Sensors in Škoda vehicles

Engine

Self-study programme

Introduction

New trends in the automotive industry require new modern technologies with high reliability, low production cost, miniaturisation and high accuracy with minimal delay time.
The ever-increasing demands placed on vehicles are closely associated with the dynamic development of electronics and advanced technologies.There are new control and regulating functions available not only for the control of the engine and the chassis, but also in terms of security and comfort of the occupants. In connection herewith new electronic elements, called senders, measure scalar physical quantities and vector quantities. The main requirement here is that the signals from these senders and sensors are evaluated and processed within a very short time. The vehicle is therefore capable to react to outside influences in real-time or resolve crisis situations.
This brochure provides the user with theoretical information as well as practical information, where the measured variables and their measurement principles are described. Thus, it provides a complete overview of senders used in a particular unit and can at the same time be issued for all series type vehicles. Or, in contrast, the code of the individual sender can be used in order to identify the unit or type of vehicle in which the sender is installed.

Contents

Contents

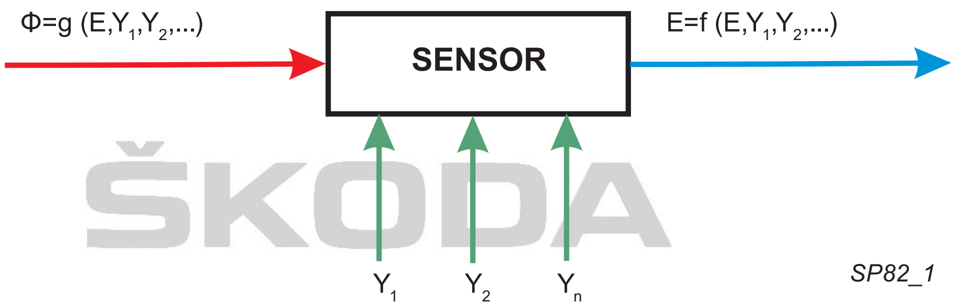
You will find the instructions for the assembly and disassembly, repair, diagnostics and detailed user information in the workshop manuals, the diagnostic unit VAS 505x and in the onboard literature.

The time for going to press was on the 12/2009.
This brochure is not subject to update.

Term, definition, use of vehicles

The term "sender" is a synonym for the term sensor. The senders convert a physical or chemical variable ***Φ*** into an electrical variable ***E*** taking into account the interfering variables Y_i. All of the following are considered variables; current, voltage and their amplitudes, frequency, periods, phases and oscillation pulse duration, "resistance", "capacity" and "inductance".

A sender can be characterised by the following mathematical equations:



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Sensors and actuators are used to create the interface between the vehicle and the digital control unit that performs the processing. Relays or valves are considered actuators. The signal sent by the sender is converted into a standard by means of the circuits, which can be processed by the corresponding control unit.

Classification

In view of the **task** and use, the senders are structured as follows:

- function sensor, control and regulating sensor
- safety and security sensor
- sensors for the onboard computer of the vehicle

Furthermore, the senders are divided according to their **characteristics**:

- continuous linear
- continuous nonlinear
- discontinuous two-stage (snap-action sensors)

Another classification criterion is the **output signal**:

- continuous analog (current, voltage, ...)
- discontinuous two and multi-stage snap-action sensor (binary, analog, digitally coded)

Main requirements, trends

Requirements		Measures
high reliability	→	robust proven technology
low production costs	→	efficient mass production
operating conditions	→	resistant encapsulation
small dimension	→	technology of miniaturisation
high accuracy	→	compensation of faults in the sensor

Position sender (path/angle)

Measured properties, measurement principles

Depending on the principle of sensing, this sender category can be divided into contact senders and contactless senders, which are not subject to wear. They are therefore more reliable and have a longer life. One drawback is its price.
Angle senders are also referred to as "incremental senders" (progressive senders). In these systems, the information of the absolute position is lost when the supply voltage is turned off.

Measured property	Range
Position of the throttle valve in the petrol engine	0 - 90°
Position of the accelerator pedal / the brake	0 - 30°
Path and position of the control rod in the pump	0 - 21 mm
Rotation angle of the flow regulator in the pump	0 - 60°
Gauge in the fuel tank	5 - 20 mm
- Stroke of the clutch actuator	0 - 50 mm
Torsion angle (torsional moment)	1° - 4°

Potentiometric sensors

The basic design elements of a potentiometer are the rotor and the resistance path, which consist either of a wire winding or a conductive carbon layer.

