

**Produkt / Product:** Planar Wide Band Lambda Sensor

**Typ / Type:** LSU4.9

**Bemerkung / Comment:** All data given in this document are nominal values and might be subject of change at all time.

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**General**

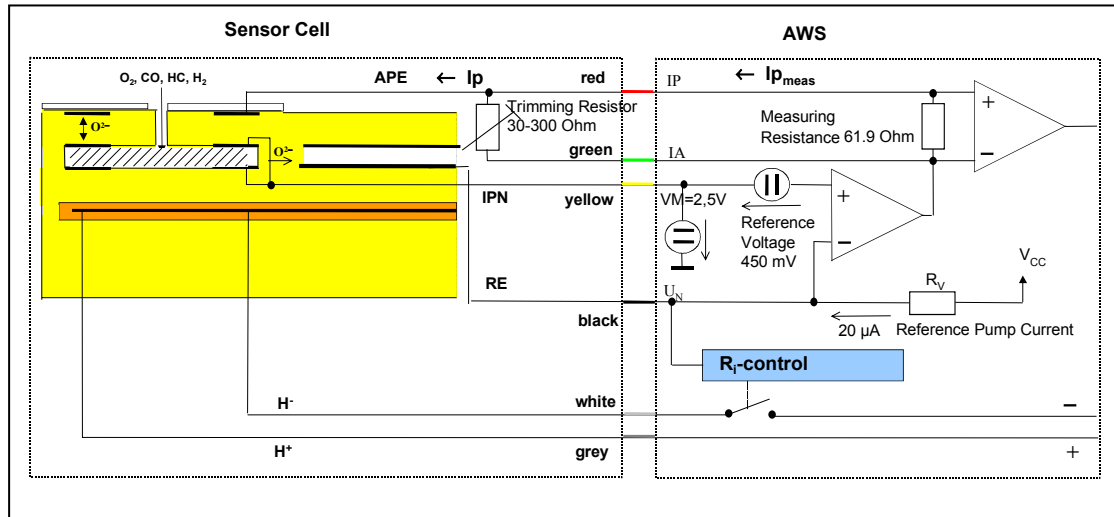
The wide band lambda sensor LSU is a planar ZrO<sub>2</sub> dual cell limiting current sensor with an integrated heater. It is used to measure the oxygen content and the λ-value of exhaust gases in automotive engines (gasoline and diesel). Its monotonic output signal in the range of λ=0.65 to air makes the LSU capable of being used as an universal sensor for λ=1 measurement as well as for other λ ranges.

The connector module contains a trimming resistor, which defines the characteristics of the sensor and is necessary for the sensor function.

The wide band sensor LSU operates only in combination with a special LSU control unit (e.g. AWS control box, LA4 or CJ125 IC).

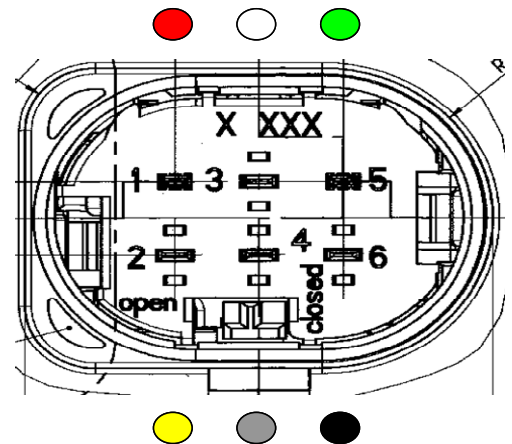
**1. Characteristics**

**1.1 Circuit of LSU and control unit**



**1.2 Electrical connection:**

- Pin1: Pumping Current APE red
- Pin2: Virtual Ground IPN yellow
- Pin3: Heater Minus H- white
- Pin4: Heater Vbatt H+ grey
- Pin5: Trim Current RT green
- Pin6: Nernst Voltage RE+ black



### 1.3 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  $\lambda=1$  Nernst cell  $R_{i,N}$   
for new sensors (operating and calibration point)  
(measured with AC  $f = 1...4$  kHz)

300  $\Omega$

Max. current load of  $\lambda=1$  Nernst cell  
Continuous AC ( $f = 1...4$  kHz)  
for  $R_{i,N}$  measurement

$\leq 250$   $\mu\text{A}$

Recommended value for reference pumping current  
continuous

= 20  $\mu\text{A}$

Max. pumping current into pump cell ( $I_p$ )

