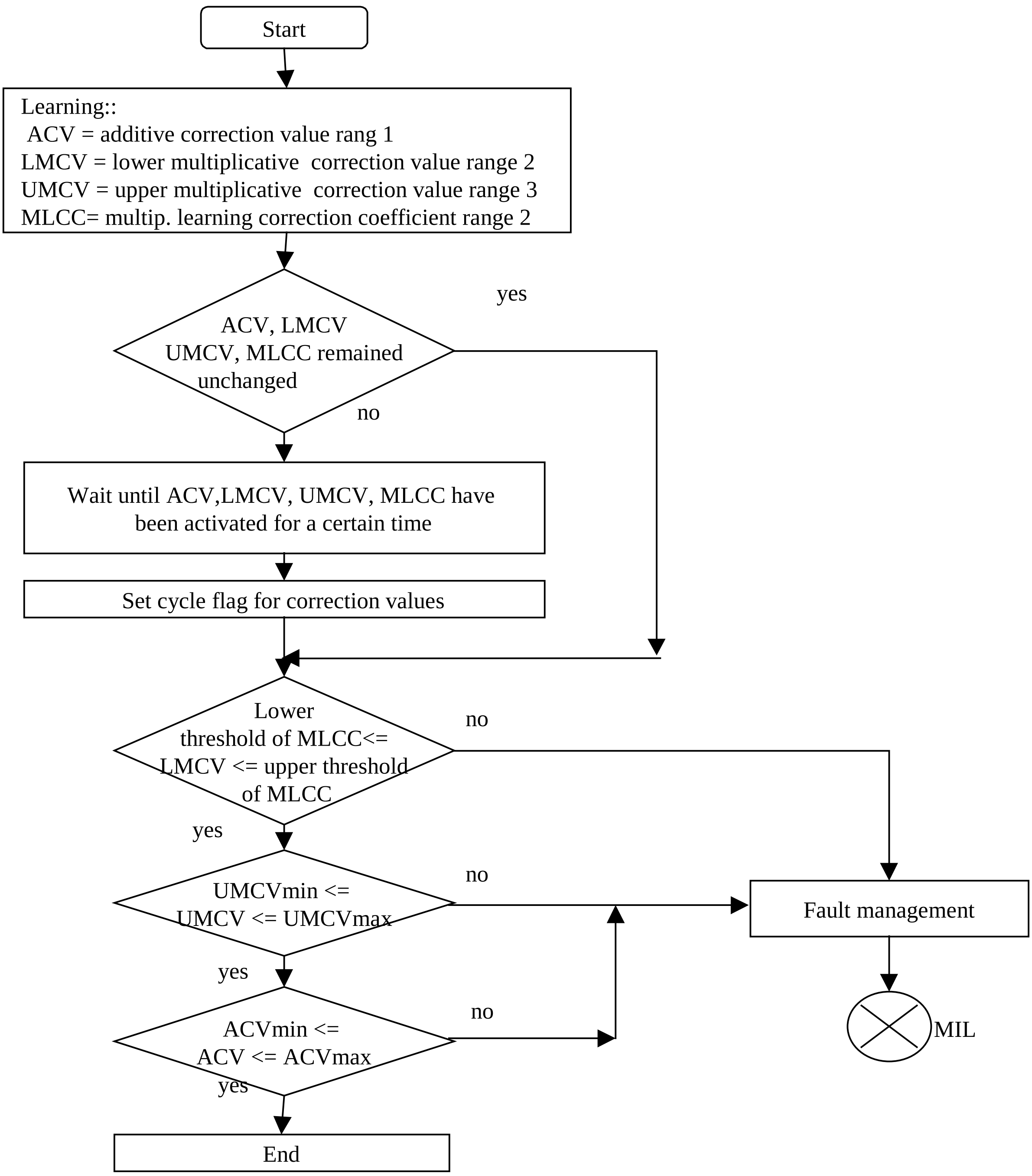
Each value is adapted in its corresponding range only. But each adaptive value corrects the pilot control within the whole load/speed range by using a linear interpolation formula. The stored adaptive values are included in the calculation of the pilot control just before the closed loop control is active.

<u>Diagnosis of the fuel delivery system</u>

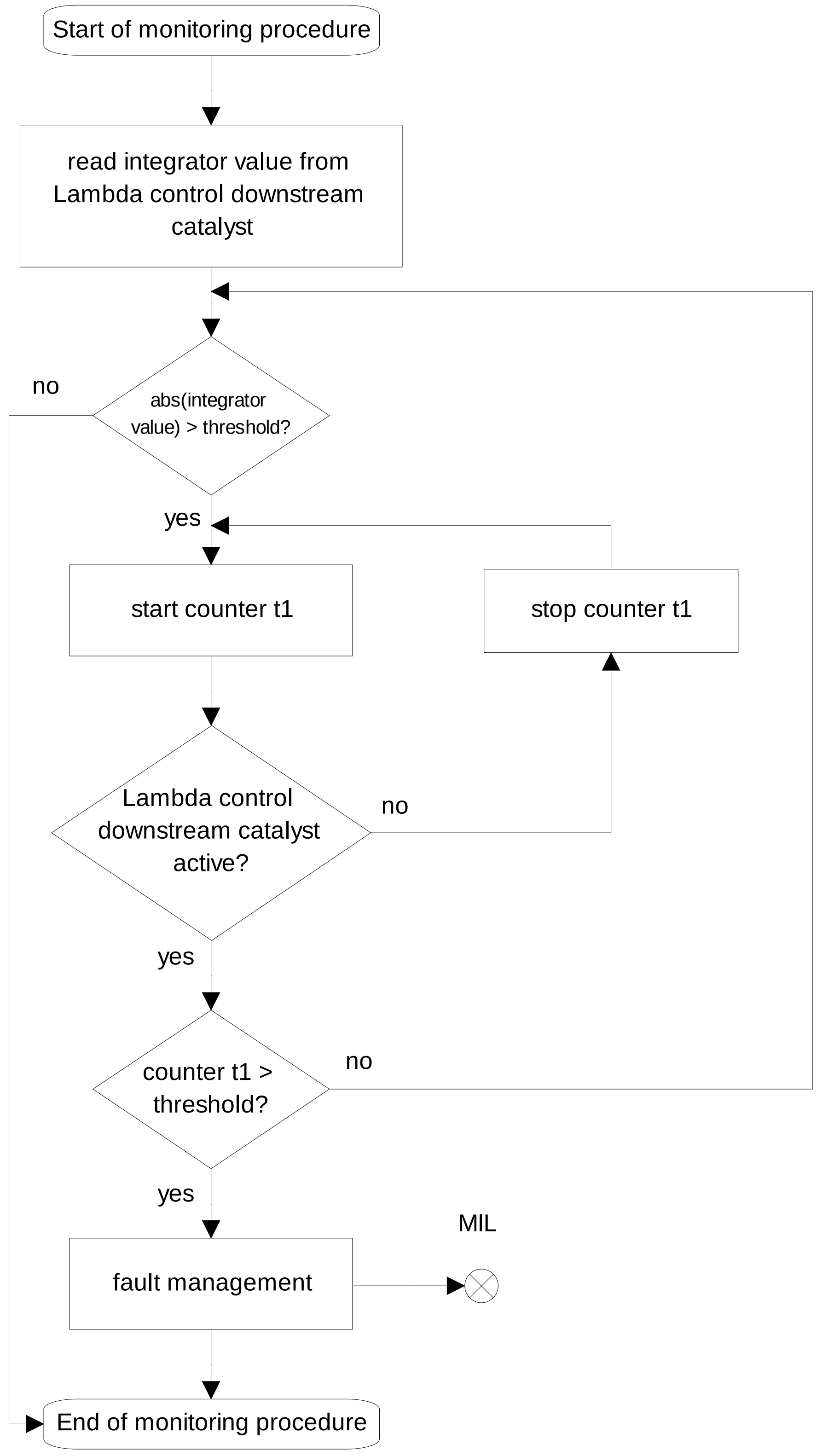
Faults in the fuel delivery system can occur which cannot be compensated for by the adaptive pilot control.

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.

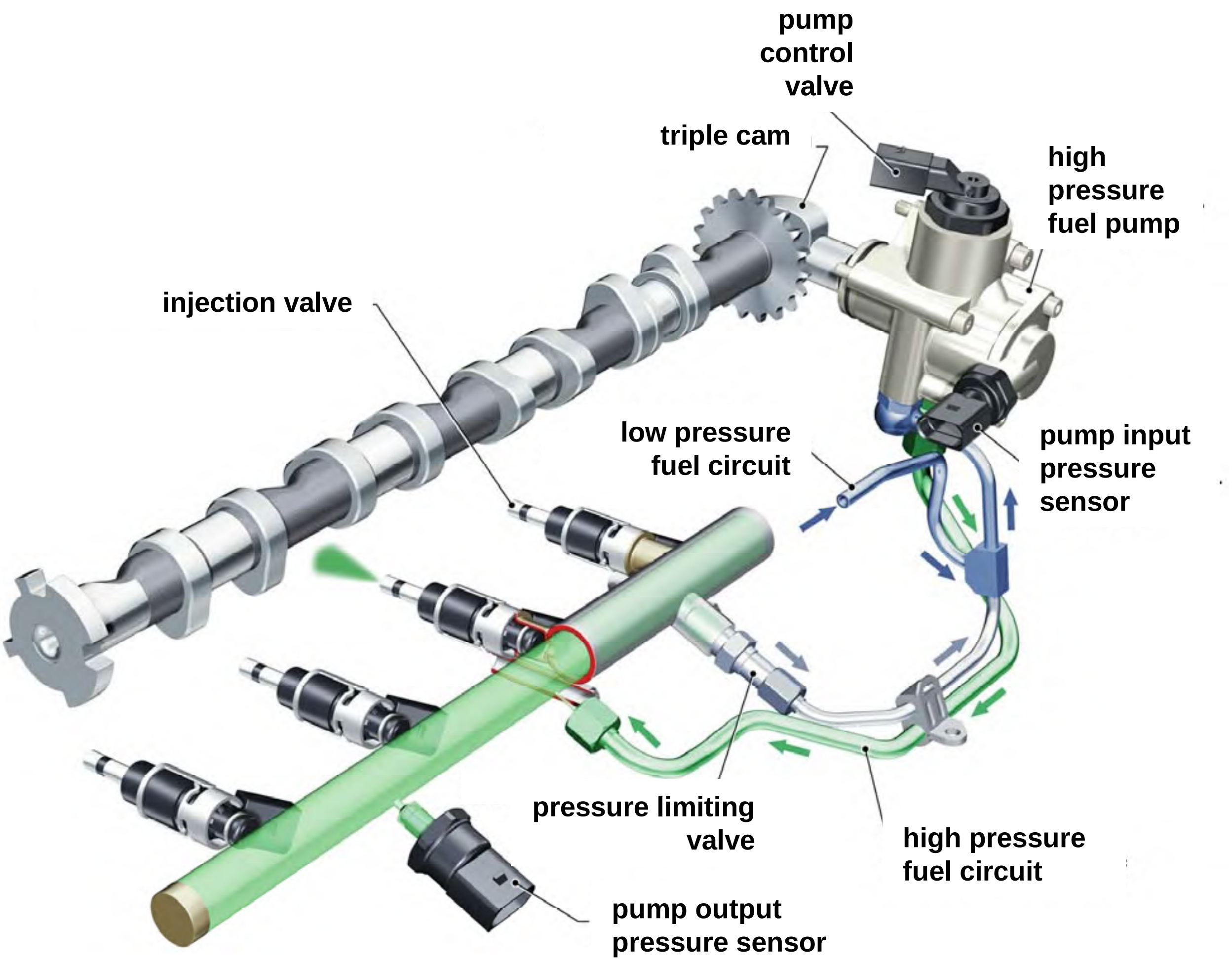

Start
Learning::
ACV = additive correction value rang 1
LMCV = lower multiplicative correction value range 2
UMCV = upper multiplicative correction value range 3
MLCC= multip. learning correction coefficient range 2
ACV, LMCV
UMCV, MLCC remained
unchanged
yes
no
Wait until ACV,LMCV, UMCV, MLCC have
been activated for a certain time
Set cycle flag for correction values
Lower
threshold of MLCC<=
LMCV <= upper threshold
of MLCC
no
yes
UMCVmin <=
UMCV <= UMCVmax
no
yes
Fault management
ACVmin <=
ACV <= ACVmax
no
yes
MIL
End

Flow chart: Fuel trim



.06.04.00 Fuel Pressure Monitoring

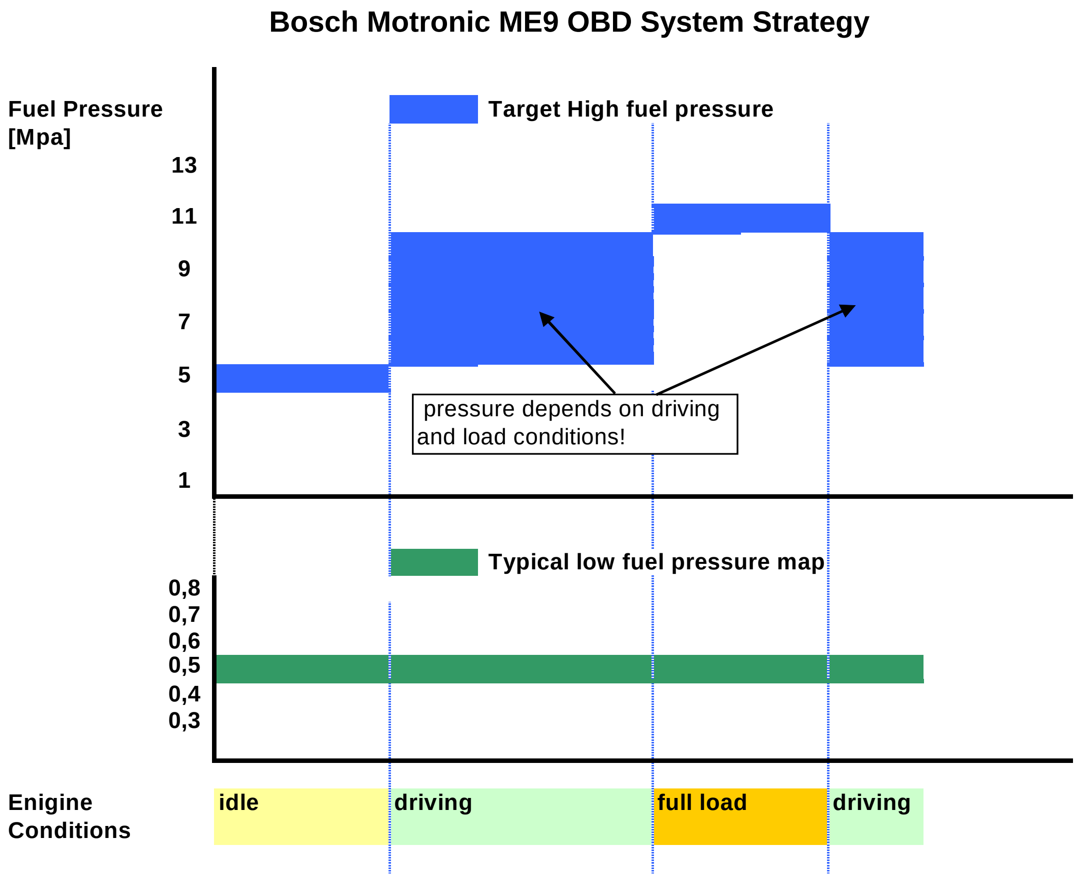
.06.05.00 General Description



(Example only)

Low fuel pressure system:
The low pressure system is the fuel delivery system to the high pressure system. In order to keep the delivery pressure in a certain range the fuel pressure is controlled via fuel pressure sensor. This low pressure system has no direct impact on Air/Fuel mixture and emissions.

High fuel pressure system:
The electrical controlled, mechanical-driven high pressure fuel pump provides the injection pressure. The fuel sensors and the control valve in the high pressure system controlled the high pressure between approximately 3 and 12 MPa. The target pressure depends mainly on engine speed and torque request.



.06.05.00 Monitoring function description

Technical Description of Pinpoint-Strategy for the High-pressure Fuel Injection System

A) Strategy description

The pinpointing-strategy is based on the fact that incorrect pressure information will cause Lambda deviations due to the pressure based calculation of the injection time.
Incorrect pressure information can only be caused by positive or negative offset-faults of the high pressure sensor.
However faults of the pump control valve also influence the pressure control activity but they will be normally completely corrected (Lambda deviation ~0) through the calculation of the corresponding injection time.

Through combination and evaluation of the following characteristics therefore a differentiation of faults and drifts between sensor and actuator is possible:
pressure deviation
pressure control activity
fuel trim activity

Pinpointing schematic

	Pressure deviation (p_set – p_cur)	Pressure control activity	Fuel trim activity	P-Code
Positive offset - high pressure sensor	~ 0 or < 0	< - threshold	> threshold	P12A2
Negative offset - high pressure sensor	~ 0 or > 0	> + threshold	< threshold	P12A1
Stuck closed - pump control valve	~ 0 or **<** 0	< - threshold	~ 1	P12A4
Stuck open - pump control valve	> 0	> + threshold	~ 1 or > threshold*	P0087
High pressure limiting valve opens at lower pressure	> 0	> + threshold	~ 1 or > threshold*	D

*: due to limitation of the injection time

B) Definitions

Pressure deviation
Remaining difference between actual rail-pressure and nominal rail-pressure (basically calculated on engine speed and torque request)

Pressure control activity
Total pressure control output consisting of proportional value, integral value and adaptation value. The total pressure control output influences the pilot control of the high pressure control valve in order to adjust the nominal pressure value.

Fuel trim activity
Correction factor of the Lambda-controller including the additive and multiplicative correction values of the fuel trim.

C) Basic requirements of the diagnostic routine:
pressure control unit active
fuel trim control unit active
no fault of the front and rear O2 sensors
no engine warm-up actions

.07.00.00 Oxygen Sensor Monitoring

.07.01.00 Calibrations with ASIC CJ 110

.07.01.01 General Description

The Lambda control consists of a linear Oxygen sensor upstream catalyst and a 2 point oxygen sensor downstream catalyst.

.07.01.02 Monitoring function description

The sensors are monitored by several single monitoring procedures under the following basic conditions.

- engine operates in a specific range of speed/load map and
- modelled catalyst temperature is above a specific value

The following checks will be performed on the linear oxygen sensor upstream catalyst:

Heater Coupling Check (P0130)
This monitoring will detect any short circuits between sensor heater and the Nernst cell of the Oxygen sensor by monitor the Lambda signal. The amplitude signal of Lambda is untypical and changed in the same velocity than heater duty cycle.

Response Check (P0133)
Any change in the dynamic behaviour of the Oxygen sensor due to ageing, heater fault or contamination will be detected by check of actual amplitude ratio check with stored values.

Signal activity and rationality checks (P0130)
The Lambda value of oxygen sensor upstream catalyst is compared to the sensor voltage downstream catalyst. Additionally, a check is performed by checking the sensor voltage range. Three diagnostics paths cover the air fuel ratio range of Lambda value (e.g. Lambda=1, lean, rich). A corresponding reaction of sensor voltage downstream catalyst is expected. (see chart)

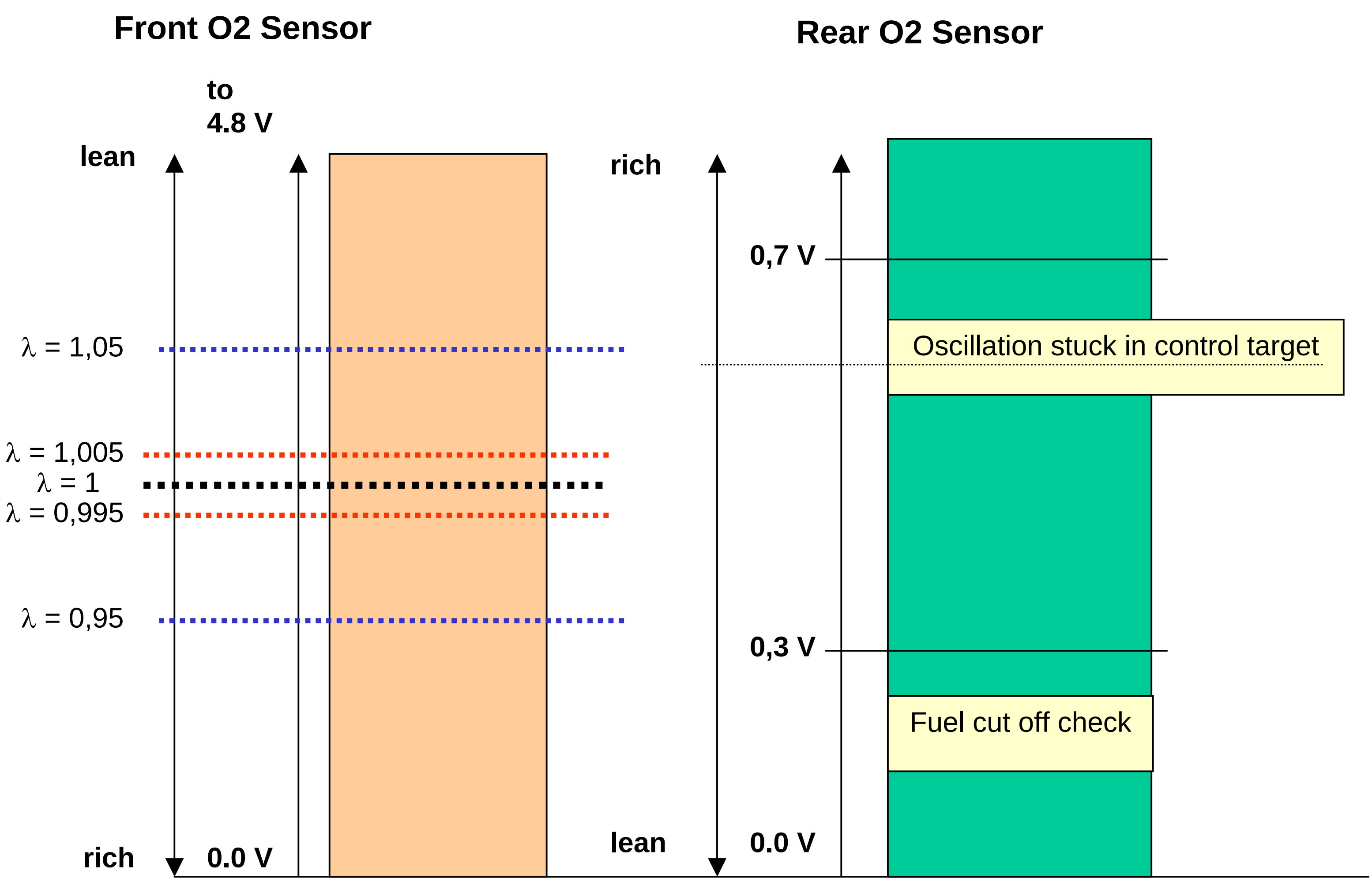
The following checks will be performed on the oxygen sensor downstream catalyst:

Oscillation Check (P0139)
The function checks whether the sensor output voltage of oxygen sensor downstream catalyst always remains above or below a specified threshold.

Fuel cut off Check (P0139)
During coasting, the ECM is monitoring the downstream sensor voltage which has to go under a specific lean threshold.

Output voltage (P0137), Short to battery (P0138) and signal activity check (P0140)
In case the rear O2 sensor readiness is given an certain sensor signal is expected. If The sensor is bellow or above some signal thresholds, a fault will be stored.

