

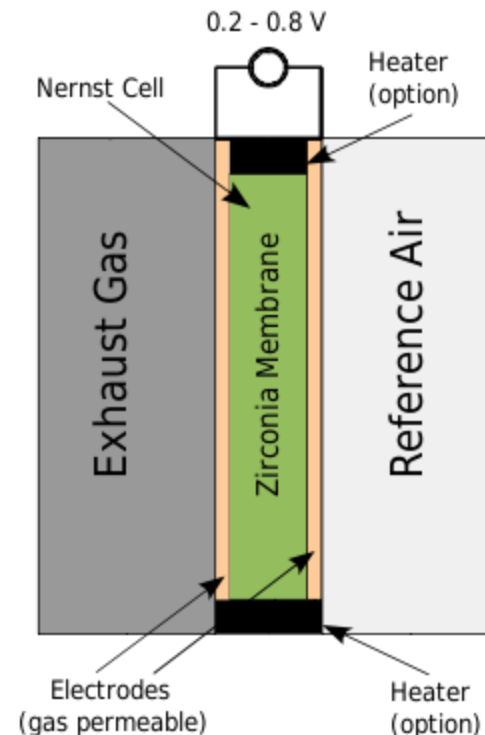


What's Lambda Sensor?

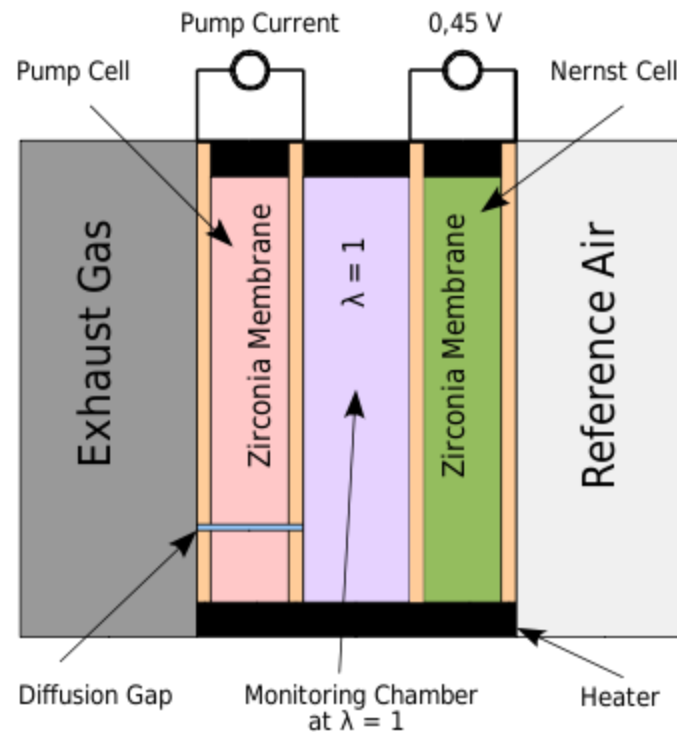
- Used to measure the proportion of oxygen (O₂) in the gas or liquid being analyzed.
- Developed by the [Robert Bosch GmbH](#) during the late 1960s (Dr. Günter Bauman)
- The original sensing element is made with a thimble shaped [zirconia ceramic](#) coated on both the exhaust and reference sides with a thin layer of [platinum](#) and comes in both heated and unheated forms
- The planar-style sensor entered the market in 1998 (also pioneered by Bosch) and significantly reduced the mass of the ceramic sensing element as well as incorporating the heater within the ceramic structure. This resulted in a sensor that started sooner and responded faster.
- The sensor does not actually measure oxygen concentration, but rather the difference between the amount of oxygen in the exhaust gas and the amount of oxygen in air.

The zirconium dioxide, or zirconia, lambda sensor is based on a solid-state electrochemical fuel cell called the Nernst cell. Its two electrodes provide an output voltage corresponding to the quantity of oxygen in the exhaust relative to that in the atmosphere.

The zirconia sensor is of the "narrow band" type, referring to the narrow range of fuel/air ratios to which it responds



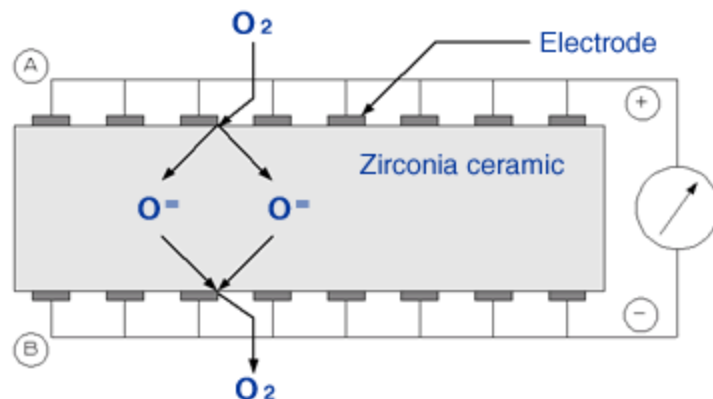
A variation on the zirconia sensor, called the "wideband" sensor. It is based on a planar zirconia element, but also incorporates an electrochemical gas pump. An electronic circuit containing a [feedback](#) loop controls the gas pump current to keep the output of the electrochemical cell constant, so that the pump current directly indicates the oxygen content of the exhaust gas.



