Produkt / Product: **Planar Wide Band Lambda Sensor with pumped O2 reference**

Typ / Type: **LSU4.9**

Bestellnummer / Part Number: 0 281 004 001 ... 0 281 004 200
0 258 0.. ...

Angebotszeichnung / Offer Drawing: A 258 ... ...

Bemerkung / Comment:

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1	-	**Erstausgabe / First Edition**	13.07.07	GS-SI/ENX4-Ham gez. Hamann	GS-SI/ENX gez. Dr. Stanglmeier
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					DS-SEN/EDS3 gez. Dr. Funk
					DS/EEC4 gez. Dr. Buchenau

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The validity of this TKU includes also the above mentioned documents.

General

The wide band lambda sensor LSU is a planar ZrO2 dual cell limiting current sensor with an integrated heater. It is used to measure the oxygen content and the λ-value of exhaust gases. Lambda describes the ratio of available air mass in the combustion chamber and theoretically necessary air mass for stoichiometric combustion.
This document is valid for application in
- automotive spark-ignition engines using gasoline fuel
- passenger cars with diesel engine using diesel fuel.

The wide band sensor LSU operates only in combination with a special LSU control unit (e.g. AWS control box or CJ125 IC). The connector module (RB150) contains a trimming resistor, which defines the characteristics of the sensor and is necessary for the sensor function. Therefore a removal of the connector is not allowed.

Note: values signed with [N] in this document are nominal values or guide values. They depend directly on other values which are specified with tolerances elsewhere in this paper.

1. Characteristics

1.1 Electrical connection

Connector	6 pole	
Range of trim resistor	30 ... 300Ω	[N]

1.2 Sensor element

The heater supply voltage must be controlled, so that the temperature of the sensor is kept at the operation point. The temperature is determined by measuring the internal resistance of the sensor's Nernst cell $R_{i,N}$

Nominal internal resistance of λ=1 Nernst cell for new sensors (operating and calibration point) (measured with AC f = 3 kHz)	$R_{i,N}$	= 300 Ω	[N]
Max. current load of λ=1 Nernst cell Continuous AC (f = 3 kHz) for $R_{i,N}$ measurement	$I_{N,max}$	≤ 250 µA	

O_2 reference pumping current $I_{p,Ref}$ (current source with max. 2.5V)

- minimum necessary value for sensor function	$I_{p,Ref,min}$	≥ 10 µA
- maximum allowed value		
- continuous	$I_{p,Ref,max}$	≤ 25 µA
- short time (max. 25h without interruption)	$I_{p,Ref,max}$	≤ 75 µA
- recommended value for ref. pumping current		
- continuous	$I_{p,Ref}$	= 20 µA
- short time for 10s during heat up	$I_{p,Ref}$	= 60 µA

Max. pumping current I_p into pump cell

- for rich gas signal (λ≥0,65)	$I_{p,max,rich}$	≥ -9 mA
- for lean gas signal (air)	$I_{p,max,lean}$	≤ 6 mA

Pumping current I_p must only be activated after the heater has been switched on and the sensor element reached a sufficient temperature (internal resistance of λ=1 Nernst cell $R_{i,N}$ ≤ 1kΩ).

1.3 Isolation resistance

(all measurements in static air, heater off)

- between housing and each heater- and sensor circuit connector pin, for new sensors at room temperature, measured with 800V DC — ≥ 30 MΩ
- between sensor signal circuit (IPN connected to virtual ground VM, see section 9.7) and heater circuit at 600°C hexagon temperature, new and after aging acc. to section 4.1, measured with 12V DC: — ≥ 1 MΩ
- between sensor signal pin APE and housing at 600°C hexagon temperature, new and after aging acc. to section 4.1, measured with 12V DC: — ≥ 100 kΩ

  Note: for heavy sooted or wet sensors the isolation resistance temporary can decrease below this value

Isolation resistance of wire harness see section 8.5 (installation instructions)

1.4 Signal coupling between heater and sensor signal

Measurement of the sensor signal with sensor operated by control unit. Sensor is heater-controlled to operating temperature, heating with V_{Batt}=13V, heater duty cycle frequency 100 Hz. Signal filter of pumping current with R = 33 kΩ and C = 100 nF. The temperature of the hexagon is 600°C.

Sensor signal due to signal coupling	$\Delta I_{p,meas}$	≤ 0.19 mA

1.5 Heater supply

Nominal voltage:	$V_{H,nom}$	= 7.5 V	[N]
Nominal heater power at 7.5 V heater supply at thermal equilibrium in air:	$P_{H,nom}$	= 7.5 W	[N]
Heater cold resistance at room temperature for new sensors, including cable and connector:	$R_{H,cold}$	= 3.2±0.8 Ω	
Minimum heater cold resistance at -40°C:	$R_{H,cold,min}$	= 1.8 Ω	[N]

Note: the influence of the cable length between ECU and lambda sensor in Diesel systems must be considered by measuring the actual heater power demand according to 0 281 YE0 030/032.

1.6 Heater strategy

When the heater is ramped up after dew point end, the heater power must be limited as follows.

Maximum initial value of heater voltage $V_{H,eff}$ during the heat-up phase:
(for gasoline engines dependent on the temperature of the sensor at start)

T_{Sensor} [°C]	-40	-10	20	50
Operation in gasoline engine: $V_{H,eff,max}(t=0)$ [V]	8.5	9.5	10.5	10.5
Operation in diesel engine: $V_{H,eff,max}(t=0)$ [V]	8.2			

