Project: MSS54

Module: Lambda sensor aging monitoring

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1st General

This function “Lambdason aging monitoring” is used to detect aging effects of the sensor before the catalytic converter (VKAT) or a defective sensor after the catalytic converter (NKAT) and thus prevent an inadmissible exceedance of the emission limits.

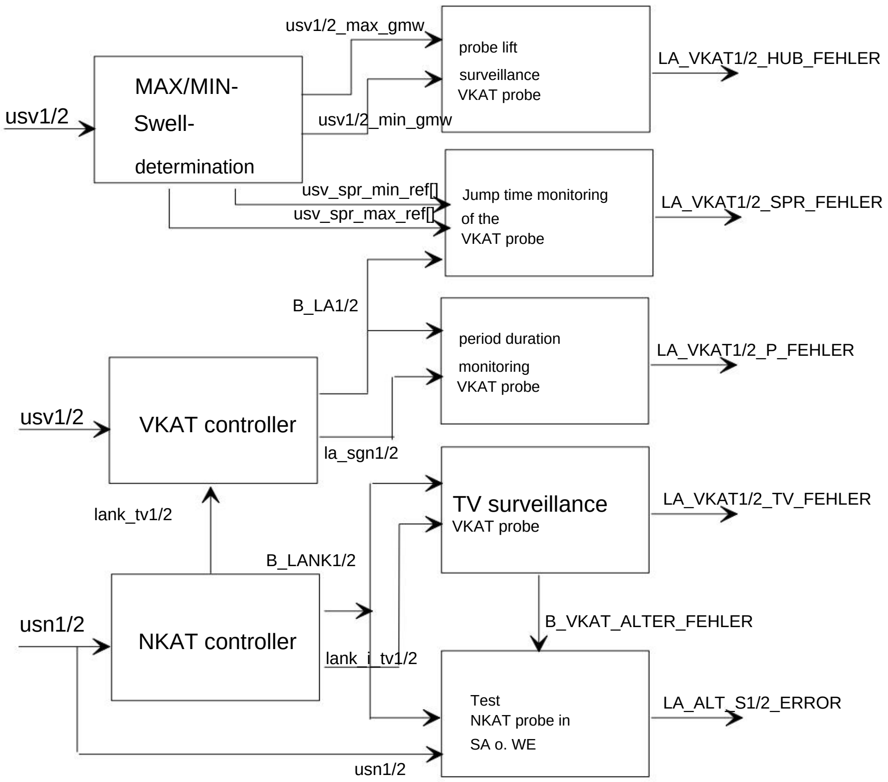
An aged sensor can lead to an increase in exhaust gas values both statically (by shifting the characteristic curve) and dynamically (“slow” sensor).

The control variable of the NKAT controller (TV shift) is used to detect and correct a shifted characteristic curve. The following diagnostics are used for monitoring:

• TV surveillance
• Checking the sensor behind the catalytic converter during acceleration or when reinstalling

To detect a too slow lambda sensor in front of the catalytic converter,
the • stroke monitoring
• Period duration monitoring
• Jump time monitoring
of the probe signal.

1.1. Overview of lambda sensor aging monitoring



1.2. Switch-off conditions of the lambda sensor aging monitoring

The functions will be stopped as soon as one of the following conditions is met:

- **Dropout detection error**
  => B_AUSS_FEHLER

- **Throttle potentiometer error**
  => !B_WDK_FEHLERFREI_DPR

- **Probe heating error VKAT or NKAT**
  => B_LSHV1/2_ERROR
  => B_LSHN1/2_ERROR

- **NW - Error**
  => B_TPU_360MODE

- **Error in the tank ventilation system or in the diagnosis**
  => B_TEV_FEHLER

- **UBATT - threshold** was exceeded
  => ub <= K_ED_UBMIN
  => B_UB_FEHLERZ

- **Errors for the VKAT or NKAT sensors regarding exceeded adaptation error thresholds**
  => LAA1/2_SCHW

- **Secondary air injection is active during SL diagnosis or secondary air fault is present**
  => B_SLP_ON (is also set here; but is not queried in the diag. - is set via LA conditions intercepted.)
  => B_SLS_KLEMM_FEHLER
  => B_SLV_SH_TO_GND

- **Functional Check TEV is active in idle**
  => B_TEFC_LL_CHECK

- **Fuel system diagnosis detects an error**
  => B_KSD1/2_ERROR

- **Stroke monitoring detects too small an amplitude**
  => B_LA_VKAT1/2_HUB_FEHLER

- **CAT protection is active when the tank is empty**
  => B_KATS_MD_RED

All these general switch-off conditions are summarized in one condition **B_LA_ALTER_AUS** (BIT0/1 in la_alter_st), which is used for all lambda sensor aging monitoring functions.

2. TV monitoring of the VKAT regulator (only for 6-cylinder)

In the 2-probe system, the shift in the VKAT probe characteristic curve due to aging is superimposed on the TV shift of the NKAT controller. However, if the value of the TV shift leaves a permitted range, this indicates a probe error in the VKAT probe.

This diagnosis takes place in 1s intervals.

2.1. Switch-on and switch-off conditions for the ageing monitoring of the VKAT probe

Switch-on condition:

* In order to be able to start this diagnosis at all, it must be ensured that the determination of the I component of the NKAT controller is active.
=> **B_LANK1/2_I**

* Furthermore, it must be ensured that the probe signal is within the filter band. swinging is
=> **B_LANK_TAU1/2_OK**

* To activate the function, BIT0 must be set in the application **constant K_LA_OBD_FREIGABE** set. (LA_ALT_TV_FREIGABE)

Switch-off conditions:

The function is stopped as soon as a

• **KAT conversion** error
An old or defective catalytic converter causes a TV shift, which can lead to a VKAT sensor being incorrectly identified as defective. A defective VKAT sensor, in turn, blocks the KAT conversion, so that a defective catalytic converter cannot be identified at all.

=> already in the condition !B_LANK1/2_I

• **a general switch-off condition** exists
=>B_LA_ALTER_AUS

• another **VKAT sensor error** was reported
=> B_LA_ALTER_P_FEHLER
=> B_LA_ALTER_SPR_FEHLER

If all switch-on conditions are met and no switch-off condition is active, the Diagnosis enabled => BIT6 / BIT7 in la_alter_st

2.2. Functional definition of the aging monitoring of the VKAT probe

This diagnosis runs continuously in 1s intervals. As soon as the TV shift to be monitored exceeds or falls below the diagnosis thresholds, the diagnosis counter is treated accordingly.

The averaged I-component of the trim control is monitored => lank_i_tv_gem[]

If this averaged TV shift exceeds the **max. threshold K_LA_ALT_TV_MAX,** the diagnostic counter **la_alt_tv_max[]** is incremented by **K_LA_ALT_TV_INC .**

If the TV shift lank_i_tv_gem falls below the **minimum threshold K_LA_ALT_TV_MIN,** the diagnostic counter **la_alt_tv_min[]** is incremented by **K_LA_ALT_TV_INC .**

If **no threshold is exceeded or undershot,** the corresponding diagnostic counter is decremented by **K_LA_ALT_TV_DEC.**

In general, the diagnostic counters la_alt_tv_min/max are limited to ZERO and max. 255.

A VKAT sensor is said to be defective as soon as

la_alt_tv_max[] > K_LA_ALT_TV_MAX_COUNT

or

la_alt_tv_min[] > K_LA_ALT_TV_MIN_COUNT

is; in this case the state **B_LA_ALTER_TV_FEHLER1/2** (LA_VKAT1/2_TV_FEHLER) set.