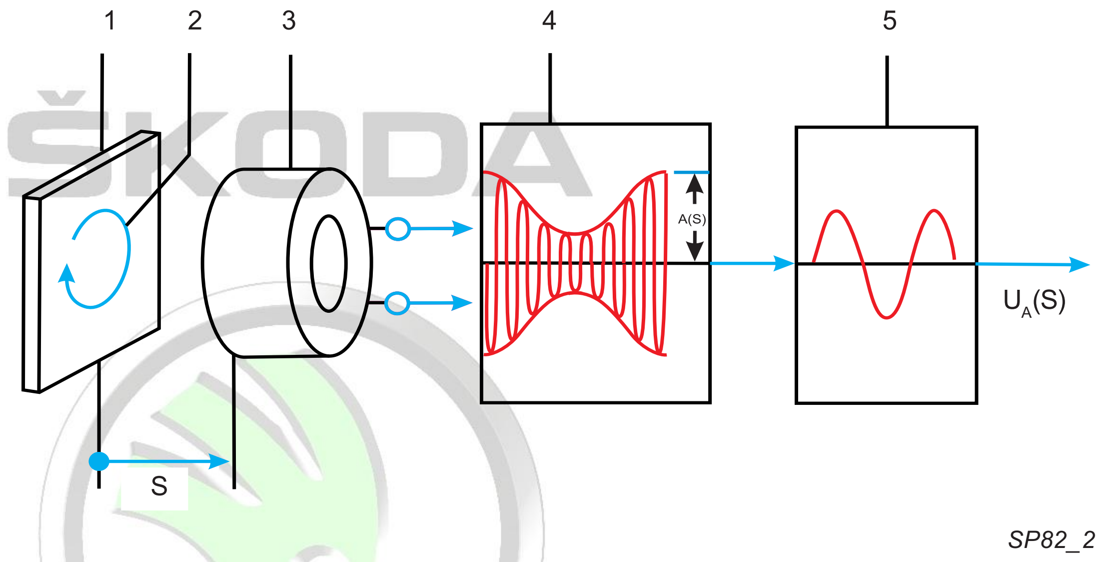
Advantages:
- simple design
- measuring range (measuring stroke = supply voltage)
- no electronics required
- resistance to interference voltages

Disadvantages:
- mechanical wear and subsequent failure
- problems in the liquid medium
- variable resistance between the rotor and the path
- lifting the rotor in case of vibrations
- noise
- limited miniaturisation

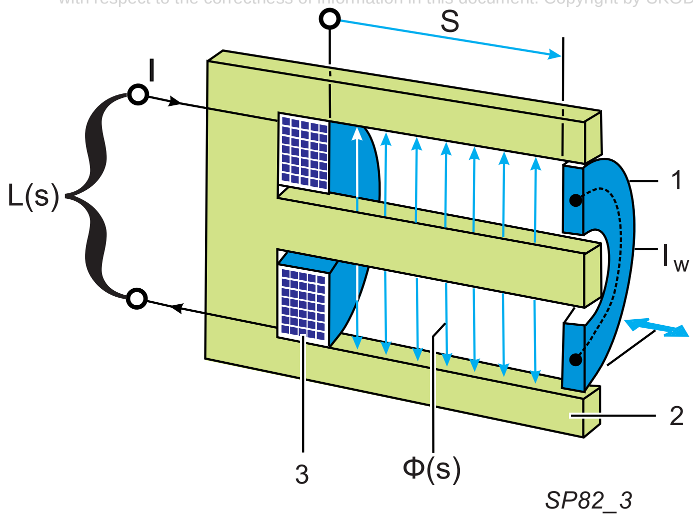
Usage:
- turning angle sensor of throttle valve (M-Motronic)
- accelerator pedal position sender, accelerator pedal module
- fuel gauge sender

Magnetic inductive sensors

If an electrically conductive plate (Al, Cu) approaches a coil through which flows an alternating current, its active resistance as well as its inductance will both change. It is caused by eddy currents arising in the plate. Here we speak of *sensors using eddy currents*. In principle, *sensors with a short-circuit ring* typically have a soft-magnetic core consisting of sheet metals. Here the moving part is in the shape of the ring (Al, Cu).