- for rich gas signal ( $\lambda \geq 0,65$ )

$\geq -9$  mA

- for lean gas signal (air)

$\leq 6$  mA

### 1.4 Isolation resistance

(all values for new sensors in static air, heater off)

- between housing and each heater- and  
sensor circuit connector pin at room  
temperature

$\geq 30$  M $\Omega$

- between sensor signal circuit and heater  
circuit at 600°C hexagon temperature

$\geq 1$  M $\Omega$

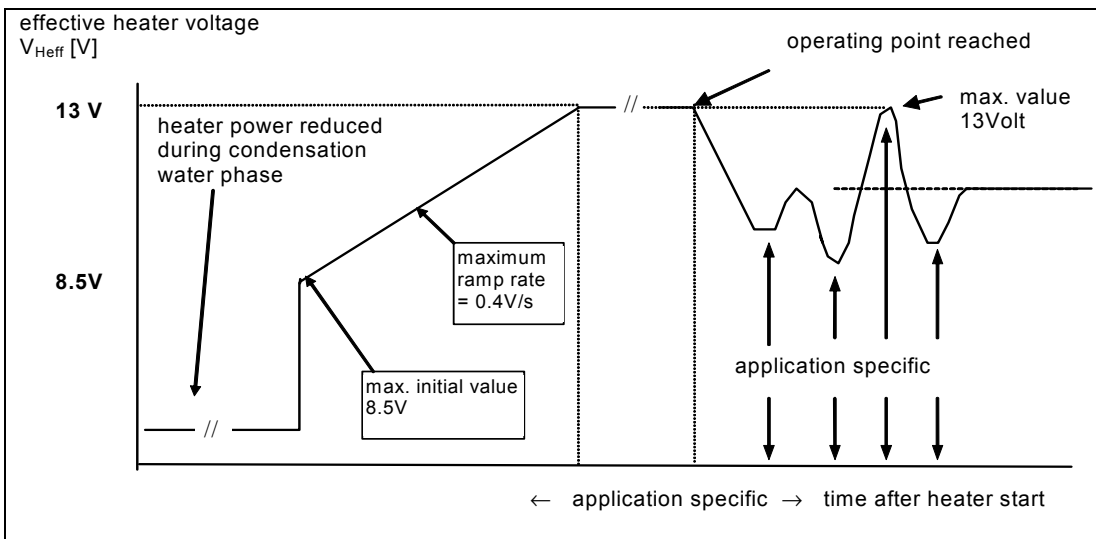
- between sensor signal pin APE and housing  
at 600°C hexagon temperature:

$\geq 100$  k $\Omega$

**1.5 Heater supply**

Nominal voltage:	7.5 V
Nominal heater power at 7.5 V heater supply at thermal equilibrium in air:	approx. 7.5 W
Nominal heater cold resistance at room temp. for new sensor, including cable and connector	3.2 Ω
Minimum heater cold resistance at -40°C:	1.8 Ω

**1.6 When the heater is switched on, heater power must be limited as follows:**



Maximum permissible heat up rate with limited heater power to reduce the thermal stresses in the heat-up phase

During the condensation water phase the heater power must be limited to rule out thermo shock damage of the sensor ceramic.

Heater voltage during condensation water phase  $V_{H,eff} \leq 2 \text{ V}$

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

- short time  $\leq 30\text{sec}$  (200h cumulated time):  $\leq 13 \text{ V}$
- continuous:  $\leq 12 \text{ V}$

Maximum system supply voltage  $V_{batt,max}$   $\leq 16.5 \text{ V}$

Minimum system supply voltage  $\geq 10.8 \text{ V}$   
 at this system supply voltage the function of the sensor is given in typical applications. This must still be tested in the resp. application.