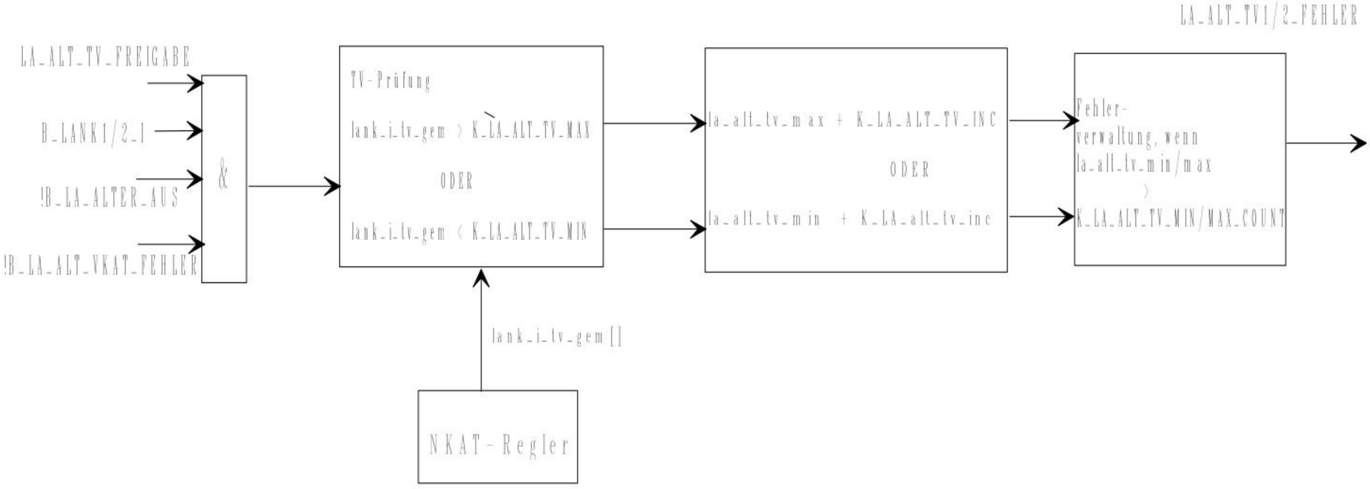
Once this error is detected, the following diagnostics are blocked:
- ÿ Period duration measurement
- ÿ Jump time measurement
- ÿ Monitoring of the NKAT probe (SA/WE check)
- ÿ KAT conversion

If the min. or max. diagnostic counter threshold is exceeded, the diagnostic function **ed_report** is used to enter either the error of the type **"TV threshold exceeded"** (SH_TO_UB) or **"TV threshold not reached"** (SH_TO_GND) in the error memory (the entry appears immediately in the error memory - debounce counter etc. = 1 - because the debounce algorithm is involved in the decrementation of the diagnostic counter.

The error type **“no error present”** (NO_ERROR) is called when the readiness formation requires it or when the diagnostic counter is at ZERO for an entered error.
In order to prevent a turbo recovery when the engine is started again, the diagnostic counter is stored in a non-volatile memory if an error occurs.

The MIL lamp is activated when the diagnosis detects a limit violation on two consecutive driving cycles (DrCy).

2.3. Graphical representation of the aging monitoring of the VKAT probe



3. Period monitoring of the VKAT probe signal

This function detects a deterioration in the dynamics of the VKAT lambda probe, which leads to a deterioration in the exhaust gas values.

This period measurement is performed every 10ms; directly after the VKAT and NKAT functionalities. The diagnosis itself takes place in 100ms intervals.

3.1. Switch-on conditions for period duration monitoring

The function is released when

• there is **no general switch-off condition**
=> !B_LA_ALTER_AUS

* BIT1 is set **in** the application constant **K_LA_OBD_FREIGABE**
=> LA_ALT_P_RELEASE

• there is **no air mass error**
=> !B_HFM_FAILURE

• **Lambda control VKAT** is active

=> B_LA1/2

• the **speed is in a certain window** and there is **no N-dynamics**
=> **K_LA_ALT_P_N_MIN < n < K_LA_ALT_P_N_MAX**
=> !B_N_DYNAMIK

• the **load is in a certain window** and there is **no RF dynamics**
=> **K_LA_ALT_P_RF_MIN < rf < K_LA_ALT_P_RF_MAX**
=> !B_RF_DYNAMIK_LA

• the exhaust gas temperature is **above a threshold value**
=> **tabg > K_LA_ALT_P_TEMP**

• the **tank ventilation valve** is closed **(!B_TE_SPUEL)** or the time **K_LA_ALT_P_TE_T** has elapsed after the valve was opened .

• there is no trimming due to **catalytic converter clearing**
=>!B_LA_KA

• no trimming by **NKAT diagnosis** is present
=>la_alter_s_tv == 0

• there is no **OBD-VKAT sensor error**
=> !B_LA_ALTER_TV_FEHLER
=> !B_LA_ALTER_SPR_FEHLER

These conditions are summarized in **B_LA_ALTER_P1/2** (BIT0/1 in la_alt_p_st).

3.2. Period duration measurement

The period duration is measured between **two RICH-LEAN jumps** of the sensor signal (transition from la_sgn: -1 => +1; +blocking time).

First, it must be ensured that one is in a **stationary lambda range** (control deviation <= 5%, B_LA1/2_DYNAMIK). Since disturbances can occur after a jump, the period duration measurement is only started after the blocking time **K_LA_ALT_P_VERZ_T** has elapsed.
carried out. If the sensor signal is at the "lean" mixture level at the end of the measurement, the period duration measurement is evaluated as valid. This blocking time is processed after each RICH-LEAN jump. This determined period duration is corrected by the **current TV shift** la_p_tv1/2 (= la_sum_tv1/2) and then, before the actual evaluation, weighted with a weighting factor from the map **KF_LA_ALT_P_FAK_N_RF** => this value can be found in **la_alt_p_mess_of[]**

The mean value **la_alt_p_mess1/2** is calculated from these values using a PT1 filter (K_LA_ALT_P_TAU) .

To make the period duration monitoring more reliable, a defined number of **K_LA_ALT_P_ANZ_SPR** of valid measured periods hidden **from** the start of the function ie the period counter *la_alt_p_anz_spr* is always reset when the switch-on conditions are no longer met.

If the sum of all valid measured periods exceeds the number **K_LA_ALT_P_ANZ_DIAG** *(la_alt_p_anz_diag) ,* the averaged period **la_alt_p_mess1/2** is compared with an upper limit **K_LA_ALT_P_MAX** and a lower value **K_LA_ALT_P_MIN .**
However, if there is a KAT conversion error **(B_LA_KONV_FEHLER) ,** stricter thresholds are used - **K_KAT_P_MAX_KONV** and **K_KAT_P_MIN_KONV.**

After the diagnostic time has expired, the **ed_report** function is used to enter either the error of the type **"exceeding the period duration threshold"** (SH_TO_UB) or **"falling below the period duration threshold"** (SH_TO_GND) or **"no error present"** (NO_ERROR) into the error memory - LA_VKAT1/2_P_ERROR.

This error entry also only occurs once during an engine run (debounce counter etc. = 1). The MIL lamp is activated when the diagnosis detects a threshold being exceeded on two consecutive driving cycles (DrCy).

