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

Typ / Type: **LSU ADV for use in gasoline systems**

Bestellnummer / Part Number: 0 258 0.. ...

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

Bemerkung / Comment: This document refers to the design type with protection tube “TP3” for use in gasoline systems.

Nr. Index	Seite Page	Änderung Revision	Datum Date	GS-SI/ENX9	GS-SI/ PJ-LSU4	GS-SI/ENX
1	-	**Erstausgabe / First Edition**	16.03.09	gez. Schichlein	gez. Albrecht	gez. Stanglmeier

Contents

Reference Specifications

Application guideline for gasoline systems	Y 258 E00 018
Handling instruction	Y 258 E00 000
Temperature measurement sensors	Y 258 E00 006
Measuring procedure for temperature and thermo shock for gasoline systems	Y 258 E00 007
LSU test bench and test method	Y 258 E00 005
DLA-M Test Bench for response time measurement of LSU ADV lambda sensors	Y 258 E00 027

This TKU is also valid for these documents.

General

The wide band lambda sensor LSU ADV is a planar ZrO_2 dual cell limiting current sensor with an integrated heater. It is used to measure the oxygen content and the λ-value of exhaust gases of combustion engines. The LSU ADV has been designed and tested only for use in the exhaust gas system of combustion engines.

This document refers to application in passenger cars with gasoline engine and operation with gasoline as fuel.

The wide band sensor LSU operates only in combination with a special LSU control unit (CJ125 ASIC). The functional characteristics given in this document are only valid for operation with the CJ125 according to module specification and with recommended operational parameters. The sensor must not stay in the exhaust gas stream when it is not heated or when the control unit is switched off.

Remarks: Values marked 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 document.

1. Characteristics

1.1 Electrical connection — 5 pole

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 measured 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 for new sensors. Continuous AC (f = 3 kHz) for $R_{i,N}$-measurement	$I_{N,max}$	≤ 80 µA	
O_2 reference pumping current (current source with max. 2.5V)			
• minimum necessary value for sensor function	$I_{p,Ref,min}$	≥ 10 µA	
• nominal value continuous	$I_{p,Ref}$	= 20 µA	
• maximum value continuous	$I_{p,Ref,max}$	≤ 25 µA	
• short time for 10 s in the ramp up phase			
- recommended	$I_{p,Ref}$	= 20 µA	
- maximum	$I_{p,Ref,max}$	≤ 75 µA	
Max. pumping current into pump cell (I_P)			
• for rich gas signal ($\lambda \geq 0.65$)	$I_{p,max,rich}$	≥ -4 mA	
• for lean gas signal (air)	$I_{p,max,lean}$	≤ 4 mA	

Pumping current Ip must only be activated after the heater has been switched on and the sensor element has reached a sufficient temperature (internal resistance of λ=1 Nernst cell $R_{i,N} \leq 2.3$ kΩ).
For correct operation, the reference pumping current must be activated as soon as possible after the beginning of the heater profile. The voltage between RE-cable and IPN-cable must be < 1.8 V when the heater profile is activated (see section 9.5).

Note: if the reference pumping current deviates from its nominal value, the sensor accuracy might be limited during this time.

1.3 Isolation resistance

(all measurements in static air, heater off)

- between housing and each heater- and sensor circuit connector pin at room temperature, measured with 800 V DC — $\geq$ 10 MΩ

- between sensor signal circuit (IPN connected to virtual mass VM, see section 9.5) and heater circuit at 650°C hexagon temperature, new and after aging acc. to section 4.1, measured with 12 V DC: — $\geq$ 1 MΩ

- between sensor signal pin APE and housing at 650°C hexagon temperature, new and after aging acc. to section 4.1, measured with 12V DC: — $\geq$ 100 kΩ

Isolation resistance of wire harness see section 8.4 (installation instructions).

1.4 Coupling between heater and sensor signal

Heating of the sensor with 9.4 W, potential between heater circuit and signal circuit with amplitude of 13 V and frequency of 20 Hz. Sensor signal evaluated with control unit over signal filter (R = 33 kΩ, C = 100 nF). Lab test is performed at room temperature, the specified value is also valid at hexagon temperature 650°C.

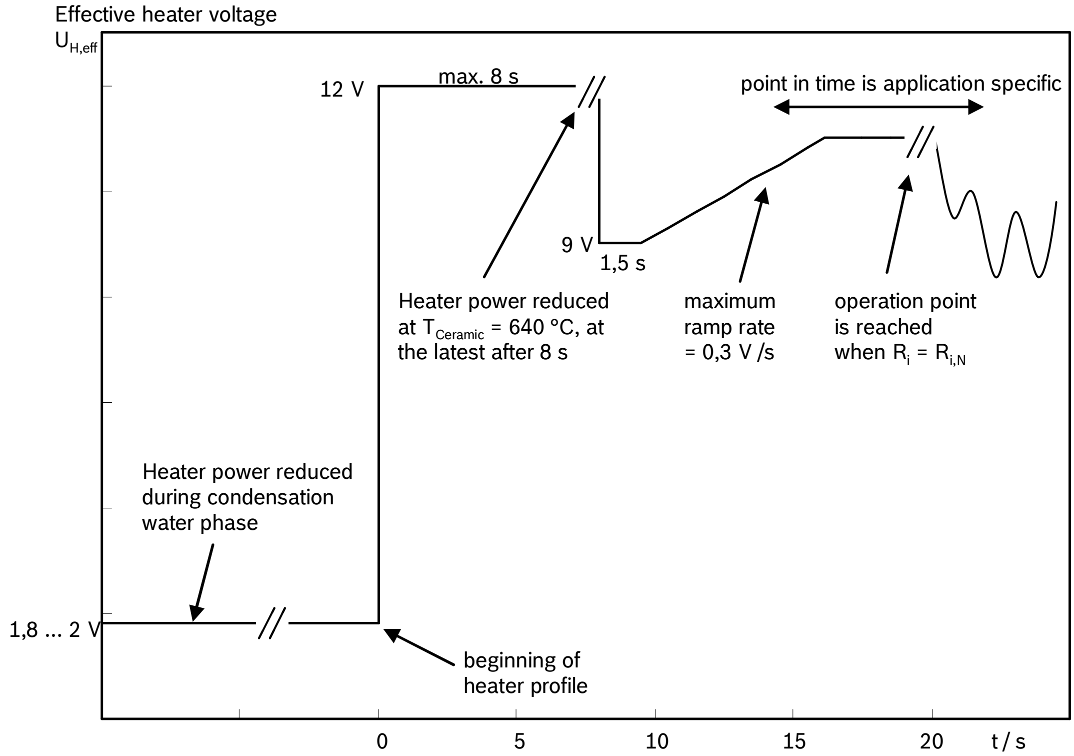
Sensor signal due to coupling:	$\Delta I_{p,meas}$	$\leq$ 40 µA	