- The two-step Lambda oxygen sensors operate in accordance with the principle of the galvanic oxygen-concentration cell with solid-state electrolyte (Nernst principle). The ceramic element is conductive for oxygen ions from a temperature of approximately 350 °C (safe, reliable operation at >350 °C).
- The different oxygen content on both sides of the sensor generates an electrical voltage between the two boundary layers.
- Whereas response times at ceramic temperatures below 350 °C are in the seconds range, at optimum temperatures of around 600 °C the sensor responds in less than 50 ms. When the engine is started therefore, the Lambda control is switched off until the minimum operating temperature of about 350 °C is reached. During this period, the engine is open-loop-controlled.

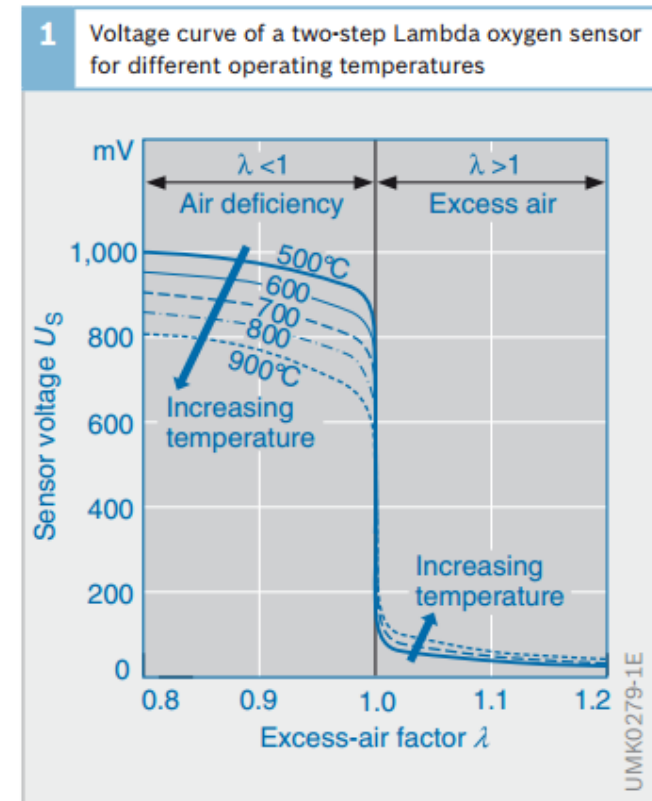
How to measure Lambda?

- not at all, it can only be calculated
- non-linear relation between partial pressure of O_2 and I , based on theory of Brettschneider / Pischinger
- at rich mixtures ($\lambda < 1$), no free oxygen in exhaust gas
- physical effect of oxygen ion transport through zirconiumdioxid ceramic (Nernst effect)
- Nernst voltage at $\lambda = 1$ about 450 mV



Theoretical Nernst equation

$$E = \frac{RT}{nF} \ln \frac{P_R}{P_M}$$



Design

LSH25 finger-type sensor

Sensor ceramic element with protective tube

The solid electrolyte is a ceramic element which is impermeable to gas. It is a mixed oxide comprising the elements zirconium and yttrium in the form of a tube closed at one end (finger, Fig. 3). The surfaces have been provided on both sides with electrodes made from a microporous, thin noble-metal layer.

The ceramic body protrudes into the exhaust pipe, and the platinum electrode on its outside surface acts as a catalytic converter in miniature. Exhaust gas which reaches this electrode is processed catalytically and brought to a stoichiometrical balance ($\lambda = 1$). In addition, the side that is exposed to the exhaust gas has a porous, ceramic multiple layer (spinel layer) to protect it against contamination and

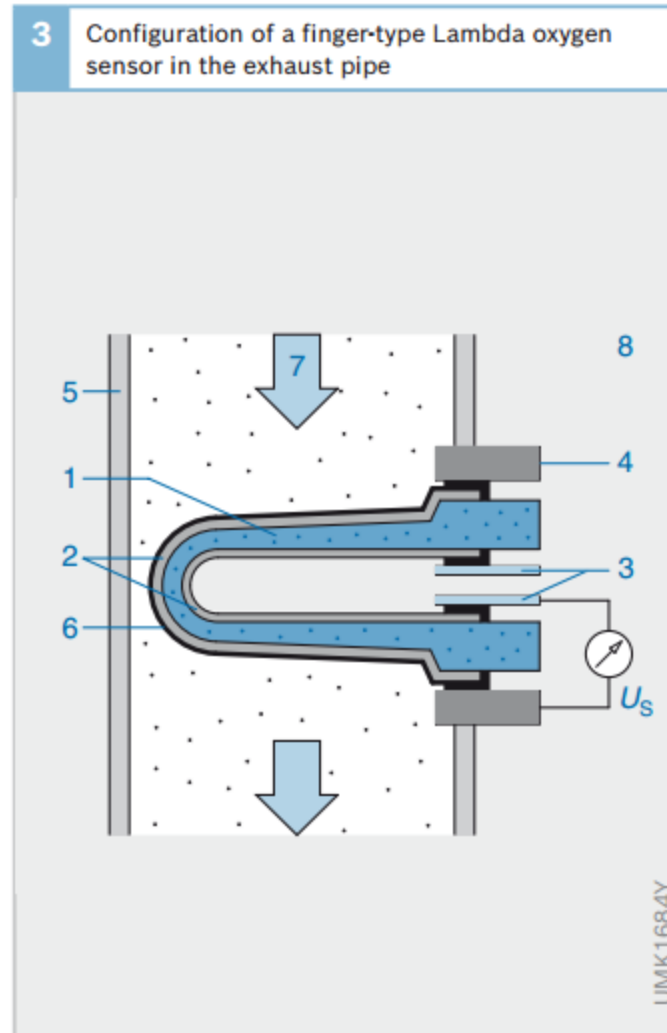


Fig. 3

- 1 Sensor ceramic element
- 2 Electrodes
- 3 Contacts
- 4 Housing contact
- 5 Exhaust pipe
- 6 Ceramic protective layer (porous)
- 7 Exhaust gas
- 8 Outside air
- U_s Sensor voltage