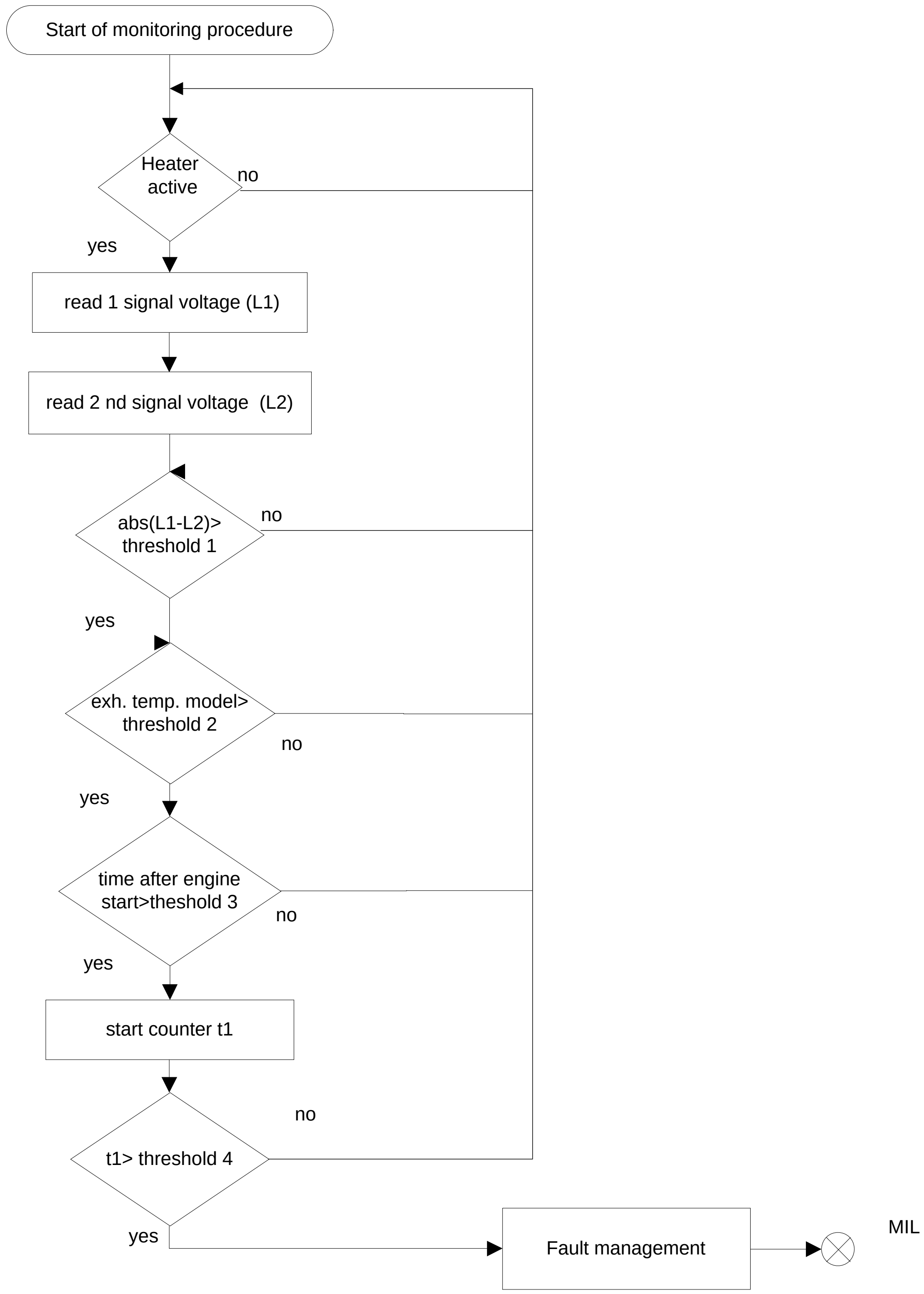
.07.01.03 Chart(s) and flow chart(s)



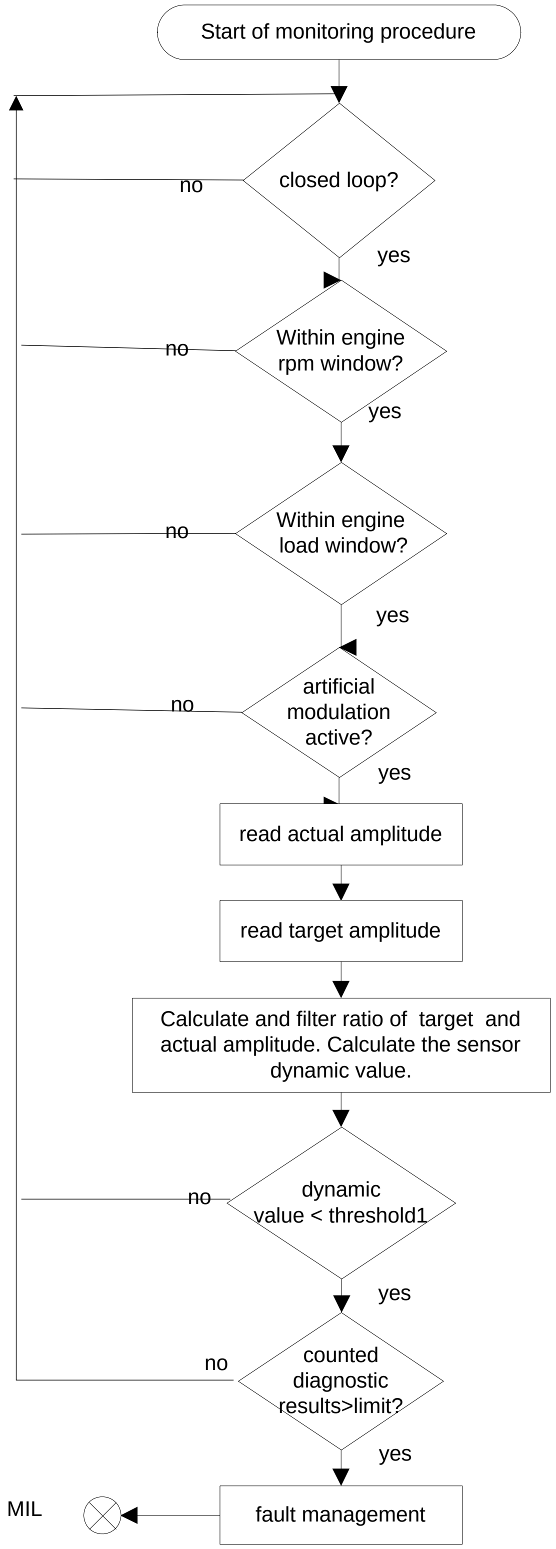
Based on the sensor comparison malfunction will be detected if:

- front sensor near lambda = 1 and rear sensor shows >0.7V or < 0,3 V
- front sensor lean (lambda > 1.05) and rear sensor rich (>0.7V)
- front sensor rich (lambda > 1.05) and rear sensor lean (<0.3V)
- rear sensor is not oscillation at reference point (e.g.0.6V)
- during fuel cut off rear sensor signal goes not under threshold (e.g. 0.2V)

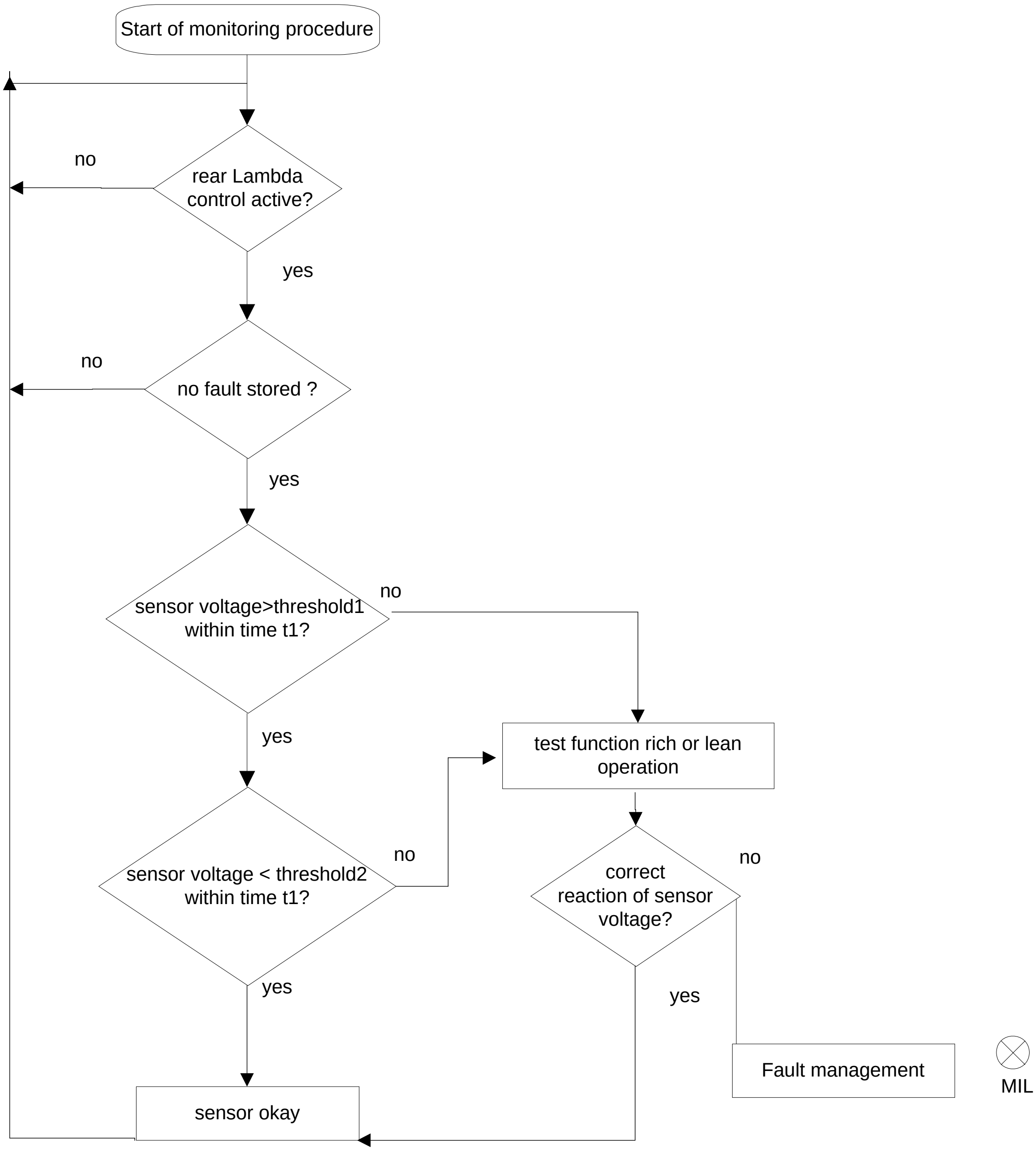
Front O2 Sensor Heater Coupling Monitoring	
DTC's	P0130
Threshold 1	Malfunction signal change / msec; typical value: 2 (V/ms)
Threshold 2 / 3	typical value: 200 °C / 25sec
Threshold 4	Monitor time length: 30 amplitudes



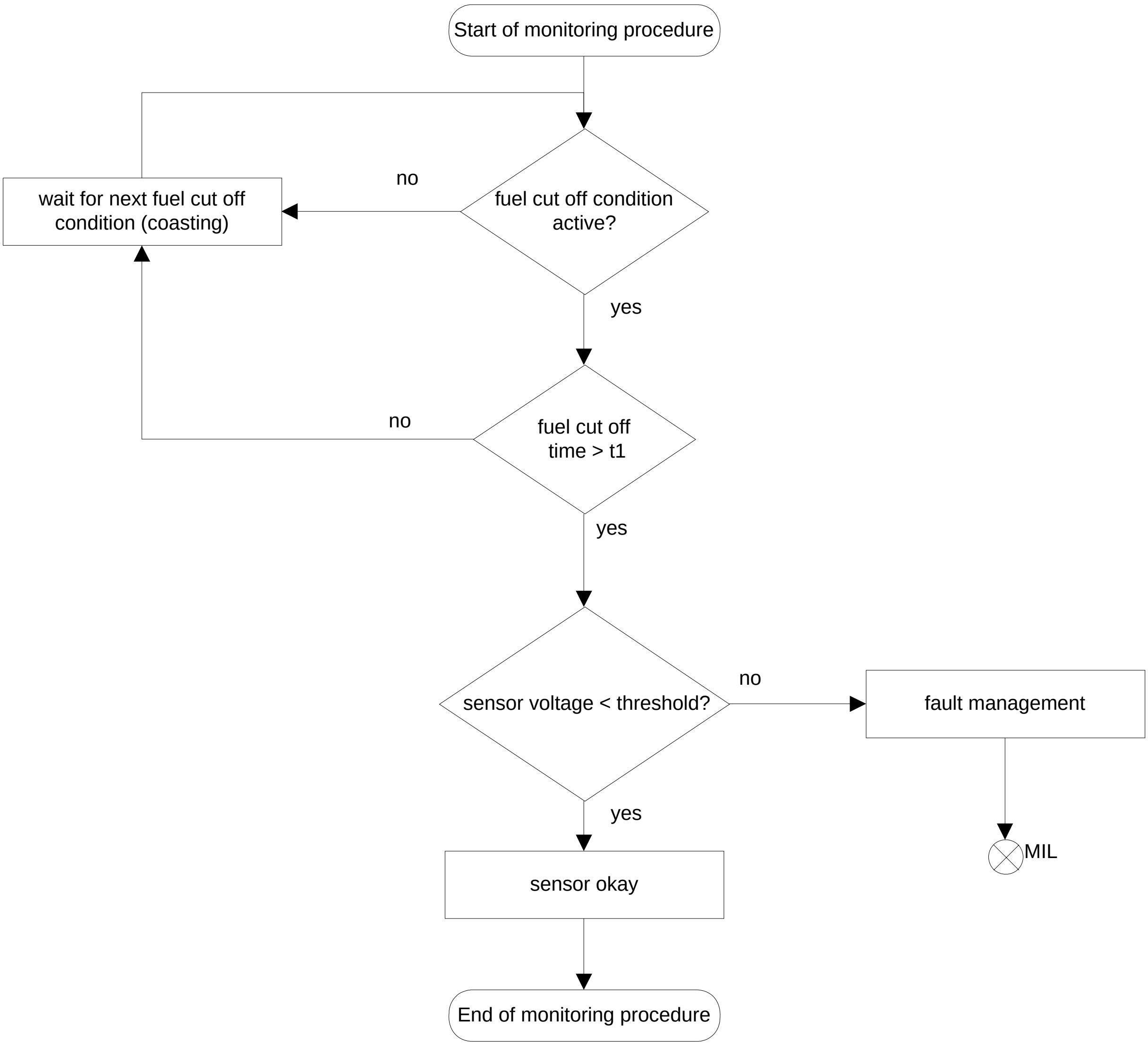
Front O2 Sensor Response Check	
DTC's	P0133
Threshold 1	Malfunction criteria
Limit	Monitor time length 30 amplitudes



Rear O2 Sensor Oscillation check	
DTC's	P0139
Threshold 1 and 2	Malfunction Criteria; typical values: 0.58 .. 0.6V
Limit	Monitor time length 30 amplitudes



Rear O2 Sensor Fuel Cut Off Check	
DTC’s	P0139
Time t1	Duration of fuel cut off phase; Typical value 5s
Threshold	Malfunction criteria; typical value: < 0.2V



.07.02.00 Oxygen Sensor Heater Monitoring

.07.03.01 General description (ASIC CJ 110)

For proper function of the Lambda sensor, the sensor element must be heated.

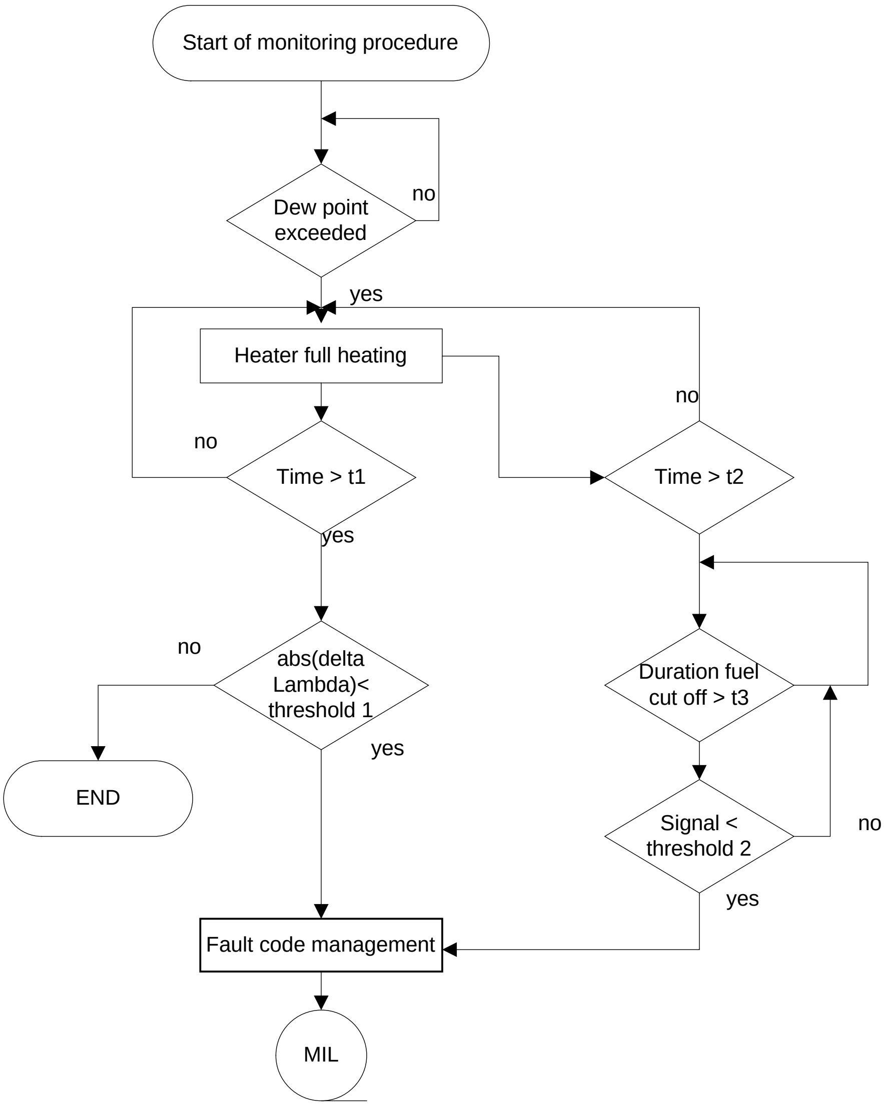
.07.02.02 Monitor function description

Linear Oxygen sensor upstream catalyst Any fault in regard to sensor heater will either result in a lost or in a delay of sensor readiness. The diagnosis measures the time between the heater is switched on and the oxygen sensor readiness. The sensor readiness is indicated by a corresponding sensor voltage variation.

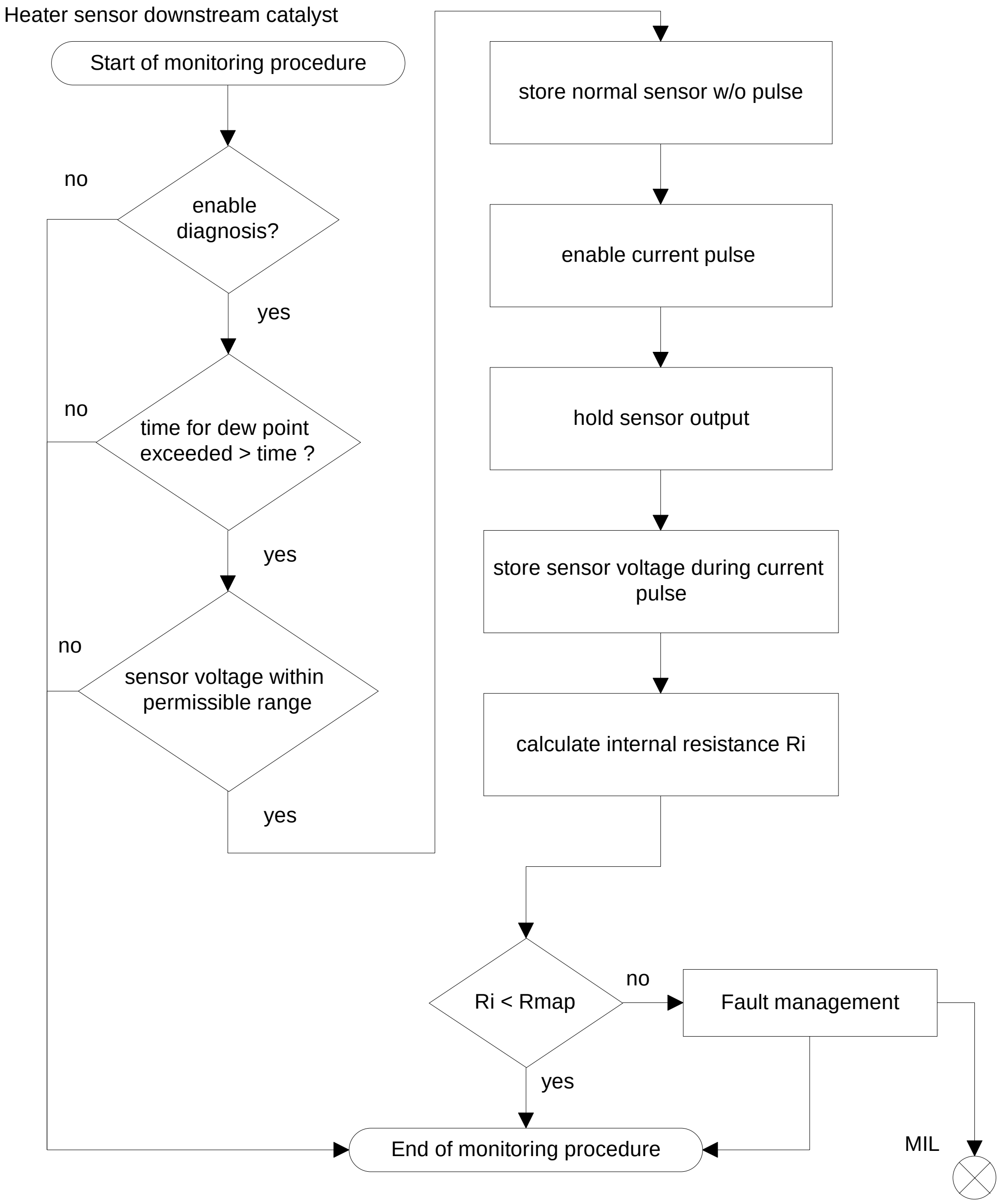
Oxygen sensor downstream catalyst (2 point sensor)
For diagnostic of the sensor heater a specific current pulse is supplied via a load resistance and the voltage is measured. The intern resistance of the sensor heater is calculated with the voltage deviation. The result will be compared with a reference map resistance which considers ageing and sampling deviations. In case of internal resistance > map resistance the diagnosis stores a fault and the MIL will be illuminated.

07.02.03 Chart(s) and Flow Chart(s)

Oxygen Sensor Heater Upstream Catalyst	
DTC's	P0135
Time t1 / t2	Duration full heating ; typical value 25s / 70s
Time t3	Duration fuel cut off ; typical value 3 s
Threshold 1	Malfunction criteria; delta lambda
Threshold 2	Malfunction criteria; sensor voltage



Oxygen Sensor Heater downstream Catalyst	
DTC's	P0141
Enable criteria	Modelled exhaust temperature, IAT
Ri < Rmap	Comparison of actual and calculated resistance



.07.03.00 Calibrations with ASIC CJ 125/120

.07.03.01 General Description

The Lambda control consists of a linear Oxygen sensor upstream catalyst and a 2 point oxygen sensor downstream catalyst.

.07.03.02 Monitor function description

The following checks will be performed on the linear oxygen sensor upstream catalyst:

Rationality Check
Any deviation from the characteristic curve of oxygen sensor upstream catalyst due to poison, ceramic cracks, characteristic shift down (CSD) or a leakage between both Oxygen sensors will be detected by the control loop downstream catalyst and by comparison of the sensor signals.
The integrator value of the second control loop detects small shifts of the sensor characteristic to lean or to rich. The signal comparison during steady state conditions quickly detects major deviations in sensor characteristics caused by serious faults (e.g. ceramic cracks).

For the fault decision the downstream Oxygen sensor has to be checked too (Oscillation and/or fuel cut-off check).

Heater Coupling Check
This monitoring function will detect any short circuits between sensor heater and the Nernst cell of the Oxygen sensor by watching the Lambda signal. The Lambda value variation is checked by the ECM. The heater is operated by a pulsating signal with a frequency of two Herz. The sensor signal characteristic is checked for noises with a significant level and a frequency of the heater operation. If the level of noises is greater than a threshold, a low resistance short-cut between heater and pump current or the current of the Nernst cell is detected.

Dynamic Check
Any change in the dynamic behaviour of the Oxygen sensor due to ageing, heater fault or contamination will be detected by check of actual amplitude ratio check with stored values.

Wire and IC-Check
The hardware of the Oxygen sensor consists of an IC (CJ 125) with the capability of self-diagnostics. The self-diagnostic functions of the IC detects communication faults between ECM and the sensor, insufficient voltage supply, shorts in the sensor lines to ground and to battery.
Open wire on the four sensor lines, adjustment line (IA), virtual mass line (VM), pump current line (IP) and Nernst voltage (UN) will be detected by a system plausibility check. The evaluations of the system plausibility is based on sensor voltage, internal resistance, target Lambda, actual Lambda and the reaction of the controller.

The following checks will be performed on the oxygen sensor downstream catalyst:

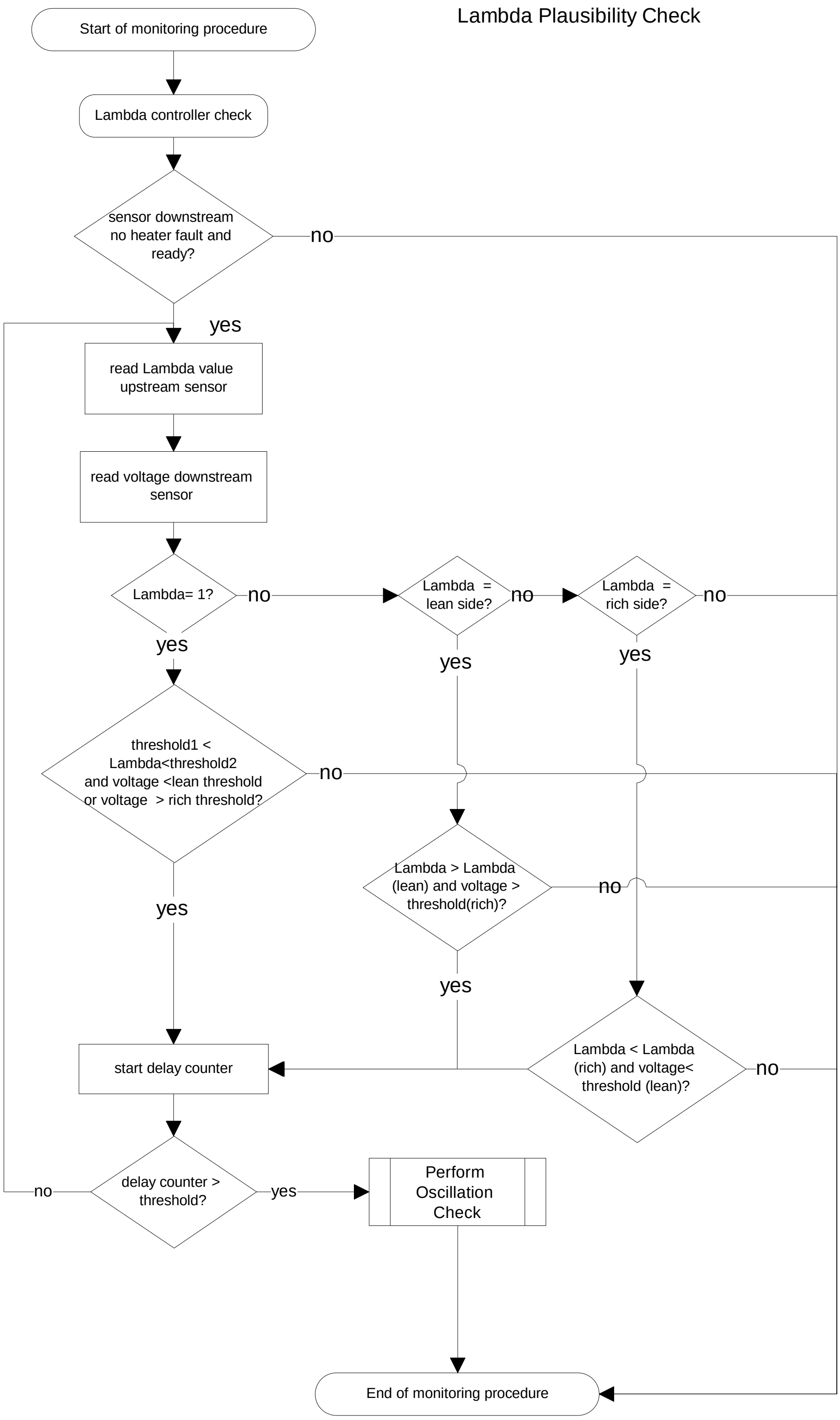
Oscillation Check
The function checks whether the sensor output voltage of the oxygen sensor downstream catalyst always remains above or below a specified threshold.