1.5 Heater supply

Nominal heater power at 7.5 V heater supply at thermal equilibrium in air	$P_{H,nom}$	= 8.7 W	[N]
Nominal heater cold resistance at room temperature for new sensor, including cable and connector:	$R_{H,cold}$	= 2.6 Ω ± 0.6 Ω	
Minimum heater cold resistance at -40°C:	$R_{H,cold,min}$	= 1.6 Ω	[N]

1.6 Heating profile

When the heater is switched on, heater power must be applied as follows:



To rule out thermo shock damage of the sensor ceramic, the heater power must be limited during the condensation water phase - see measuring method Y 258 E00 007. When the ambient temperature is above 0 °C it is possible, under certain conditions, to begin the heater ramp before the end of the condensation water phase has been reached. This operation mode must be tested and released in consultation with Bosch. The procedure is described in document Y 258 E00 007 (gasoline systems).

Heater voltage during condensation water phase:	$V_{H,eff}$	= 1.8 V ... 2.0 V

The following heating profile must be applied:

• heater voltage at t = 0 s until $T_{Ceramic}$ = 640 °C is reached or at the latest at t = 8 s	$V_{H,eff}$	≤ 12 V
• heater voltage at $T_{Ceramic}$ = 640 °C or at latest at t = 8 s for 1.5 s	$V_{H,eff}$	≤ 9 V
• ramp rate	$\Delta V_{H,eff}/\Delta t$	≤ 0.3 V/s

(t = 0: end of condensation water phase)

If the ceramic temperature $T_{Ceramic}$ is not controlled during the heat-up phase, the 12 V-phase must be ended after 5 s. If $U_{H,eff}$ < 12 V the light-off time acc. to section 3.2 can not always be reached.

Maximum permissible effective heater voltage $V_{H,eff}$ to reach the operating point

• short time ≤ 30 sec (200h cumulated time):	$V_{H,eff}$	≤ 12 V
• continuous:	$V_{H,eff}$	≤ 11 V

Maximum system supply voltage $V_{Batt,max}$	$V_{Batt,max}$	≤ 16.5 V
• short time voltage peak for 60 ms (10 times over lifetime, $T_{ceramic} \geq 20$°C)	$V_{Batt,max}$	≤ 28 V

Minimum frequency of heater voltage control:	f_H	$\geq$ 100 Hz
Recommended frequency of heater voltage control:	f_H	= 100 Hz

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

Remark: Heater duty cycles with $f_H \geq 100$ Hz have not been tested. Their use has to be clarified with Bosch. The LSU may be used in 24 V grids only with voltage converters.

2. Application conditions

2.1 Temperature measurements

Temperature measurements are performed with a special sensor equipped with NiCrNi thermocouples. Sensor Type "MABCD" has measurement points at the upper side of the PTFE formed hose ($T_{upperhose}$), the cable grommet ($T_{grommet}$), the hexagon of the sensor housing ($T_{hexagon}$) and for the exhaust gas temperature ($T_{exhaustgas}$).

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

2.2 Storage temperature (passive):

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

Storage conditions see handling instruction Y 258 E00 000

2.3 Operating temperatures

Exhaust gas:	$T_{Exhaustgas}$	$\leq$ 930°C
Hexagon of the sensor housing:	$T_{Hexagon}$	$\leq$ 650°C
Cable grommet (PTFE formed hose)		
• sensor side:	$T_{Grommet}$	$\leq$ 250°C
• cable side (upperhose crimp):	$T_{Upperhose}$	$\leq$ 200°C
Cable and protective sleeve: (additional assembled parts such as clips or cable ties according to supplier spec or offer drawing)	T_{Cable}	$\leq$ 250°C
Connector RB150-5-Pole (TCI 1 928 A01 15T-000): for connectors according to customer requirements according to specification of connector manufacturer	$T_{Connector}$	$\leq$ 140°C

2.4 Maximum temperatures

2.4.1 (maximum 250 h accumulated over life time)

Exhaust gas:	$T_{Exhaustgas}$	$\leq$ 1030°C
Hexagon of the sensor housing:	$T_{Hexagon}$	$\leq$ 700°C

2.4.2 (maximum 40 h accumulated over life time)

Cable grommet (PTFE formed hose)		
• sensor side:	$T_{Grommet}$	$\leq$ 280°C
• cable side (upperhose crimp):	$T_{Upperhose}$	$\leq$ 230°C

Cable and protective sleeve: (additional assembled parts such as clips or cable ties according to supplier spec or offer drawing)	T_{Cable}	≤ 280°C
Connector RB150-5-Pole (TCI 1 928 A01 15T-000): for connectors according to customer requirements according to specification of connector manufacturer	$T_{Connector}$	≤ 150°C

Note: If the operating temperatures (section 2.3) are exceeded, the sensor accuracy might be limited during this time.
If the maximum gas temperature exceeds 930°C, or the hexagon temperature exceeds 650°C, the use of a longer thread boss is recommended (see section 8).
If the operating temperatures $T_{Hexagon}$ and $T_{Grommet}$ acc. to section 2.3 are exceeded simultaneously, it has to be assured by appropriate measurements at the customer, that the temperature at the contact pads of the sensor element remains below 400°C.

2.5 Start-stop-operation

The sensor is suitable for start-stop-operation.

The sensor has to be heated during the entire stop phase. The pumping current, I_p, must be turned off during the stop phase. The reference pumping current, $I_{p,ref}$, must stay on.

If the sensor heating is turned off during the stop phase, this has to be tested and released in coordination with Bosch.