- ramp rate $\Delta V_{H,eff} / \Delta t$ ≤ 0.4 V/s

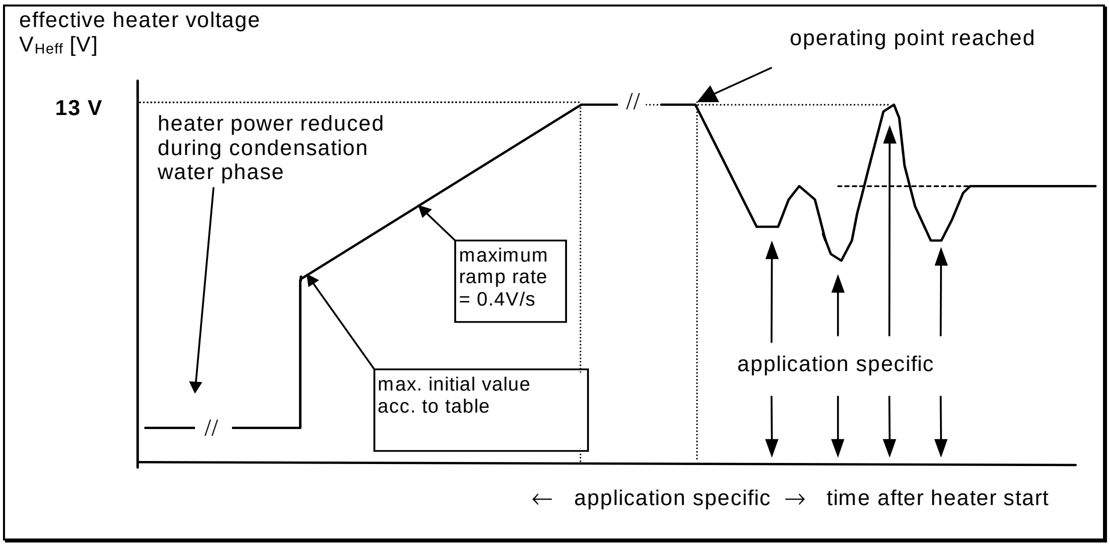


Fig. 1 Maximum permissible heat up rate with limited heater power to reduce the thermal stress in the heat-up phase

To rule out thermo shock damage of the sensor ceramic, the sensor must be operated with a defined heater power during the condensation water phase, see measuring method Y 258 E00 007 and 0 281 YE0 029.

Caution: the use of fast-light-off conditions from Y 258 E00 007 chapter 1.4 (immediate start of the sensor heater without waiting for dew point end in close to engine installations) is **not** allowed for this sensor type!

Heater voltage during condensation water phase $V_{H,eff}$ = 1.5 to 2.0 V

Maximum permissible effective heater voltage
to reach the operating point
- short time ≤ 30sec (200h cumulated time): $V_{H,eff}$ ≤ 13 V
- continuous: $V_{H,eff}$ ≤ 12 V

Maximum system supply voltage $V_{batt,max}$ ≤ 16.5 V
- short time voltage peak for 60ms $V_{batt,max}$ ≤ 28 V
  (10 times over lifetime, ceramic temp. ≥ 20°C)

Minimum system supply voltage $V_{batt,min}$ ≥ 10.8 V
at this system supply voltage the function of
the sensor is given in typical applications.
This must still be tested in the respective application.

Admissible frequency of heater voltage control	f_H	≥ 100 Hz
- recommended and lifetime tested value:	f_H	= 100 Hz

Notes:
Heater duty cycling of f_H > 100 Hz is not tested. Usage must be checked with Bosch.
The use of the sensor with 24V power systems is not permissible except if a voltage converter system is used.

Calculation of $V_{H,eff}$ over duty cycle ED: $V_{H,eff} = (ED)^{1/2} * V_{Batt}$

2. Application conditions

2.1 Temperature measurements

The sensor temperatures in operation are measured with a special sensor equipped with NiCrNi thermocouples.
The temperature measurement sensors are available in different combinations. There are measurement points at the upper side of the PTFE formed hose (“D”), the PTFE cable grommet (“C”), the hexagon of the sensor housing (“B”) and for the exhaust gas temperature (“A”).

For more information see description of temperature measurement sensors Y 258 E00 006 and measurement method Y 258 E00 007 and 0 281 YE0 029.

2.2 Storage temperature (passive): -40°C ... +100°C

Storage conditions see handling instruction Y 258 E00 000

2.3 Operating temperatures

Notes:
If the operating temperature is exceeded, the sensor accuracy might be limited during this time.

If the max. gas temperature exceeds 930°C or hexagon temperature exceeds 600°C, the use of a longer thread boss is recommended.

Exhaust gas	$T_{Exhaustgas}$	≤ 930°C
Hexagon of the sensor housing	$T_{Hexagon}$	≤ 600°C
Cable grommet (PTFE formed hose)		
- sensor side (grommet)	$T_{Grommet}$	≤ 250°C
- cable side (upperhose crimp)	$T_{Upperhose}$	≤ 200°C
Cable and protective sleeve: (additional assembled parts such as clips or cable ties according to supplier spec or offer drawing)	T_{cable}	≤ 250°C
Connector RB150: (s. TKU-RB150, 1 928 A00 15T-0)	$T_{connector}$	≤ 140°C

2.4 Maximum temperatures

2.4.1 (max. 250 h accumulated over lifetime)

Exhaust gas	$T_{Exhaustgas}$	≤ 1030°C
Hexagon of the sensor housing	$T_{Hexagon}$	≤ 680°C

2.4.2 (max. 40 h accumulated over lifetime)

Cable grommet (PTFE formed hose)		
- sensor side (grommet)	$T_{Grommet}$	≤ 280°C
- cable side (upperhose crimp)	$T_{Upperhose}$	≤ 230°C
Cable and protective sleeve:	T_{cable}	≤ 280°C

(additional assembled parts such as clips or cable ties according to supplier spec or offer drawing)

Connector RB150:	$T_{connector}$	≤ 150°C

(s. TKU-RB150, 1 928 A00 15T-0)

2.5 Fluids in the exhaust gas system

When fluids (especially condensation water) are present at exhaust side, the heater power of the sensor must be limited, see 1.6.

2.6 Exhaust gas pressure

Absolute pressure at continuous operation	P_{gas}	≤ 250 kPa

2.7 Permissible vibrations

(measured at the sensor housing)

Stochastic vibrations: (peak level)	≤ 1000 m/s^2
Sinusoidal vibrations:	≤ 300 m/s^2
- vibration amplitude	≤ 0.3 mm

2.8 Permissible fuel additives

Gasoline: in accordance with DIN EN228 for commercially available unleaded fuel.

Diesel: the sensor LSU4.9 is designed for use with all commercially available diesel fuels.
The testing was done with gasoline and diesel fuel acc. to DIN EN 228 resp. DIN EN 590. All other fuels can only be tested and released project specific in accordance with Bosch.

2.9 Oil consumption and oil brand

Permissible figures and data must be determined by the customer by the way of adequate large-scale tests.

2.10 Lifetime

The technical development of the sensor is aligned to a service life of 250.000 km and a maximum life time of 15 years.