Fuel cut off Check
During coasting, the ECM is monitoring the downstream sensor voltage, which has to go below a specific lean threshold. The diagnostic is enabled if coasting was detected for a specific time.

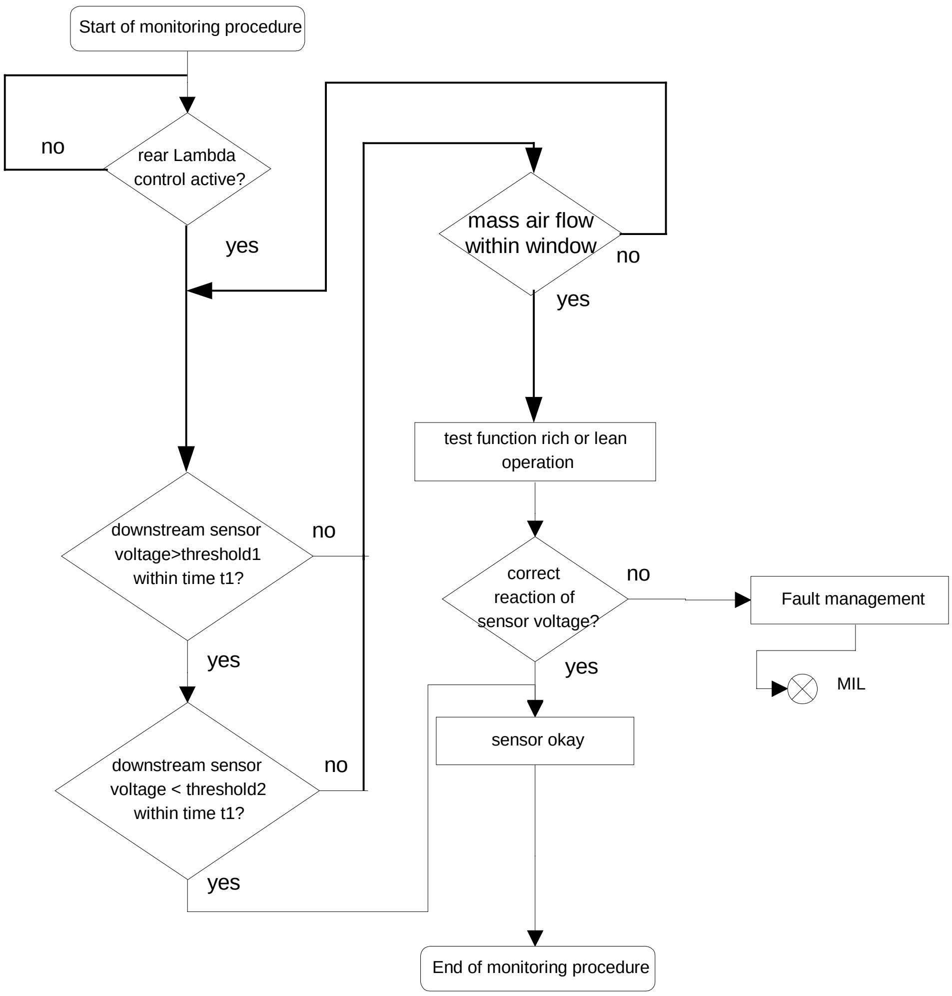
Signal check, Short to battery check and signal activity check
In case the rear O2 sensor readiness is given a certain signal voltage is expected. If the sensor is bellow or above some signal thresholds, a fault will be stored.

.07.03.03 Chart(s) and Flow Chart(s)

Flow chart: Rationality Monitoring (Oxygen Sensor Upstream Catalyst)



Flow chart: Oscillation Monitoring (Oxygen Sensor Downstream Catalyst)



Flow Chart: Fuel Cut-Off Monitoring (Oxygen Sensors Downstream Catalysts)

See other calibrations.

.07.04.00 Oxygen Sensor Heater Monitoring (ASIC CJ 125/120)

.07.04.01 General description

For proper function of the Oxygen sensors, the sensor element must be heated up. The heating up is controlled by the heater control.

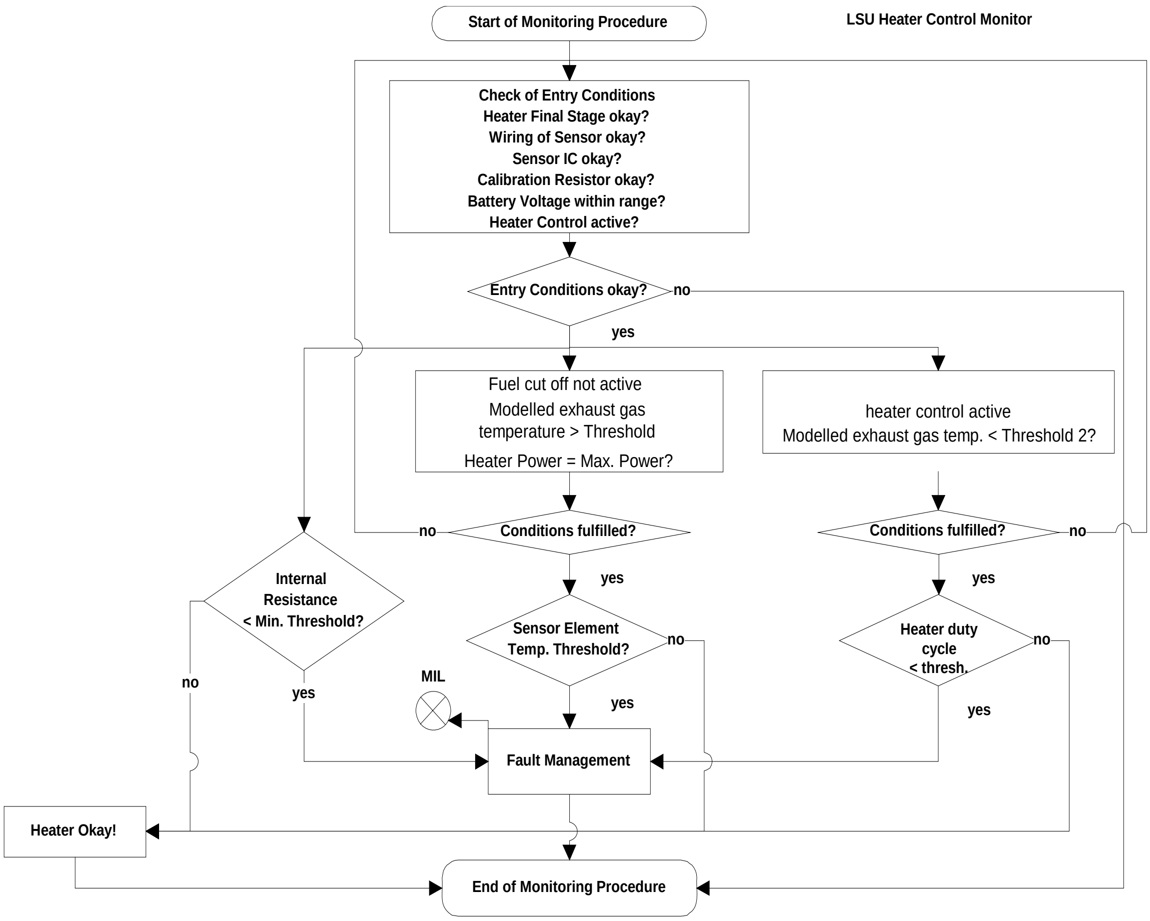
.07.04.02 Monitor function description

Linear Oxygen sensor upstream catalyst
Any fault in regard to sensor heater will either result in a lost or in a delay of sensor readiness.

Oxygen sensor downstream catalyst (2 point sensor)
For diagnostic of the sensor heater a specific current pulse is supplied via a load resistance and the voltage is measured. The intern resistance of the sensor heater is calculated with the voltage deviation. The result will be compared with a reference resistance map which considers ageing and sampling deviations. In case of internal resistance > map resistance the diagnosis stores a fault and the MIL will be illuminated.

.07.04.03 Chart(s) and Flow Chart(s)

Flow Chart: Oxygen Sensor Heater Control Upstream Catalyst



Flow Chart: Oxygen Sensors downstream catalyst

See other calibrations

.07.05.00 SULEV applications

.07.05.01 General description

The Lambda control consists of a linear Oxygen sensor (LSU) upstream catalyst and two Oxygen sensors (LSF1 and LSF2) downstream front catalyst and post main catalyst. The control loops downstream catalysts correct deviations of the upstream oxygen sensor (LSU).
All three sensors are monitored by several single monitoring procedures under the following basic conditions.

.07.05.02 Monitor function description

The following checks will be performed on the linear oxygen sensor (LSU) upstream catalyst:

Plausibility Check
Any deviation from the characteristic curve of oxygen sensor upstream catalyst due to poison, ceramic cracks, characteristic shift down (CSD) or a leakage between booth Oxygen sensors (LSU and LSF 1) will be detected by the control loop downstream catalyst and by comparison of the sensor signals.
The integrator value of the second control loop detects small shifts of the sensor characteristic to lean or to rich. The signal comparison during steady state conditions quickly detects major deviations in sensor characteristics caused by serious faults (e.g. ceramic cracks).

For the fault decision the Oxygen sensor downstream the first portion of the catalyst has to be checked too (Oscillation and/or fuel cut-off check).

Heater Coupling Check
This monitoring function will detect any short circuits between sensor heater and the Nernst cell of the Oxygen sensor by watching the Lambda signal. The Lambda value variation is checked by the ECM. The heater is operated by a pulsating signal with a frequency of two Herz. The sensor signal characteristic is checked for noises with a significant level and a frequency of the heater operation. If the level of noises is greater than a threshold, a low resistance short-cut between heater and pump current or the current of the Nernst cell is detected.

Dynamic Check
Any change in the dynamic behavior of the Oxygen sensor due to aging, heater fault or contamination will be detected by watching the slope of the Lambda value during the switch from lean to rich fuel mixture (natural frequency control of fuel mixture active). If the slope of the sensor signal exceeds a specific value the monitoring function is calculating the ratio of actual Lambda slope versus target Lambda slope. If a specific numbers of those slope ratios are less than a threshold, a fault is detected.

Check for Sensor at ambient air (out of exhaust system)
Under the condition of active injection valves and a Lambda value of < 1.6, a voltage significant less than 4.2 V is expected at the self-diagnostic IC of the LSU.

Wire and IC-Check
The hardware of the Oxygen sensor consists of an IC (CJ 125) with the capability of self-diagnostics. The self-diagnostic functions of the IC

detects communication faults between ECM and the sensor, insufficient voltage supply, shorts in the sensor lines to ground and to battery.
Open wire on the four sensor lines, adjustment line (IA), virtual mass line (VM), pump current line (IP) and Nernst voltage (UN) will be detected by a system plausibility check. The evaluations of the system plausibility is based on sensor voltage, internal resistance, target Lambda, actual Lambda and the reaction of the controller.

<u>The following checks will be performed on the oxygen sensors (LSF1 and LSF2) downstream catalyst:</u>

<u>Oscillation Check</u>
The function checks whether the sensor output voltage of oxygen sensors (LSF 1 and LSF2) downstream catalyst always remains above or below a specified threshold.

The second control loop is designed as a natural frequency control and based on the Oxygen sensor (LSF1) post front catalyst. The voltage of the LSF1 triggers the change of fuel mixture. If the trigger point is not crossed although the control loop is closed, a timer is started. In case of no signal change within a specific time, ECM enforces a specific mixture change while watching Oxygen sensor (LSF1) voltage.

In case of Oxygen sensor (LSF1) signal shows permanently “lean” voltage, ECM is forcing an enrichment of mixture. If sensor voltage shows still lean, a “stuck low” fault is detected.

In case of Oxygen sensor (LSF1) signal shows permanently “rich” voltage, ECM enables lean out of mixture. If sensor voltage shows still rich, ECM is watching the sensor signal during the next coasting condition. In case of no signal change during coasting, a “stuck high” fault is detected.

The third control loop is designed as commanded control and based on the Oxygen sensor (LSF2) post main catalyst. The controller maintains an optimal constant voltage of the third control loop. The target voltage depends on the operating point and is taken from a map. During active control, the target voltage switches between rich and lean. In case of no reaction of the Oxygen sensor (LSF2) output according the commanded control, ECM is forcing the same enrichment/ lean out of fuel mixture in order to monitor the sensor output voltage.

<u>Fuel cut off Check</u>
During coasting, the ECM is watching the downstream sensor voltage, which has to go under a specific lean threshold. The diagnostic is enabled if coasting was detected for a specific time and the integrated air mass exceeds a specific threshold.

<u>Offset monitoring Oxygen sensor (LSF1) downstream first portion of the catalyst</u>

If the integral portion of the third control loop is exceeding a specific threshold while commanded control is active, an offset fault for the Oxygen sensor post front catalyst is detected.

Monitoring of electrical errors of sensor upstream and downstream catalyst

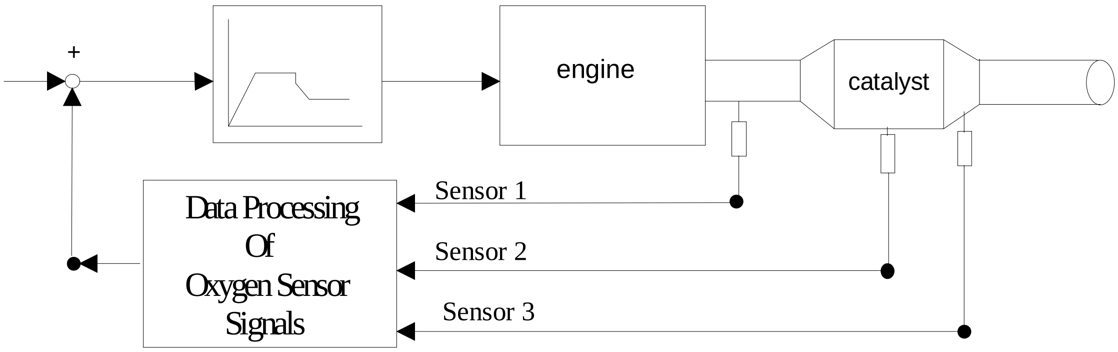
<u>Implausible voltages</u>

ADC-voltages exceeding the maximum threshold VMAX are caused by a short circuit to UBatt.

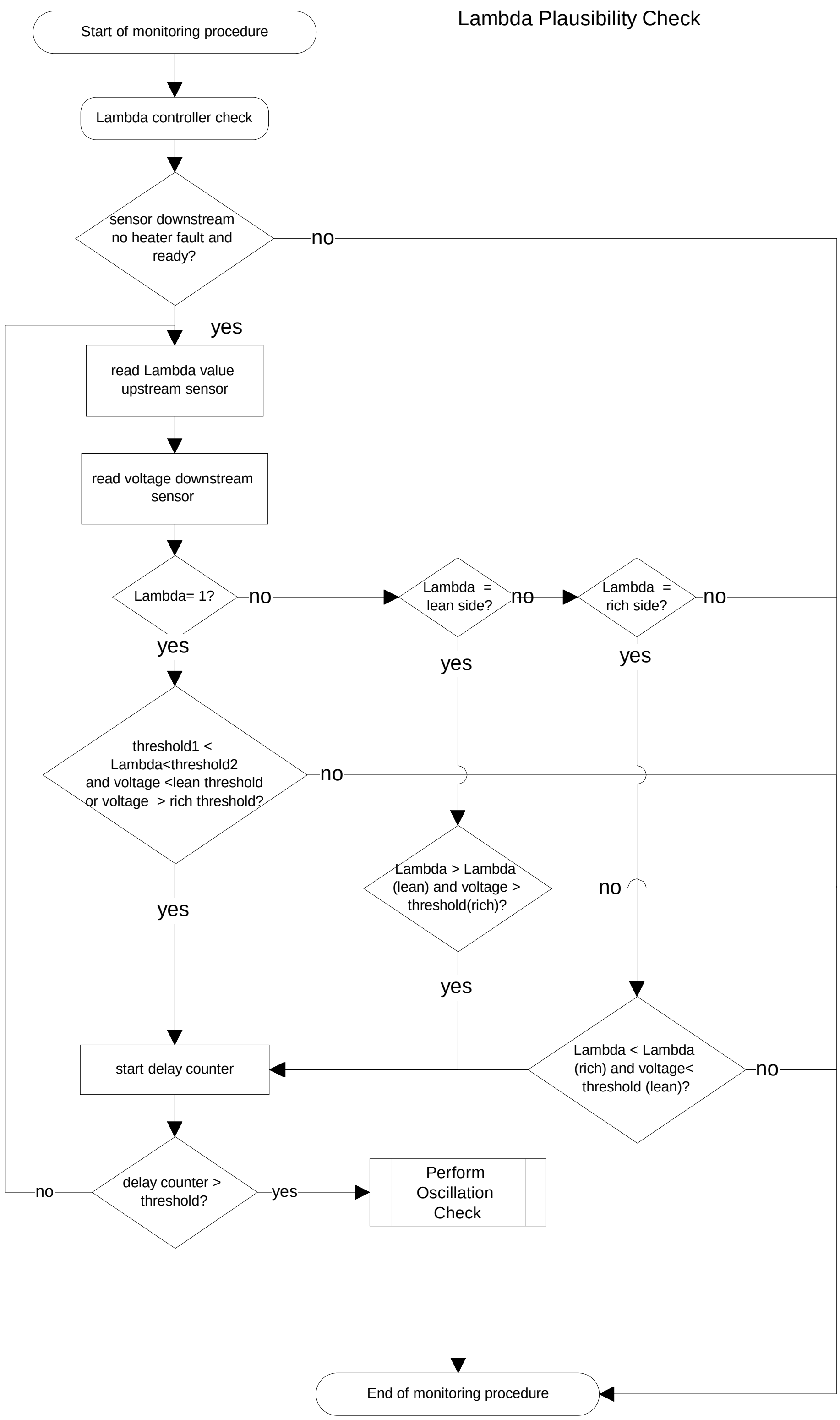
ADC-voltages falling below the minimum threshold VMIN are caused by a short circuit of sensor signal or sensor ground to ECM ground.

An open circuit of the sensors (upstream and downstream catalyst) can be detected, if the ADC-Voltage is remaining in a specified range after the sensor has been heated.

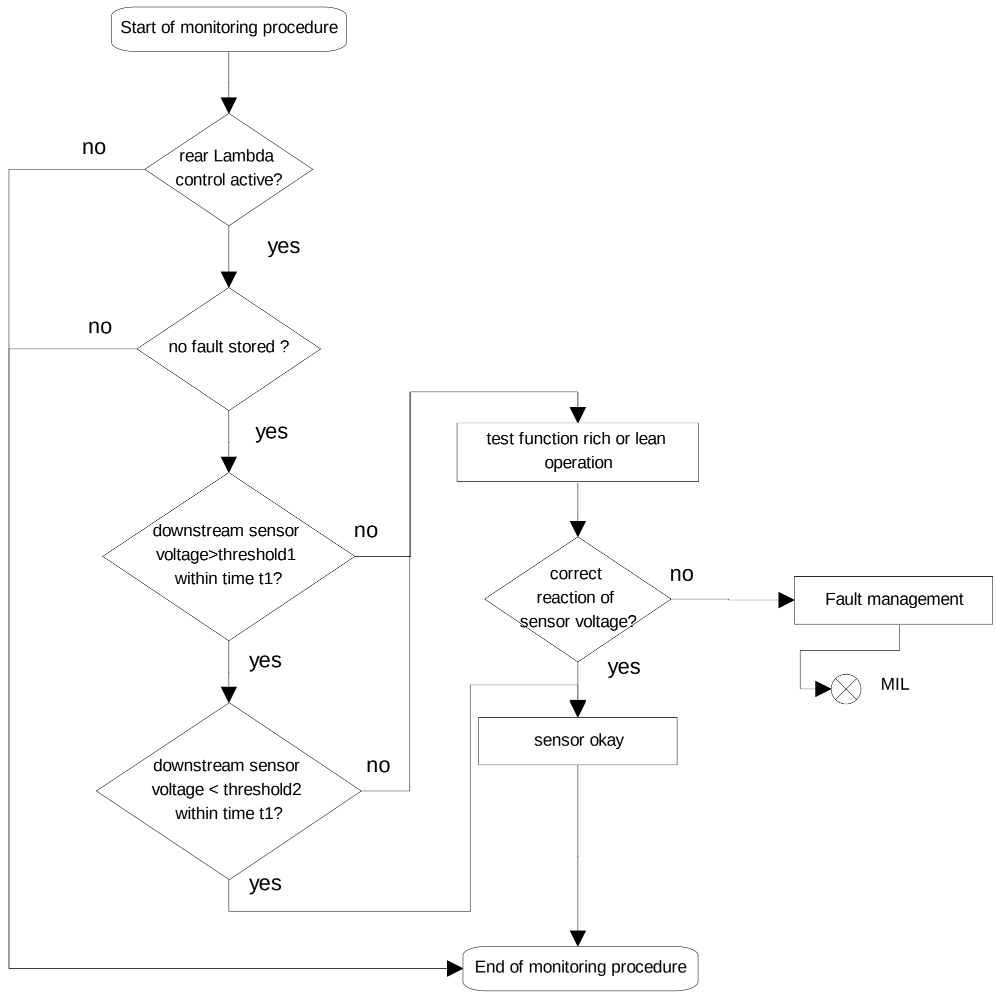
.07.05.03 Chart(s) and flow chart(s)



Flow chart: Plausibility Monitoring (LSU O2 Sensor Upstream Catalyst) SULEV applications

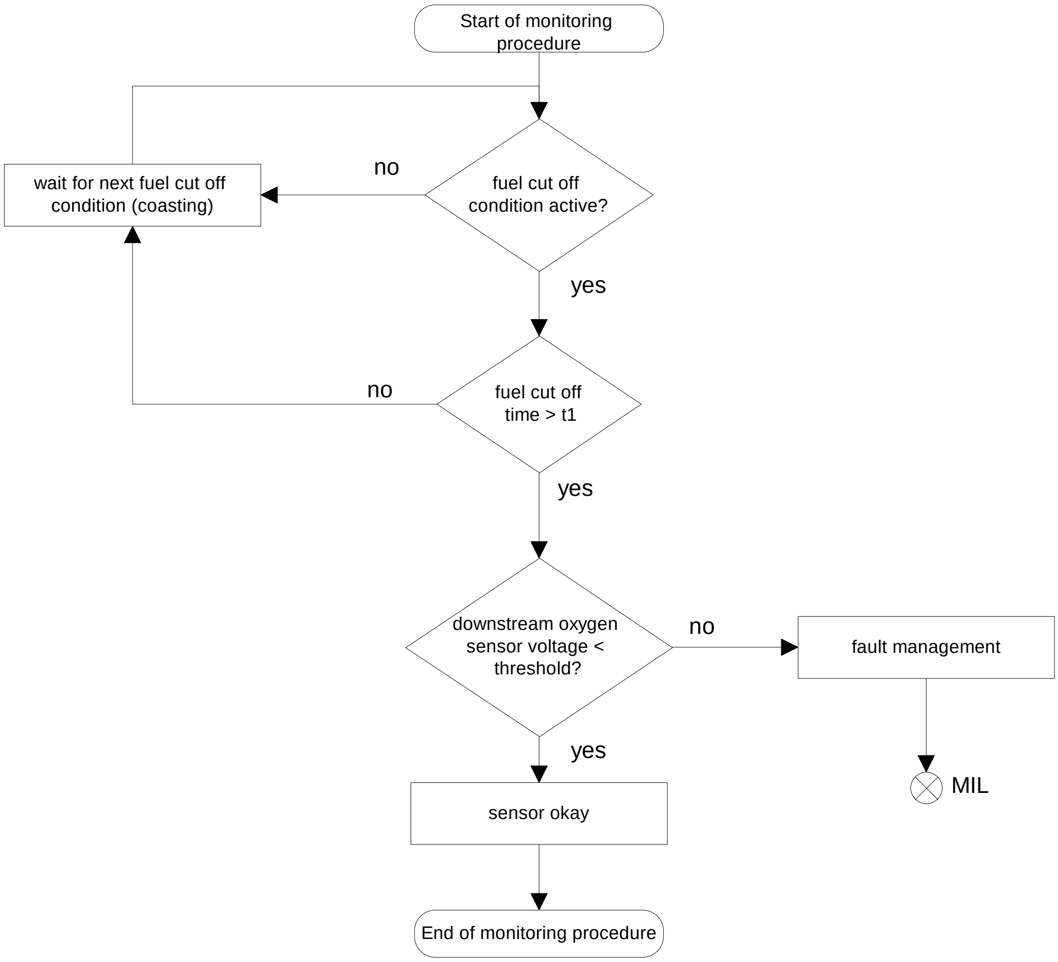


Flow chart: Oscillation Monitoring (LSF1/2 O2 Sensor Downstream Catalyst)

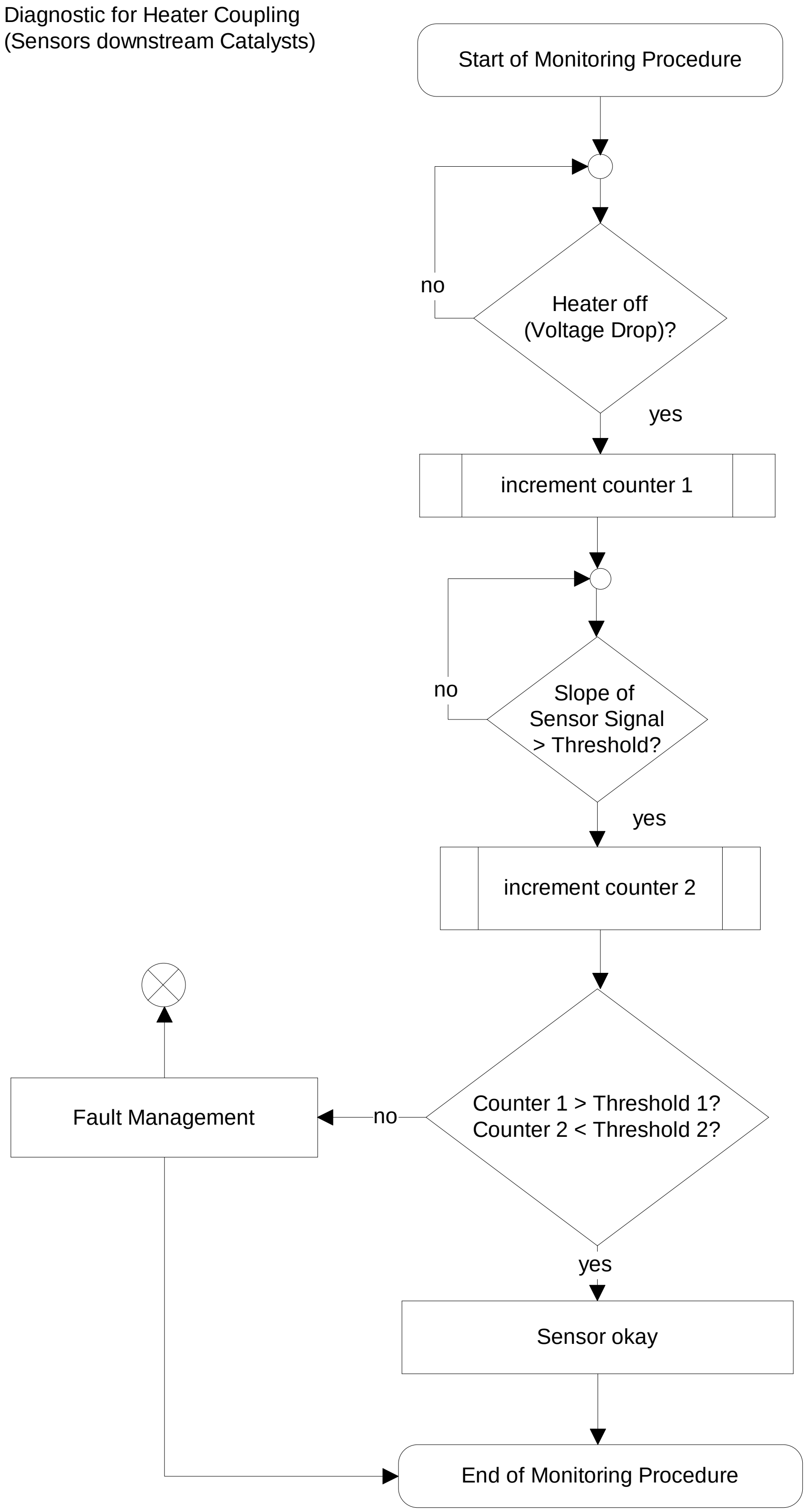


Fuel Cut-Off Monitoring (LSF1/LSF2, Oxygen Sensors Downstream Catalysts

Fuel cut-off check



Oxygen Sensors Monitor Heater Coupling (LSF1 / LSF2)



.07.06.00 Oxygen Sensor Heater Monitoring (SULEV)

.07.06.01 General description

For proper function of the Oxygen sensors, their ceramic elements must be heated. A non-functioning heater delays or prevents either the sensor readiness (LSU) or the proper signal output (LSF1/LSF2) for closed loop control and thus influences emissions.