When the adaptation data is deleted or if an error occurs when reading from the FLASH, the period duration **la_kat_p_mess1/2** is reset to the INIT value ((K_LA_ALT_P_MAX + K_AL_ALT_P_MIN)/2). Otherwise, **la_kat_p_mess1/2** is initialized with the **last value saved in the FLASH** at each restart .

3.2.1. Determination of a valid period

To determine a valid period duration, an auxiliary variable la_p_mess_st was introduced.

From the first measurement after the switch-on conditions have been met:

Set auxiliary variable to starting point la_p_mess_st = 0xFF
1. Increasing the delay time for a FAT->LEAN jump
la_p_mess_st = la_p_mess_st + 0x80 = 0x7F (= invalid measurement)

2. Check after delay time in which area you are now standing
on LEAN: store start time for subsequent period duration measurement; la_p_mess_st = 0x80 **on BOLD:** this
is an invalid range; a measurement cannot be started from here;
la_p_mess_st = 0xFF

3. Increase the delay time at the next FAT->LEAN jump;
la_p_mess_st = la_p_mess_st + 0x80

4. Check after delay time in which area you are now standing:
to MAGER & la_p_mess_st == 0: valid measurement performed; store start time for subsequent period measurement;
la_p_mess_st = 0x80

to MAGER & (la_p_mess_st == 0x7F || la_p_mess_st == 0xFF):
previous measurement was not started because

was in an invalid range;
Start time for measurement can now be saved,
since you are now in a valid area;
la_p_mess_st = 0x80

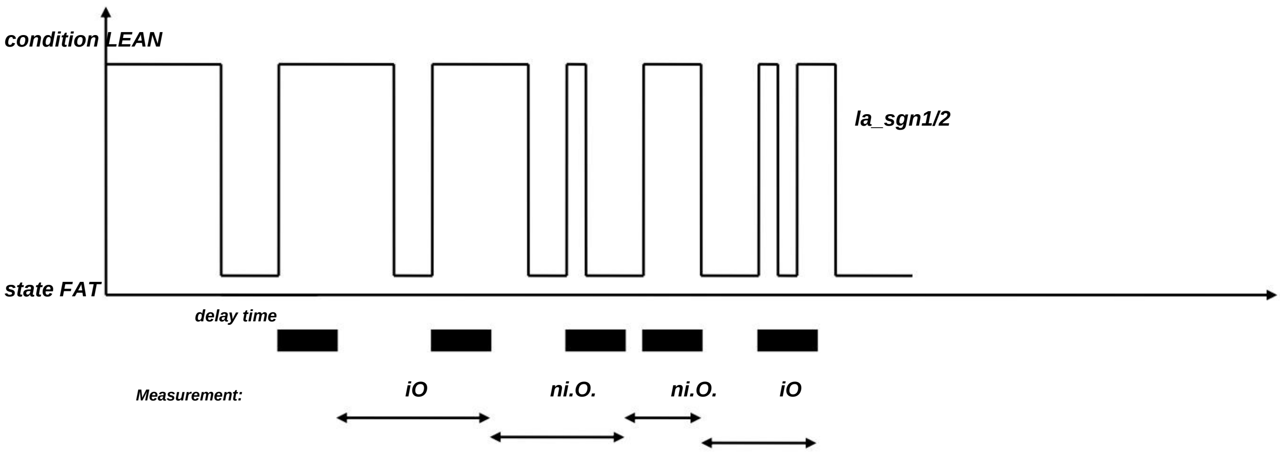
in BOLD: this is an invalid area; a measurement cannot be started from here

if you came out of a valid range (la_p_mess_st == 0), a fault has occurred; measurement is aborted => la_p_mess_st = 0xFF

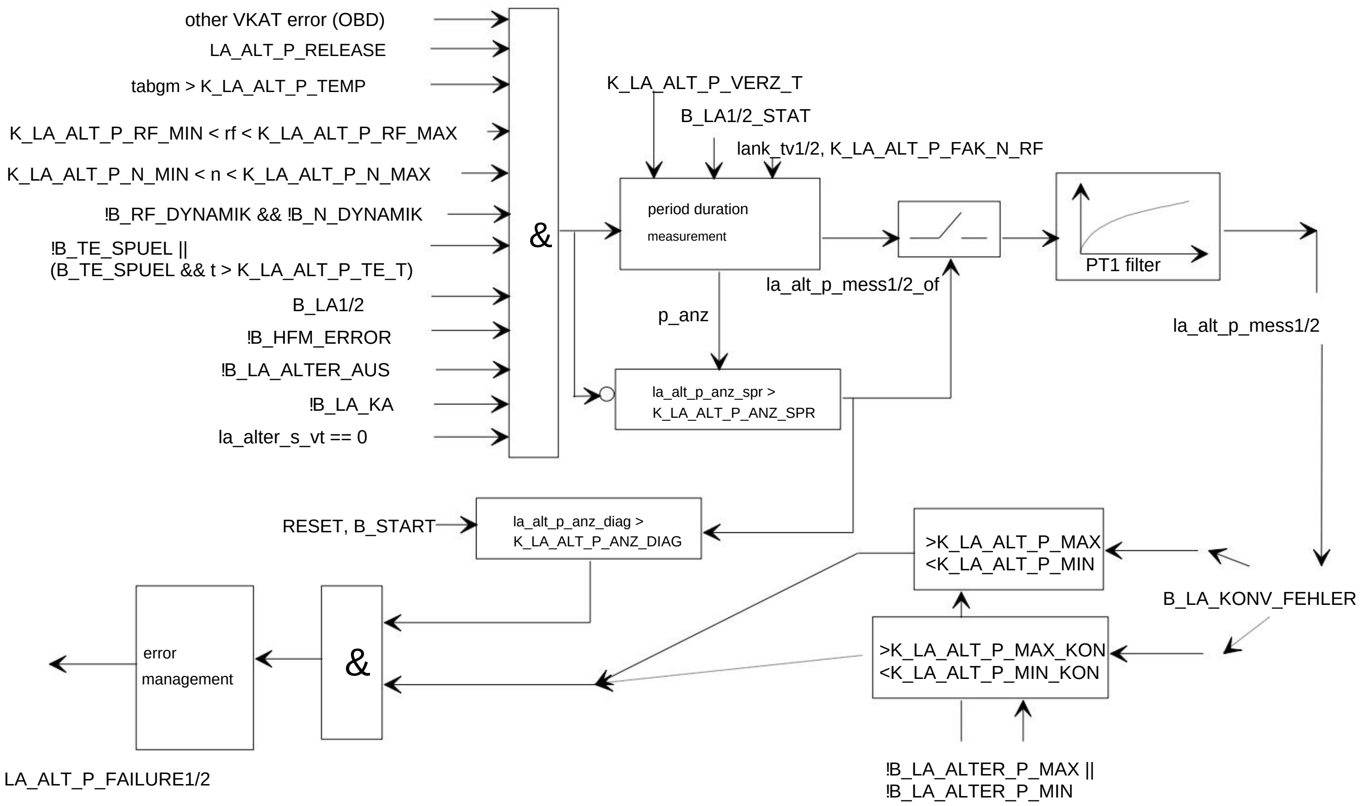
If you have already left an invalid range (la_p_mess_st == 0x7F), the Auxiliary variable is not changed (consecutive faulty periods are thus easy to recognize)

Jump back to point 4

3.2.2. Graphical representation of a measurement



3.3. Graphical representation of the period measurement



4. Stroke monitoring of the probe signal VKAT

One way to diagnose the VKAT probe is to monitor the probe stroke.