The following conditions must be fulfilled in order to reach this service life:

- Application conditions acc. to section 1 and 2.
- Installation conditions acc. to section 8.
- Checking of each application/installation location according to application guideline Y 258 E00 018 resp. 0 281 YE0 028.
- For the electrical connection of the lambda sensor the RB approved sensor connector module acc. to TKU-RB150, 1 928 A00 15T-0 with gold plated sensor signal contacts for the sensor signal circuit must be used.

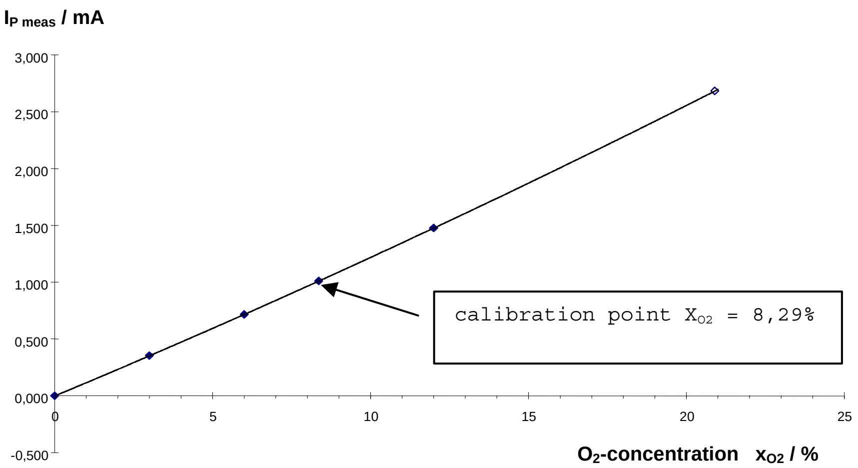
The commercial warranty and liability is regulated in the conditions of delivery, independent of the above figures. The aforesaid information on lifetime for which the product has been construed shall in no case be a guarantee regarding the condition or quality of the product.

3. Test data (functional values)

Special hints for carrying out test bench measurements:
The measurement is done with the sensor operated with an AWS control unit. The given tolerances are only for the lambda sensor. The heater power is closed-loop controlled while the measurement is done, so that the nominal sensor internal resistance is reached. The reference pumping current is continuous 20µA for all measurements. The signal $I_{p,meas}$ is the current through a measuring resistance of 61.9Ω.
Due to the technical design of the gas test benches these measurement data cannot be used for capability calculations.

3.1 Nominal characteristic line [N]

For a synthetic gas (measurement in LSU test bench acc. to Y 258 E00 005) the following nominal characteristic line is reached:



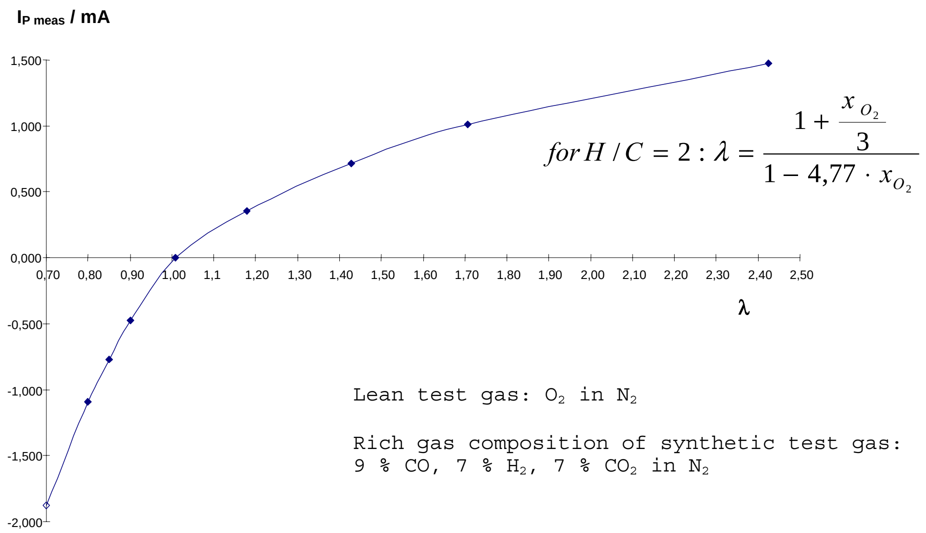


Fig. 2 Nominal characteristic line

O_2-conc. x_{O2} [%]						3.0	6.0	8.29	12.0	20.95
λ-value	0.65	0.70	0.80	0.90	1.00	1.18	1.43	1.70	2.42	air
$I_{p,meas}$ [mA]	-2.45	-1.99	-1.13	-0.49	-0.010	0.33	0.67	0.94	1.38	2.53

(*) All data "after test bench run" are references for endurance and environmental tests in chapter 4.

3.2 Light-off time

Measurement of the light-off time of the sensor in synthetic gas test bench at 20°C gas temperature acc. to test method Y 258 E00 004:

	New	After test bench run (*)
light-off time [s]	≤ 10	≤ 10

Note: these light-off times are reached using the defined maximum heat up ramp for gasoline (s. chapter 1.6). In the engine the time to reach sensor readiness might differ, depending on installation and gas temperature conditions, especially by delay times due to condensation water in the exhaust gas system.

3.3 Tolerances for λ=1 and frequency

Measurement in synthetic gas test bench at 350°C gas temperature acc. to test method Y 258 E00 004:

		New	After test bench run (*)
3.3.1	λ static (pump current $I_{P,meas}$=0)	1.016 ± 0.006	1.016 ± 0.008
3.3.2	λ dynamic	1.013 ± 0.006	1.013 ± 0.008
3.3.3	Frequency [Hz]	2.2 ± 0.8	2.2 ± 1.0

Note: the parameter λ_{static} is replaced by the pumping current at λ=1.0 (see chapter 3.4.2) for the application in Diesel engines.

3.4 Tolerances for rich and lean gas and for λ=1

Measurement in LSU test bench at 20°C gas temp. acc. to Y 258 E00 005:

		New	After test bench run (*)
3.4.1	λ signal at λ=1.7:	1.70 ± 0.05	1.70 ± 0.15
3.4.2	Pumping current [µA] $I_{p,meas}$ at λ = 1.0	-10 ± 12	-10 ± 14
3.4.3	λ signal at λ=0.8:	0.80 ± 0.01	0.80 ± 0.04

For other λ values and operating conditions the λ tolerances can be calculated.