Minimum frequency of heater voltage control  $\geq 20 \text{ Hz}$   
 - recommended value:  $\geq 100 \text{ Hz}$

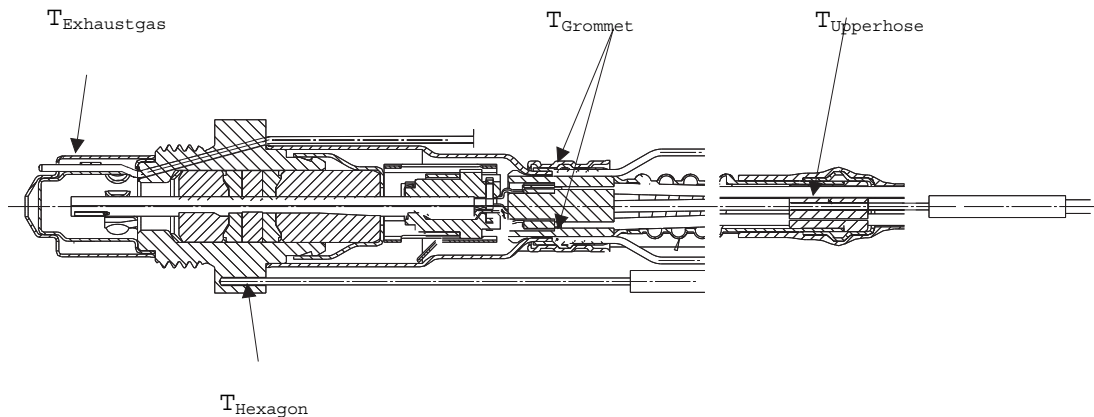
Note: the use of the sensor with 24V power systems is not permissible except if a voltage converter system is used.

Note: duty cycle =  $(V_{H,eff} / V_{batt})^2$

**2. Application conditions**

**2.1 Temperature measurements**

Temperature measurements are performed with a special sensor equipped with NiCrNi thermocouples, see sketch. 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 ( $T_{Exhaustgas}$ ). These sensors are available from Bosch.



**2.2 Operating temperatures**

Exhaust gas ( $T_{Exhaustgas}$ ):	$\leq 930^{\circ}\text{C}$
Hexagon of the sensor housing ( $T_{Hexagon}$ ):	$\leq 600^{\circ}\text{C}$
Cable grommet (PTFE formed hose)	
- sensor side ( $T_{Grommet}$ ):	$\leq 250^{\circ}\text{C}$
- cable side (upperhose crimp, $T_{Upperhose}$ ):	$\leq 200^{\circ}\text{C}$
Cable and protective sleeve:	$\leq 250^{\circ}\text{C}$
Connector:	$\leq 120^{\circ}\text{C}$

**2.3 Maximum temperatures**

**2.3.1** (max. 250 h accumulated over lifetime)

Exhaust gas ( $T_{Exhaustgas}$ ):	$\leq 1030^{\circ}\text{C}$
Hexagon of the sensor housing ( $T_{Hexagon}$ ):	$\leq 680^{\circ}\text{C}$

**2.3.2** (max. 40 h accumulated over lifetime)

Cable grommet (PTFE formed hose)	
- sensor side ( $T_{Grommet}$ ):	$\leq 280^{\circ}\text{C}$
- cable side (upperhose crimp, $T_{Upperhose}$ ):	$\leq 230^{\circ}\text{C}$
Cable and protective sleeve:	$\leq 280^{\circ}\text{C}$

**2.4 Exhaust gas pressure** (absolute pressure)

- continuous:  $\leq 2.5 \text{ bar}$
- short time, max. 250h cumulated over lifetime  $\leq 4 \text{ bar}$

**Notes:**

If the operating temperature (2.2) or the max. continuous exhaust gas pressure (2.4) is exceeded, the sensor accuracy might be limited during this time.

**2.5 Permissible vibrations**

Stochastic vibrations: (peak level)  $\leq 1000 \text{ m/s}^2$

Sinusoidal vibrations:  $\leq 300 \text{ m/s}^2$

**2.6 Corrosion, humidity**

The lambda sensor has been developed and tested for use in automotive vehicles, e.g.

- damp heat cycling acc. to IEC 68-2-30 test Db (21 days, 40°C)
- salt mist test acc. to IEC 68-2-11 test Ka, test time 288 h
- temperature cycling test acc. to IEC 68-2-14 test Na, 250 cycles -40°C / 130°C
- sulfur dioxide test with general condensation of moisture acc. to DIN EN ISO 6988, 6 cycles of 24h
- submergence test IPx7 acc. to IEC 529

**2.7 Permissible fuel additives**

In accordance with DIN EN228 for commercially available unleaded fuel or EN590 for diesel fuel.