For this purpose, the mean maximum (usv1/2_max_gemw) and the mean minimum (usv1/2_min_gmw) probe voltages are determined.

This measurement is taken every 10ms - the diagnosis is processed continuously

4.1. Switch-on conditions for stroke monitoring

The function is released

• within an RF band

K_LA_USV_GMW_RF_MIN < rf < K_LA_USV_GMW_RF_MAX

The reason for this is that at a very low rf, the probe signal becomes extremely low and thus distorts the minimum mean value. The same thing happens in the opposite direction at very high rf - here the upper mean value is distorted.

• the **lambda controller must be active** (B_LA1/2)

4.2. Determination of mean values

To determine the mean values, voltage signals that are above or below limit voltages are used.

The **limit stresses** are determined as follows and must meet the following conditions:

if

(usv1/2_max_gmw - usv1/2_min_gmw) <= (2 * K_LA_USV_GMW_HYS)

=> usv1/2_limit_ob = usv1/2_limit_unt =
(usv1/2_max_gmw + usv1/2_min_gmw) /2

as soon as

usv1/2_limit_ob >= usv1/2_limit_unt

=> usv1/2_limit_ob = usv1/2_max_gmw + K_LA_USV_GMW_HYS

usv1/2_limit_unt = usv1/2_min_gmw - K_LA_USV_GMW_HYS

The **mean values** are calculated using **PT1 averaging ,** where the **filter constant is K_LA_USV_GMW_TAU .**

The voltages that are above or below the limit voltages are included in the averaging.

Condition:

- usv1/2 > usv1/2_grenz_ob

  => usv1/2_max_gmw = pt1(usv1/2, usv1/2_max_gmw, K_LA_USV_GMW_TAU)

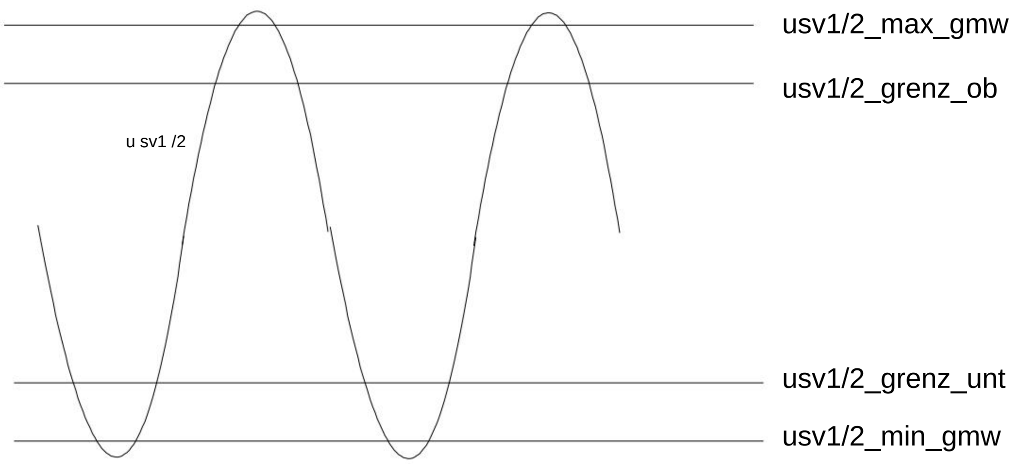
- usv1/2 < usv1/2_grenz_unt

  => usv1/2_min_gmw = pt1(usv1/2, usv1/2_min_gmw, K_LA_USV_GMW_TAU)

INITIALIZATION:

The values are reinitialized as follows during a RESET, a new driving cycle or after clearing the error memory.

usv1/2_min_gmw = K_LA_USV_GMW_MIN_INI
usv1/2_max_gmw = K_LA_USV_GMW_MAX_INI
usv1/2_limit_ob = K_LA_GRENZ_INI
usv1/2_limit_unt = K_LA_GRENZ_INI



4.3. Stroke diagnosis

This diagnosis occurs every 100ms if the following conditions are met.

• the **lambda controller must be active** (B_LA1/2)

• a certain number of P-jumps must have taken place
(will be reset when LA becomes inactive)

la_p_spr_count1/2 > K_LA_USV_HUB_P_SPR

probe stroke:

la_vkat1/2_hub = usv1/2_max_gmw - usv1/2_min_gmw

A **probe stroke error** occurs when the stroke falls below a certain threshold

la_vkat1/2_hub < K_LA_USV_HUB_DIAG

=> LA_VKAT1/2_HUB_FEHLER

Measures:

In case of a lifting error

• the lambda control of the affected bank is stopped by the operational readiness withdrawn

• the adaptation is blocked and reset

• the VKAT and NKAT probe diagnosis is blocked

• the KSD diagnosis is blocked

• the KAT conversion diagnosis is blocked

5th Jump time monitoring of the probe signal VKAT

Both sensors in front of the catalytic converter are monitored separately for rich and lean switching times.

This can be used to detect a deterioration in the dynamics of the VKAT lambda probe, which leads to a deterioration in the exhaust gas values.

This measurement is taken every 10ms until the diagnostic time has expired.

5.1. Switch-on conditions for monitoring

The function is released when

• there is **no general switch-off condition**
=> !B_LA_ALTER_AUS

* BIT **7** is set in the application constant **K_LA_OBD_FREIGABE**
=> LA_ALT_SPR_FREIGABE

• there is **no air mass error**
=> !B_HFM_FAILURE

• **Lambda control VKAT** is active and there is **no LA dynamic**
=> B_LA1/2
=> !B_LA1/2_DYNAMIK

• the **speed is in a certain window** and there is **no N-dynamics**
=> **K_LA_ALT_SPR_N_MIN < n < K_LA_ALT_SPR_N_MAX**
=> !B_N_DYNAMIK

• the **load is in a certain window** and there is **no RF dynamics**
=> **K_LA_ALT_SPR_RF_MIN < rf < K_LA_ALT_SPR_RF_MAX**
=> !B_RF_DYNAMIK_LA

• the **reference thresholds from which the jump time is determined** are calculated
=> B_LA_ALTER_SPR_REF1/2

• the exhaust gas temperature is **above a threshold value**
=> **tabg > K_LA_ALT_SPR_TEMP**

• there is no trimming due to **catalytic converter clearing and sufficient air through the catalytic** converter
=>!B_LA_KA && !(la_kat_ausr_st & BIT_KA_LANK_ML_SCHW)

• there is no trimming by **NKAT diagnosis**
=>la_alter_s_tv == 0

• there is no **OBD-VKAT sensor error**

=> !B_LA_ALTER_TV_FEHLER
=> !B_LA_ALTER_P_FEHLER

These conditions are summarized in **B_LA_ALTER_SPR1/2** (BIT0/1 in la_alt_spr_st).

5.2. Determination of reference thresholds

Relative thresholds are used to determine the switching times of the sensor (rich -> lean and lean -> rich). These relative thresholds are 10% and 90% of the signal swing, respectively.

The signal stroke is made up of the upper signal value usv1/2_max_gmw and the lower signal value usv1/2_min_gmw (for determination, see stroke monitoring).

The reference thresholds are recalculated every 1 s.