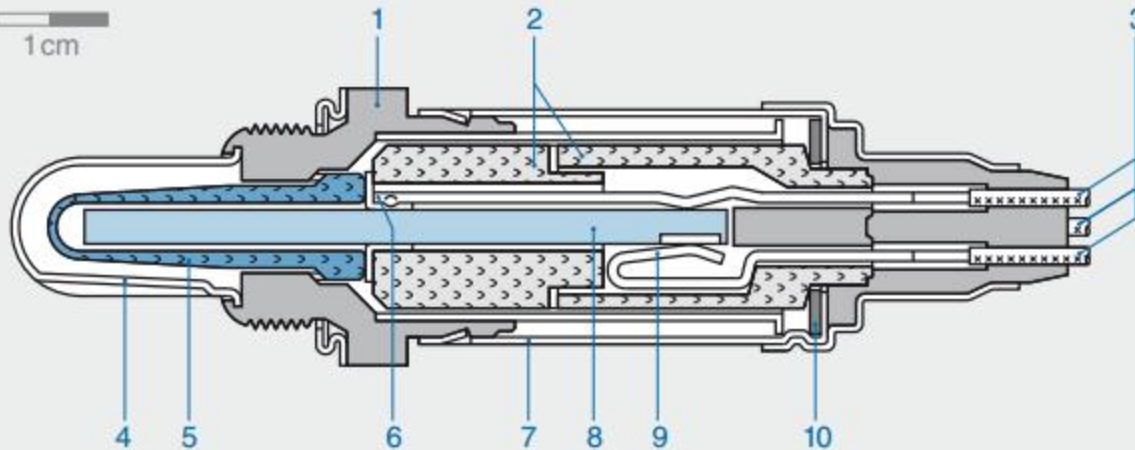
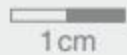
The Lambda Sensor

LSH Two Steps LAMBDA Sensor

2 LSH25 heated finger-type Lambda oxygen sensor (view and section)



UMK1450Y



UMK0143Y

Fig. 2

- 1 Sensor housing
- 2 Ceramic support tube
- 3 Connecting cable
- 4 Protective tube with slots
- 5 Active sensor ceramic
- 6 Contact element
- 7 Protective sleeve
- 8 Heater element
- 9 Clamp-type connections for the heater element
- 10 Disk spring

Fig. 4

- 1 Porous protective layer
- 2 Outer electrode
- 3 Sensor foil
- 4 Inner electrode
- 5 Reference-air-channel foil
- 6 Insulation layer
- 7 Heater
- 8 Heater foil
- 9 Connection contacts

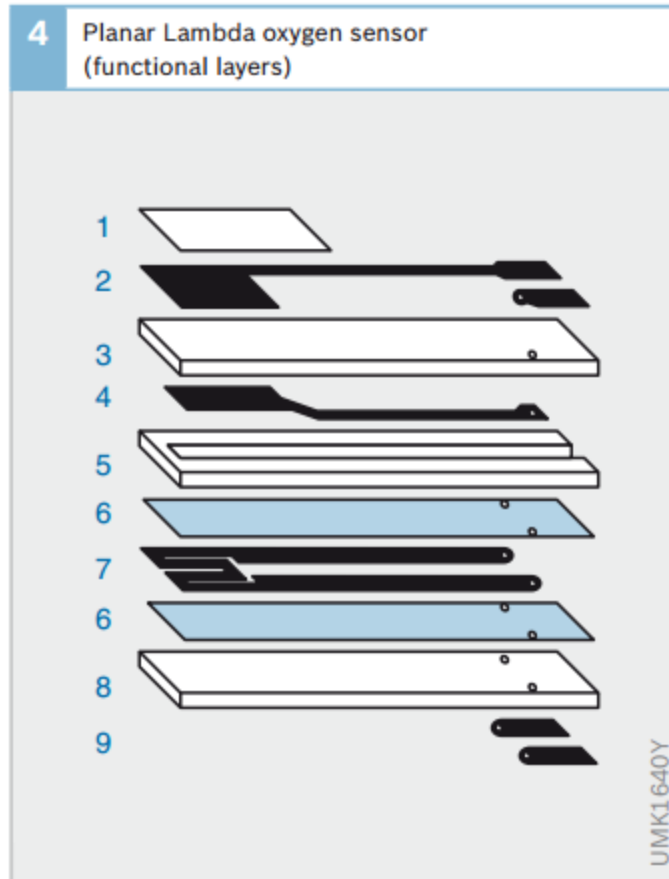
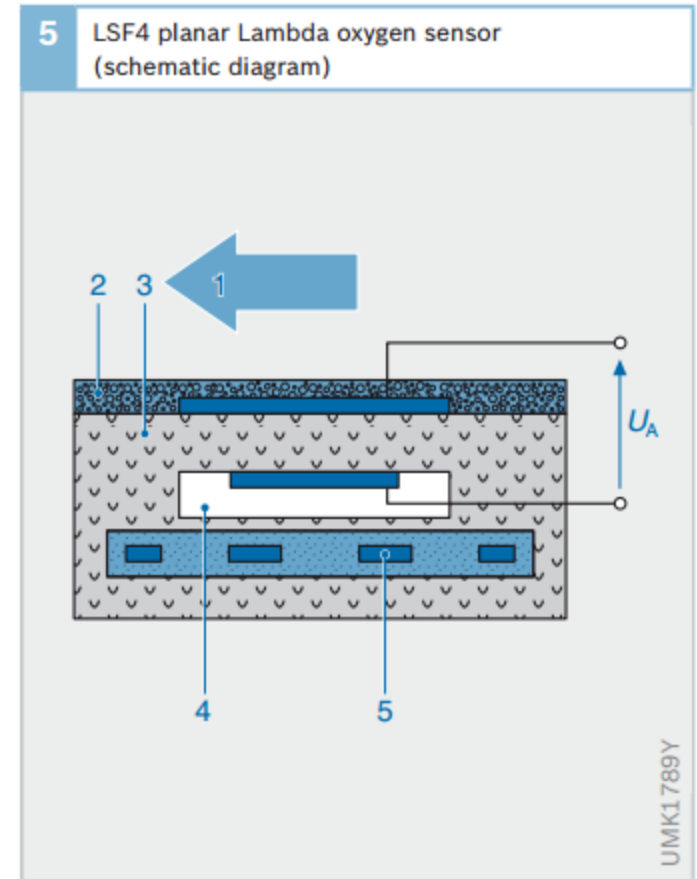