Oxygen sensor upstream catalyst (LSU)

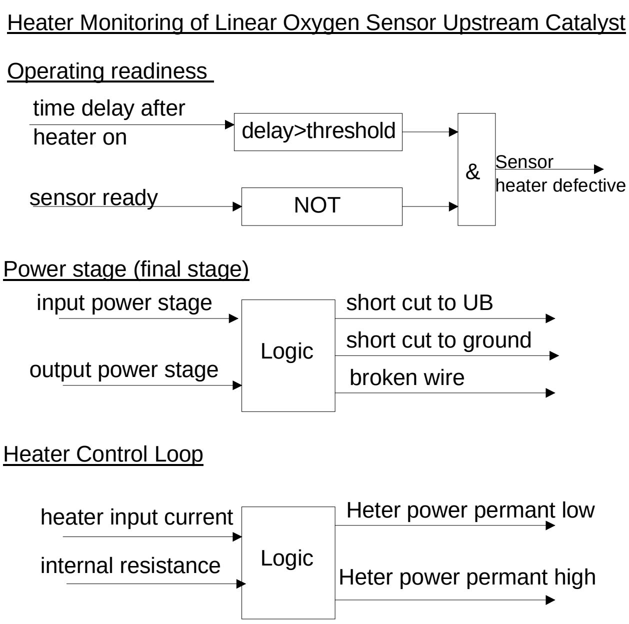
The heater control loop is integrated within the oxygen sensor hardware and has to achieve a target temperature of about 750 °C of the ceramic element.

Oxygen sensors downstream catalysts (LSF1 and LSF2)

For diagnostic of the sensor heater a specific current pulse is supplied via a load resistance and the voltage is measured. The intern resistance of the sensor heater is calculated with the voltage deviation. The result will be compared with a reference map resistance, which considers aging and sampling deviations. In case of internal resistance > map resistance the diagnosis stores a fault and the MIL will be illuminated.

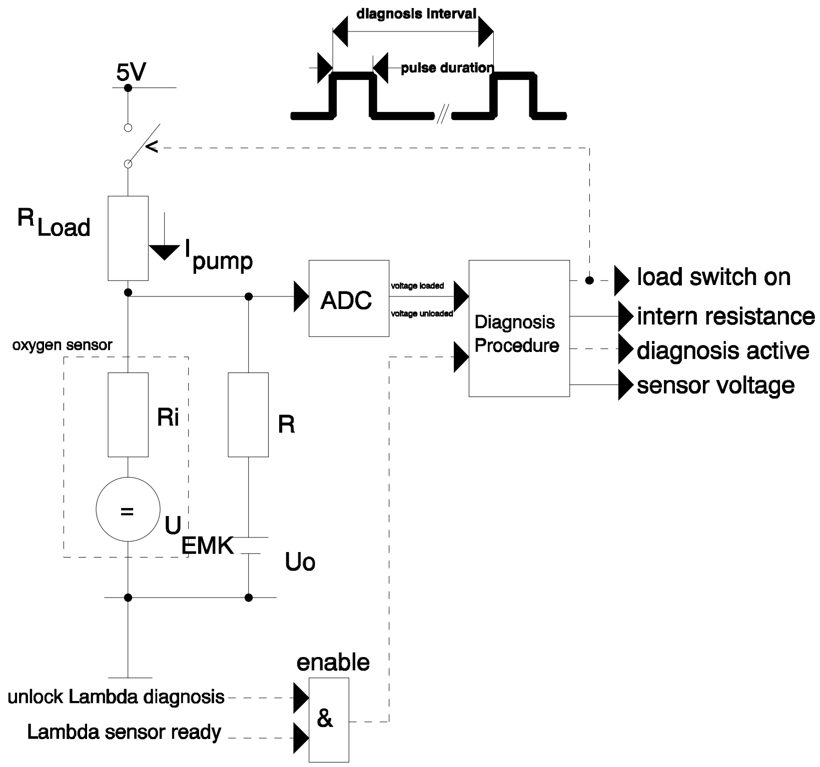
.07.06.02 Monitor function description)

Monitoring Structure (Oxygen sensor upstream catalyst)



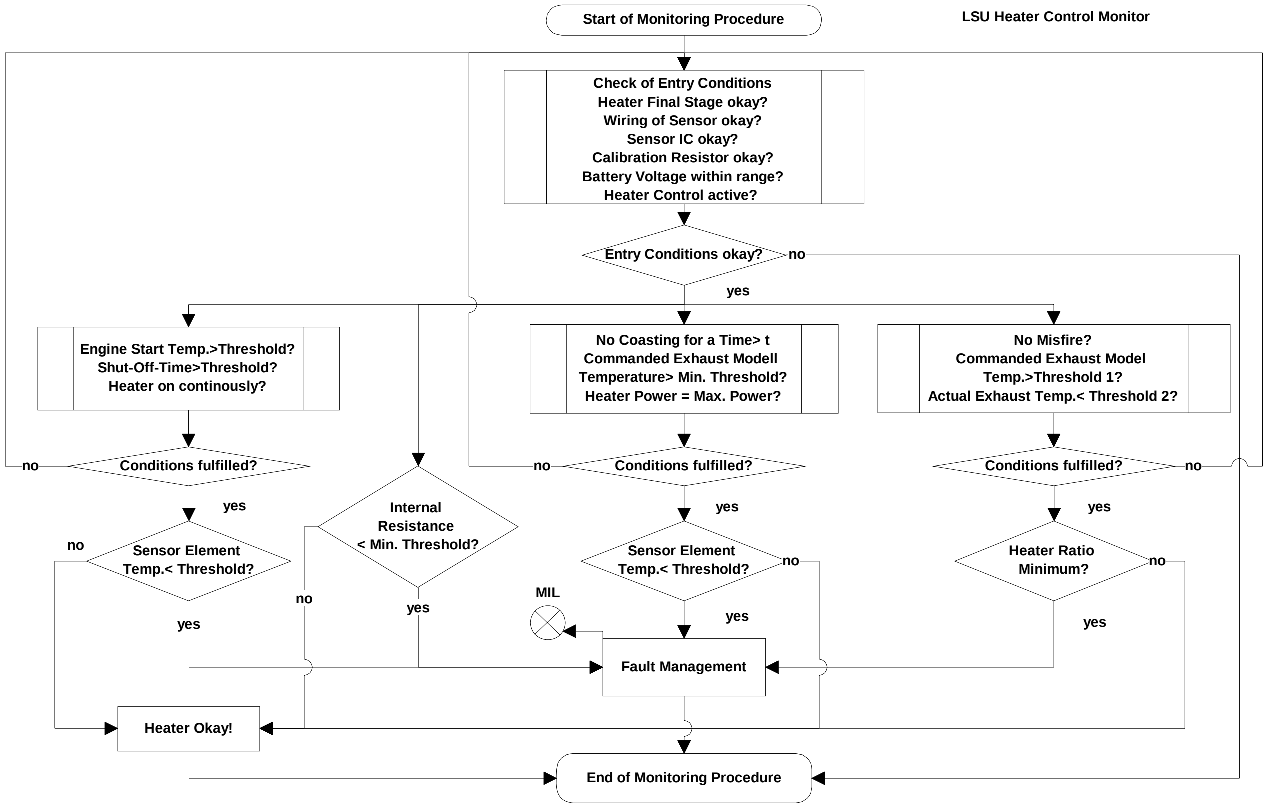
Characteristics: - Switch on of sensor heater is ECM controlled

Monitoring Structure (Oxygen Sensor Downstream Catalyst)



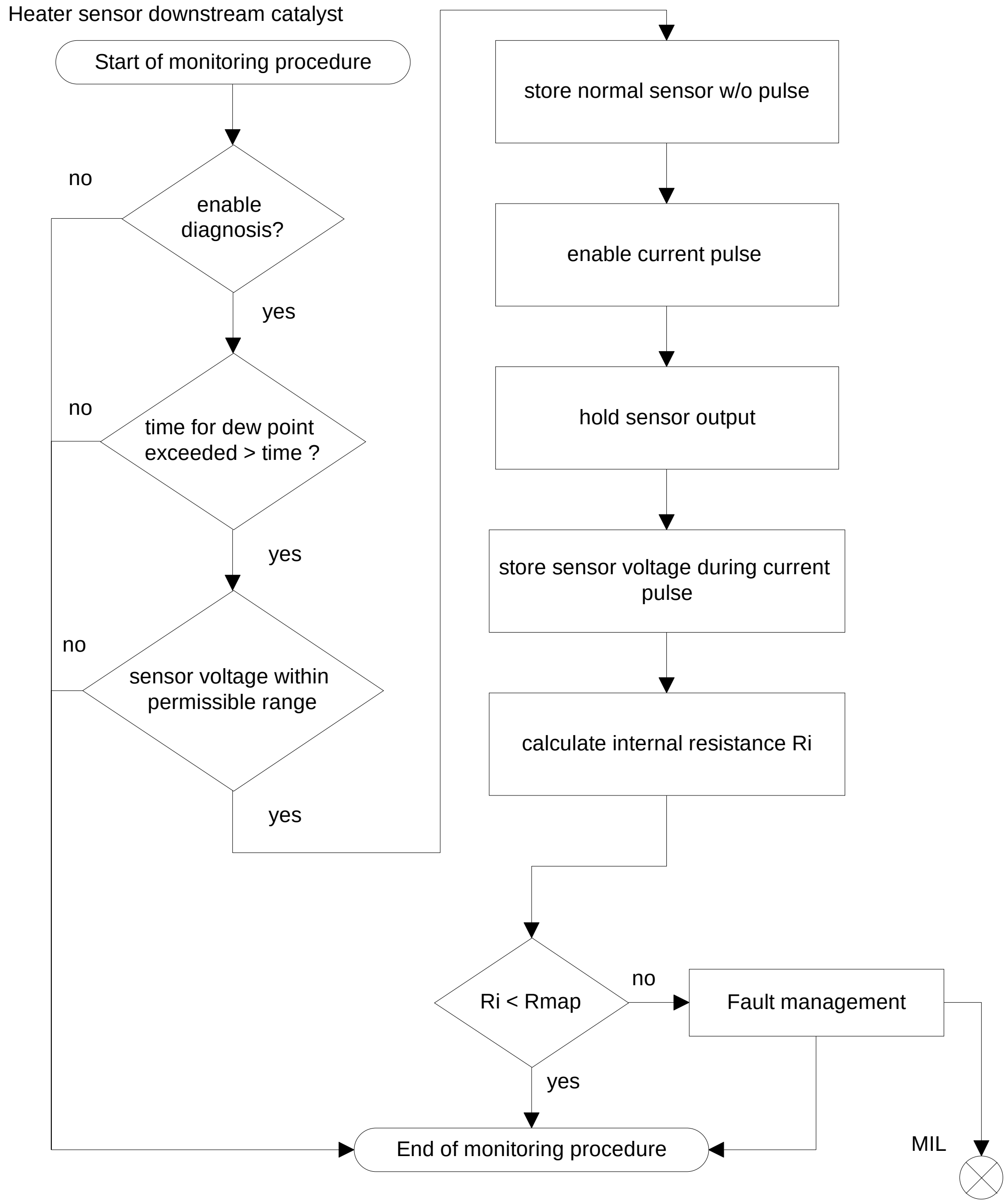
.07.06.03 Chart(s) and Flow Chart(s)

Flow Chart: LSU, Oxygen Sensor Heater Control Upstream Catalyst (SULEV calibration)



Flow Chart: LSF1/LSF2, Oxygen Sensors downstream catalyst

SULEV applications



.08.00.00 EGR MONITORING

not applicable

.09.00.00 PCV Monitoring

The PCV system assures that no gas from the crankcase system escapes into the atmosphere.

All connectors which are not necessary to open during typical maintenance / repair actions are implemented as hard to open.

All easy to open connectors are monitored by the OBD system.

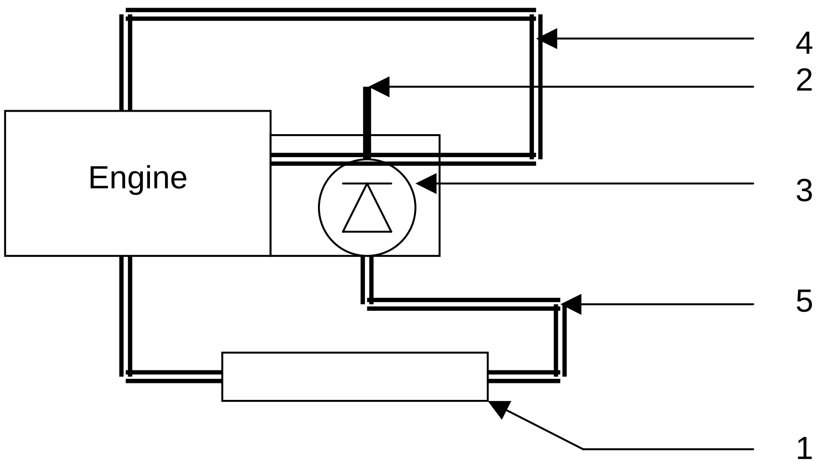
.10.00.00 Engine Coolant System Monitoring

.10.01.00 General description

The engine cooling system consist of five main parts.

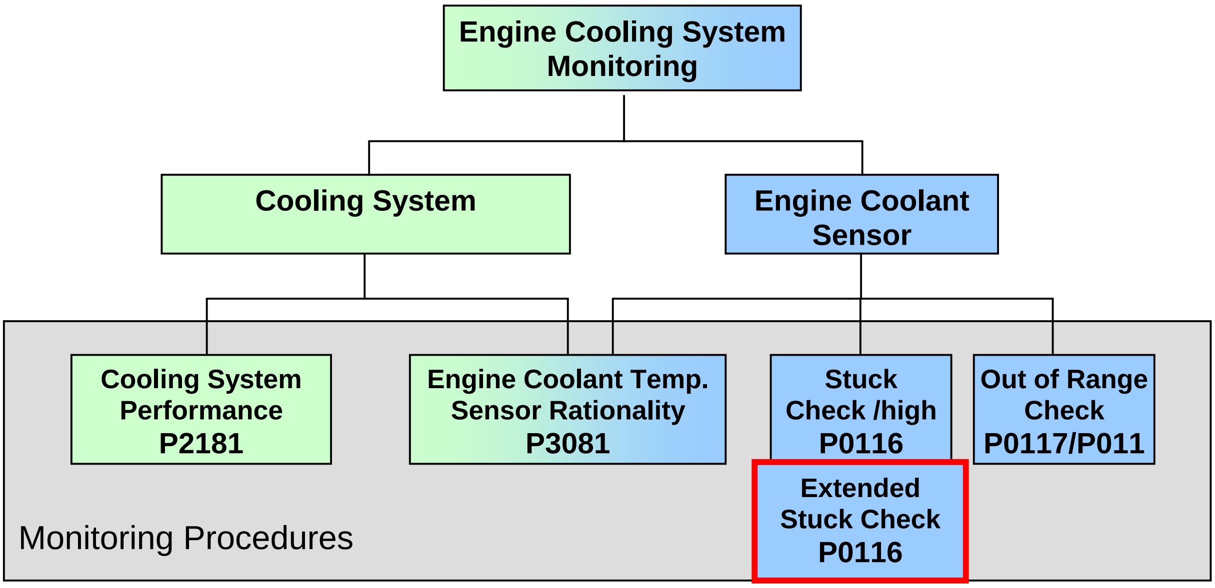
1. The Engine Cooler
2. The Engine Coolant Temperature Sensor
3. The Thermostat Valve
4. The small Cooling Circuit
5. The large Cooling Circuit

During heating up the Engine the coolant flows first inside the small cooling circuit. After the coolant reach a sufficient temperature the thermostat valve will open the large cooling circuit to integrate the engine cooler.
The engine coolant temperature sensor measures a mixed temperature between the coolant coming from the small and large cooling circuit.

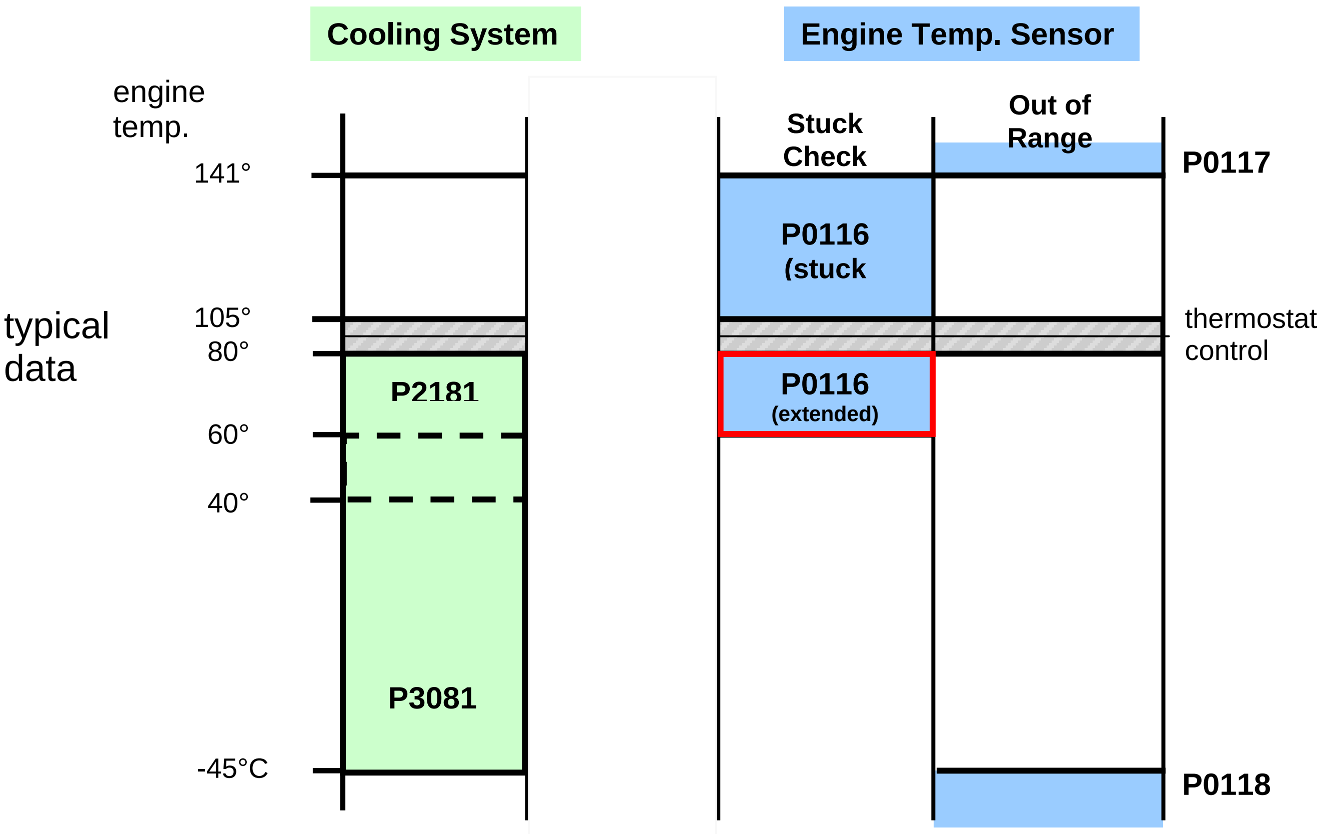


.10.01.02 Monitor Functional Description

The engine cooling system monitoring strategy consists of two main diagnostic parts.



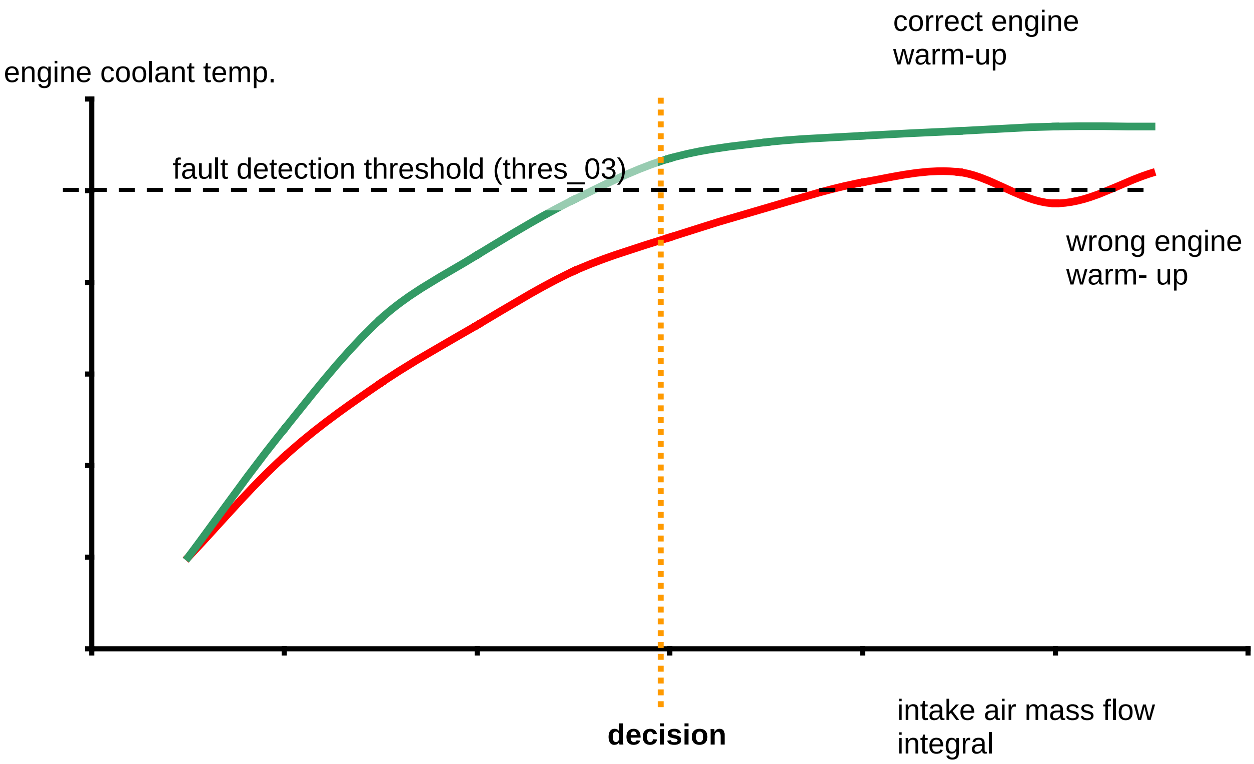
Each of the engine cooling monitoring function has its own special engine temperature range in which it will be enabled.