If condensation water is present in the exhaust gas system, the sensor has to be heated with reduced heater power acc. to section 1.6. After the end of the condensation water phase, the sensor has to be heated up according to the heating profile in section 1.6.

2.6 Liquids in the exhaust gas system

When condensation water is present at exhaust side (i.e. before dew point is reached), the heater power of the sensor must be limited, see section 1.6.

2.7 Exhaust gas pressure (absolute pressure)

• continuous	p_{gas}	≤ 2.5 bar

Note: If the maximum continuous exhaust gas pressure is exceeded, the sensor accuracy might be limited during this time.

2.8 Permissible vibrations

(measured at the sensor housing)

Stochastic vibrations: (measured at the peak level)	≤ 1000 m/s^2
Sinusoidal vibrations	≤ 300 m/s^2
• vibration displacement:	≤ 0.3 mm

2.9 Permissible fuel and fuel additives

The LSU ADV has been designed for use with all commercially available gasoline and diesel fuels. Testing has been performed with gasoline fuel in accordance with DIN EN228 for commercially available unleaded fuel.

For a specific project, another fuel type can only be released after the specific fuel has been tested in coordination with Bosch.

2.10 Permissible operating modes

in gasoline systems

- intake-manifold fuel injection
- gasoline direct injection at $\lambda = 1$

Another operating mode can only be released for a specific project after it has been tested in coordination with Bosch.

2.11 Oil consumption

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

2.12 Life time

The technical development of the sensor is aligned to a service life of 250,000 km and a maximum life time of 15 years. Failure criterion is the non-compliance with the measurement data as mentioned under section 6.

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

- Application conditions acc. to sections 1 and 2.
- Installation conditions acc. to section 8.
- Checking of each application/installation location according to application guideline Y258 E00 018.
- Usage of an RB approved sensor connector with gold plated sensor signal contacts.

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

2.13 Intended use

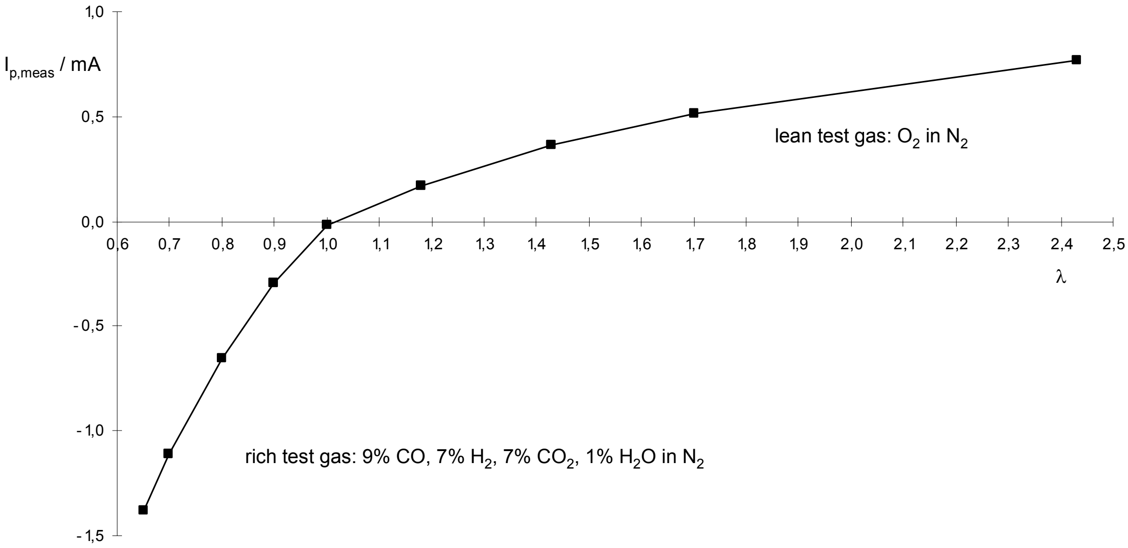
If according to the supply agreement between the customer and Bosch, Bosch will be responsible for delivered products being fit for the use or purpose intended and/or having a defined level of quality, such responsibilities are subject to the application of the product conforming to the agreed upon environment, installation and stress conditions, as such are referenced in this document. When the product during the Bosch release procedures has successfully met the testing specifications agreed to, or provided by, the customer it is deemed to fully cover all requirements, if any, that the product be fit for the use or purpose intended and/or have a defined level of quality. The customer shall be responsible for the system application, which includes ensuring that the product application and all environmental, installation and stress conditions to which the product will be exposed are covered by such testing. The customer shall be responsible for making sure that the product will not be exposed to conditions in excess of those referenced in such testing specifications.

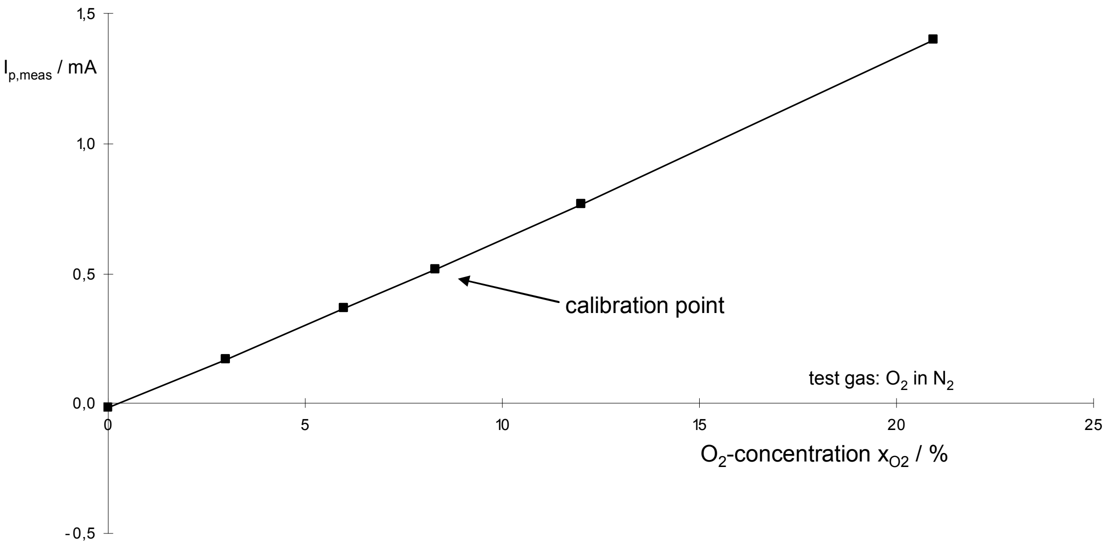
3. Test data (functional values)

Special hints for performing test bench measurements:
The measurement is done with the sensor operated with an electronic control unit. The given tolerances are only validated 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 and maintained. The reference pumping current is a continuous 20 µA for all measurements. The signal, $I_{p,meas,}$ is the current through a measuring resistance (see section 9) at p_{gas} = 1013 hPa.
Due to the technical design of the gas test benches, these measurement data cannot be used for capability calculations.