Fig. 5

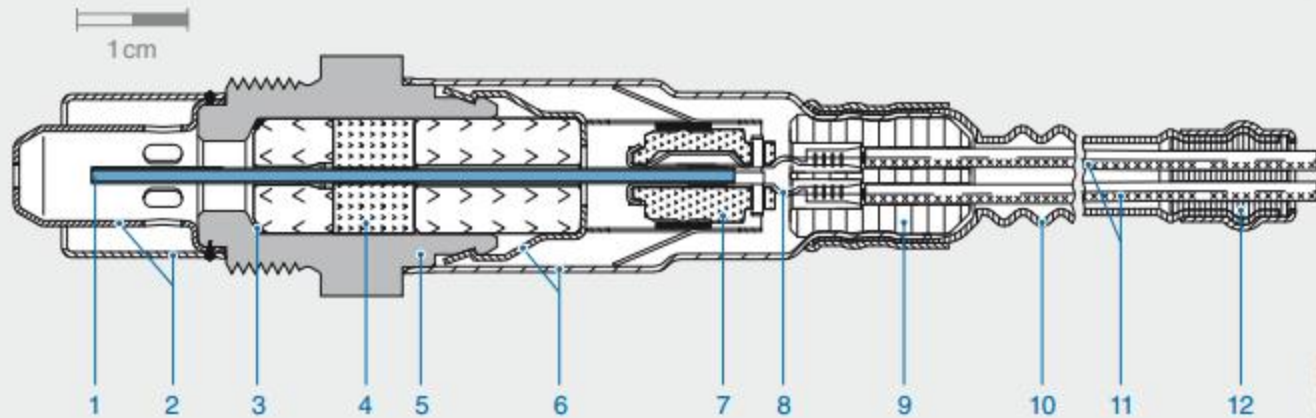
- 1 Exhaust gas
 - 2 Porous ceramic protective layer
 - 3 Measuring cell with microporous noble-metal layer
 - 4 Reference-air channel
 - 5 Heater
- U_A Output voltage



The Lambda Sensor

LSF4 planar Lambda oxygen sensor

6 LSF4 planar Lambda oxygen sensor (view and section)



UMK1606Y

UMK1607Y

Fig. 6

- 1 Planar measuring cell
- 2 Double protective tube
- 3 Sealing ring
- 4 Seal packing
- 5 Sensor housing
- 6 Protective sleeve
- 7 Contact holder
- 8 Contact clip
- 9 PTFE grommet
- 10 PTFE shaped sleeve
- 11 Five connection cables
- 12 Seal