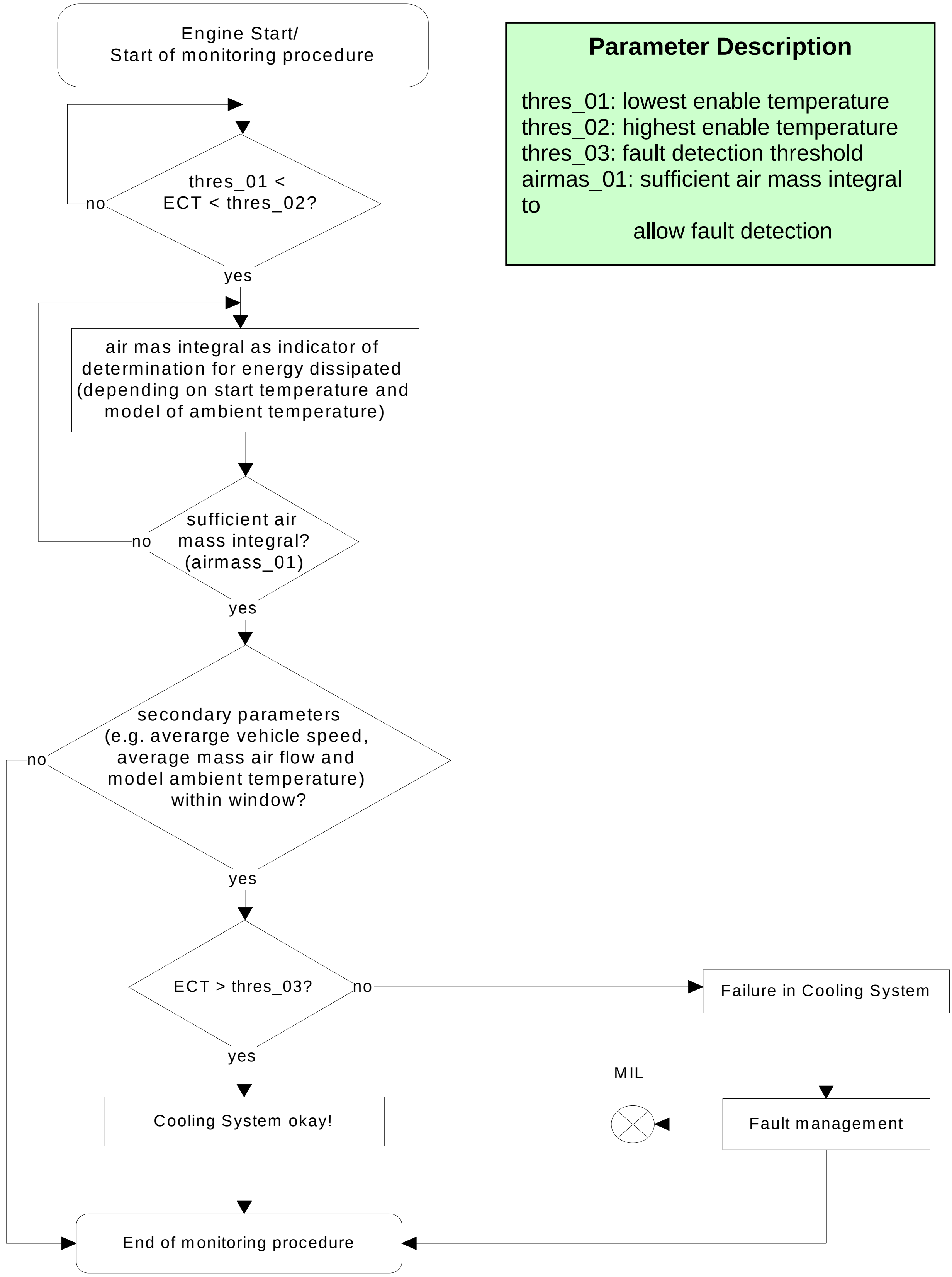
.10.03.00 Charts and Flow Charts

Cooling System Performance (P2081)

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

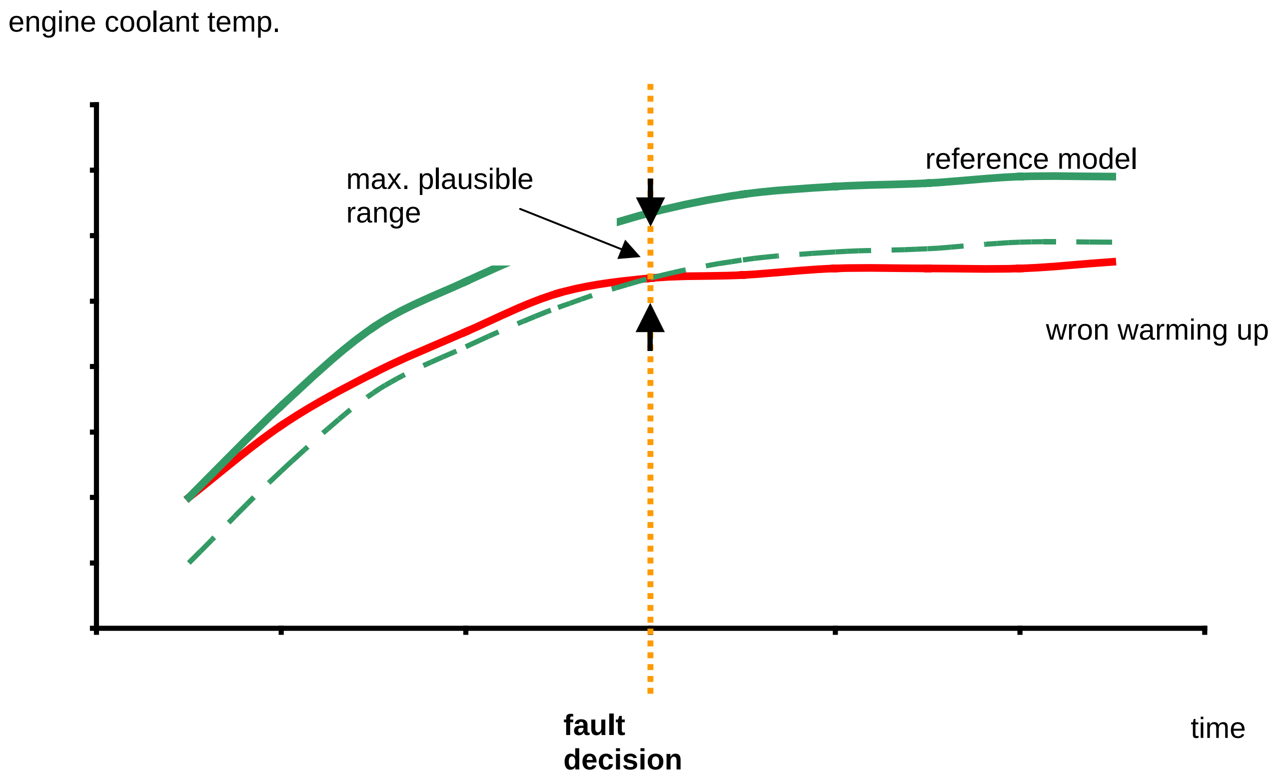


Flow Chart Cooling System Performance (P2081)

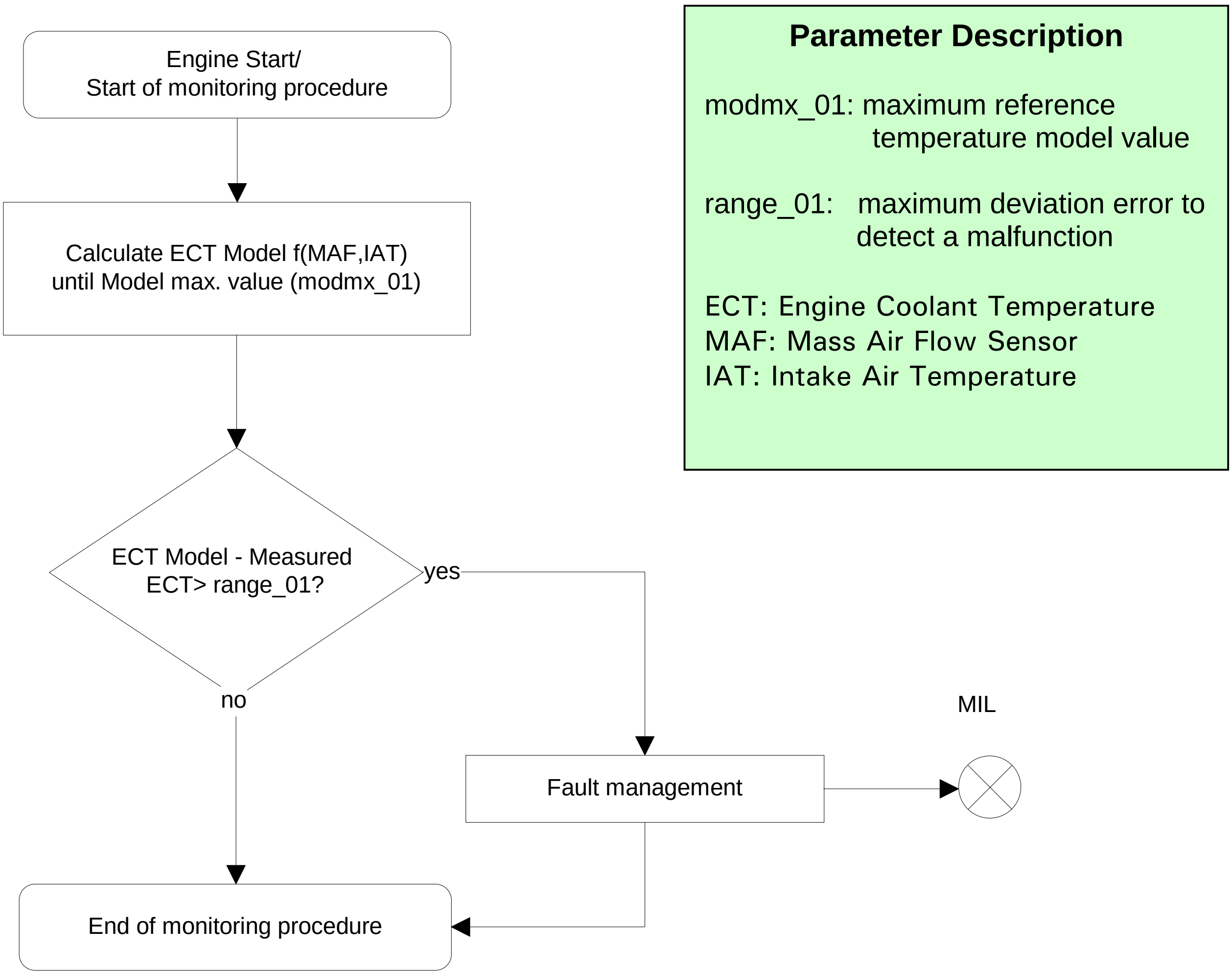


Engine Coolant Temp. Sensor Rationality (P3081)

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

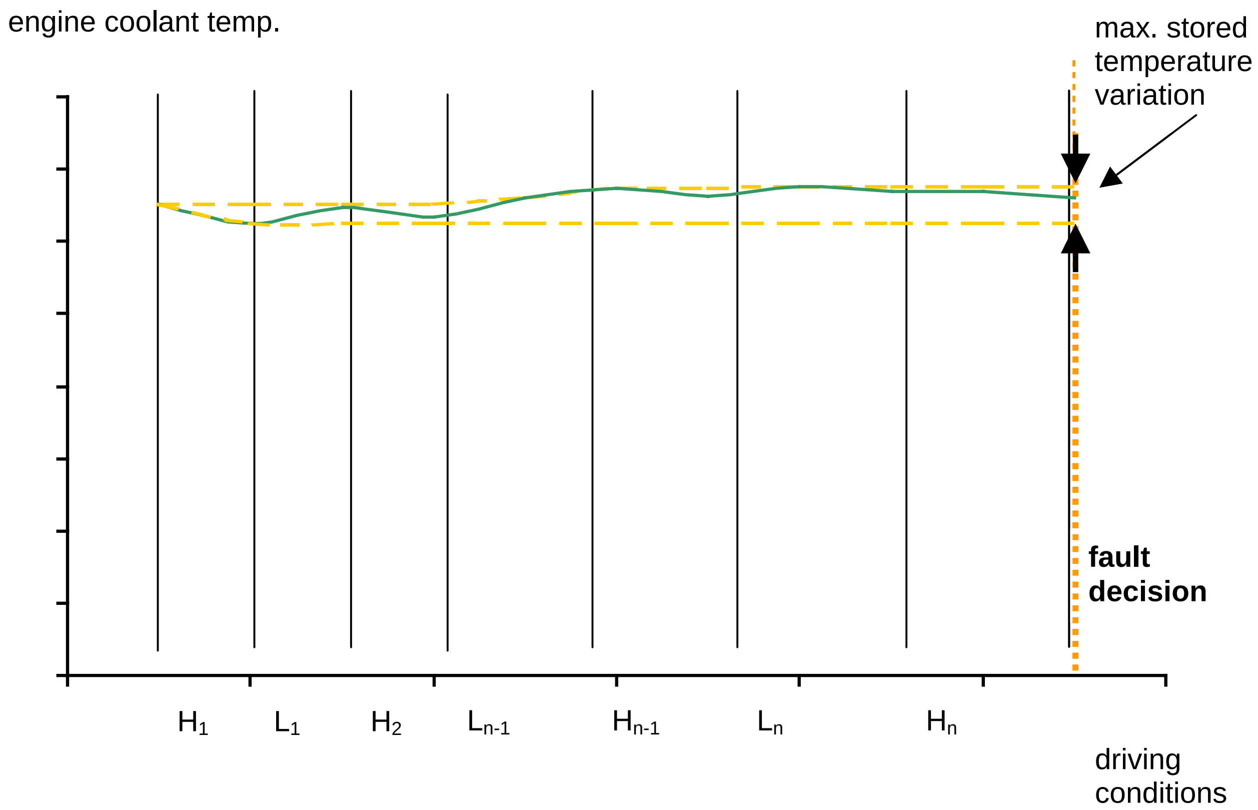


Flow Chart Coolant Temperature Sensor Rationality (P3081)



Engine Coolant Temperature Sensor Stuck High (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 stucks at high values.



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

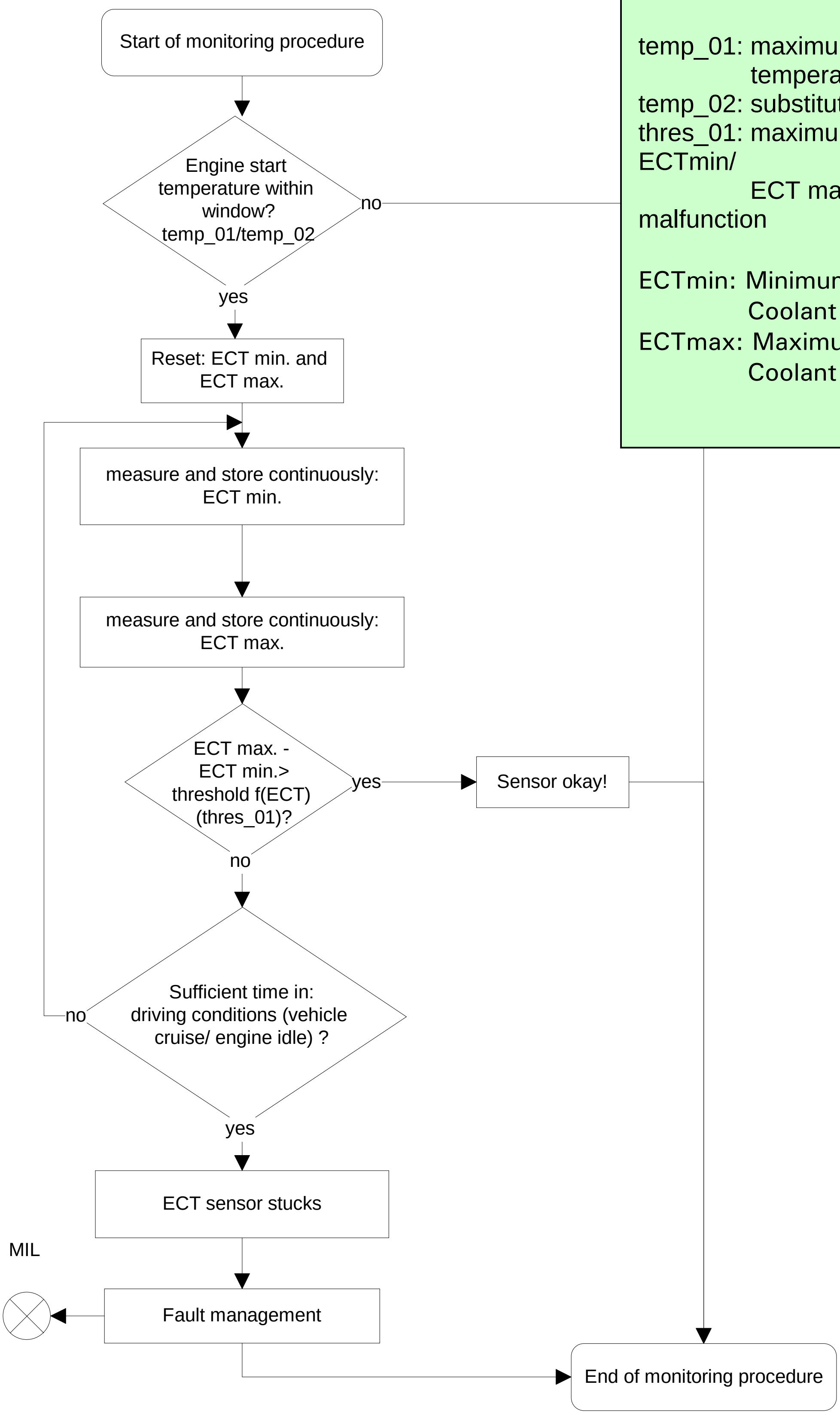
L: driving conditions with low cooling performance (idle)

Flow Chart Engine Coolant Temperature Sensor Stuck High (P0116)

Parameter Description

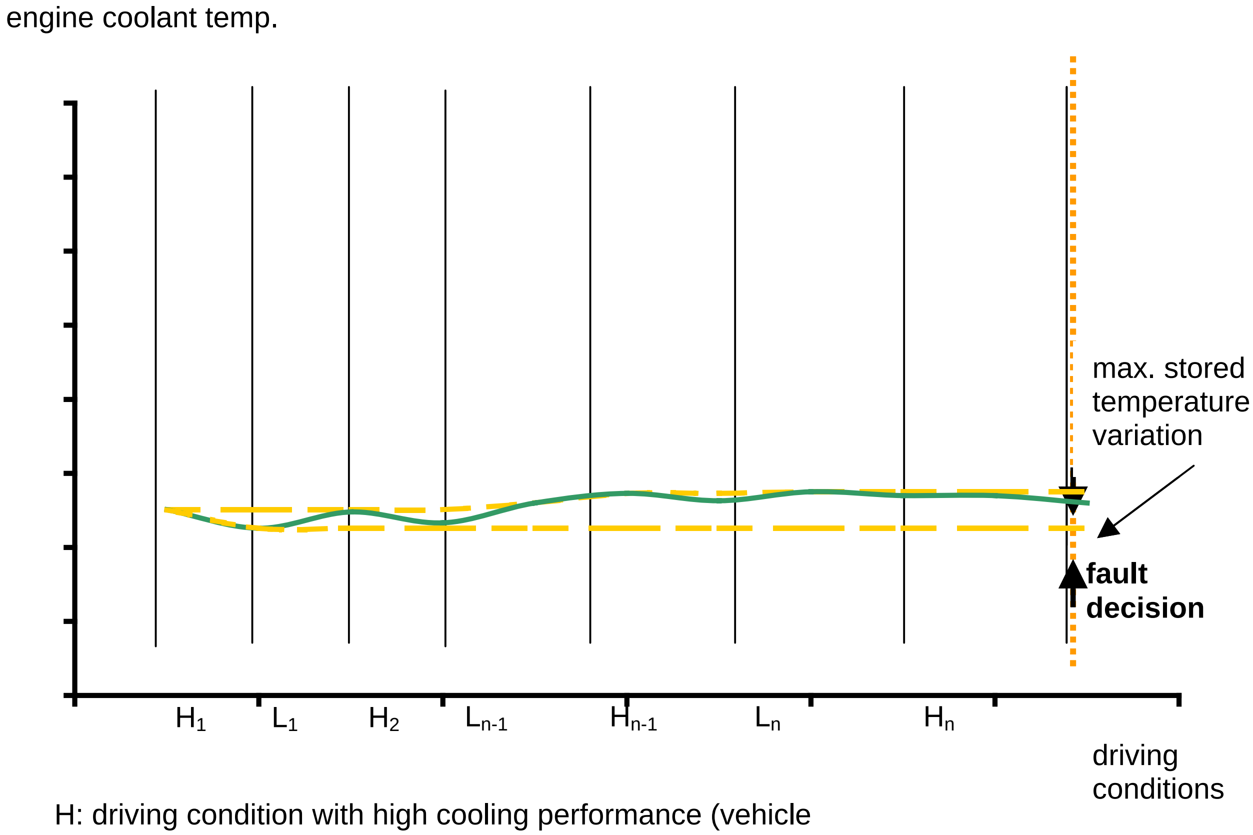
temp_01: maximum engine start temperature
temp_02: substitute model temp
thres_01: maximum diff. between ECTmin/ ECT max to detect a malfunction

ECTmin: Minimum of stored Engine Coolant temperature
ECTmax: Maximum of stored Engine Coolant temperature



Engine Coolant Temperature Sensor Stuck Low (P0116)

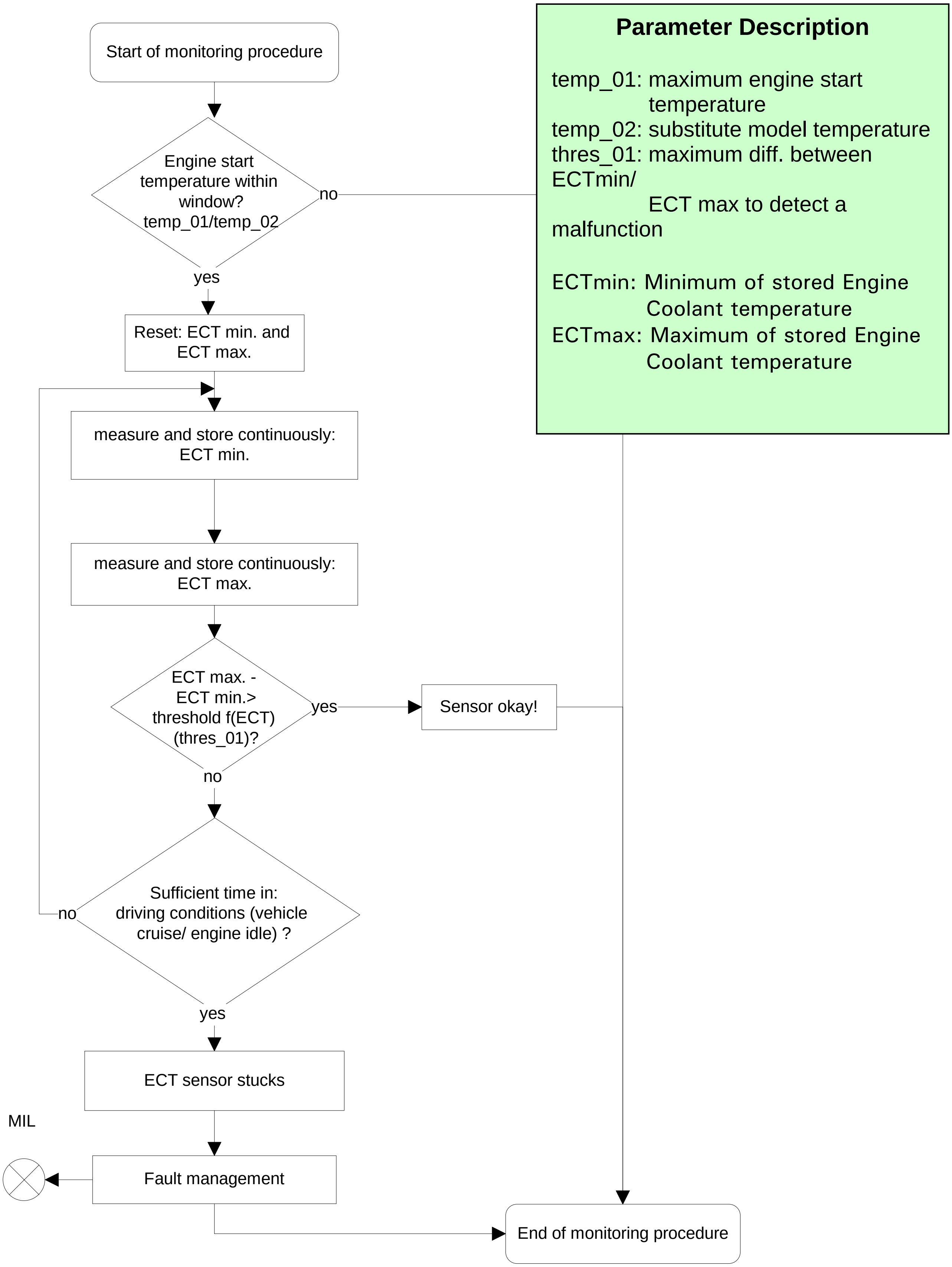
After engine start the system stores continuously the lowest and highest ECT below the thermostat control temperature for a driving cycle. In case that after several driving conditions the difference between ECT max and ECT min is lower than the threshold the sensor stucks at low values.