1	Damping plate
2	Eddy currents
3	Air-cored coil
4	Oscillator with variable damping
5	Demodulator
s	Measured path
A(s)	Voltage of the oscillator
$U_A(s)$	Output voltage



1	Short-circuit ring
2	Soft-magnetic core
3	Coil
●	Current
I_W	Eddy current
L(s)	Measured inductance path S
Φ(s)	Specified magnetic flux path S

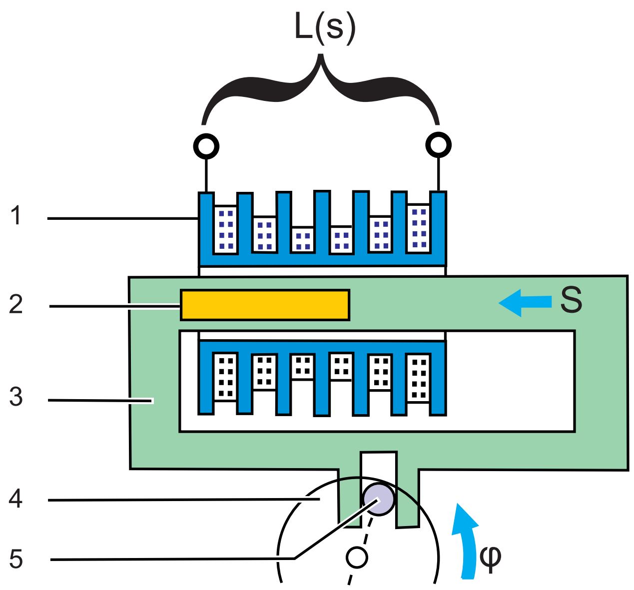
Advantages:
- linear curve over the entire length
- measuring range (measuring stroke = supply voltage)
- application under really extreme conditions

Disadvantages:
- robust design
- insensitivity to interferences

Usage:
- sensor of constrictor for series pumps (installed load sensor, EDC sensor)
- angle sender for the rotary injection pump

Position sender (path/angle)

The last representative of the magnetic inductive sensors is the *sender with plunger*, which works on the principle that the inductance of the coil changes by means of a movable core. It is made of solid iron (wire), rolled plate or ferrite.



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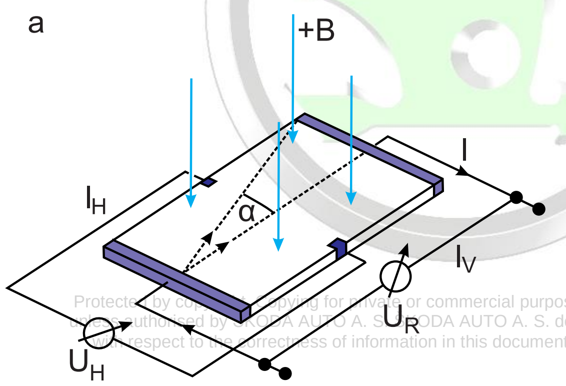
1	Multi-chamber coil
2	Ferrite core
3	Plastic press-in part with sliding-block guide
4	Rotational axis with pilot pin 5
L(s)	Measured inductance path S
φ	Measured angle

Usage:
- angle sender for the rotary injection pump

Magnetostatic sensors

If the magnetic induction ***B*** passes vertically through a thin semiconductor wafer fed by an electrical current, the Hall voltage U_H, which is directly proportional to the size of the magnetic field, can be measured perpendicularly to the flow direction. This phenomenon is called the *Hall effect* . At the same time, however, the resistance of the wafer increases, which is called the *Gauss effect - magnetoresistance*. The *Hall sender* eliminates the disadvantages of the inductive sensors, using the rotating flow principle "Spinning Current", whereby the production cost is also minimal.



Switching arrangement

B	Magnetic induction
●	Current through the wafer
I_H	Hall current
I_V	Supply current
U_R	Longitudinal voltage
α	Engine displacement by the magnetic field

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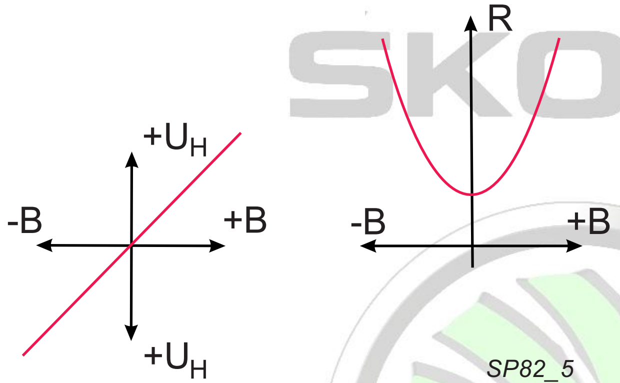