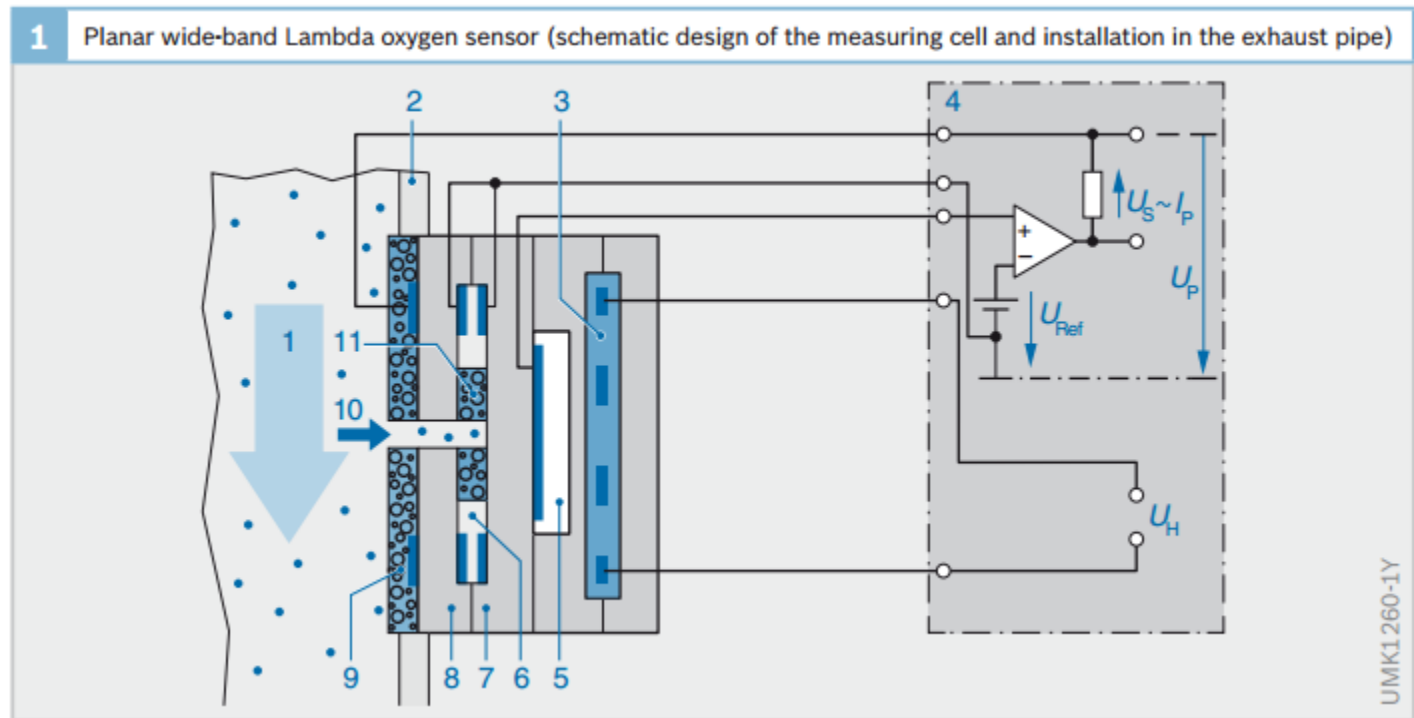
LSU4 planar wide-band Lambda oxygen sensor

- Wide-band Lambda oxygen sensors make precise measurements not only at the stoichiometric point $\lambda = 1$, but also in the lean range ($\lambda > 1$) and in the rich range ($\lambda < 1$)
- It features a measuring cell made of zirconium-dioxide ceramic (ZrO_2), and is a combination of a Nernst concentration cell (sensor cell which functions in the same way as a two-step Lambda oxygen sensor) and an oxygen pump cell for transporting the oxygen ions.

LSU4 planar wide-band Lambda oxygen sensor

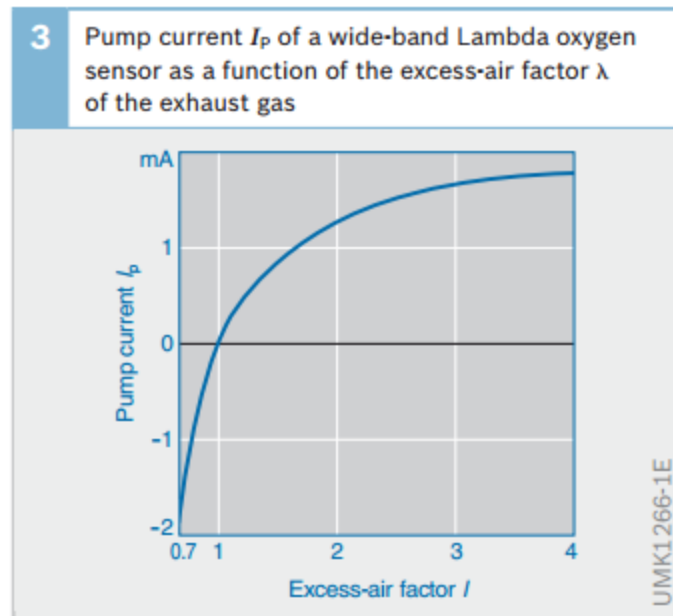
Fig. 1

- 1 Exhaust gas
 - 2 Exhaust pipe
 - 3 Heater
 - 4 Control electronics
 - 5 Reference cell with reference-air channel
 - 6 Diffusion gap
 - 7 Nernst concentration cell with Nernst measuring electrode (on the diffusion-gap side) and reference electrodes (on the reference-cell side)
 - 8 Oxygen-pump cell with pump electrode
 - 9 Porous protective layer
 - 10 Gas-access passage
 - 11 Porous diffusion barrier
- I_p Pump current
 U_p Pump voltage
 U_H Heating voltage
 U_{Ref} Reference voltage (450 mV, corresponds to $\lambda = 1$)
 U_s Sensor voltage



LSU4 planar wide-band Lambda oxygen sensor

- An integral heater (3) heats up the sensor quickly so that it soon reaches its operating temperature of 650 to 900 °C needed for generating a usable signal. This function decisively reduces the effects that the exhaust gas temperature has on the sensor signal.