3.1 Nominal characteristic line

For a synthetic gas (rich: 9% CO, 7% H_2, 7% CO_2, 1 % H_2O in N_2; lean: O_2 in N_2) in a laboratory measurement acc. to Y 258 E00 005, the following characteristic line is measured:





O_2-Konz. x_{O2} [%]					0.00	3.00	6.00	8.29	12.0	20.95
λ-Wert	0.65	0.70	0.80	0.90	1.00	1.18	1.43	1.70	2.43	air
$I_{p,meas}$ [mA]	-1.38	-1.11	-0.65	-0.30	-0.02	0.17	0.36	0.52	0.77	1.40

The λ-values for $\lambda \geq 1$ in the above table can be calculated by $\lambda = \dfrac{1 + \dfrac{H/C}{H/C+4} \cdot x_{O_2}}{1 - 4.77 \cdot x_{O_2}}$ for an assumed H/C-ratio of H/C = 2.
For other H/C-ratios in a lean exhaust gas of combustion engines the corresponding λ-values can be calculated by the above formula.

3.2 Light-Off Time

Measurement of the light-off time of the sensor in LSU test bench acc. to test method Y 258 E00 005:

The light-off time is defined as the time between start of the heater ramp until the pumping current $I_{p,meas}$ stabilizes in a tolerance band of +/-10% of the final value in lean exhaust gas at λ = 1.7 and +/-25% in rich exhaust gas at λ = 0.8.

	new	after test bench run
Light-off time	≤ 5 s	≤ 5 s

Note: In the engine, the light-off time might differ, depending on installation and gas temperature conditions.

3.3 Tolerances

Measurement in LSU test bench according to Y 258 E00 005:

	new	after test bench run
Pump. curr. $I_{p,meas}$ [mA] at λ = 0.8 (*)	-0.652 ± 0.032	-0.652 ± 0.046 (*)
Pump. curr. $I_{p,meas}$ [mA] at λ = 1.0	-0.018 ± 0.008	-0.018 ± 0.008
Pump. curr. $I_{p,meas}$ [mA] at λ = 1.7	0.515 ± 0.022	0.515 ± 0.036 (*)

(*) equivalent to ΔIp/Ip = ±7 %.

The λ-value where the pumping current equals zero($I_{p,meas}$ = 0) is denoted as the characteristic value "λ_{static}". The corresponding O_2-concentration is:

$$x_{O_2}(I_{p,meas} = 0) = \frac{-I_{p,meas}(\lambda = 1)}{I_{p,meas}(\lambda = 1.7) - I_{p,meas}(\lambda = 1)} \cdot 0.0829 \cdot$$

Therefore $\lambda_{static} = \dfrac{\frac{1}{3} x_{O_2}(I_{p,meas} = 0) + 1}{1 - 4.77 \cdot x_{O_2}(I_{p,meas} = 0)}$.

For other λ-values and operating conditions the λ-tolerances can be calculated as follows:
For λ > 1 and small values of $\Delta I_{p,meas}/I_{p,meas}$: $\Delta\lambda = \lambda(\lambda - 1) \cdot \dfrac{\Delta I_{p,meas}}{I_{p,meas}}$.
with $I_{p,meas}$: pumping current.

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

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

The r-value is the relative deviation of the sensor signal from the nominal value in air according to section 3.1.

Relative deviation $r = \left[\frac{I_{p,meas} - I_{p,\text{nominal}}}{I_{p,\text{nominal}}}\right]_{an\ Luft}$

with $I_{p,\text{nominal}}$: value from the nominal characteristic curve in section 3.1.

Measurement in LSU test bench acc. to Y 258 E00 005:

	new	after test bench run
Relative deviation r [%]	0 ± 4	0 ± 7

3.5 Curvature of the characteristic line (t_0-value)

In lean gas, the signal is not completely linear in relation to O_2. The curvature is defined as the relative deviation of $I_{p,meas}$ that is calculated by linear extrapolation of the characteristic line between λ = 1.0 and λ = 1.7 to air, and the $I_{p,meas}$ measured in air.

$$t_0 = \frac{I_{p,meas}(air) - I_{p,extra.}(air)}{I_{p,extrap.}(air)} \text{ with}$$

$$I_{p,extrap.}(air) = \frac{20.95}{8.29} \cdot \left(I_{p,meas}(\lambda = 1.7) - I_{p,meas}(\lambda = 1)\right) + I_{p,meas}(\lambda = 1)$$

From the tolerance of the curvature, tolerances at other λ-operating points can be estimated („calibration during fuel-cut off").