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

L: driving conditions with low cooling performance (idle)

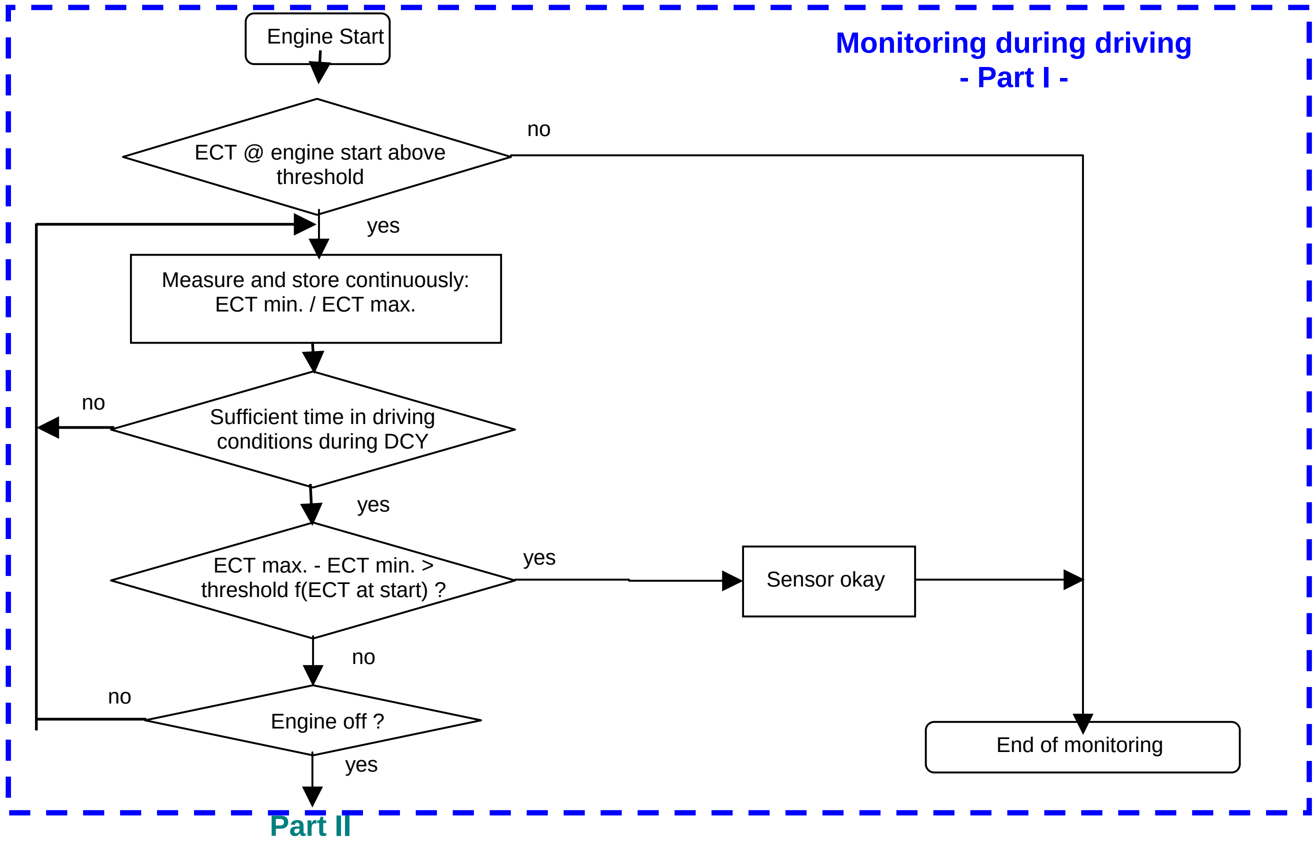
Flow Chart Engine Coolant Temperature Sensor Stuck Low (P0116)



Flow Chart Engine Coolant Temperature Sensor Stuck Test (all temperatures above threshold) (P0116)

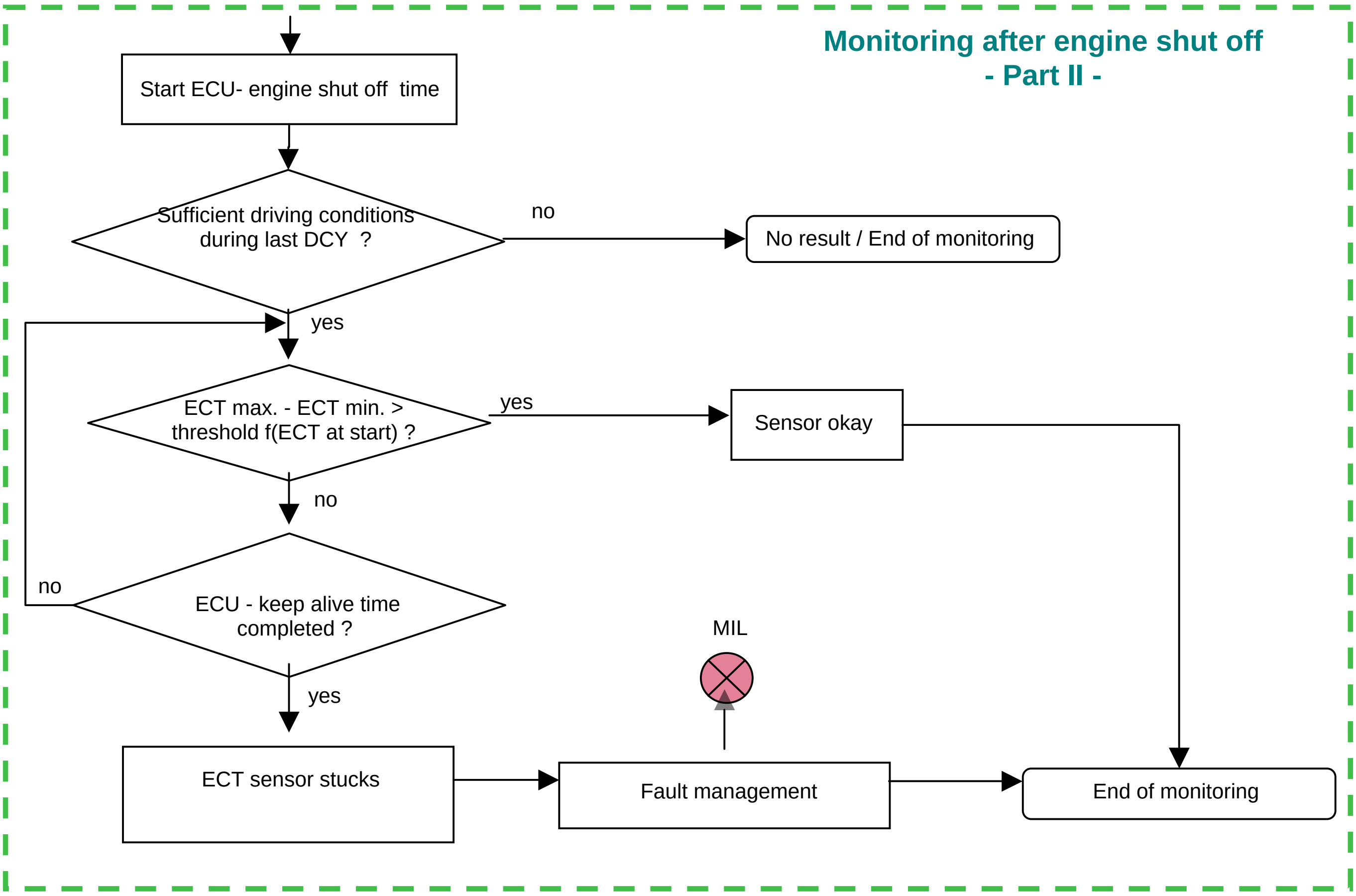
Monitoring of engine temperature during normal DCY and during engine shut off time

Part I:



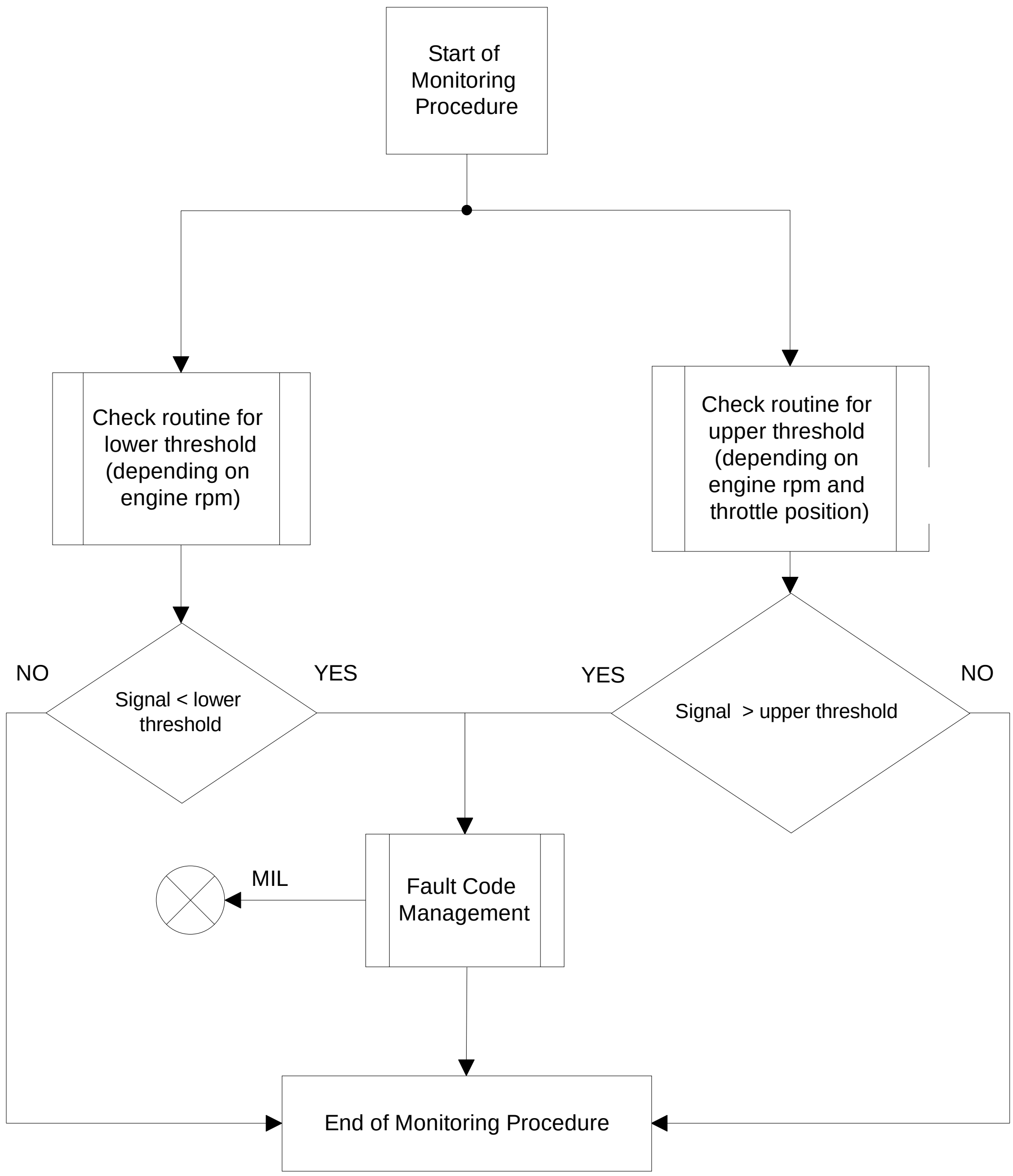
Monitoring of engine temperature during normal DCY <u>and</u> during engine shut off time

Part II:



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.



.11.00.00 Cold Start Emission Reduction Strategy Monitoring

.11.01.00 General Description

The key parameters in our 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.

The fuel system controls the cold start of the engine based on throttle angel and engine speed. The throttle angel during cold start is adjusted based on the signals from MAF and ambient pressure sensor and intake air temperature.

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
2. fuel mixture (engine Lambda)
3. ignition timing
4. camshaft position

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 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. MAF
4. Ambient pressure sensor
5. Intake air temperature sensor
6. Ignition coils
7. Variable valve timing system
8. Camshaft/crankshaft alignment
9. Phase sensor
10. Engine speed sensor

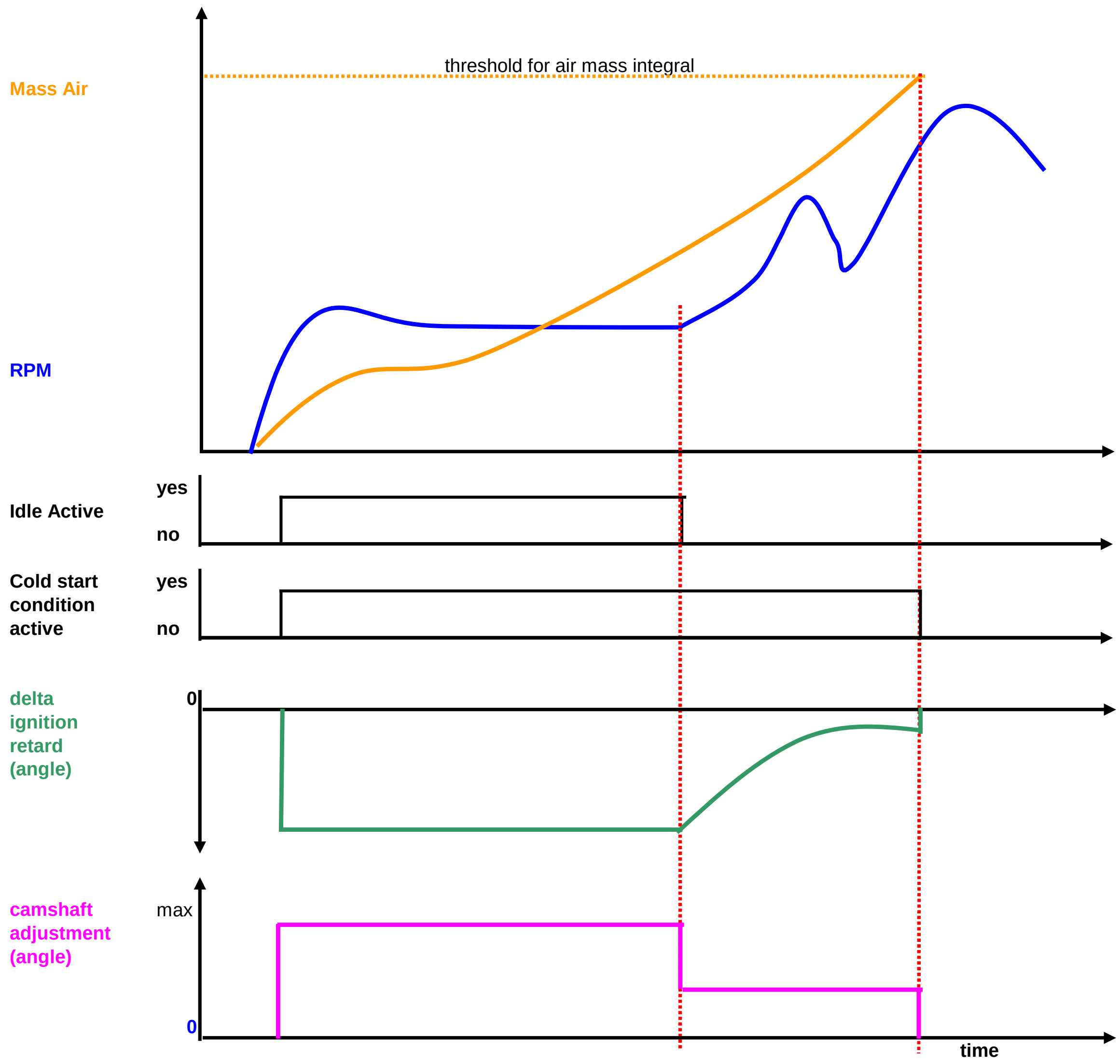
.11.02.00 Monitoring function description

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. During a cold start condition a pull-back on ignition retard is allowed only in certain range. This range will be determined by definition of the maximum value for ignition retard.
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).

.11.03.00 Charts and flow charts

The parameters with determine cold start conditions are:

1. Mass air integral below threshold
2. Engine coolant start temperature within an range
3. Altitude below threshold



.12.00.00 Air Conditioning (A/C) System Component Monitoring

The engine control module compensates the additional AC load via engine torque.
The components of the AC systems are not used for OBD functions and can not disable monitors independent of separate or integrated climatic control modules. Integrated climatic control modules may be a separated part of the ECM as “box in a box” unit.

.13.00.00 Variable Valve Timing and/or Control (VVT) System Monitoring

.13.01.00 General Description

In order to optimize engine torque, horsepower and engine emission the vehicle of this OBD group are equipped with an continuous variable valve timing camshaft on the intake side.

.13.02.00 Monitor function description

The VVT system will be monitored as presented and accepted during ARB meeting dated October, 15 2002 for:

Slow response“:

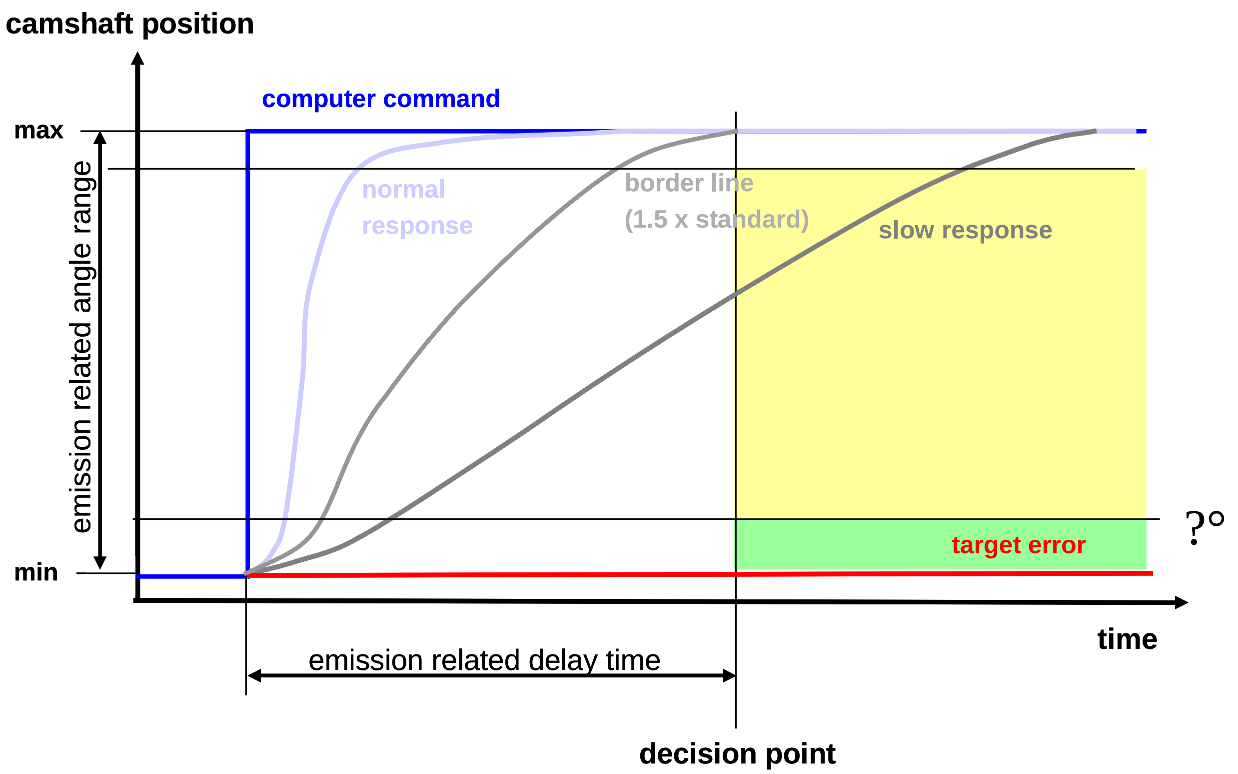
Slow response of camshaft system causing an emission increase to 1.5 x standard (slow response failure).

and

„Target error“:

Camshaft system does not react to computer command (stuck failure).

.13.03.00 Charts and flow charts



.14.00.00 Direct Ozone Reduction (DOR) System Monitoring

not applicable

.15.00.00 Particulate Mater (PM) Trap Monitoring

not applicable

.16.00.00 Comprehensive Components Monitoring

Flow Charts in addition to the summary table explanations:

.16.01.00 Injection Valve

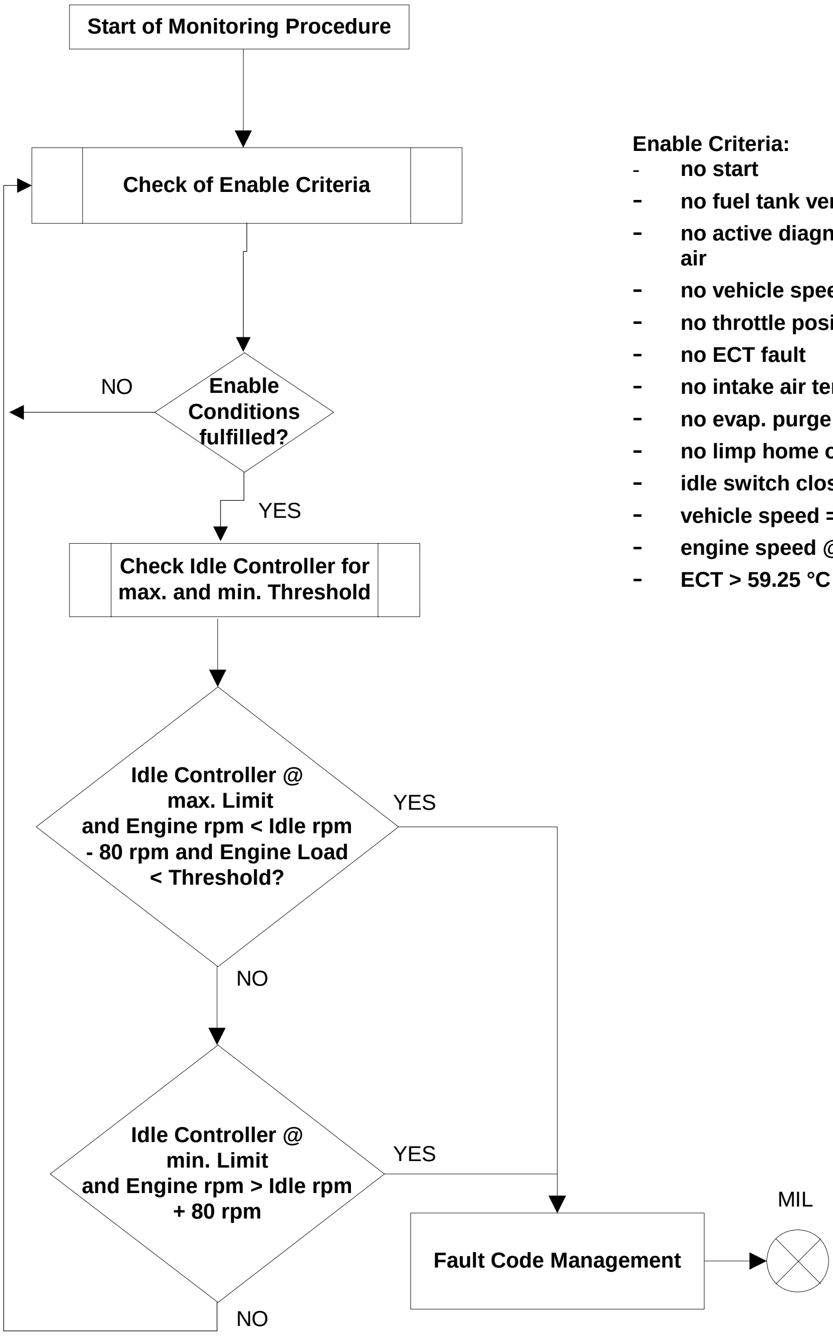
Check is performed while using Output Stage Check 16.09.12:

.16.02.00 Fuel Pump Relay

Check is performed while using Output Stage Check 16.09.12:

.16.03.00 Idle Controller

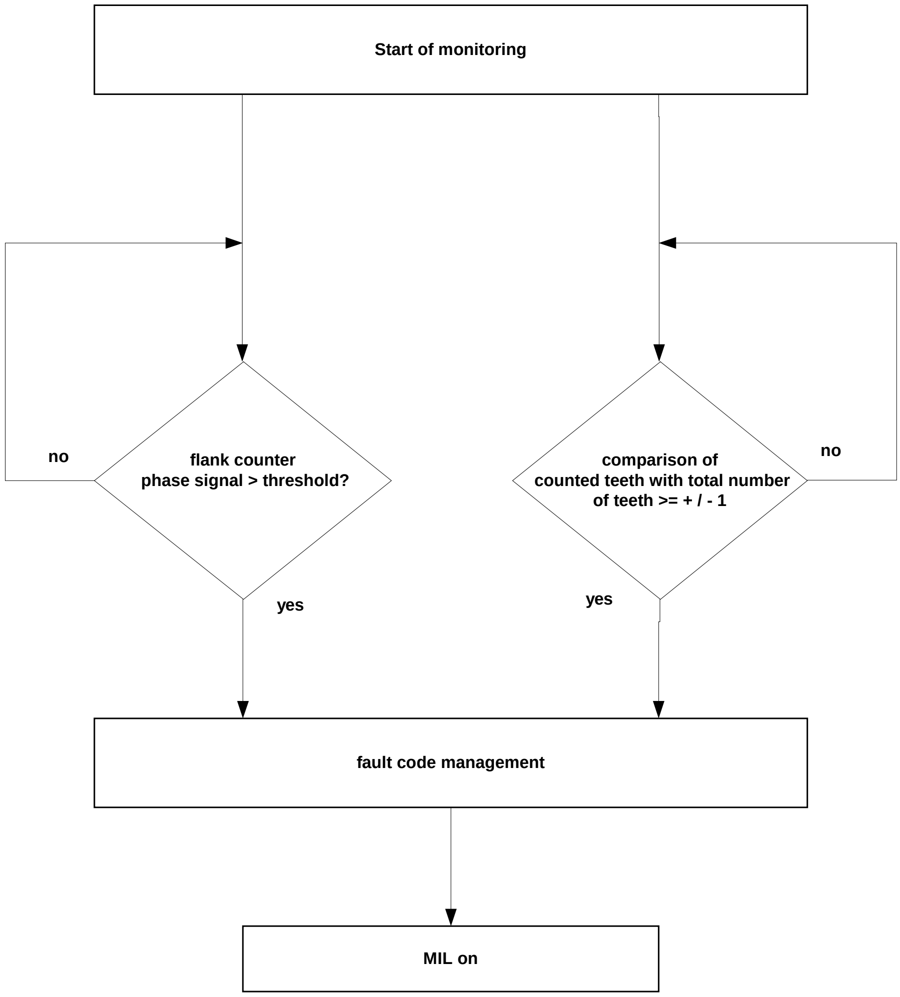
(Idle Control Check)