For λ>1 and small values of $\Delta I_{P,meas}/I_{P,meas}$:

$$\Delta\lambda = \lambda(\lambda - 1)\cdot\frac{\Delta I_{p,meas}}{I_{p,meas}}$$

For a H/C-ratio of H/C=2:

$$\lambda = \frac{1 + \frac{x_{O_2}}{3}}{1 - 4.77 \cdot x_{O_2}}$$

(with $I_{p,meas}$ = measuring current, x_{O2} = oxygen concentration)

Note: changes in the test gas composition, especially of the H_2-concentration, will have an influence on the characteristics of the sensor. These influences are stronger in rich gas then under lean gas conditions.

3.5 Tolerance of the sensor signal in air (r-value)

The r-value is the relative deviation of the sensor signal from the nominal value on air as in 3.1 (O_2–content = 20.95%)

$$\text{Relative deviation} \quad r = \left[\frac{\text{Ip measured} - \text{Ip nominal}}{\text{Ip nominal}}\right]_{in\ air}$$

with $I_{p,nominal} = I_{p,meas}$ value from the nominal characteristic curve in 3.1

Measurement in LSU test bench at 20°C gas temp. acc. to Y 258 E00 005:

	New	After test bench run (*)
Relative deviation r [%]	0 ± 7	0 ± 12

3.6 Relative deviation of the characteristic curve camber from the nominal characteristic curve (t-value)

In lean gas, the signal is not completely linear in relation to O_2. To have the possibility of calibrating the characteristic of a sensor by measuring the signal in air (calibration during fuel cut-off), the relative deviation "t" of the characteristic curve camber at the calibration point of λ=1.7 from the nominal curve is defined as:

$$\text{Relative deviation} \quad t = \left[\frac{\text{Ip measured} - \text{Ip nominal}}{\text{Ip nominal}}\right]_{at\ \lambda=1.7} - \left[\frac{\text{Ip measured} - \text{Ip nominal}}{\text{Ip nominal}}\right]_{in\ air}$$

with $I_{p,nominal} = I_{p,meas}$ value from the nominal characteristic curve in 3.1

Specification:
Measurement in LSU test bench at 20°C gas temp. acc. to Y 258 E00 005:

	New	After test bench run (*)
Relative deviation t [%]	0 ± 2	0 ± 2

3.7 Pressure dependency of the sensor signal (k-value)

A change of the exhaust gas pressure leads to a deviation of the sensor signal (see diagram), which can be approximately described in lean gas as follows:

$$I_{p,meas}(p) = I_{p,meas}(p_0) \cdot \frac{p}{k+p} \cdot \frac{k+p_0}{p_0}$$

with p_0 = 1013 hPa (reference pressure)

In rich gas the equation is only valid for p≤160 kPa. Above p>160 kPa the nominal values can be taken from the diagram.

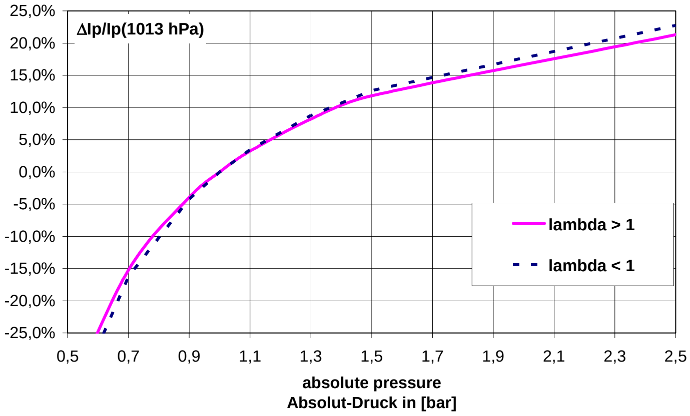


Fig. 3 Pressure dependence of the pumping current

The factor k is depending on operating mode „rich" or „lean" and is approx.: $k_{rich\ gas}$ = 61 kPa (at p=150 kPa) [N]

Specification:
Measurement in LSU test bench at 20°C gas temp. acc. to Y 258 E00 005:

	New	After test bench run (*)
$k_{lean\ gas}$ [kPa] (measured at λ=1.7,p=400 kPa)	53 ± 10	55 ± 12

3.8 Temperature dependency of the sensor signal and the internal resistance of the Nernst-cell $R_{i,N}$

A temperature change of the sensor ceramic gives a deviation of the sensor output signal of approx. $\Delta I_{P,meas}/I_{P,meas}$ = 4%/100°C [N]

The temperature is known by measuring the internal resistance of the Nernst cell $R_{i,N}$ and the following curve:

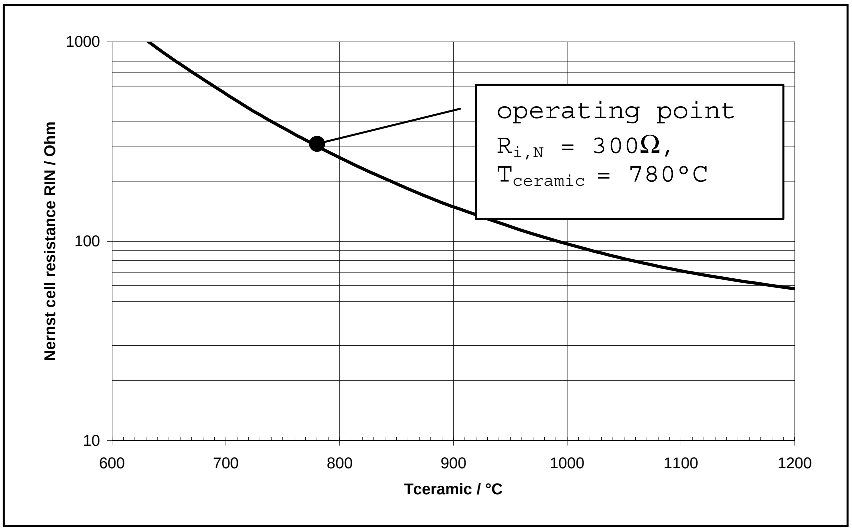


Fig. 4: Temperature dependency of the inner resistance of the nernst cell for a new sensor

Guide value [N] for operating point:

- new sensor: $R_{i,N}$ = 300Ω, $T_{ceramic}$ = 780°C
- after 3000h endurance run: $R_{i,N}$ = 300Ω, $T_{ceramic}$ = 880°C

Note: these values are guide values. The specification of tolerances is covered by section 3.4 (Tolerances in rich and lean gas), because the sensor is power-controlled to reach the operating point $R_{i,N}$ in these measurements. So all tolerances of the $R_{i,N}$ and $I_{P,meas}$ temperature dependency are included in the total sensor tolerance.