Specification:
Measurement in LSU test bench acc. to Y 258 E00 005:

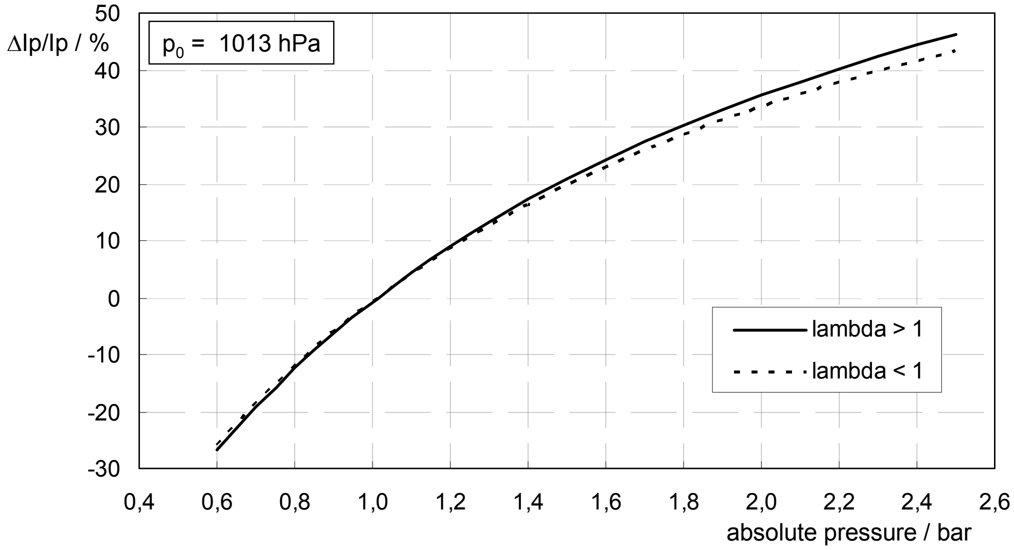
	new	after test bench run
Curvature of char. line t_0 [%]	4.9 ± 2.1	4.9 ± 2.1

3.6 Pressure dependency of the sensor signal ("k"-value)

A change of the exhaust gas pressure leads to a deviation of the sensor signal, which can be approximately described 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 = 1.013 bar (reference pressure).

The factor k is dependent on the operating mode, „rich" or „lean", and is approx.:
$k_{lean\ gas}$ = 1.15 bar $k_{rich\ gas}$ = 1.05 bar [N]



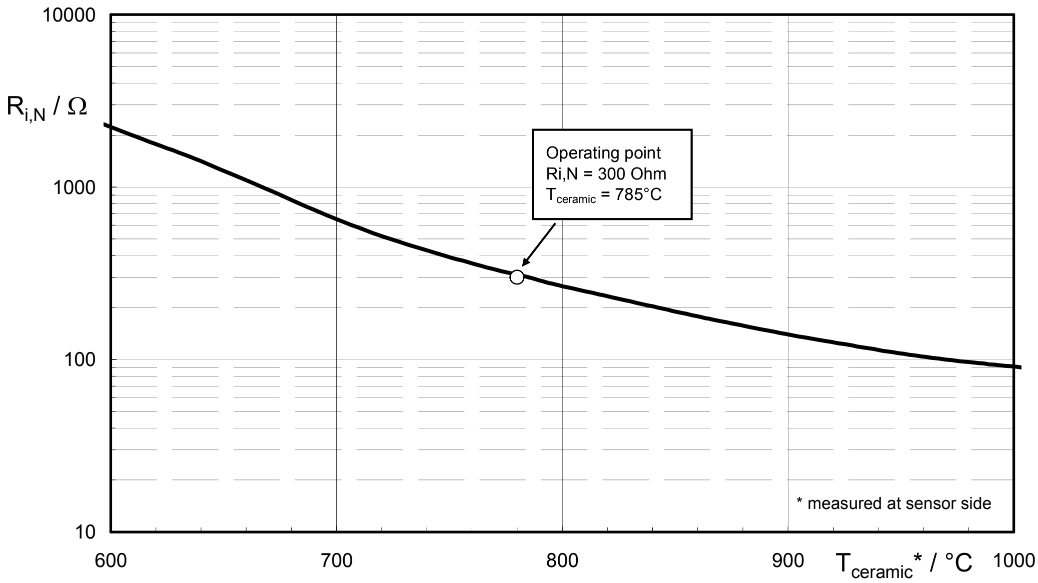
Specification:
Measurement in LSU test bench acc. to Y 258 E00 005:

	new	after test bench run
$k_{lean\ gas}$ [bar] (measured at λ = 1.7; p = 4 bar)	1.15 ± 0.30	1.15 ± 0.30

3.7 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 approximately $\Delta I_{P,meas}/I_{P,meas}$ = 3% / 100°C [N].

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



Guide value [N] for operating point:

- new: $R_{i,N}$ = 300 Ω, $T_{ceramic}$ = 785 °C
- after 3000 h test bench run: $R_{i,N}$ = 300 Ω, $T_{ceramic}$ = 885 °C

Note: these values are guide values. The specification of tolerances is covered by section (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 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 $R_{i,N}$ = 450 Ω and $R_{i,N}$ = 200 Ω (by variation of heater power). For new sensors, the deviation is:

$\frac{\Delta I_{p,meas}}{I_{p,meas}} = \frac{I_{p,meas,200\Omega} - I_{p,meas,450\Omega}}{I_{p,meas,200\Omega}}$ [%]	3.4 ± 2.5

3.8 Dynamic response

Dynamic response time, τ_{63}, of the sensor at a λ-step from an O_2/N_2 gas mixture (e.g. λ = 1.3) to air.

Specification:
Measurement in a laboratory test bench acc. to Y258 E00 027 designed for measuring the dynamic lambda response under mass flow conditions.

		new	after test bench run
gasoline design type (section 7.2)	τ_{63} [ms]	≤ 100	≤ 100

4. Environmental test specification

Each test must be carried out with new sensors. After completion of the tests, the sensors must be within the tolerances as specified in sections 3.3 and 3.8 („after test bench run"), unless otherwise specified. During testing, the sensors are operated by a control unit, unless otherwise specified.