The Lambda Sensor

LSU4 planar wide-band Lambda oxygen sensor

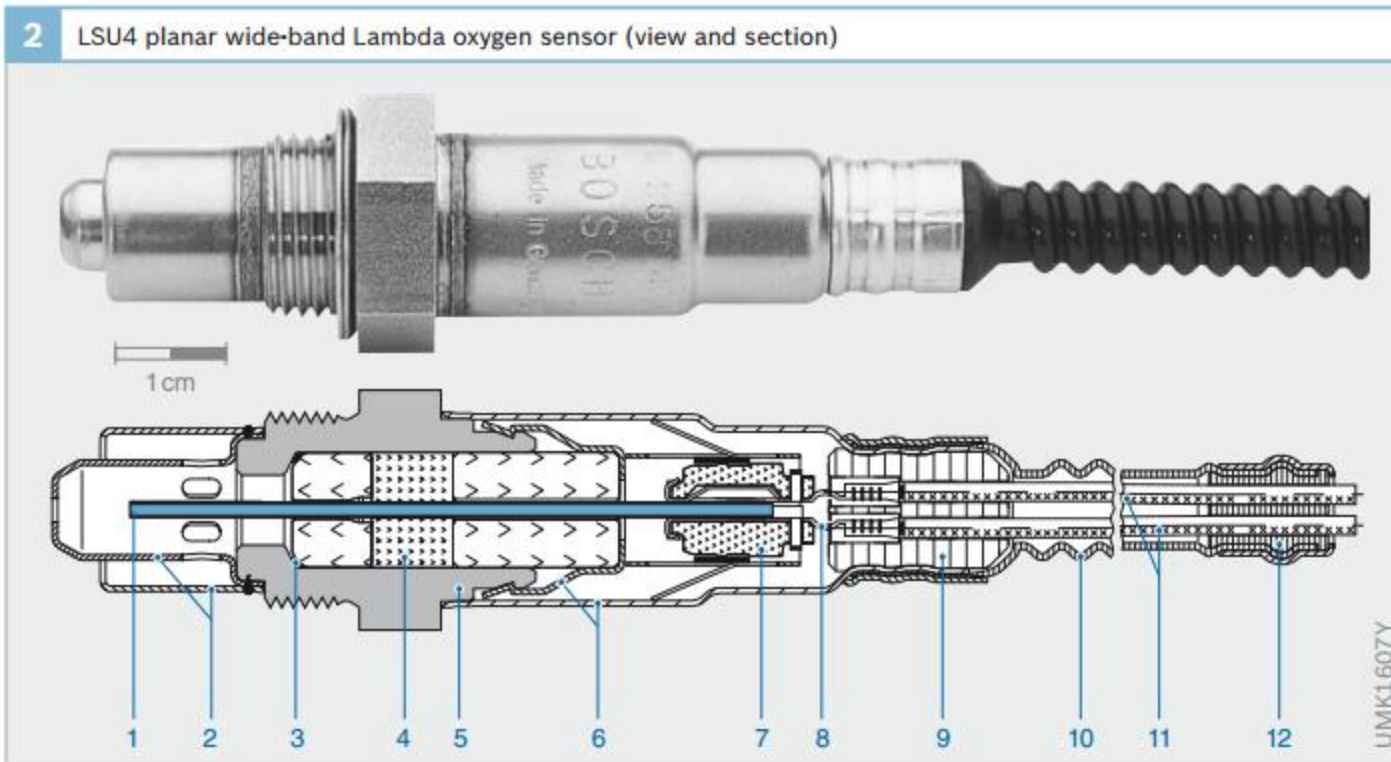
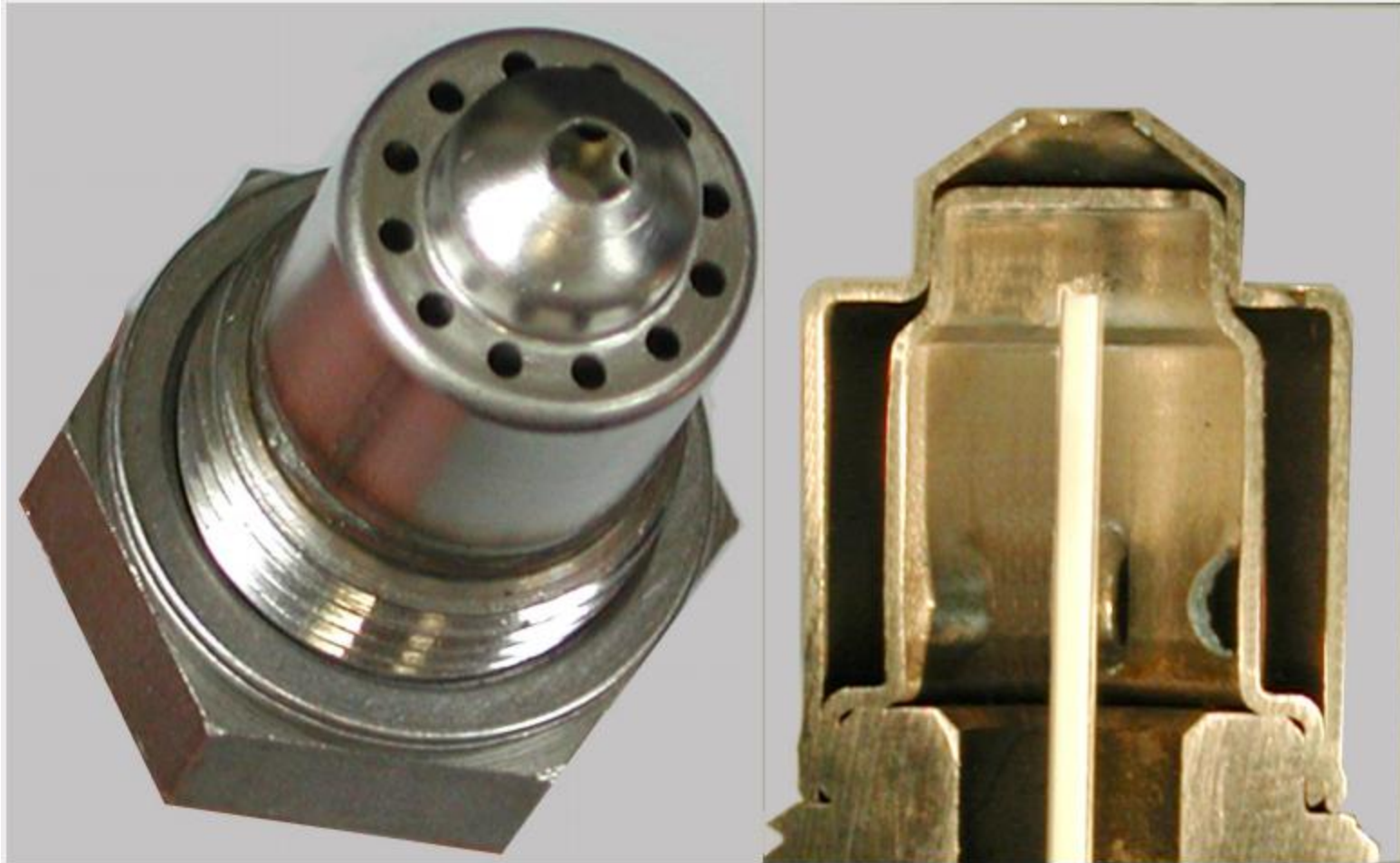