Prerequisite: a certain number of **P-jumps** after LA-Active must have expired:

la_p_spr_count1/2 > K_LA_USV_SPR_P_SPR

Determination:

- **usv_spr_min_ref** [ ] = usv1/2_min_gmw
  + ((usv1/2_max_gmw - usv1/2_min_gmw) * 0.1)

  => **10%** of the signal swing, based on the lower signal value
  => set **BIT2** in **la_alt_spr_st**

- **usv_spr_max_ref** [ ] = usv1/2_min_gmw
  + ((usv1/2_max_gmw - usv1/2_min_gmw) * 0.9)

  => 90% of the signal swing, relative to the lower signal value
  => set **BIT3** in **la_alt_spr_st**

5.3. Monitoring for turning points

In order to detect improper switching of the probe, the probe signals are monitored for reversal points (RICH / LEAN peak) during the measurement of the switching times. If a reversal point is detected, this signal change is not used for diagnosis

FAT peak (fat -> lean jump):

usv1/2(n) > usv1/2(n-1) + K_LA_ALT_SPR_HYS

Signal rises again by more than K_LA_ALT_SPR_HYS during a signal change after MAGER to.

LEAN peak (lean -> rich - jump):

usv1/2(n) < usv1/2(n-1) - K_LA_ALT_SPR_HYS

Signal drops again by more than K_LA_ALT_SPR_HYS during a signal change to BOLD.

5.4. Determination of switching times

5.4.1. Determination of the switching time from RICH to LEAN

The lambda sensor signals are sampled in 10ms intervals. As long as the sensor signal is greater than the upper reference threshold, the jump time counter is set to zero. As soon as the threshold is undershot, the counter is increased with each sampling process until the signal falls below the lower threshold.

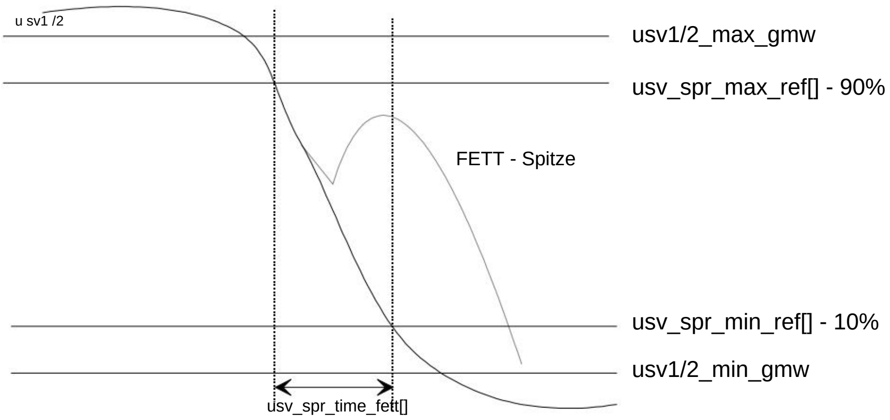
For

usv_spr_max_ref [ ] > usv1/2 > usv_spr_min_ref [ ]

=> usv_spr_time_fett(n) = usv_spr_time_fett(n-1) + 1

In general, **BIT4 / Bank1** or **BIT5 / Bank2** in the status byte **la_alt_spr_st** is set as soon as the probe voltage **exceeds the upper reference voltage usv_spr_max_ref** and is only reset when the lower reference voltage **usv_spr_min_ref is undershot.**

If a fat peak occurs during the determination, the determination of the switching time is aborted and the respective switching time is not processed further. In this case, BIT4 / Bank1 or BIT5 / Bank2 is withdrawn again.



5.4.2. Determination of the switching time from LEAN to RICH

The lambda sensor signals are sampled in 10ms intervals. As long as the sensor signal is less than the lower reference threshold, the jump time counter is set to zero. As soon as the threshold is exceeded, the counter is increased with each sampling process until the signal exceeds the upper threshold.

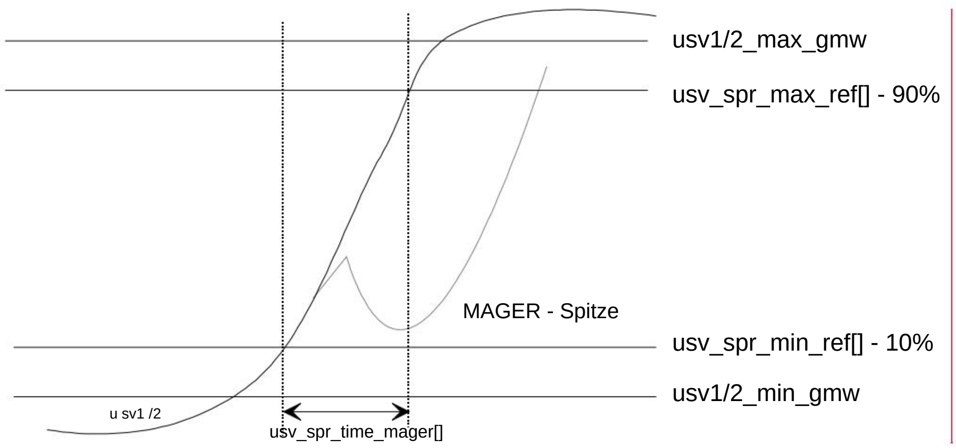
For

usv_spr_min_ref [ ] < usv1/2 < usv_spr_max_ref [ ]

=> usv_spr_time_lean(n) = usv_spr_time_lean(n-1) + 1

In general, **BIT6 / Bank1** or **BIT7 / Bank2** in the status byte **la_alt_spr_st** is set as soon as the probe voltage **falls below the lower reference voltage usv_spr_min_ref** and is only reset when the upper reference voltage **usv_spr_max_ref is exceeded.**

If a lean peak occurs during the determination, the determination of the switching time is aborted and the respective switching time is not processed further. In this case, BIT6 / Bank1 or BIT7 / Bank2 is withdrawn again.



5.4.3. Averaging of switching times

Since the switching times of the sensors vary greatly, an average is constantly calculated over the entire diagnostic time (K_LA_ALT_SPR_ANZ_FAT / K_LA_ALT_SPR_ANZ_MAGER measurements).

Theoretical jump time - depending on the operating point:

la_alt_spr_m/f_grenz[] = KF_LA_ALT_SPR_MAGER/FETT_GRENZ(n,rf)

Determination of quotient - inclusion of the theoretical jump time:

usv_spr_m/f_quot[] = usv_spr_time_lean/fat[] / la_alt_spr_m/f_limit[]

Summing up the quotients:

usv_spr_m/f_quot_sum(n)[] = usv_spr_m/f_quot_sum(n-1)[] + usv_spr_m/f_quot[]

averaged “jump time”:

usv_spr_mager/fett_gem[] = usv_spr_m/f_quot_sum[] / la_alt_spr_anz_m/f[]

=> the result is a **quality indicator** and not a time in msec. The actual jump time, which is also output via the scan tool, would be as follows:

actual jump time = quality factor * theoretical jump time

5.5. Jump time diagnosis

The actual diagnosis is made via the quality feature usv_spr_mager/fett_gem:

When the complete diagnosis has been completed on both banks, ie

la_alt_spr_anz_m = K_LA_ALT_SPR_ANZ_MAGER
AND la_alt_spr_anz_f = K_LA_ALT_SPR_ANZ_FETT

is checked for exceedance of the limit values:

If

usv_spr_mager_gem[] > K_LA_ALT_SPR_M_QUOT

OR

usv_spr_fett_gem[] > K_LA_ALT_SPR_F_QUOT

With the function **ed_report** either the error type **"Jump time LEAN too long"** (SH_TO_UB) or **"Jump time RICH too long"** (SH_TO_GND) is entered into the error memory **-** LA_VKAT1/2_SPR_FEHLER.