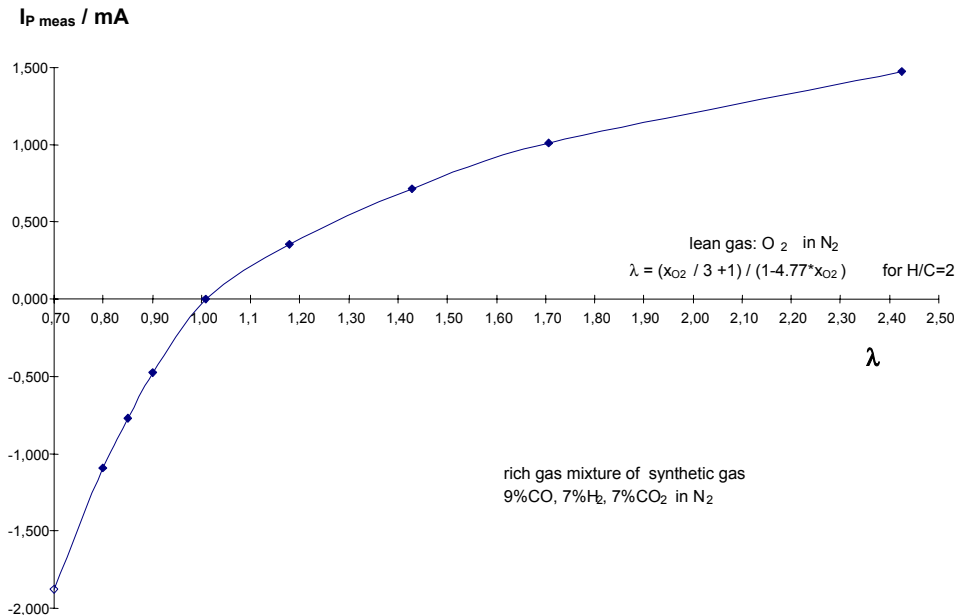
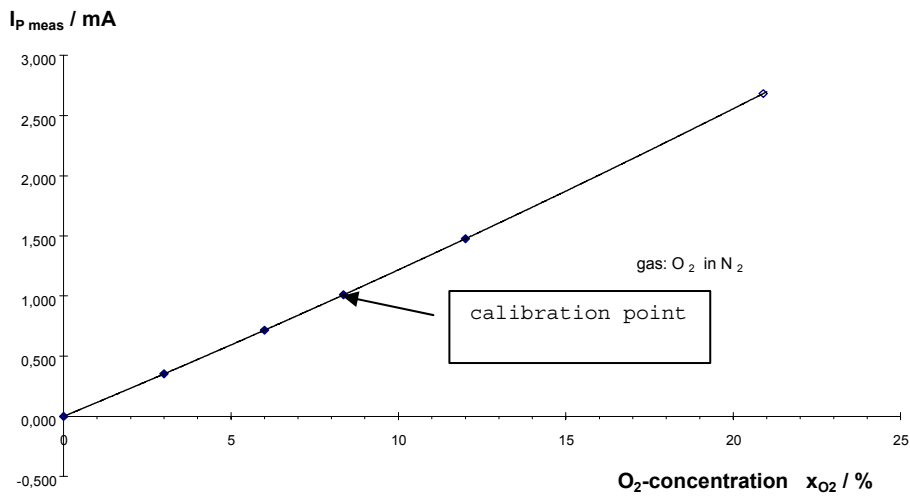
Contamination by other fuels, additives or oil consumption must be determined by the customer by the way of adequate large-scale tests.

**3. Functional values**

All data must be regarded as nominal values, measured under the following conditions:

The sensor is operated with circuit as in section 1.1. The heater power is closed-loop controlled, so that the nominal sensor internal resistance is reached. The measurement is done in a lab test bench at  $p_{gas}=1013hPa$ . 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 than under lean gas conditions.