The dependency of the sensor output from the sensor internal resistance results from these values. It is measured and specified as follows:

The sensor output $I_{P,meas}$ is measured (in air at room temperature) in the points $R_{i,N}$ = 450Ω and $R_{i,N}$ = 200Ω (by variation of heater power). For new sensors the deviation is

$\frac{\Delta I_{p,meas}}{I_{p,meas}} = \frac{I_{p,meas,200\Omega} - I_{p,meas.,450\Omega}}{I_{p,meas,200\Omega}}$	0.0506 ± 0.0316

4. Environmental test specification

Each test must be carried out with new sensors. After the tests the sensors must meet the functional values in 3.3 and 3.4 ("after test bench run"), if not otherwise specified. The tests are carried out operated with a control unit, if not otherwise specified.

4.1 Engine endurance runs

4.1.1 Endurance run in gasoline engine

For measurements of functional values after endurance test the sensors have to be fitted into the exhaust system of a λ=1 controlled gasoline engine. The sensors are operated with a control unit in this test (closed loop control of heater power).
Speed and load are changed in a 6-cycle program so that a temperature curve is reached in the sensor tip as per sketch.
- Fuel: according to DIN EN228 for commercially available unleaded fuel.
- Oil consumption ≤ 0.01 l/h.
- Oil brand: multi-range oil viscosity 10 W 40, API specification SF.

Compliance with the temperature limits as per section 2.3 must be ensured by adequate cooling. The exhaust gas temperature is set by varying engine speed and load. The temperature at the hexagon is limited by additional air cooling.
After the test the functional values in section 3.2 to 3.7 ("after test bench run") must be fulfilled.

Test time: up to 3000h

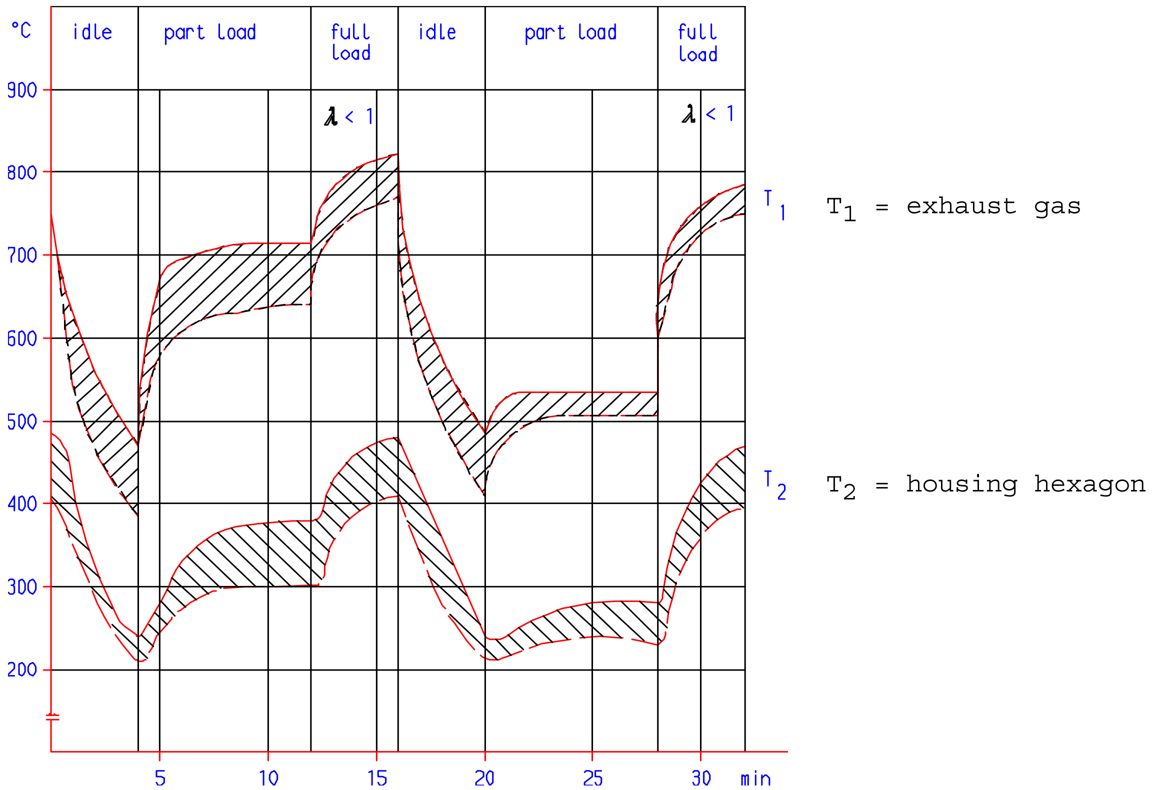


Fig. 5: Profile of the endurance run in gasoline engine

4.1.2 Endurance run in diesel engine

For measurements of functional values after endurance test the sensors have to be fitted into the exhaust system of adiesel engine. The sensors are operated with a control unit in this test (closed loop control of heater power).
Speed and load are changed in a 5-cycle program so that a temperature curve is reached in the sensor tip as per sketch.
- Fuel: according to DIN EN 590 for commercially available diesel fuel.
- Oil brand: commercially available multi-range oil.
- The exhaust gas temperature is set by varying engine speed and load.

After the test the functional values in section 3.2, 3.3.3, 3.4 to 3.7 ("after test bench run") must be fulfilled.