This error entry also only occurs once during an engine run (debounce counter etc. = 1). The MIL lamp is activated when the diagnosis detects a threshold being exceeded on two consecutive driving cycles (DrCy).

6th Testing the probe behind catalytic converter

This check is carried out during acceleration or during re-insertion. In this case, the sensor voltage must fall below or exceed a defined voltage threshold.
This diagnosis must be run through completely once per engine run (either the test after SA or WE).

The diagnosis is always restarted with a RESET; if you just click on START, all times and air mass quantities etc. are reset. However, a diagnosis that has already expired will not be restarted.

6.1. Determination of the probe position

Since this check takes place during the attack or during re-insertion of WE, the initial position of the NKAT probe must be checked before the diagnosis.

The review takes place when

- the engine is running (B_ML)
&&
- you are not in SA (!B_SA)
&&
- no NKAT diagnosis is currently running (!B_LA_ALTER_DIAG)

The probe voltage usn1/2 is checked to see whether it exceeds the threshold K_LA_ALTER_US_FETT and falls below the max. threshold K_LA_ALTER_US_FETT.

If **directly before SA**

usn1/2 > K_LA_ALTER_US_FETT (la_alt_mess_st, BIT2/3)

AND

usn1/2 < K_LA_ALTER_US_FETT_MAX (la_alt_mess_st, BIT6/7)

you are dealing with a **rich mixture** and thus the signal can be monitored **at SA .** If the signal is **below the threshold K_LA_ALTER_US_FETT** at this time, the signal can be checked **when it is reinstated .**

6.2. Conditions for the diagnostic window

The check is performed when you are in the defined *diagnostic window* for the *entire diagnostic duration :*

- the function must be activated via the application constant **K_LA_OBD_FREIGABE, BIT2** be
- a certain speed range must be maintained
  K_LA_ALTER_S_NMIN < n < K_LA_ALTER_S_NMAX
- the engine (time after START) must have **been running longer than K_LA_ALTER_S_TML**
- the catalytic converter temperature **tkatm** must exceed a certain threshold **K_LANK_TKAT_SCHW exceeded** (lank_st_ein1/2, BIT_LANK_TKAT_SCHW)
- **no catalytic converter protection when the tank** is empty
  ÿ !B_KATS_MD_RED
- there are **no dropouts**
  ÿ !B_AUSS_FEHLER
- there are **no secondary air faults**
  ÿ !B_SLS_KLEMM_FEHLER
  ÿ !B_SLV_SH_TO_GND
- **no other VKAT sensor error** is present
  ÿ !B_LA_VKAT1/2_P/SPR_FEHLER
  ÿ !B_LA_VKAT1/2_HUB_FEHLER
  ÿ !B_LA_VKAT1/2_TV_FEHLER
- there is **no KSD error**
  ÿ !B_KSD1/2_ERROR

6.3. Defined initial state for the test

For the test, both for SA and for reinstatement,

• you are in the **thrust state for longer** than a **time K_LA_ALTER_S_SA_T**

&&

• an applicable **air quantity K_LA_ALTER_S_ML** must have flowed through the KAT

=> thus a defined condition for diagnosis has been described.

However, there is **an exception when testing during a flare-up** - if **the test is positive before the defined initial state is reached** (as described below), **the diagnosis is not aborted but recognized as having been carried out.** The aim is to make a positive diagnosis during a flare-up as quickly as possible, since a diagnosis during a flare-up is relatively critical.

6.4. Testing in the thrust

If all test conditions are met, i.e.

- you are in the diagnostic window
- the probe position was in the fat before SA
- a defined SA has expired (with exception)
- the NKAT probe readiness is given (B_LANK_SONDE_BEREIT)
- no electrical probe error and heating error is present (!B_LASV/N_FEHLER, !B_LSHV/N_FEHLER)

then the probe voltage usn1/2 is compared with a threshold K_LA_ALTER_S_SA_US, which must be exceeded at SA.

If

usn1/2 > K_LA_ALTER_S_SA_US

then it can be assumed that the lambda probe NKAT is so aged that it either takes too long to fall below this threshold (ie probe too slow) or it can no longer follow the mixture (gets stuck).

If the probe is recognized as OK, ie the probe signal falls below the threshold **-** even during the defined SA *(usn1/2 < K_LA_ALTER_S_SA_US),* the diagnosis for this driving cycle is terminated and the error counter la_alter_s_count1/2 is reset.

To avoid misdetections, an error is only entered with the **ed_report** function if the error counter **la_alter_s_count1/2** is greater than **K_LA_ALTER_S_COUNT** (the error counter is always incremented when a check, regardless of whether SA or WE, is not recognized as valid). In this case, the error of the type **"Voltage too rich in SA"** (OPENLOAD) is entered in the error location **LA_NKAT1/2_S_FEHLER .**

6.5. Testing upon reinsertion

If all test conditions are met, i.e.

- you are in the diagnostic window
- the probe position was in the lean range before SA
- only after the defined SA you get into WE
- the NKAT probe readiness is given (B_LANK_SONDE_BEREIT)
- no electrical probe error and heating error is present

then the sensor voltage usn1/2 is compared with a threshold K_LA_ALTER_US_FETT, which must be exceeded during WE.

As soon as the voltage during this WE diagnosis

usn1/2 > K_LA_ALTER_US_FETT

is assumed that the sensor is OK. The diagnosis is terminated for this driving cycle, the error counters la_alter_s_count1/2 are reset and the
Enrichment measures regarding the diagnosis withdrawn (explanation follows).

If the sensor voltage has not exceeded the diagnostic threshold during the waiting time **K_LA_ALTER_S_WE_T** (is raised during the transition to WE), an error is not entered immediately, but an additional enrichment **la_alter_s_tv1/2** (is added to la_sum_tv1/2) is determined from the characteristic curve **KL_LA_ALTER_S_TV** (depending on the air mass). This enrichment is effective for a time **K_LA_ALTER_S_TV_T;** if KAT - clearing is active, this is aborted.

To ensure a clear diagnosis is possible during the enrichment phase, the air flow is also checked. Only when sufficient exhaust gas has flowed through the catalytic converter **(la_alt_s_we_ml > K_LA_ALTER_S_WE_ML)** and the sensor has still not exceeded the diagnostic threshold (despite additional enrichment) is it recognized as defective.

Otherwise, the diagnosis will be aborted after the time has elapsed.

Interruption of WE diagnosis:

Generally, a WE diagnosis is aborted by an SA phase. However, there is now a special condition: ***SA can be detected during switching operations*** (depending on how SA is applied) .

This detection of SA during switching operations interrupts the WE diagnosis. This can lead to a defective sensor not being detected in a diagnostic cycle because the WE part is never completed. To counteract this, the WE diagnosis is only paused and not interrupted during SA phases shorter than a certain time.