Fig. 2

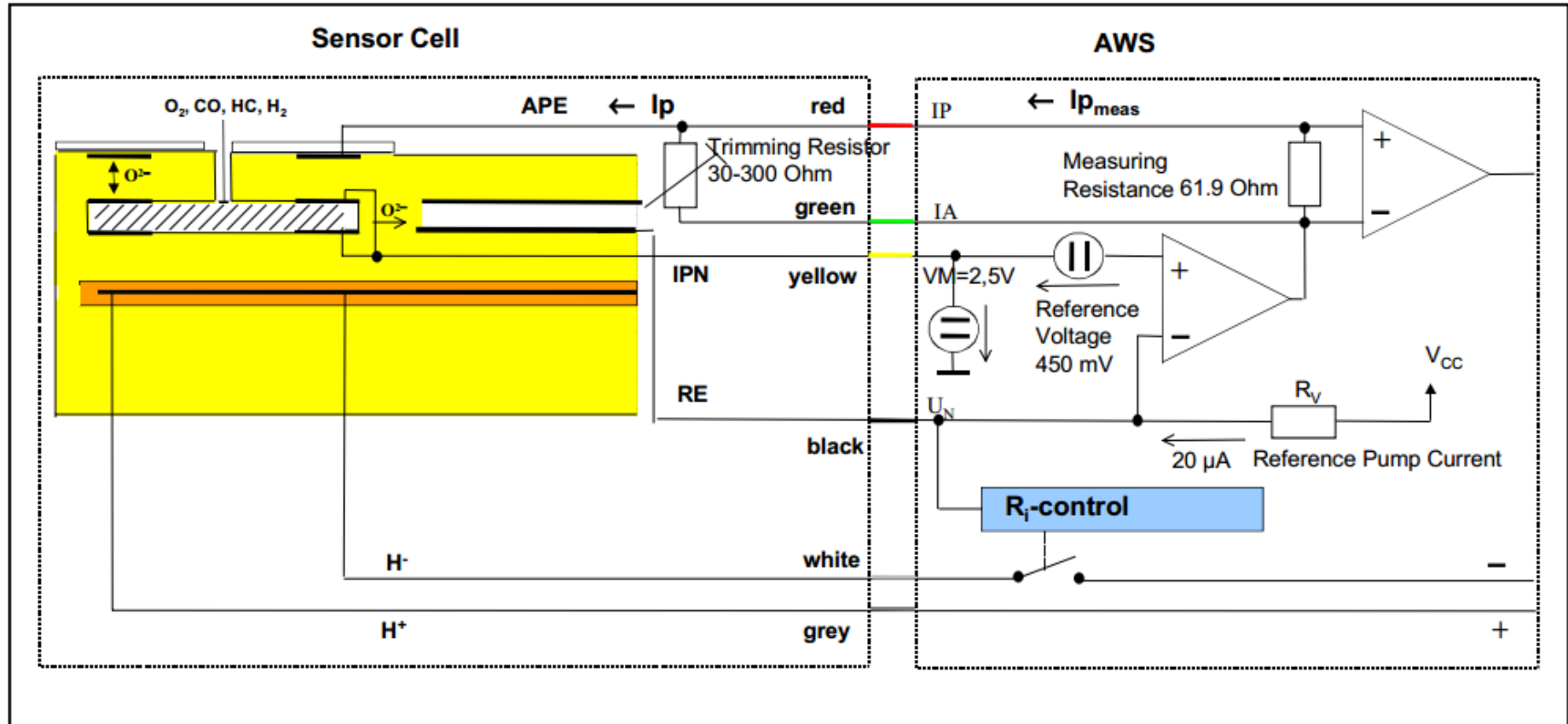
- 1 Measuring cell (combination of Nernst concentration cell and oxygen-pump cell)
- 2 Double protective tube
- 3 Sealing ring
- 4 Seal packing
- 5 Sensor housing
- 6 Protective sleeve
- 7 Contact holder
- 8 Contact clip
- 9 PTFE grommet
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The Lambda Sensor