Test time: up to 3000h

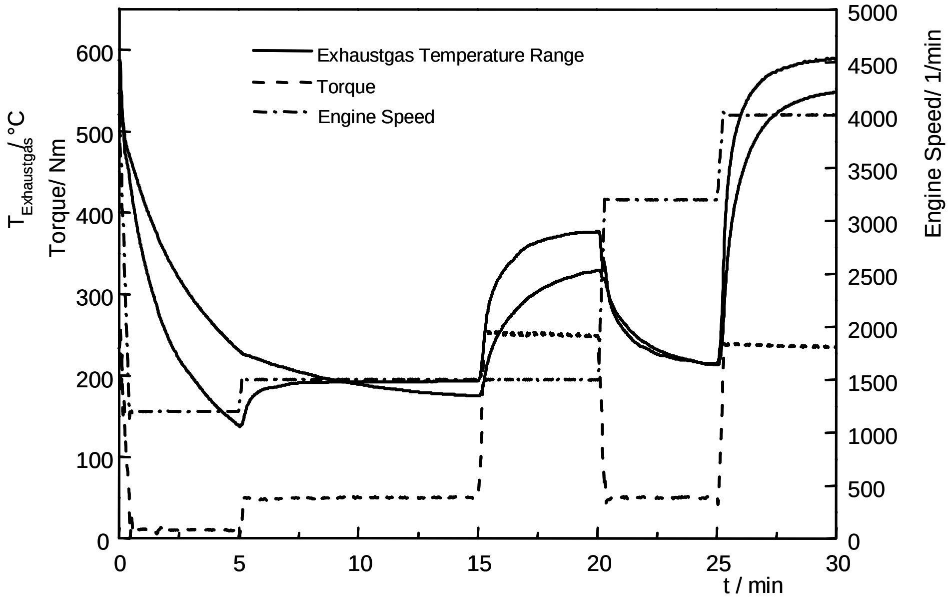


Fig. 6: Profile of the endurance run in diesel engine

4.1.3 Aging by operation in air

For measurement of the characteristic shift under continuous lean conditions, the sensors are operated in calm air (room temperature). The sensors are operated with a control unit in this test (closed loop control of heater power). The signal output is monitored during the test.

Test duration:	100 h
Test evaluation: Signal drift	≤ 7%

4.2 Poisoning endurance runs

4.2.1 Test of sensitivity to silicon in gasoline fuel

Engine test run with additional silicon (Octamethylcyclotetrasiloxane) content in fuel.
The sensors are fitted in the exhaust pipe of a λ=1 controlled gasoline engine as in 4.1.1, but operated under the following conditions:

exhaust gas temperature:	400°C
test time:	6 h
Added silicon amount during runtime:	0.79 g

After the test the sensors must meet the functional values in 3.3 to 3.5 (values "after test bench run").

4.2.2 Test of sensitivity to sulfur in fuel

Engine test run with high sulfur content in fuel.
The sensors are fitted in the exhaust pipe of a λ=1 controlled gasoline engine as in 4.1.1, but operated under the following conditions:

exhaust gas temperature:	200°C (idle operation)
test time:	500 h
Added sulfur amount during runtime:	188 g

After the test the sensors must meet the functional values in 3.3 to 3.5 (values "after test bench run").

4.2.3 Test to oil component sensitivity

Engine test run with additional oil components in fuel.
The sensors are fitted in the exhaust pipe of a λ=1 controlled gasoline engine as in 4.1.1, but operated under the following conditions:

exhaust gas temperature (cycle):	30 min at 400°C 30 min at 700°C
test time:	100 h

Engine oil with high additives is mixed into the fuel. The whole amount of added oil additives is for the complete test (the P/Ca ratio is constant over the test):

P [g]	Ca [g]
40	51

After the test the sensors must meet the functional values in 3.3 to 3.5 (values "after test bench run").

4.2.4 Test of sensitivity to silicon additives in diesel fuel

Engine test run with additional silicon content in fuel.
The test is carried out as in the diesel endurance run (4.1.2), except:

Test duration:	750 h
Added silicon amount during runtime:	20 g

Si amount is determined from fuel analysis in the inflow of injector.

After the test the sensors must meet the functional values in 3.3.3, 3.4, 3.5 (values “after test bench run”).

4.2.5 Test to sensitivity to Cer and iron additives in diesel fuel

Engine test run with additional iron additives in fuel (diesel additive for soot filter regeneration).
The test is carried out as in the diesel endurance run (4.1.2), except:

Test duration:	750 h
Added Fe amount during runtime:	227.5 g
Added Cer amount during runtime:	530.0 g

Fe and Cer amount is determined from fuel analysis in the inflow of injector.

After the test the sensors must meet the functional values in 3.3.3, 3.4, 3.5 (values “after test bench run”).

4.3 Environmental tests

4.3.1 Sinusoidal vibration test acc to IEC 68-2-6 test Fc

Test equipment: electrodynamic vibrator
Test:
50 to 160 Hz with amplitude ≤ 0.3 mm
160 to 2000 Hz at constant acceleration of ± 300 m/s^2.

Frequency change velocity:	1 octave/min.
Test duration:	24 h to be performed in all 3 perpendicular planes.
Ambient temperature:	25 ± 3 °C.

4.3.2 Random vibration test

Test equipment:	Random vibration test bench as per Bosch standard N42 AP 411.
Acceleration:	1000 m/s^2 (peak level)
Test duration:	24 h
Ambient temperature:	25 ± 3°C

4.3.3 Test with damp heat, cyclic (12+12-hour cycle)
acc. to IEC 68-2-30, test Db

No. of cycles:	21
max. air temperature:	40°C

The heater has to be switched off during this test.

4.3.4 Salt mist test acc. to IEC 68-2-11, test Ka

Testing time:	288 h

The sensor heating is switched on 5 minutes before and during testing. In order to prevent water from reaching the exhaust side sensor ceramic, a stainless steel sleeve is screwed onto the sensor thread for proper sealing.

4.3.5 Change of temperature acc. to IEC 68-2-14, test Na

Minimum temperature:	-40 °C
Maximum temperature:	130 °C
Exposure duration at each temp.:	30 min.
No. of temperature cycles:	250

The heater has to be switched off during this test.

4.3.6 Sulfur dioxide test with general condensation of moisture acc. to DIN EN ISO 6988

(Corrosion in humid SO_2 atmosphere)

No. of cycles: 6 (24 h for each cycle)

The heater has to be switched off during this test.
In order to protect the exhaust side sensor ceramic, a stainless steel sleeve is screwed onto the sensor thread for proper sealing.

4.3.7 Submergence test acc. IEC 529, IPx7

Water level 150 mm above sensor cable outlet. Test duration is 30 min. The connection system must be out of the water during the test. The sensor is operated with a LSU control unit in this test, the sensor signal is monitored.

Test evaluation: the sensor signal must be $I_{p,meas} \leq 2.95mA$

4.3.8 Wire pull test

The mounted sensor has to withstand an axial force of 100 N applied to the wire harness for 1 min.

4.3.9 Fuel resistance test (FVP-test)

The exhaust gas side of the sensor is exposed to Pentan vapor in a test chamber (pressure 100hPa). The soak time is 2 h. After this the sensor is removed and then operated with a control unit. The sensor signal in ambient air is monitored for 120 min.