Stopping WE diagnostics (all values are frozen) if:

la_alt_s_sa_we < K_LA_ALTER_S_SA_WE_T

otherwise the WE diagnosis is aborted and the SA path of the diagnosis is run through.

la_alt_s_sa_we: Time from detection of the state SA

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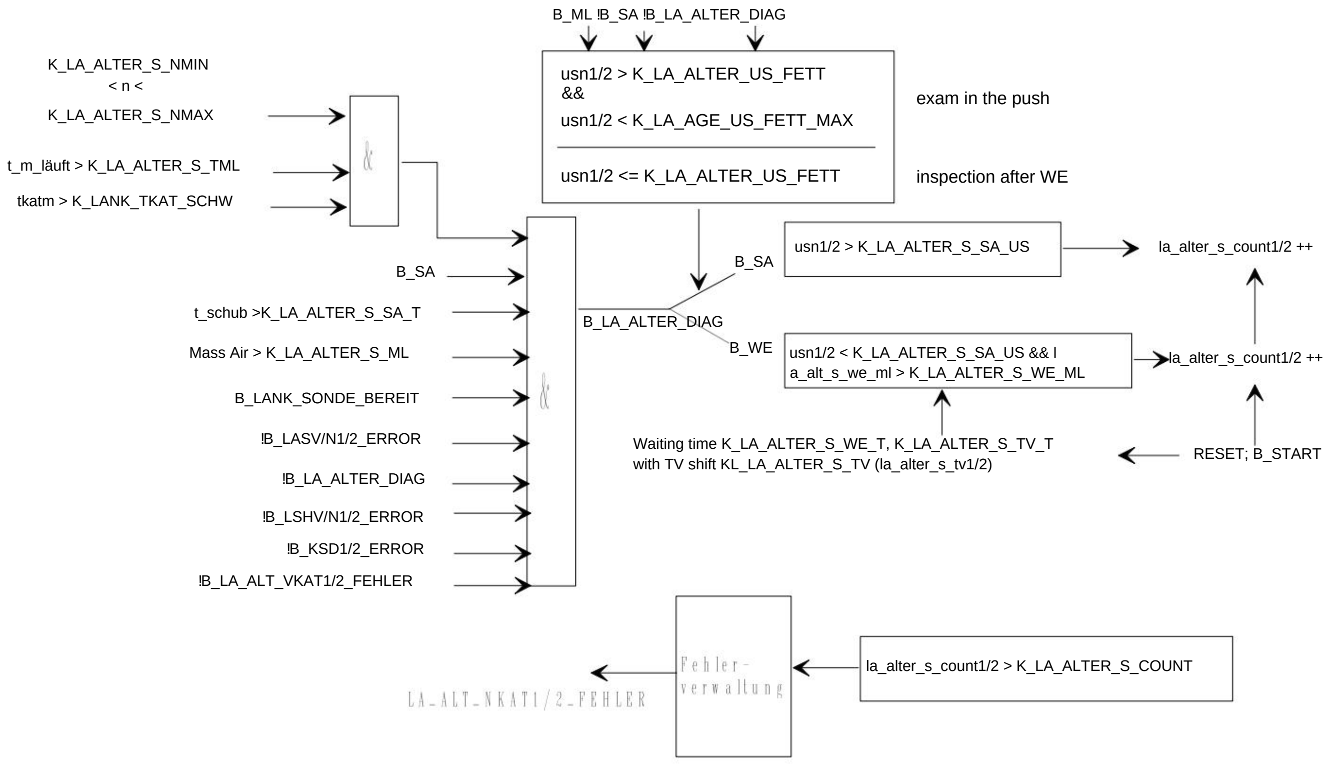
To avoid misdetections, an error is only recorded with the **ed_report** function if the error counter **la_alter_s_count1/2** is greater than **K_LA_ALTER_S_COUNT**
(the error counter is always incremented when a check, regardless of whether SA or WE, is not recognized as valid). In this case, the error of the type **"Voltage too lean after WE"** (IMPLAUSIBLE) is entered in the error memory at error location LA_NKAT1/2_S_FEHLER.

This error entry only occurs once during an engine run (debounce counter etc. = 1).
The MIL lamp is activated when the diagnosis detects a threshold being exceeded on two consecutive driving cycles (DrCy).

6.6. Graphical representation



7th variables and constants

TV monitoring of the VKAT controller: la_alter_st:

bit position	la_alter_st
Bit0	B_LA_ALTER_AUS1- general switch-off condition Bank1
Bit1	B_LA_ALTER_AUS2- general switch-off condition Bank2
Bit2	B_LA_ALT_TV_MAX1 - max. threshold exceeded
Bit3	B_LA_ALT_TV_MAX2 - max. threshold exceeded
Bit4	B_LA_ALT_TV_MIN1 - min. threshold exceeded
Bit5	B_LA_ALT_TV_MIN2 - min. threshold exceeded
Bit6	B_LA_ALT_TV_AKTIV1 - TV diagnosis VKAT1 running
Bit7	B_LA_ALT_TV_AKTIV2 - TV diagnosis VKAT2 running

Period duration monitoring of the VKAT probe signal: la_alt_p_st:

bit position	la_alt_p_st
Bit0	B_LA_ALTER_P1 - Diagnostic conditions fulfilled - VKAT1
Bit1	B_LA_ALTER_P2 - Diagnostic conditions fulfilled - VKAT2
Bit2	Locking time after RICH-LEAN jump for VKAT1 has expired
Bit3	Lockout time after RICH-LEAN jump for VKAT2 has expired
Bit4	B_LA_ALTER_P_MAX1 - Period duration too long - VKAT1
Bit5	B_LA_ALTER_P_MAX2 - Period duration too long - VKAT2
Bit6	B_LA_ALTER_P_MIN1 - Period duration too short - VKAT1
Bit7	B_LA_ALTER_P_MIN2 - Period duration too short - VKAT2

Jump time monitoring of the VKAT probe signal: la_alt_spr_st:

bit position	la_alt_spr_st
Bit0	B_LA_ALTER_SPR1 - Diagnostic conditions fulfilled - VKAT1
Bit1	B_LA_ALTER_SPR2 - Diagnostic conditions fulfilled - VKAT2
Bit2	Reference thresholds for VKAT1 are determined
Bit3	Reference thresholds for VKAT2 are determined
Bit4	Jump time determination FAT->LEAN takes place - VKAT1
Bit5	Jump time determination FAT->LEAN takes place - VKAT2
Bit6	Jump time determination LEAN->FAT takes place - VKAT1
Bit7	Jump time determination LEAN->FAT takes place - VKAT2

Testing the NKAT probe : la_alt_nkat_st:

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bit position	la_alt_nkat_st
Bit0	B_LA_ALTER_S_SA_BED1- Diag. Bank1 is executed
Bit1	B_LA_ALTER_S_SA_BED2- Diag. Bank2 is executed
Bit2	B_LA_ALTER_SA_DIAG1- Diag. Active after SA - Bank1
Bit3	B_LA_ALTER_SA_DIAG2- Diag. After SA active - Bank2
Bit4	B_LA_ALTER_SA_PHASE - def. SA phase is reached
Bit5	B_LA_ALTER_WE_DIAG - Diagnosis active at WE
Bit6	B_LA_ALTER_WE_TIME - Waiting time without further enrichment has expired
Bit7	B_LA_ALTER_WE_TV_TIME - Waiting time with additional enrichment has expired

Testing the NKAT probe : la_alt_mess_st

bit position	la_alt_nkat_st
Bit0	FAT-LEAN jump - period duration measurement
Bit1	FAT-LEAN jump - period duration measurement
Bit2	B_LA_ALTER_US1_FETT - Probe voltage NKAT1 is in the fat before SA
Bit3	B_LA_ALTER_US2_FETT - Probe voltage NKAT2 is in the fat before SA
Bit4	B_LA_ALTER_DIAG1 - general diagnosis/Bank1 is active
Bit5	B_LA_ALTER_DIAG2 - general diagnosis/Bank2 is active
Bit6	B_LA_ALTER_SA_OK1 - Probe voltage NKAT1 is in the rich, but not above the MAX rich threshold
Bit7	B_LA_ALTER_SA_OK2 - Probe voltage NKAT2 is in fats, but not over MAX fat threshold