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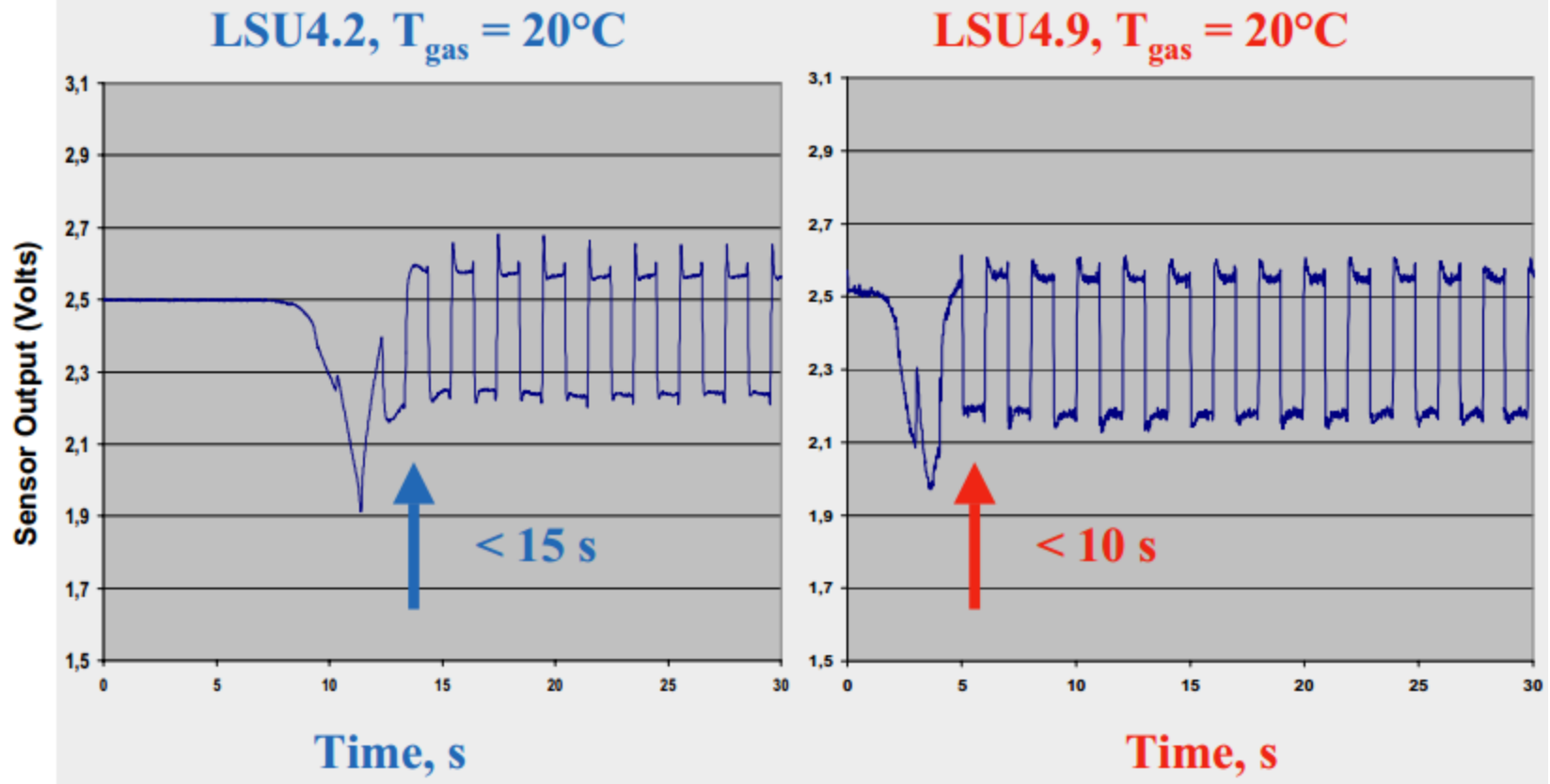


Circuit of LSU and control unit



	LSU 4.2	LSU 4.9	ADV-G
Nominal internal resistance of $\lambda=1$ Nernst cell	100 Ohms	300 Ohms	300 Ohms
Response time to gas change	< 80 ms	< 50 ms	< 30 ms
for rich gas signal ($\lambda \geq 0.65$)	> -9mA	> -9mA	> -4mA
for lean gas signal	< 18mA	< 6mA	< 4mA
Heater supply			
Nominal voltage:	9.5 V	7.5 V	7.6 V
Nominal heater power at nominal heater supply voltage	10 W	7.5 W	8.7 W
Robustness (Thermal Shock)	*	**	***
Diesel / gasoline DI capabilities (particles and soot)	*	**	x
Max Temp of sensor housing (Hexagon)	650 oC	680 oC	700 oC
Lifetime	160000 km or 10 years	250000 km or 15 years	250000 km or 15 years
Light off time	< 20s	< 10s	< 5s even @ cold exhaust gas

FLO Comparison: LSU4.2 vs. LSU4.9



What is precision (accuracy) of LSU Sensors?

The accuracy of the system 'lambda probe – Lambda meter' is mainly determined by the lambda probe.

- the accuracy of the lambda probe (LSU4.9 as an example) is given at two points, see TCI
- @ $\lambda = 1.7$: $1.7 \pm 0.05 \rightarrow \pm 3\%$
- @ $\lambda = 0.8$: $0.8 \pm 0.01 \rightarrow \pm 1.25\%$