4.1 Engine endurance runs

4.1.1 Endurance run in gasoline engine

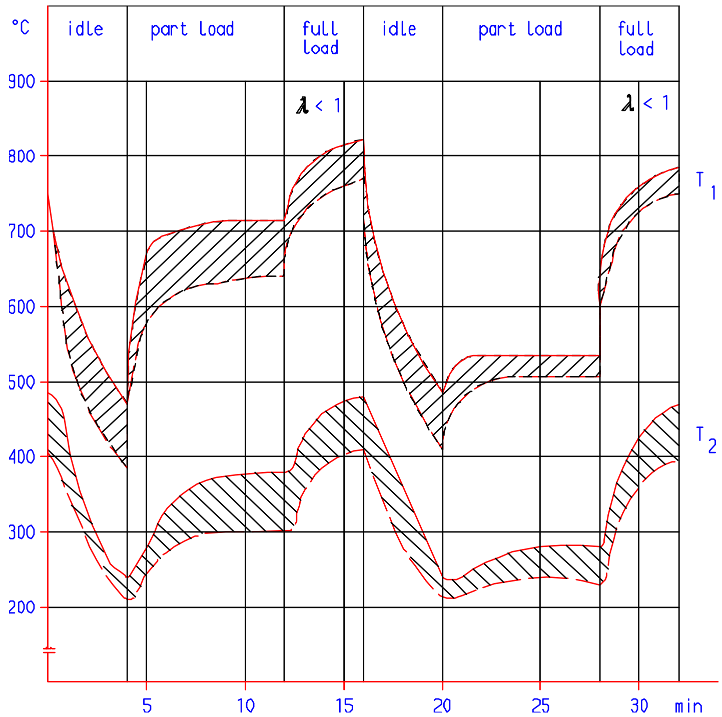
For measurements of functional values after endurance test the sensors have to be fitted into the exhaust system of a λ=1 controlled gasoline engine. The sensors are operated with a control unit in this test (closed loop control of heater power).
Speed and load are changed in a 6-cycle program so that a temperature curve is reached in the sensor tip as per sketch.

- Fuel: according to DIN EN228 for commercially available unleaded fuel.
- Oil consumption ≤ 0.04 l/h.
- Oil brand: multi-range oil viscosity 10W-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 sections 3.2, 3.3, 3.5, 3.6 and 3.8 ("after test bench run") must be fulfilled.

Test time: 3000 h (500 h product audit)



T_1 = exhaust gas

T_2 = housing hexagon

4.1.2 Test to silicon sensitivity (gasoline engine)

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

exhaust gas temperature:	400°C
test time:	6 h
Si-mass added over run time:	0.79 g

4.1.3 Test to sulfur sensitivity

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

exhaust gas temperature:	200 °C (idle operation)
test time:	500 h
sulfur-mass added over life time:	188 g

4.1.4 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 engine as in section 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:	200 h
fuel consumption in the test:	8.5 l/h

Engine oil with high additives is mixed into the fuel. The whole amount of added oil additives is for the complete test:

P [g]	Ca [g]
20	26

4.2 Further tests

4.2.1 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%

4.2.2 Sinusoidal vibration test acc to DIN EN 60068-2-6 Test Fc

Test equipment: electrodynamic vibrator
Test between

- 50...160 Hz at constant amplitude ≤ 0.3 mm and between
- 160...500 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.

4.2.3 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

4.2.4 Test with damp heat, cyclic (12+12-hour cycle) acc. to DIN EN 60068-2-30, Test Db

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

The heater has to be switched off during this test.

4.2.5 Salt mist test acc. to DIN EN 60068-2-11 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.

4.2.6 Change of temperature acc. to DIN EN 60068-2-14 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.

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

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.

4.2.8 Submergence test acc. to IEC 60529 * CEI 60529 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. In the test time the signal must be stable.

Test evaluation: the sensor signal in air must be $I_{p,meas} \leq 1.61$ mA.

4.2.9 Wire pull test

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

4.2.10 Fuel resistance test (FVP-test)

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

Test evaluation: the sensor signal in air must be $I_{p,meas} \leq 1.61$ mA.

4.2.11 Fine leak test

The gas leakage is measured from exhaust gas side with an air pressure of 4 bar (sensor not heated). The leakage rate must be smaller than 0.2 ml/min.

4.2.12 Drop test acc. to DIN EN 60068-2-32 test Ed proc. 1

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

5. Performing tests

Test procedure	Section	100% test	Lot release test	Product audit test	Design verification 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	
Coupling of heater duty cycle	1.4			x	
Functional test in rich gas λ=0.8		x			
Functional test in lean gas λ=1.7 (sensor calibration)		x		x	
Tolerances	3.3		x		
Light off time	3.2			x	
Curvature	3.5			x	
Pressure dependency	3.6			x	
Dynamic	3.8			x	
Engine endurance run gasoline, t = 500 h	4.1.1			x	
Engine endurance run gasoline, t = 3000 h	4.1.1				x
Silicon sens. test (gasoline)	4.1.2				x
Sulfur sensitivity test	4.1.3				x
Oil component sens. test	4.1.4				x
Operation in air	4.2.1			x	
Sinusoidal vibration test	4.2.2				x
Random vibration test	4.2.3				x
Test with damp heat	4.2.4				x
Salt mist test	4.2.5				x
Change of temperature	4.2.6				x
Sulfur dioxide test	4.2.7				x
Submergence test	4.2.8			x	
Wire pull test	4.2.9			x	
Fuel resistance test (FVP)	4.2.10			x	
Fine leak test	4.2.11			x	
Drop test	4.2.12				x

Note: All production lots are tested by lot release tests. Product audit tests are performed for monitoring the product quality on a regular basis. Design validation tests are only performed with new sensor types in the design verification phase.

6. Evaluation of field parts

When evaluating field returned parts, proper functionality is determined by testing the returned parts and obtaining the following characteristic data:

- Functional values from sections 3.3 (tolerances "after test bench run").

7. Design types

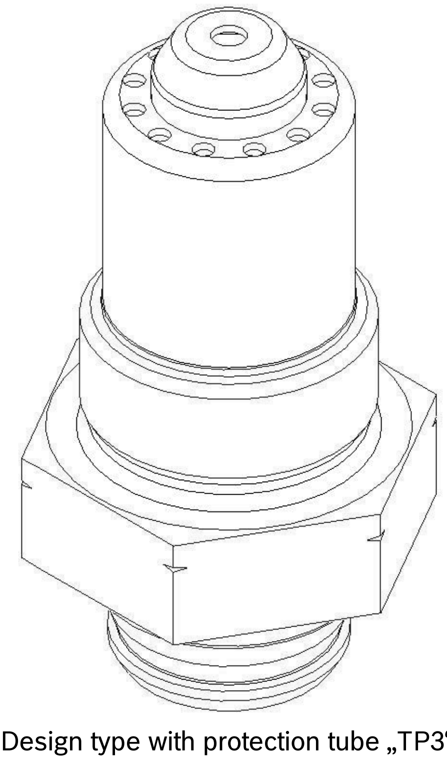
The following types are available:

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.