**3.1 Nominal characteristic line**



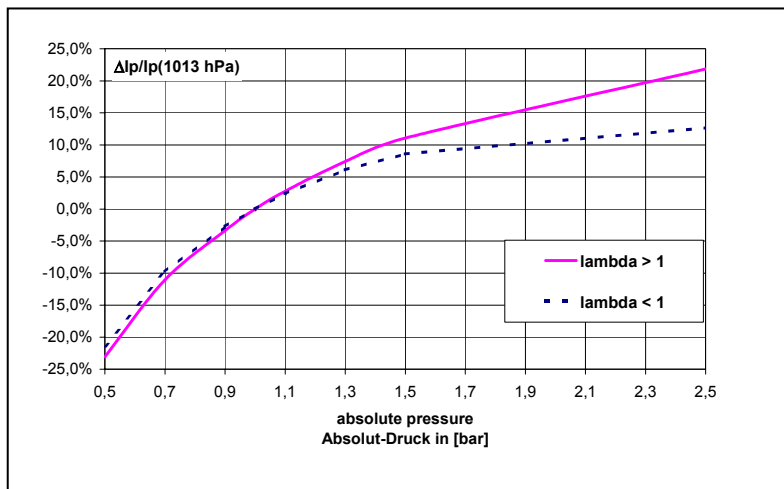
O <sub>2</sub> -conc. x <sub>O2</sub> / %						3.0	6.0	8.29	12.0	20.95
λ-value	0.65	0.70	0.80	0.90	1.016	1.18	1.43	1.70	2.42	air
I <sub>P, meas</sub> / mA	-2.22	-1.82	-1.11	-0.50	0.00	0.33	0.67	0.94	1.38	2.54

**3.2 Time to activity (light-off time)**

Guide value for the time to activity after switching on the sensor heater ("light-off time") ≤ 10 s

**3.3 Pressure dependency of the sensor signal**

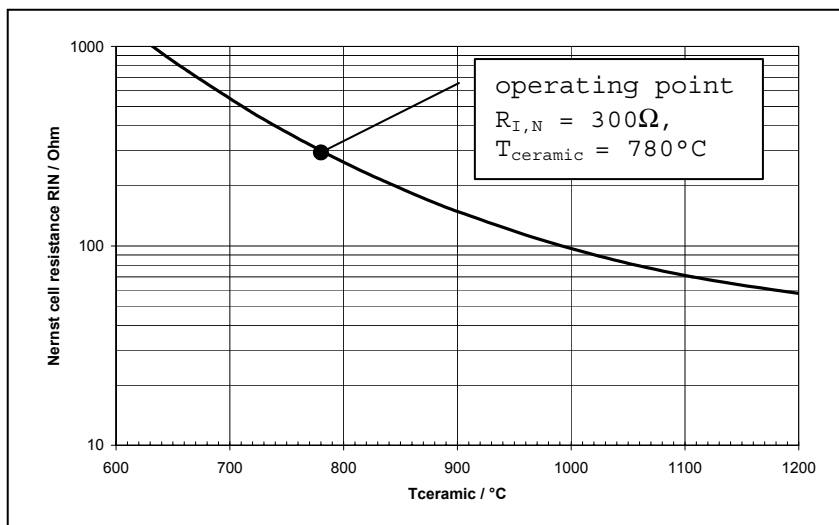
A change of the exhaust gas pressure leads to a deviation of the sensor signal, which can be approximately described as follows:



**3.4 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.  $\Delta I_{P,meas}/I_{P,meas} = 4\%/100^\circ\text{C}$

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





#### 4. Installation instructions

The lambda sensor has been developed and tested for use in automotive engines only.

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.

- 4.1** Installation in the exhaust system must be at a point guaranteeing representative exhaust gas composition whilst also satisfying the specified temperature limits.
- 4.2** The heater power must always be switched on power controlled (e.g. duty cycled heater power), starting with a maximum ramp-up duty cycle as shown in the diagram 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.
- 4.3** The sensor ceramic element is heated up quickly after heater start. After heating up the ceramic all occurrence of condensation water, which could damage the hot ceramic, must be ruled out.

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.

##### 4.3.1 Design measures:

- Locate sensor as close to the engine as possible, respecting max. 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 condensation water. A downwards 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 heating-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 of condensation water
- The sensor thread boss must be designed as shown in 4.9 to reach a rapid heat up of the sensor protection tube area. Make sure, that the protection tube is fully reaching into the exhaust gas stream.

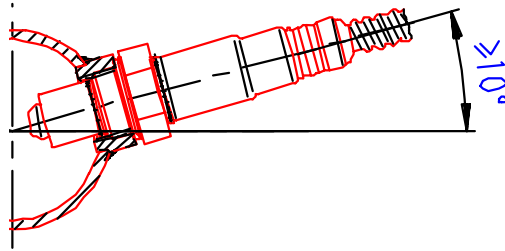
##### 4.3.2 System measures:

- Never switch on sensor heating resp. control unit before engine start.
- Delay of sensor heater start or reduced heater power (see section 1.6)

- 4.4** Installation angle must be inclined at least 10° towards horizontal (electrical connection upwards). Thus preventing the collection of liquids between sensor housing and sensor element during the cold start phase.