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 switch closed
- vehicle speed = 0 mph
- engine speed @ idle
- ECT > 59.25 °C

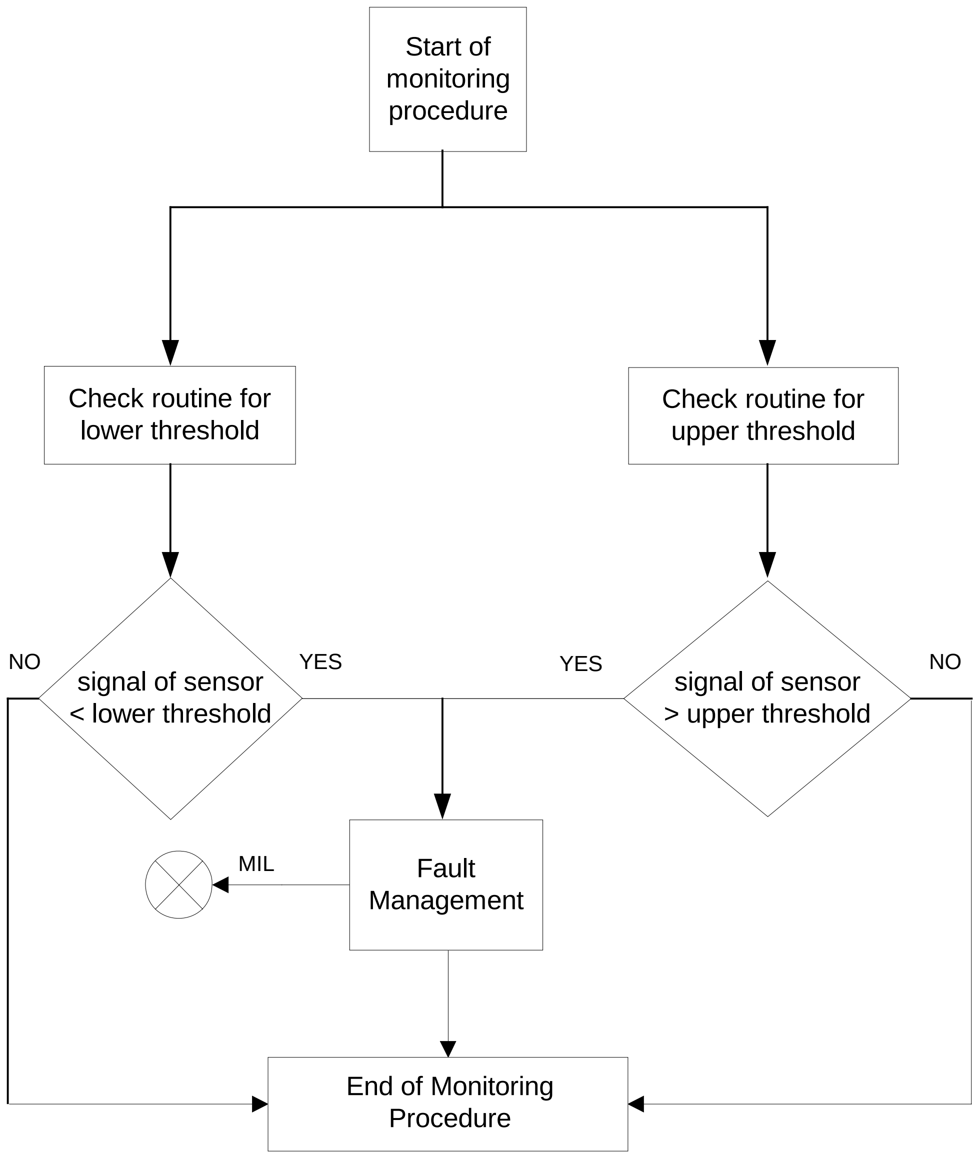
.16.04.00 Engine Speed Sensor:



.16.05.00 Warm-up Bypass valve:
(not applicable)

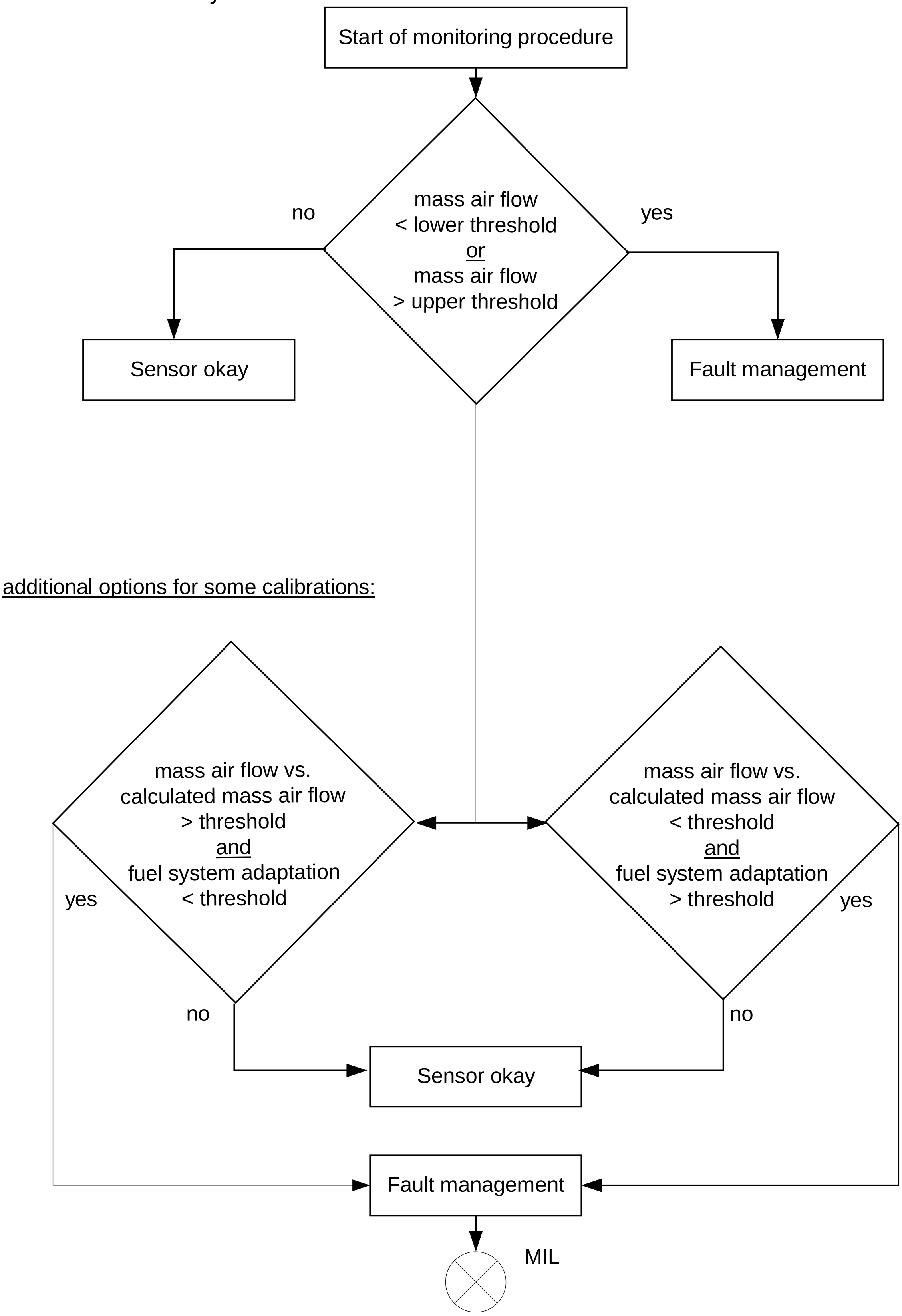
.16.06.00 Signal Range Check for different sensor

IAT
MAF
ECT
Camshaft position sensor
Charge pressure control valve

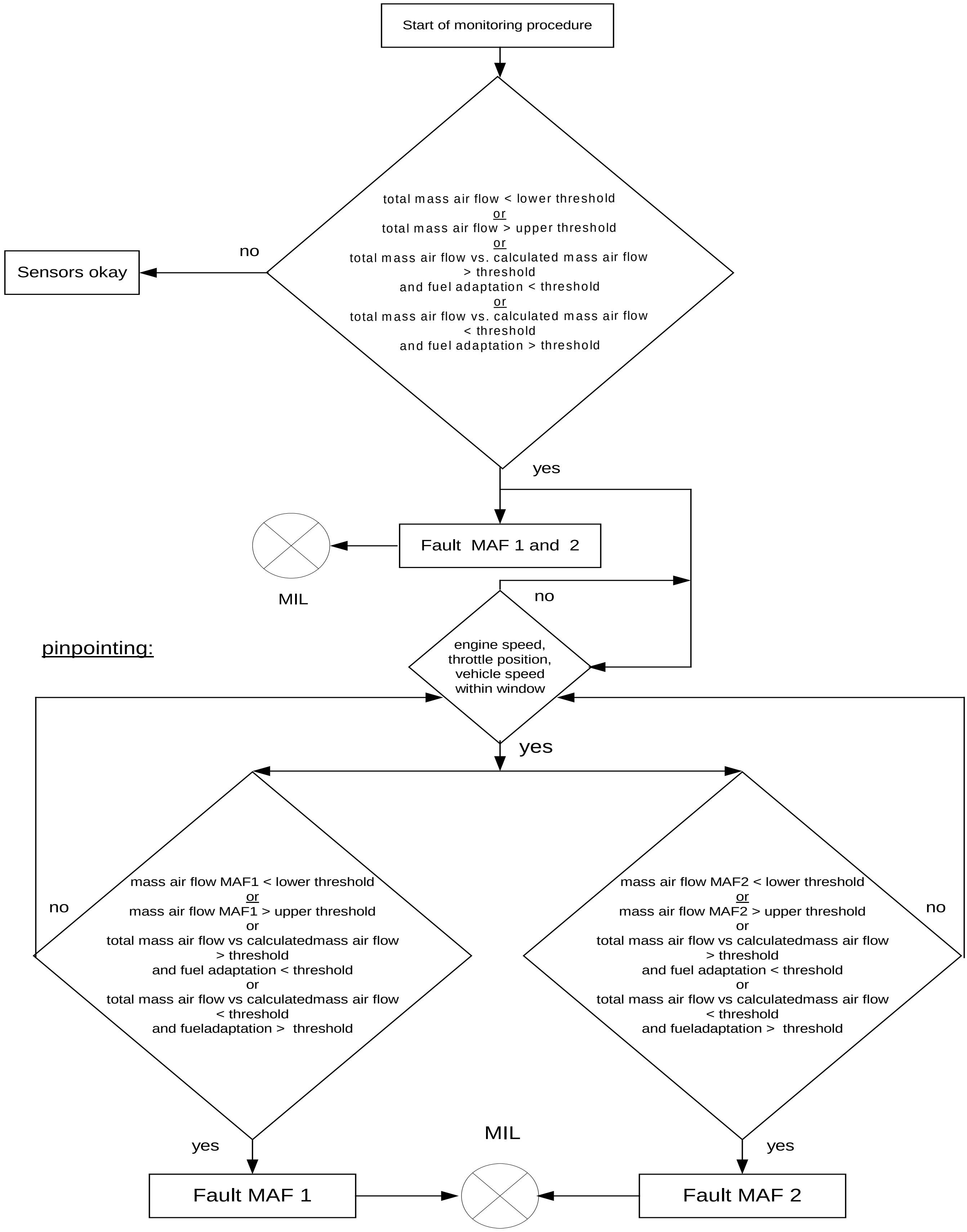


.16.07.00 Rationality Mass Air Flow Sensor (MAF)

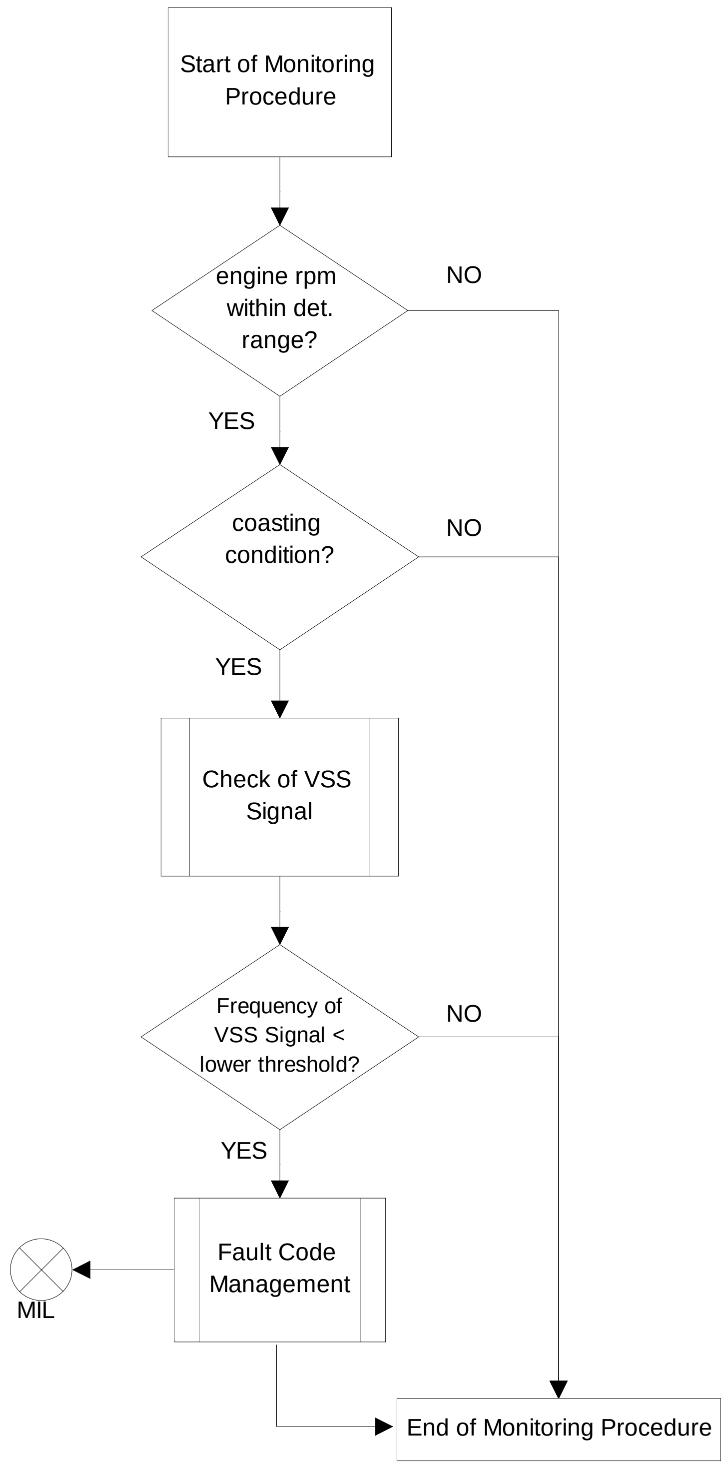
One MAF Sensor System:



Two MAF Sensors System:

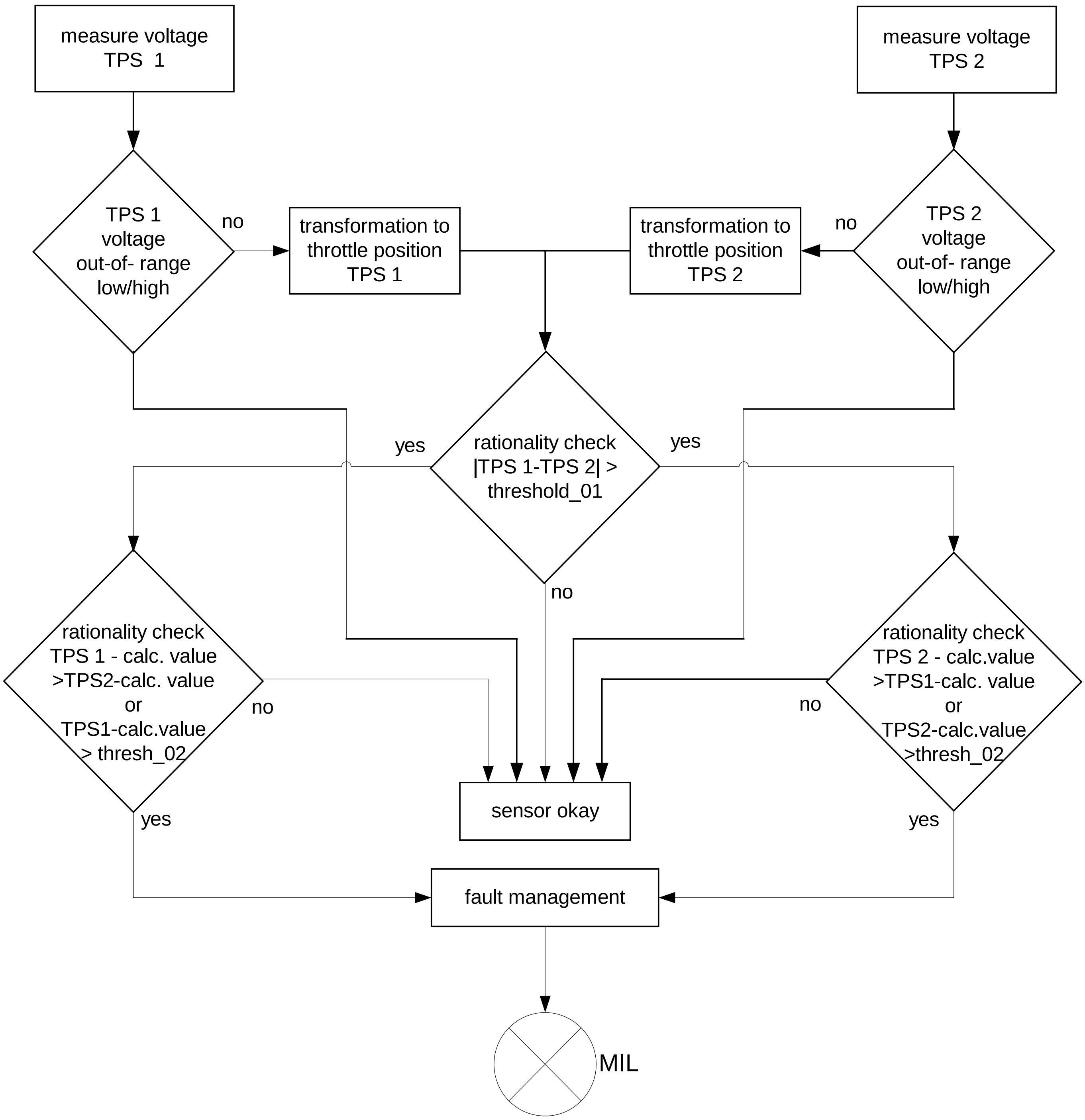


.16.08.00 Vehicle Speed Sensor (VSS)

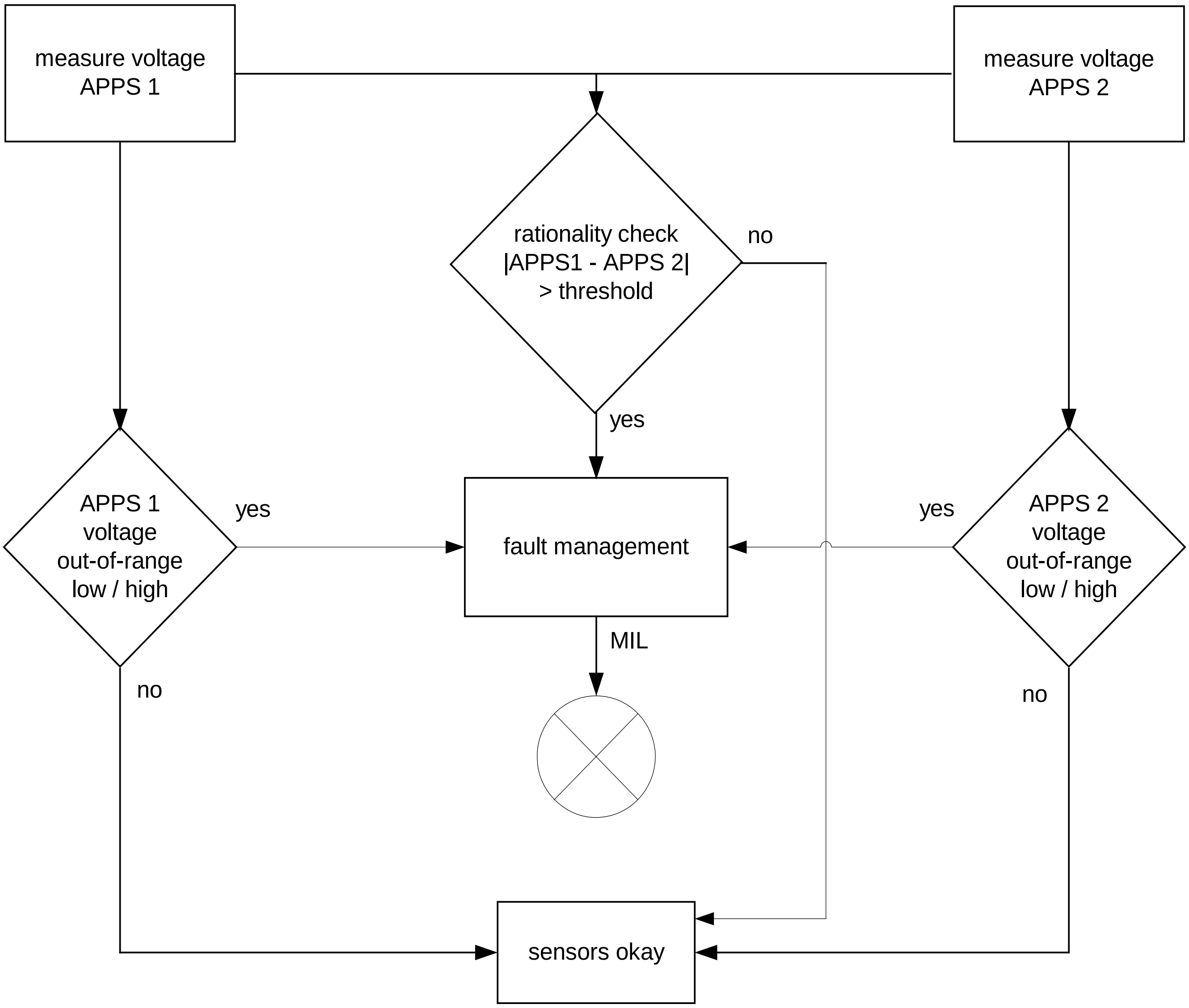


.16.09.00 Throttle Position Sensor (throttle unit with E-gas actuator)

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 a threshold value 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.