Test evaluation: the sensor signal must be $I_{p,meas} \leq 2.95mA$

4.3.10 Fine leak test

The gas leakage is measured from exhaust gas side with an air pressure of 400kPa (sensor not heated). The leakage rate must be ≤ 0.1 ml/min.

4.3.11 Drop test acc. to IEC 68-2-32 test Ed proc. 1

The sensor is dropped onto a concrete floor from a height of 1m, one time.

5. Carrying out tests

Test procedure	Section	100% test	Lot release test	Product audit test	Design verifica-tion test (DV-Test)
Isolation resistance at room temperature (heater, sensor signal circuit and housing)	1.3	x			
Isolation resistance hot (heater to sensor circuit and APE and housing)	1.3			x	
Signal coupling betw. heater and sensor signal	1.4			x	
Functional test in rich gas λ=0.8		x			
Functional test in lean gas λ=1.7 (sensor calibration)		x			
Tolerances at λ=1 (PSG)	3.3		x		
Tolerances in rich and lean gas (LSU test bench)	3.4		x		
Light-off time	3.2			x	
Tolerances of the signal in air	3.5			x	
Relative deviation	3.6			x	
Pressure dependency	3.7			x	
Engine endurance run gasoline, t=500h)	4.1.1			x	
Engine endurance run (gasoline, t=3000h)	4.1.1				x
Engine endurance run (diesel, t=3000h)	4.1.2				x
Operation in air	4.1.3			x	
Sinusoidal vibration test	4.3.1				x
Random vibration test	4.3.2				x
Test with damp heat	4.3.3				x
Salt mist test	4.3.4				x
Change of temperature	4.3.5				x
Sulfur dioxide test	4.3.6				x
Submergence test	4.3.7			x	
Wire pull test	4.3.8			x	
Fuel resistance test (FVP)	4.3.9			x	
Fine leak test	4.3.10			x	
Drop test	4.3.11				x
Silicon sens. test (gasoline)	4.2.1				x
Sulfur sensitivity test	4.2.2				x
Oil component sens. test	4.2.3				x
Silicon sens. test (diesel)	4.2.4				x
Cer + Fe sens. test (diesel)	4.2.5				x

Note:

Product audit tests are carried out for monitoring the product quality on a regular basis.
DV tests are only carried out with new sensor types in the design verification phase.

6. Evaluation of field parts

In case of complaints about the products they are effectively free of fault through attainment of the following characteristic data:

- functional values from section 3.4.1 and 3.4.3 (tolerances for rich and lean gas, values "after test bench run").

7. Design variations

The following variations are available:

7.1 PTFE formed hose

- Longer PTFE hose at cable grommet for installations with critical temperature conditions in the sensor area.
- Shortened PTFE hose at cable grommet.

Note: the temperature resistance is the same for both types at the defined measuring points.

8. Installation and operation instructions

The sensor installation point and the sensor functionality in the full system must be assured sufficiently by the customer through appropriate vehicle tests under realistic conditions of use.

8.1 Installation in the exhaust system must be at a point guaranteeing representative exhaust gas composition whilst also satisfying the specified temperature limits.

8.1.1 Tested installation positions:
- passenger car automotive spark ignition engine using gasoline fuel: after turbocharger, in front of catalyst
- passenger car diesel engine using diesel fuel: after turbocharger, in front of catalyst, after oxidation-catalyst

All other installation positions must be assured sufficiently in the respective application, in agreement with Bosch.

8.2 The lambda sensor must only be used with a appropriate control unit, e.g. vehicle ECU or AWS control box). It must be activated only after engine start. The heater power must always be switched on power controlled, e.g. duty cycled heater power.

In the heat-up phase at start the sensor is heated with reduced heater power acc. to diagram in chapter 1.6 to reduce thermal stress of the sensor element due to high peak power in the first seconds. The heater power must only be increased after all occurrence of condensation water, which could damage the hot ceramic, can be ruled out.

8.3 To allow early heating of the sensor to reach a fast sensor activity, the sensor installation location design must be selected in a way to minimize exhaust-side stressing of the sensor with condensation water.
If this is not possible by design measures, the start of the sensor heater must be delayed until demonstrably no more condensation water appears.

Note: The test method for evaluation is described in Y 258 E00 007 (for gasoline applications) and Y 281 YE0 029 (for diesel applications).

8.4 Detailed instructions and hints for
- design of the sensor installation point to avoid build up of condensation water, cooling of sensor element etc.
- positioning of the sensor in the exhaust gas stream
- design of the sensor boss
- assembly notes

are given in the following documents

For application in gasoline engines:

Y 258 E00 018	Application guideline
Y 258 E00 007	Method for temperature- and thermo shock measurement
Y 258 E00 025	Add. installation and operation instructions

For application in diesel engines:

0 281 YE0 028	DS Application guideline
0 281 YE0 029	DS Method for temperature- and thermo shock measurement
0 281 YE0 030	Application of heater power demand in Bosch Diesel-Systems
0 281 YE0 032	Application of heater power demand in non-Bosch Diesel-Systems

8.5 To ensure the necessary minimum reference pumping current, the isolation of the vehicle wire harness including all connections must be guaranteed. The minimum isolation resistance under all ambient conditions (temperature, humidity) over the whole vehicle life time must be ≥ 2MΩ between all sensor signal pins.

9. Operating instructions

9.1 Conditions for connection and electrical operation of the sensor

It must be assured, that when the sensor is operated, the connection to the control unit is not disconnected during operation, or that the control unit diagnosis recognizes a failing connection.
It is also not allowed, to disconnect or to connect the sensor to the control unit or ECU while the sensor or control unit is being operated.

Background: if the signal of the λ=1 Nernst cell is missing (e.g. connection failure), the internal control circuit can not operate correctly, so that

- an excessive pumping voltage with wrong polarization can destroy the pumping cell of the sensor

- the sensor element can be destroyed by overheating, when the closed loop heater control is not able to measure the ceramic temperature

The control unit may only be switched on after the sensor is connected completely.

The sensor cables may never be connected in the wrong way or wrong polarity, otherwise the sensor might be destroyed.

The sensor might not stay in the exhaust gas stream without the control unit connected and activated.

9.2 Use of LSU outside of the exhaust gas system

The sensor can also be used outside an exhaust gas system, e.g. in air.