7.2 Protection tube



Design type with protection tube „TP3“ for use in gasoline systems

8. Installation 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 while also satisfying the specified temperature limits.

Tested installation positions in gasoline applications:

- after turbo charger
- before catalyst

All other installation positions, e.g. before turbo charger, must be assured sufficiently in the respective application, in agreement with Bosch.

8.2 The lambda sensor must only be operated with a specially designed electronic control unit. The control unit must only be activated after engine start. For switching on the sensor the heater power must always be power controlled (e.g. duty cycled heater power).
In the warm-up phase at engine start, the sensor is operated with reduced heater power as described in section 1.6. This is necessary to reduce thermal stress of the sensor element during cold starts due to high peak power in the first seconds.
The heater power must only be increased when the presence of condensed water in the exhaust gas system can be ruled out.

8.3 The sensor ceramic element is heated up quickly after heater start. Prior to heating up the ceramic element, it must be guaranteed that there is no condensed water present. This could damage the hot ceramic element.

To allow early light-off, the sensor installation location design must be selected in a way to minimize, or eliminate, condensed water on the exhaust gas side from contacting the sensor. 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 method for application specific evaluation is described in document Y 258 E00 007 (for gasoline application).

8.4 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 $\geq 2\ M\Omega$ between all sensor signal pins.

8.5 Design measures

- Locate sensor as close to the engine as possible, respecting the maximum allowed temperature range.
- The exhaust pipe in front of the sensor must not contain any pockets, projections, protrusions, edges, flex-tubes etc. to avoid accumulation of condensed water. A downward slope of the pipe is recommended.
- Make sure that the front hole of the double protection tube does not point against exhaust gas stream.
- Attempt to achieve rapid heat-up of the exhaust pipes in the area in front of the sensor and also of the complete sensor thread boss area, to avoid developing condensed water.
- The sensor thread boss must be designed as shown in 8.12 to reach a rapid heat up of the sensor protection tube area. Make sure that the protection tube is completely in the exhaust gas stream.

8.6 System measures:

- Never switch on sensor heating or the control unit before engine start.
- Delay of sensor heater start or power control of the sensor heater, e.g. as a function of engine and ambient temperature (see section 1.6)

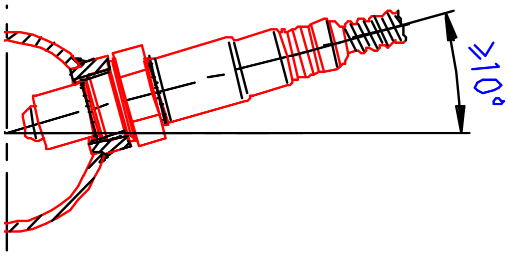
The test method for evaluation is described in document Y 258 E00 007.

8.7 Installation angle must be inclined at least 10° towards horizontal (electrical connection upwards). This prevents the collection of liquids between sensor housing and sensor element during the cold start phase.

The angle w.r.t. the exhaust gas stream should be 90°.

Other installation angles must be inspected and tested for the specific project by the customer in coordination with Bosch.

For gasoline applications, (design type with protection tube "TP3") an angle of max. 90°+15° (gas entry hole to exhast gas stream) or 90°-30° resp. is allowed.



8.8 Underfloor installation of the sensor at a distance from the engine requires an additional check of the following points:

- positioning of the sensor with respect to stone impact hazard
- positioning and fixing of cable and connector with respect to mechanical damage, cable bending stress and thermal stress.

8.9 Avoid excessive heating up of sensor cable grommet, particularly when the engine has been switched off after running under maximum load conditions.

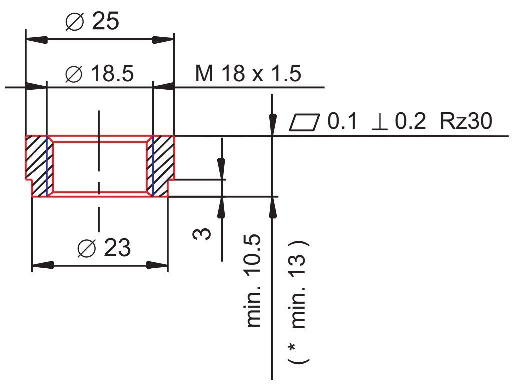
8.10 The sensor should not be exposed to continuous, one-sided dripping of water, (e.g. by the air conditioner condensed water drain). The thermal stress could lead to mechanical damage of the sensor.

8.11 The PTFE formed hose is part of the reference air volume of the sensor and must be kept sealed and undamaged. For installation, the minimum bending radius at the centerline of the hose must be 20 mm (for long PTFE hose) respectively 12 mm (for short hose). Keep the PTFE formed hose away from sharp edges and avoid contact/friction with frame/engine assembly.
The first fixing point for the cable to the car body should be 200 mm to 400 mm after the end of the PTFE formed hose, depending on movement of the exhaust system.

8.12 Recommended material for the thread boss in the exhaust pipe:

Temperature resistant stainless steel, e. g.
X 5 CrNi 18 10, DIN 17440 1.4301 or 1.4303 or SAE 30304 or SAE 30305 (US standard)
Thread boss dimensions should be as in sketch, note that sensor thread must be covered completely.

Recommendation(*): For hot applications ($T_{Hexagon}$>650°C or T_{gas}>930°C) the thread boss should be min. 13 mm to avoid overheating of the protection tube weld and to cool down the sensor hexagon.



If the protection tube welding is directly exposed to the exhaust gas (in case the installation angle is > 90° toward the exhaust gas stream) the 13mm thread must be used in order to cover the welding. The tolerance of the counter thread (6H) must be ensured after the thread boss is welded (with respect to welding distorsion).

If the length is ≥16 mm (max. 22 mm permissible) the danger of thermo shock will be increased due to condensed water forming inside the protection tube. This must be covered separately by measurements described in Y 258 E00 007.

8.13 Tightening torque: 40 Nm ... 60 Nm, material characteristics and strength of the thread must be appropriate.

8.14 Assembly with special high temperature resistant grease on the screw-in thread (e.g. Castrol Optimol Paste MF or Bostic Never−Seez Regular Grade NS42B 2).