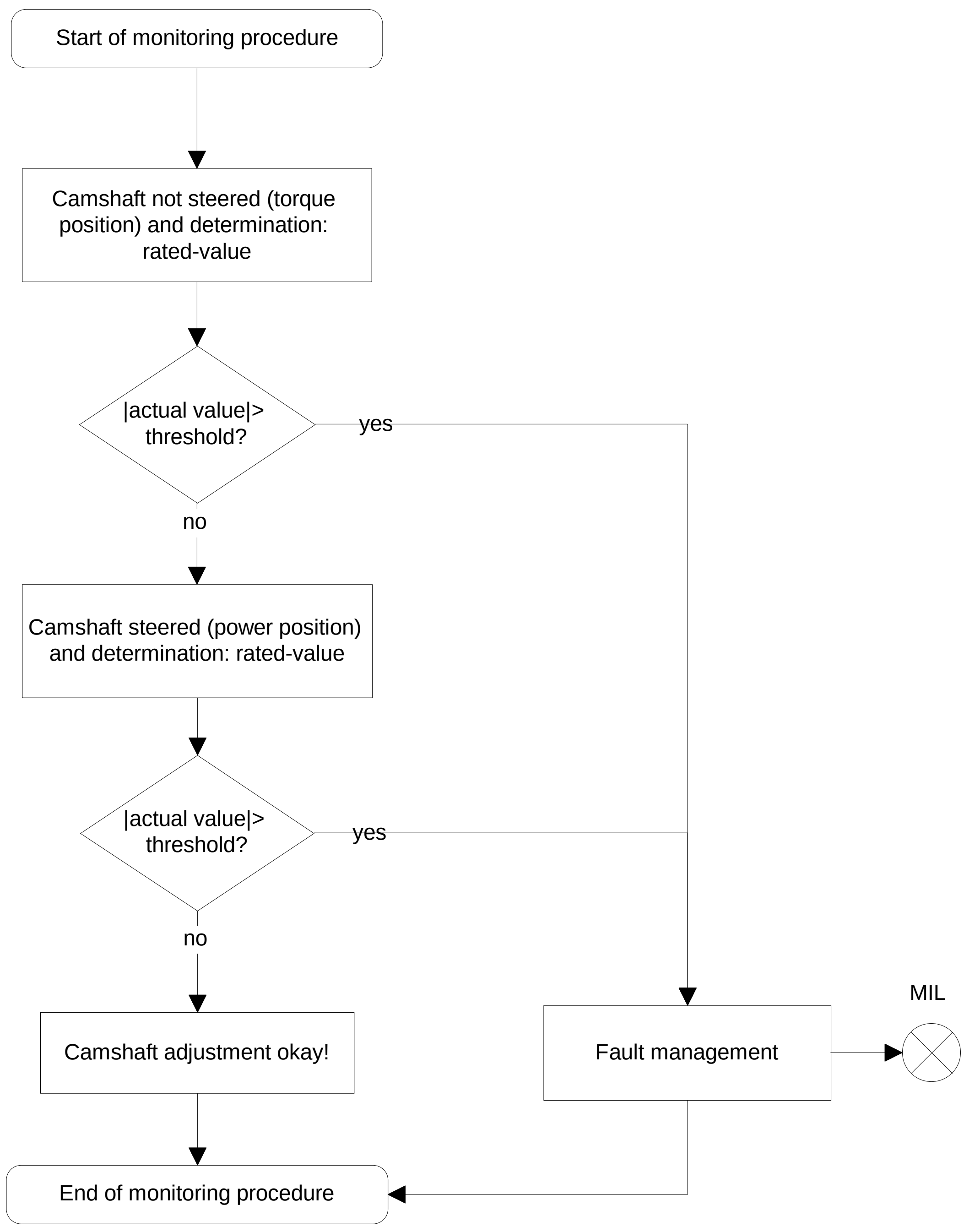


.16.10.00 Accelerator pedal position sensor (APPS)

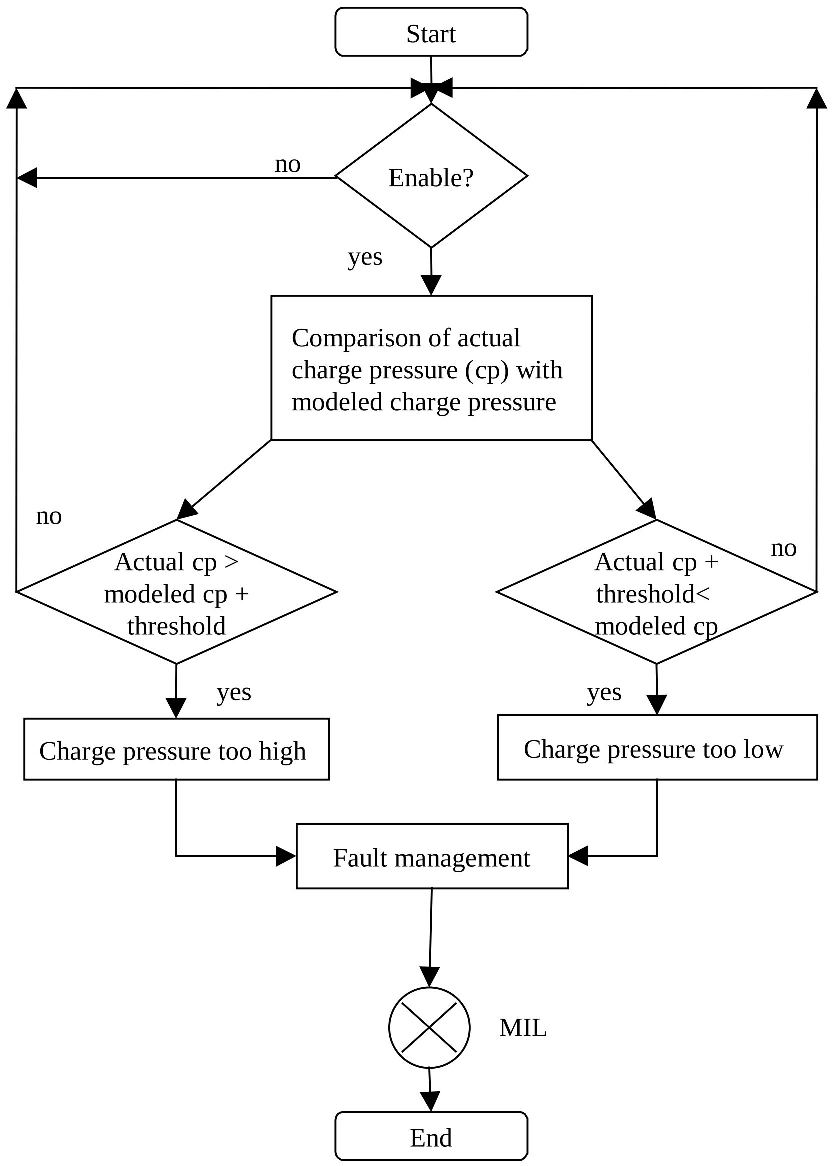


.16.11.00 Camshaft Position Sensor

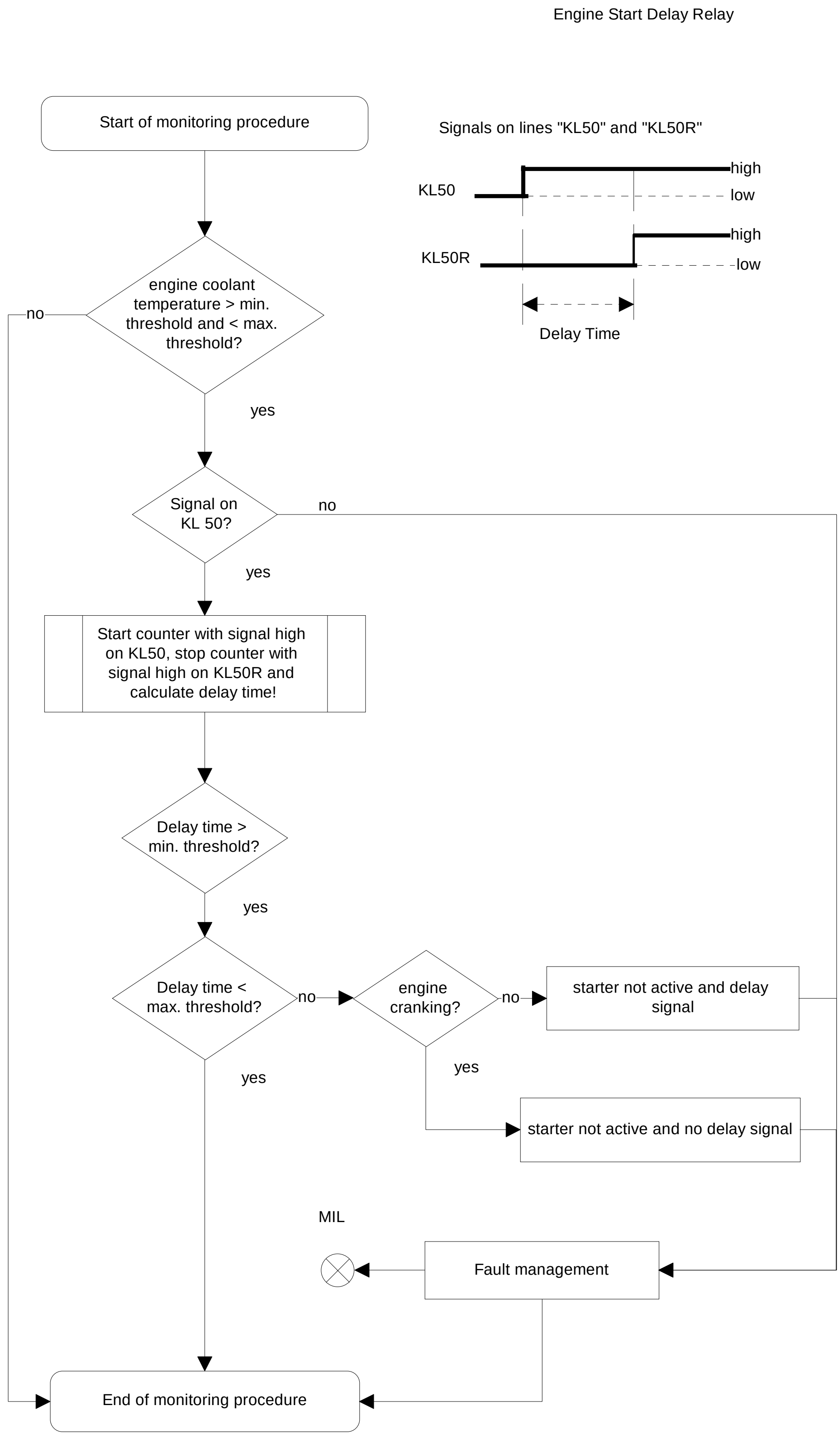
Camshaft Position Monitor



.16.12.00 Boost Pressure Control Valve



.16.13.00 Engine Start Delay Relay (SULEV)



.16.14.00 Exhaust Temperature Sensor (SULEV)

.16.14.01 General Monitoring Description

The exhaust temperature sensor (ETS) is monitored for rationality during engine cold start, where engine coolant temperature, intake air temperature and exhaust temperature are expected within the same temperature range ("stuck high" check).

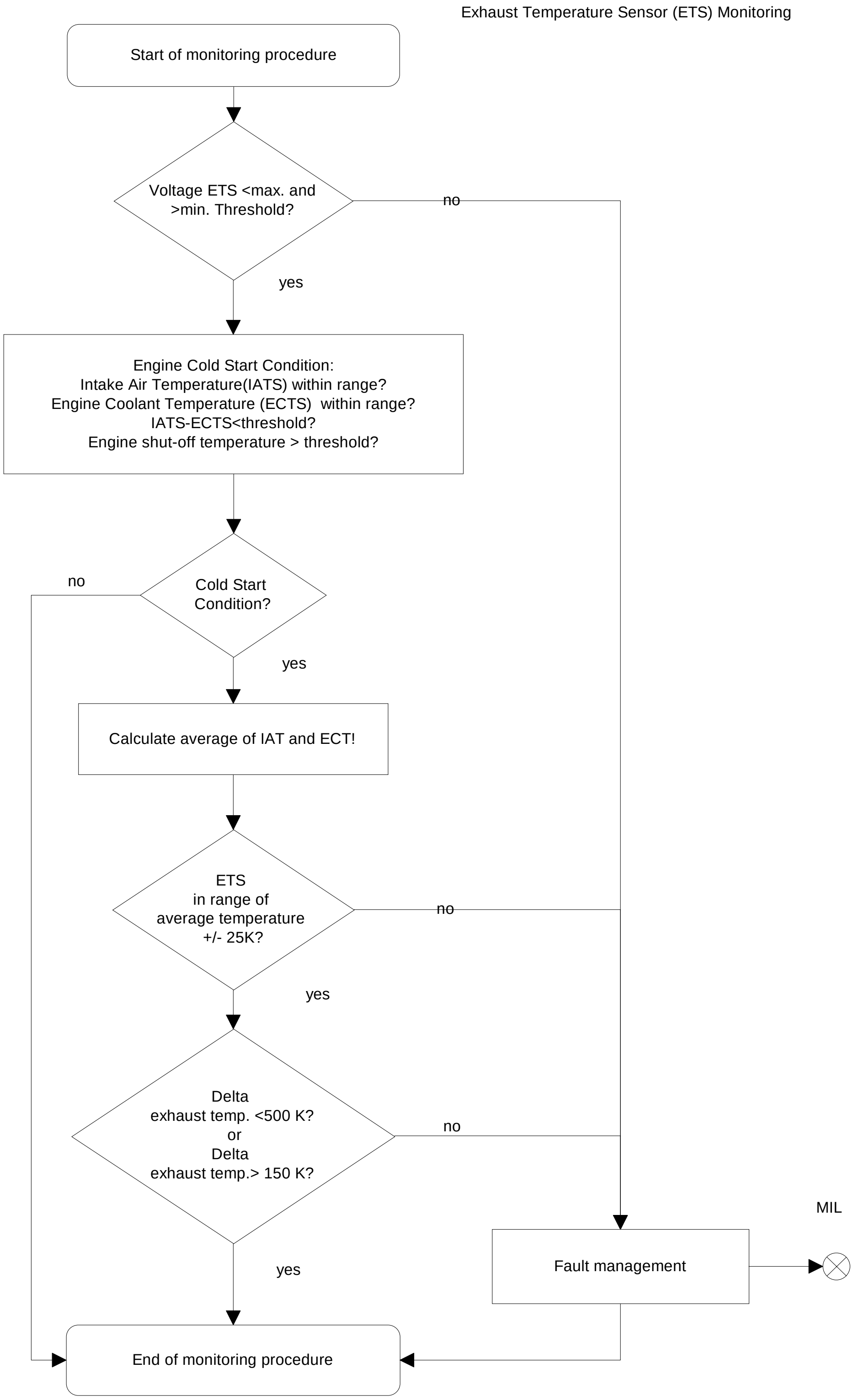
.16.14.02 Monitor function description

After engine has been cold started the slope of ETS is monitored and should not be higher than a max. threshold and not lower than a min. threshold.

Both plausibility checks are completed before the ETS information is used in other monitors (e.g. secondary air).

Additionally the final stage check monitors for shorts to ground or to battery.

.16.14.03 Chart(s) and Flow Chart (s)



.16.15.00 reserved
.16.16.00 reserved
.16.17.00 reserved
.16.18.00 reserved
.16.19.00 reserved

.16.20.00 Automatic Transmission Monitor

VW/Audi has different basic Automatic transmission systems. For each of these systems we are providing an OBD II summary table. Common OBD description from VW/Audi table TCM Groups show the references between transmission type and test groups.

.16.21.00 Output Stage Check

The output stages are integrated in manufacturer specific IC's:

The 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.

Signal tables of output stage check

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

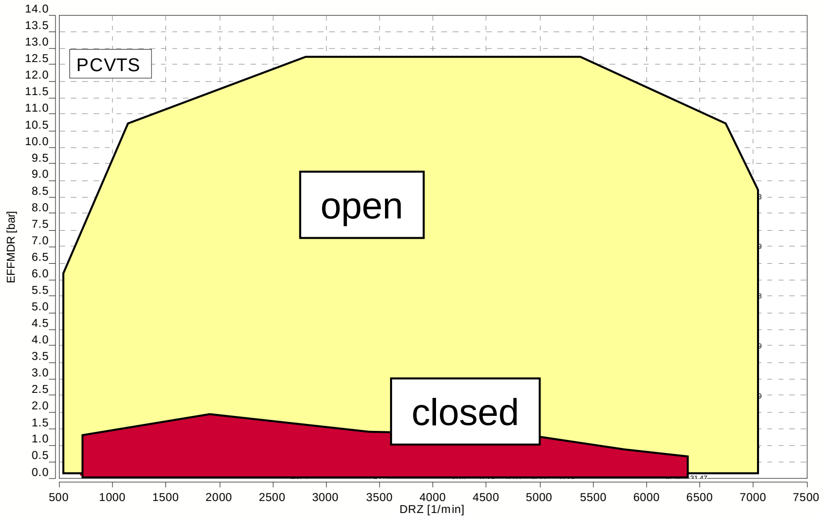
U_{in} input voltage
U_{out} output voltage
I_{out} output current

.17.00.00 Other Emission Control or Source System Monitoring

.17.01.00 Intake manifold runner flap monitoring

.17.01.01 General Description

To improve the robustness of the combustion in terms of fuel preparation, especially at low load conditions, an electrical motor driven 2-point intake manifold runner flap system is introduced.
The target position of the flaps is shown in the engine operation map beside.



The intake manifold runner flaps are located directly in the inlet area of each cylinder. The position control sensor is located inside of the actuator unit.
The spring-driven default position for the flaps is ➔ open.

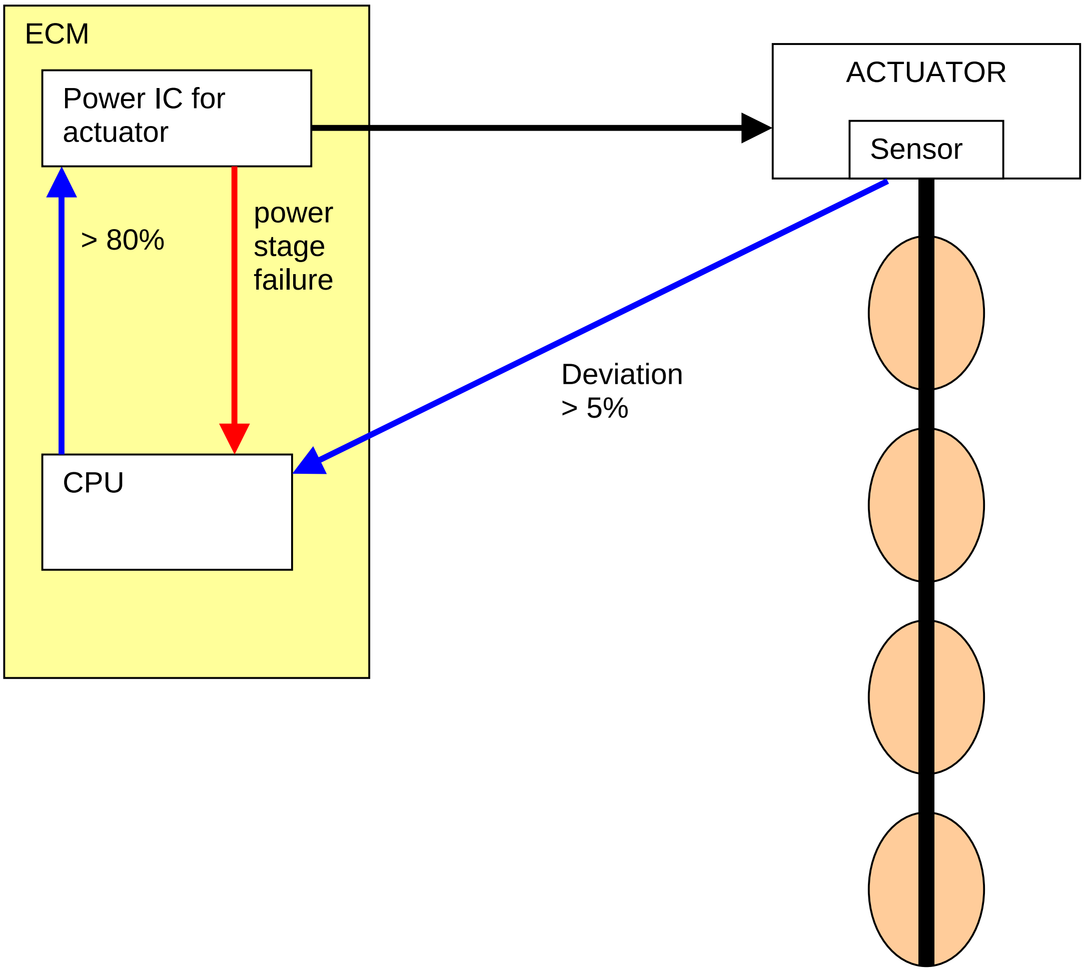
.17.01.02 Monitoring function description

Component:

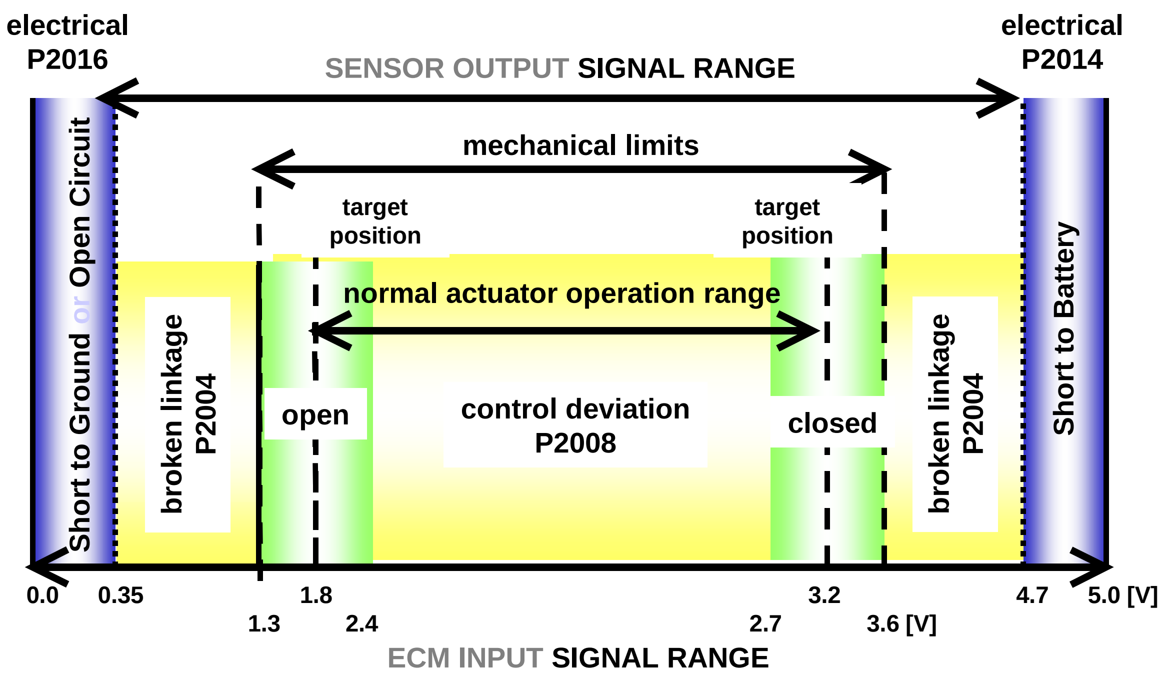
Several electrical and rationality checks are implemented to monitor the correct runner flap position and system reaction. The main signal for those monitor is the sensor position signal voltage

.17.01.03 Charts and flow charts

Electrical fault	
DTC's	P2008
Malfunction 1	Signal duty cyle > 80% and ECM power stage failure
Malfunction 2	Deviation > 5% and ECM power stage failure
Examples:	Open circuit, shorted wires, internal hardware failure
Rationality check	
DTC's	P2015
Malfunction 1	Signal duty cyle > 80%
Malfunction 2	Deviation > 5%
Examples:	High friction, stuck flaps,



Electrical fault	
DTC's	P2016 / P2016
Malfunction 1	Short to ground, open circuit / Short to battery
Rationalty check	
DTC's	P2016 / P2016 (once per driving cycle)
Malfunction 1	Sensor sent signal below mechanical linkage but no electrical fault.
Malfunction 2	Sensor sent signal above mechanical linkage but no electrical fault.
Function description	After ignition off the flaps are in the default open position. During keep alive time, an intrusive check will be performed: 1. Flaps commanded closed: mechanical limit < 3.6V expected 2. Flaps commanded open : mechanical limit > 1.3 V is expected
Example for failure	broken shaft



.18.00.00 Exemptions to Monitor Requirements

.19.00.00 reserved

.20.00.00 Parameters and conditions for closed loop operation

General

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 (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.

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 °C for binary and >685 °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 due 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 0,4V<sensor voltage<0,5V
- 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°C or the internal sensor resistor Ri < 130 Ω.

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.

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<λ<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

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

.21.00.00 Parameters / conditions for 2nd closed loop operation

Conditions for closed loop operation of the second control loop

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.

Parameters evaluated to begin closed loop (second control loop)

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 2nd 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

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 2nd control loop, P-portion of controller for 2nd control loop	Oxygen sensor monitor for secondary sensor(s). Fuel system monitor

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.

.22.00.00 Parameters / conditions for closed loop operation on SULEV

General

The SULEV concept consists of 2 catalysts and 3 control loops. The first control loop uses the Oxygen sensor pre catalyst (LSU) in the same manner conventional concepts do. The Oxygen sensor between the two bricks (LSF1) of the catalyst is the input for the second and the Oxygen sensor after the last brick (LSF2) is the input for the third control loop. Both sensors are binary Oxygen sensors. The closed loop operation of each of the control loops are in a depending order of 1^{st}, 2^{nd} and 3^{rd} control loop.
In comparison to post catalyst control loop on conventional concepts the 2^{nd} and 3^{rd} control loop are high precision loops with specific requirements for short-term correction and long term adaptation. The driving conditions have to be stable and constant to allow any corrections by these control loops. The allowed correction steps are much smaller in comparison to post catalyst control loop applications on conventional concepts.

Conditions for closed loop operation of the first control loop

The conditions for closed loop operation of the first control loop on the SULEV concept are the same as described for conventional concepts.

Conditions for closed loop operation of the second control loop

The second control loop on the SULEV concept is designed as natural frequency control loop and is based on a binary Oxygen sensor. The controller has the same capability in achieving maximum conversion on the first brick of the catalyst by using a proportional adjustment range for short-term correction and an integral adjustment range for long-term adaptation (PI-controller). Both controller ranges have individual conditions for closed loop operation.

Enable criteria for P-portion of the controller of second control loop (SULEV)

The proportional-portion of the controller corrects short term deviations.

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 2nd 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.
Engine Coolant Temperature	Engine coolant temperature has raised above a limit value of 50 °C (typical temperature value; may differ on specific application)	Engine Coolant Temperature Sensor Monitor. Engine Cooling System Monitor.
Catalyst model temperature	Exhaust Temperature > threshold (above light-off temperature), 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	Controller for the first control loop not at minimum or maximum threshold	Oxygen sensor monitor

Enable criteria for adaptive I-portion of the controller second control loop (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 1500-5000 rpm Engine Load within 15-100% (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 2nd control loop, P-portion of controller for 2nd control loop	Oxygen sensor monitor for secondary sensor(s). Fuel system monitor

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 80s.

Conditions for closed loop operation of the third control loop

The third control loop is designed like the second control loop on conventional concepts and achieves the maximum conversion of the 2nd brick of the catalyst. The controller consists of very restricted correction ranges for the short-term proportional and the long-term integral adaptive portion (PI-controller). Both controller ranges have individual conditions for closed loop operation.

Enable criteria for P-portion of the controller of third control loop (SULEV)

The proportional-portion of the controller corrects short term deviations.

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
Closed loop condition for the **second control loop**. Minimum of integrated mass air flow passed.	No fault detected in LSU System (Sensor, wiring, IC) and no fault at LSF1 and LSF2. Fuel control performs normal, no fault is detected and fuel control is not temporarily disabled.	Oxygen sensor monitor for the front sensor(s). Oxygen sensor monitor for the first downstream sensor(s) and Oxygen sensor monitor for the second downstream sensor(s). Monitor of the mass air flow meter (out of range, rationality). Fuel system monitor
Oxygen Sensor for 3rd 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 (above light-off temperature), 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	Controller for the first control loop not at minimum or maximum threshold	Oxygen sensor monitor

(**LSU**: Linear Oxygen Sensor**, LSF1**: 1st Binary Oxygen Sensor, **LSF2**: 2nd Binary Oxygen Sensor)

Enable criteria for adaptive I-portion of the controller third control loop (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 2700-3500 rpm Engine Load within 25-45% (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 2nd control loop, P-portion of controller for 2nd control loop	Oxygen sensor monitor for secondary sensor(s). Fuel system monitor

Typical Values (third control loop)

Given a normal cold started FTP (around 20°C) most of the concepts reaches the closed loop condition for the third control loop within 90s to 100s.