Variables:

name	Meaning	Type	Resolution
la_alter_st	Status variable for TV monitoring Diagnosis	uc	--
la_vkat1/2_tv_ed; la_vkat1/2_p_ed; la_vkat1/3_spr_ed;	variable for VKAT monitoring TV postponement period duration monitoring jump time monitoring, stroke monitoring	uc	--
tkatm	Temperature of the catalyst Status	uw	°C
la_alt_p_st	variable for period duration monitoring Additional status	uc	--
la_alt_p_mess_st	variable for period duration measurement Period duration without	uc	--
la_alt_p_mess_of	filtering Period duration with filtering	uw	ms
la_alt_p_mess	Averaged, integrated TV shift	uw	ms
lank_i_tv_gem	NKAT1/2 Number of interference suppressions	sw	ms
la_alt_p_anz_spr	d. periodic duration measurements to	uc	--
la_alt_p_anz_diag	Number of period duration measurements for diagnosis TV	uc	--
la_p_tv1/2	shift, which is effective, is subtracted from the actual period duration	sw	ms

la_alt_spr_st	Status for jump time diagnosis	uc --	
usv_spr_time_fett[]	Jump time from FAT -> LEAN	uc ms	
usv_spr_time_lean[]	Jump time from LEAN -> FAT	uc ms	
usv_spr_max_ref[]	Reference threshold max = 90% of signal swing	uw mV	
usv_spr_min_ref[]	Reference threshold min = 10% of signal swing	uw mV	
la_alt_spr_anz_m/f[]	Number of jump time measurements	uc --	
la_alt_spr_m/f_grenz[] theoretical probe jump time bold / lean usv_spr_m/		uc ms	
f_quot[quality measure actual time / theoretical time usv_spr_m/f_quot_sum		uw --	
summed quality measure usv_spr_mager/fett_ge		ul	--
m	averaged quality measure	uw --	
la_alt_nkat_st	Status for the NKAT probe diagnosis on	uc --	
la_alt_s_ml	integrated ML by KAT at SA	uw kg	
la_alter_s_count1/2	Error counter for NKAT diagnosis	uc --	
la_alter_s_tv1/2	additional TV shift for NKAT diagnosis integrated ML	uc ms	
la_alt_s_we_ml	by KAT at WE	uw kg	
la_nkat1/2_s_ed	diagnostic variable for NKAT monitoring	uc --	

Application data:

name	type	Meaning
K_LA_OBD_FREIGABE	constant	The individual diagnoses are released here BIT0: TV surveillance BIT1: Period duration monitoring BIT2: NKAT probe diagnosis BIT3: Trim control Bank1 BIT4: Trim control Bank2 BIT5: --- BIT6: KAT conversion BIT7: Jump time monitoring
K_LA_ALT_TV_MAX_COUNT	constant	MAX threshold for diagnostic counter - error entry threshold
K_LA_ALT_TV_MIN_COUNT	constant	MIN threshold for diagnostic counter - error entry threshold
K_LA_ALT_TV_INC	constant	Increment for diagnostic counter TV monitoring
K_LA_ALT_TV_DEC	constant	Decrement for diagnostic counter TV surveillance
K_LA_ALT_TV_MAX constant		MAX-Diag.schw. for TV shift
K_LA_ALT_TV_MIN	constant	MIN-Diag.schw. for TV shift
K_LA_ALT_P_TEMP	constant	exhaust gas temperature threshold
K_LA_ALT_P_TAU	constant	filtering constant period duration monitoring
K_LA_ALT_P_VERZ_T constant		Delay time "lower N- " "
K_LA_ALT_P_N_MIN constant		threshold" "upper N- " "
K_LA_ALT_P_N_MAX constant		threshold" "lower RF- " "
K_LA_ALT_P_RF_MIN constant		threshold" "upper RF-threshold" " "
K_LA_ALT_P_RF_MAX	constant	
K_LA_ALT_P_ANZ_SPR	constant	number to suppress the interference
K_LA_ALT_P_ANZ_DIAG	constant	number for diagnosis duration
K_LA_ALT_P_MAX	constant	upper diag. threshold for period duration monitoring
K_LA_ALT_P_MIN	constant	lower diag. threshold for period duration monitoring
K_LA_ALT_P_MAX_KONV	constant	upper diag. threshold for period duration monitoring - for CAT-CONV-ERROR
K_LA_ALT_P_MIN_KONV	constant	lower diag. threshold for period duration monitoring at KAT-KONV_FEHLER
KF_LA_ALT_P_FAK_N_RF	map	weighting map for monitoring period duration
K_LA_ALT_P_TE_SPU constant		min. flushing time for TE before diagnosis starts

K_LA_ALT_SPR_ANZ_ LEAN/FAT	constant	Number of jump time measurements BOLD or LEAN
K_LA_ALT_SPR_M/F_ QUOT	constant	quality threshold for the jump times - error thresholds
K_LA_USV_SPR_P_S PR	constant	Number of P-jumps before diagnosis becomes active
K_LA_ALT_SPR_HYS	constant	Hysteresis to detect FAT/LEAN peaks
K_LA_ALT_SPR_TEM P	constant	TABG threshold for diagnosis release
K_LA_ALT_SPR_N_MI N	constant	Nmin threshold for diagnostic window
K_LA_ALT_SPR_N_M AX	constant	Nmax threshold for diagnostic window
K_LA_ALT_SPR_RF_ MIN	constant	RFmin threshold for diagnostic window
K_LA_ALT_SPR_RF_ MAX	constant	RFmax threshold for diagnostic window
KF_LA_ALT_SPR_MA GER_GRENZ	constant	theoretical jump time - MAGER
KF_LA_ALT_SPR_FET T_GRENZ	constant	theoretical jump time - BOLD
K_LA_ALTER_US_FE TT_MAX	constant	max. threshold for FAT position of the NKAT probe signal
K_LA_ALTER_US_FE T	constant	max. threshold for probe position
K_LA_ALTER_S_NMIN	constant	lower N-threshold for Diag. window
K_LA_ALTER_S_NMA X	constant	upper N-threshold for Diag. window
K_LA_ALTER_S_TML	constant	min. engine running time for diag. window
K_LANK_TKAT_ SCHW	constant	minimum catalytic converter temperature for diagnostic window
K_LA_ALTER_S_SA_T	constant	Minimum duration for defined SA and examination
K_LA_ALTER_S_WE_ ML	constant	Air volume threshold for testing after WE
K_LA_ALTER_S_ML	constant	Air flow threshold for testing during overrun
K_LA_ALTER_S_SA_ US	constant	Probe voltage threshold for testing in overrun or WE
KL_LA_ALTER_S_TV	characteristic curve	additional enrichment during WE testing, depending on ml
K_LS_ALTER_S_WE_ T	constant	Waiting time without TV postponement for WE exam
K_LS_ALTER_S_TV_T	constant	Waiting time with TV postponement for WE exam
K_LA_ALTER_S_COU NT	constant	Threshold for error counter until error entry NKAT probe
K_LA_ALT_S_TKATM	constant	catalytic converter temperature threshold for vibration testing