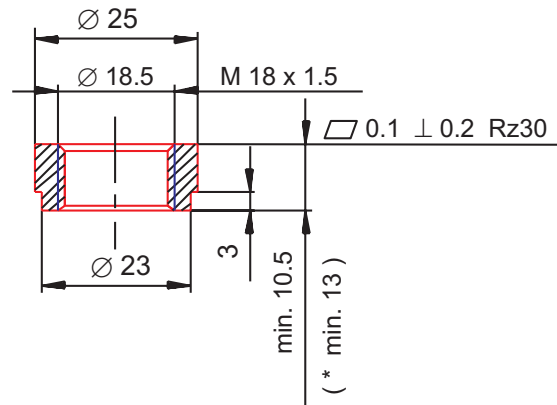
The angle against the exhaust gas stream should be aimed as 90°. Maximum inclination should be 90°+15° (protection tube towards gas stream) or 90°-30°.

Other installation angles must be inspected and tested individually.



- 4.5** Avoid excessive heating up of sensor cable grommet, particularly when the engine has been switched off after running under max. load conditions.
- 4.6** The use of cleaning/greasing fluids or evaporating solids at the sensor plug connection is not permitted.
- 4.7** Assembly with special high temperature resistant grease on the screw-in thread (e.g. Bosch-No. 5 964 080 112).
- 4.8** Tightening torque: 40-60 Nm, material characteristics and strength of the thread must be appropriate.
- 4.9** 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 ( $T_{Hexagon} > 600^{\circ}C$  or  $T_{gas} > 930^{\circ}C$ ) the thread boss should be **min.** 13mm to avoid overheating of the protection tube welding and to cool down the sensor hexagon.

If the length is  $\geq 16$ mm (max. 22mm permissible) the danger of thermo shock will be increased due to condensation water formation inside the protection tube.

- 4.10 The sensor and sensor connection must be covered when underbody sealant (wax, tar etc.) or spray oil is applied to the vehicle.
- 4.11 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  $\lambda$ -sensor, is application specific and must be determined by customer tests.
- 4.12 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.
- 4.13 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  $\geq 2M\Omega$  between all sensor signal pins.
- 4.14 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.
- 4.15 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 of the hose must be 20mm (for long PTFE hose) resp. 12mm (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 200mm to 400mm after the end of the PTFE formed hose, depending on movement of the exhaust system.
- 4.16 The sensor should not be exposed to continuous, one-sided dripping of water, e.g. by the air conditioning condensation water outlet. The thermal stress could lead to mechanical damage of the sensor.
- 4.17 The sensors must be stored in the original packaging at a dry place. Maximum storage time is 2 years.

## 5. General operating instructions

### 5.1 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  $\lambda=1$  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.

### 5.2 Use without control unit

The sensor might stay in the exhaust gas stream for a short time also if the control unit is not connected. Connect and disconnect only, when the control unit is switched off.

### 5.3 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 ( $\lambda = 1$ ) or rich gas ( $\lambda < 1$ ), 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:	$H_2O:$	$\geq 2 \text{ vol } \%$
	$CO_2:$	$\geq 2 \text{ vol } \%$

### 5.4 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.

**5.5 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 in AWS < 2.5V)

Plausibility check on air:

- sensor signal: air signal (output voltage in AWS  $\geq$  5.6V)

Heater cold resistance at room temperature:

- resistance measurement with multimeter between grey and white cable, sensor not connected to control unit:

$$R_{H,cold} = 2,5 \dots < 5 \Omega \quad (\text{sensor at room temperature})$$

Visual inspection for mechanical damage

**5.6 Sensor characteristic at low or high exhaust gas temperatures**

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

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

$$\text{Output voltage AWS} : V_{AWS} \text{ [V]} = 2.5 + 1.648 * I_{P,meas} \text{ [mA]}$$

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

with  $v=17$  (standard measuring range  $\lambda=0.8\dots\text{air}$ ) or  $v=8$  (measuring range  $\lambda=0.65\dots\text{air}$ ).

The amplification factor ( $v$ ) can be switched between  $v=8$  and  $v=17$  in the CJ125.