When used in a stoichiometric (λ = 1) or rich gas (λ < 1), e.g. measurement gas in the test bench, it must be assured, that enough O_2 donators are available in the gas to allow the pumping cell to work. Otherwise the ZrO_2 ceramic of the sensor can be reduced and the sensor destroyed.
The O_2 donator may be free oxygen (non-equilibrium measurement gas), H_2O or CO_2.

Guide values:	H_2O:	≥ 2 vol %
	CO_2:	≥ 2 vol %

9.3 Electrical heating of the sensor

The sensor heater may never be connected directly to battery voltage. It must always be controlled by the LSU control unit or the vehicle ECU.
Heating of the sensor before the engine is started is exclusively possible with a heater voltage $V_{H,eff}$ from 1.5 to 2.0 V (see chapter 1.6 heater strategy, heater voltage during condensation water phase).

9.4 General function test (at vehicles, in workshops)

The following tests can be done as a rough check of the sensor function (operation with control unit):

Plausibility check in rich exhaust gas:
- sensor signal: rich (output voltage of AWS < 2.5V)

Plausibility check on air:
- sensor signal: air signal (output voltage of AWS ≥ 5.6V)

Heater cold resistance at room temperature:
- resistance measurement with multimeter between grey and white cable, sensor not connected to control unit, connector pinout see offer drawing:
  $R_{H,cold}$ = 2 ... < 5 Ω (sensor at room temperature)

Visual inspection for mechanical damage

9.5 Sensor characteristic at high exhaust gas temperatures

Hot exhaust gas with a temperature above the operation temperature of the ceramic can lead to an increasing ceramic temperature and a deviation of the sensor output signal.

For data see section 3 (functional values).

9.6 Note for calculation of the sensor signal $I_{P,meas}$ when using a control unit AWS or CJ125:

Output voltage AWS : V_{AWS} [V] = 2.5 + 1.648 * $I_{P,meas}$ [mA]
Output voltage CJ125 : V_{CJ125} [V] = 1.5 + (61.9/1000*v) * $I_{P,meas}$ [mA]

with v=17 (standard measuring range λ=0.8...air) or v=8 (measuring range λ=0.65...air). The amplification factor v can be switched between v=8 and v=17 in the CJ125.

9.7 Connection of LSU and control unit

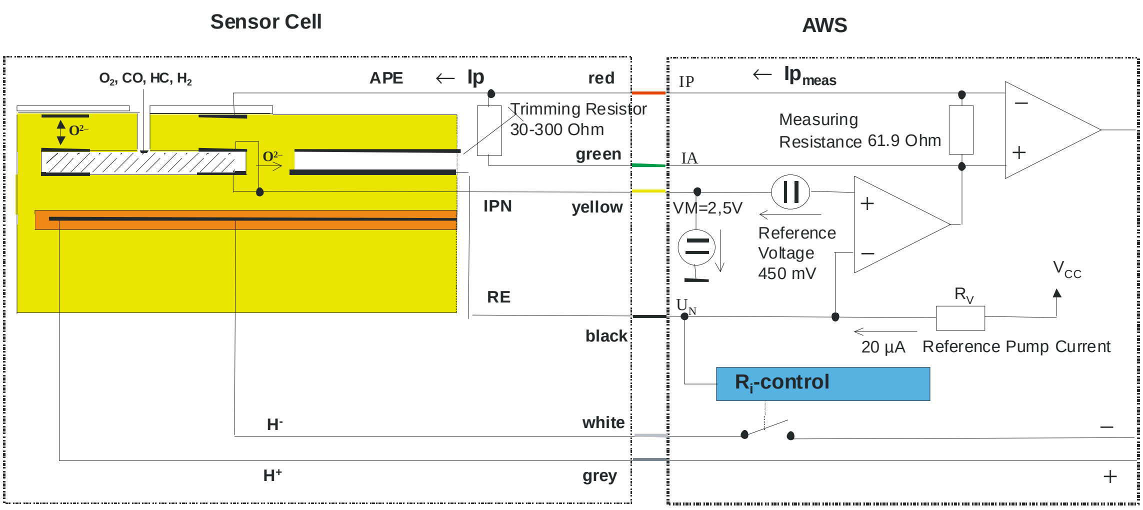


Fig. 7: Connection and control unit

10. Appendix

Symbols

$R_{i,N}$	Inner resistance of the nernst cell
$I_{N,max}$	Max. current load of nernst cell
$I_{p,Ref,min}$	Min. necessary reference pumping current
$I_{p,Ref}$	Recommended reference pumping current
$I_{p,Ref,max}$	Max. permissible reference pumping current
$I_{p,max,rich}$	Max. pumping current for rich gas
$I_{p,max,lean}$	Max. pumping current for lean gas
$U_{Batt,min}$	Min. battery voltage
U_{Batt}	Battery voltage
$U_{Batt,max}$	Max. permissible battery voltage
f_H	Heater duty cycle frequency
$U_{H,nom}$	Nominal heater voltage
$P_{H,nom}$	Nominal heater power
$R_{H,cold}$	Heater cold resistance at room temperature
$R_{H,cold,min}$	Min. heater cold resistance (at -40°C)
$U_{H,eff}$	Effective heater voltage
$U_{H,eff,max}$	Max. permissible effective heater voltage
T_{Sensor}	Sensor temperature
ED	Heater duty cycle
$T_{Exhaustgas}$	Exhaust gas temperature
$T_{Hexagon}$	Temperature at hexagon of the sensor housing
$T_{Grommet}$	Temperature at cable grommet (PTFE formed hose), sensor side
$T_{Upperhose}$	Temperature at cable grommet (PTFE formed hose), cable side
T_{Cable}	Temperature at the cables
T_{Sleeve}	Temperature at the cable sleeve
$T_{Connector}$	Temperature at the connector RB150
$I_{p,meas}$	Pumping current, measured over a measuring resistance of 61.9Ω
p_{gas}	Gas pressure
p_0	Reference pressure, ambient pressure=1013hPa
x_{O2}	Oxygen concentration
I_p	Pumping current
r	Relative deviation of $I_{p,meas}$ to nominal value in air
t	Relative deviation of characteristic curve cambering to nominal curve at the measuring point λ=1.7
$k_{rich\ gas}$	Factor describing the pressure dependence of I_p in rich gas
$k_{lean\ gas}$	Factor describing the pressure dependence of I_p in lean gas
$T_{Ceramic}$	Ceramic temperature
V_{AWS}	Output voltage of AWS control box
V_{CJxxx}	Output voltage of IC CJxxx in ECU