8.15 The use of cleaning/greasing fluids or evaporating solids at the sensor plug connection is not permitted. The substances used must be free of organic ingredients acc. to ARCO-Test-no. > 36. Exception: wetting of contact plugs with oil during punching with highly volatile punching oil Raziol CLF11.

8.16 The sensor and sensor connection must be covered when underbody sealant (wax, tar etc.), or spray oil is applied to the vehicle.

8.17 The influence of contamination which enters the exhaust gas through the intake air or as a result of fuel, oil, sealing materials etc., and thus reaches the λ-sensor, is application specific and must be determined by customer tests.

8.18 The sensor must not be exposed to strong mechanical shocks (e.g. while the sensor is installed). Otherwise the sensor element may crack without visible damage to the sensor housing.

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 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 must not stay in the exhaust gas stream when it is not heated or when the control unit is switched off.

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:	$\geq$ 2 vol %
	CO_2:	$\geq$ 2 vol %

9.3 Electrical heating of the sensor

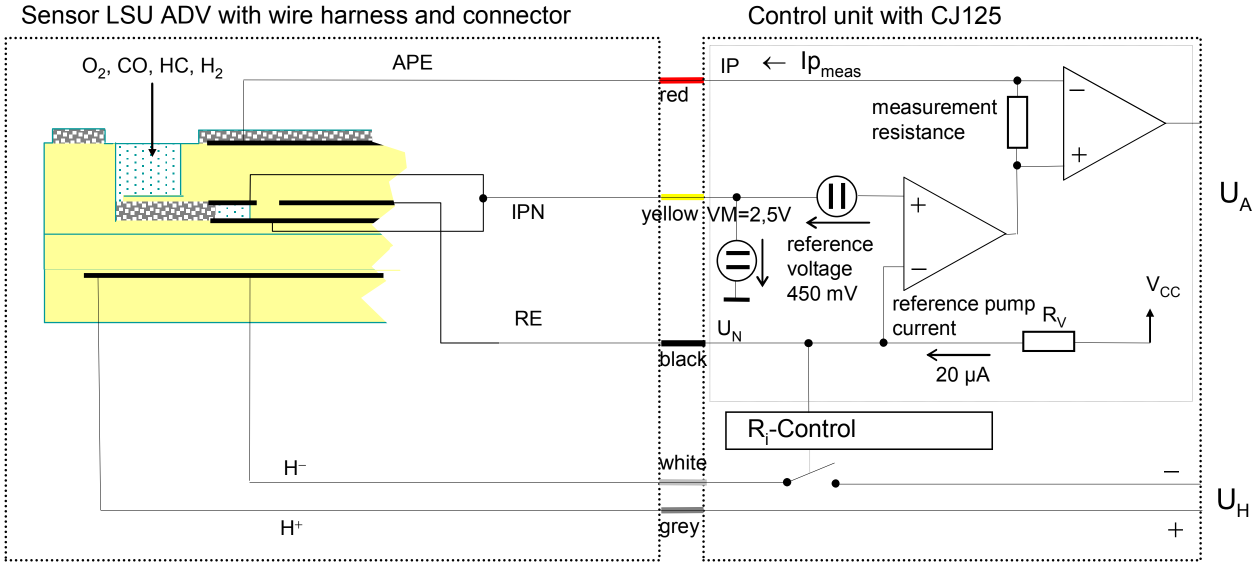
The sensor heater may never be connected directly to battery voltage. It must always be controlled by the LSU control unit or the vehicle ECU. Heating the sensor before the engine is started is not allowed.

9.4 Note for calculation of the sensor signal $I_{P,meas}$ when using a control unit

Output voltage CJ125 : U_{CJ125} [V] = 1.5 + (R_{meas} [Ohm]/1000*v) * $I_{P,meas}$ [mA]

with R_{mess} as measurement resistance. The amplification factor, v, can be switched between v = 8 and v = 17 in the CJ125. v = 17 (standard measuring range λ = 0.9 ... air) or v = 8 (measuring range λ = 0.7 ... air).

9.5 Connection of LSU and control unit



10. Appendix

Symbols

ED	Heater duty cycle
f_H	Heater duty cycle frequency
$I_{N,max}$	Max. current load of nernst cell
I_p	Pumping current
$I_{p,max,lean}$	Max. pumping current for lean gas
$I_{p,max,rich}$	Max. pumping current for rich gas
$I_{p,meas}$	Pumping current, measured over a measuring resistance of 61.9 Ω
$I_{p,Ref}$	Recommended reference pumping current
$I_{p,Ref,max}$	Max. permissible reference pumping current
$I_{p,Ref,min}$	Min. necessary reference pumping current
$k_{lean\ gas}$	Factor describing the pressure dependence of I_p in lean gas
$k_{rich\ gas}$	Factor describing the pressure dependence of I_p in rich gas
p_0	Reference pressure, ambient pressure=1013hPa
p_{gas}	Gas pressure
$P_{H,nom}$	Nominal heater power
r	Relative deviation of $I_{p,meas}$ to nominal value in air
$R_{H,cold}$	Heater cold resistance at room temperature
$R_{H,cold,min}$	Min. heater cold resistance (at -40°C)
$R_{i,N}$	Inner resistance of the nernst cell
t_0	Curvature of the characteristic line
T_{Cable}	Temperature at the cables
$T_{Ceramic}$	Ceramic temperature
$T_{Connector}$	Temperature at the connector RB150
$T_{Exhaustgas}$	Exhaust gas temperature
$T_{Grommet}$	Temperature at cable grommet (PTFE formed hose), sensor side
$T_{Hexagon}$	Temperature at hexagon of the sensor housing
T_{Sensor}	Sensor temperature
T_{Sleeve}	Temperature at the cable sleeve
$T_{Upperhose}$	Temperature at cable grommet (PTFE formed hose), cable side
$U_{H,nom}$	Nominal heater voltage
V_{AWS}	Output voltage of AWS control box
V_{Batt}	Battery voltage
$V_{Batt,max}$	Max. permissible battery voltage
$V_{Batt,min}$	Min. battery voltage
$V_{H,eff}$	Effective heater voltage
$V_{H,eff,max}$	Max. permissible effective heater voltage
x_{O2}	Oxygen concentration