Curve of Hall voltage U_H

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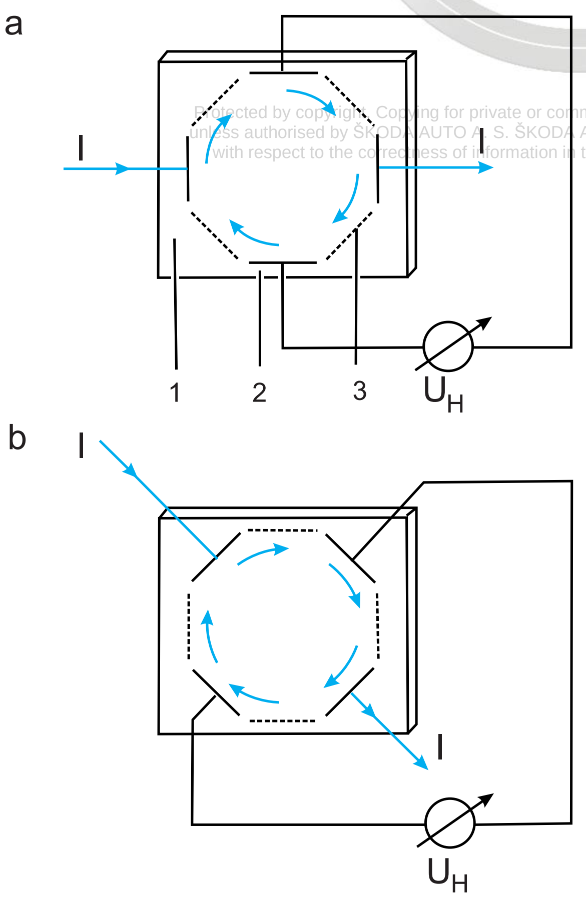
Increase in resistance R of the wafer (Gauss effect)



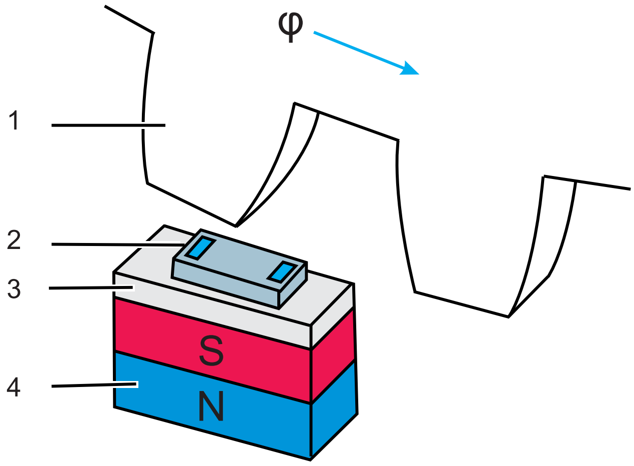
SP82_6

a Rotational phase φ_1

b Rotational phase $\varphi_2 = \varphi_1 + 45°$
1 Semiconductor wafers
2 Active electrode
3 Passive electrode
● Supply current
U_H Hall voltage

Differential Hall senders - "Gradient sensors"

Version in which two Hall senders are arranged side by side on one chip at a certain distance, whereby the difference of both voltages is evaluated electronically. Only the "gradient of the magnetic field" is sensed.



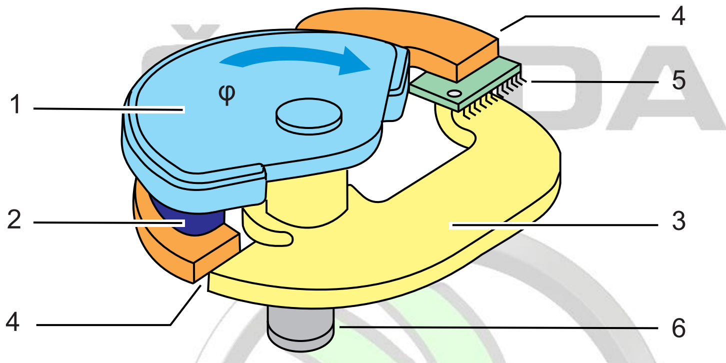
SP82_7

1 Ring gear
2 Integrated differential Hall circuit
3 Homogenised wafer
4 Permanent magnet

Usage:
- speed measurement

Angle sender for the range up to 180°

It consists of the magnetic disc of the rotor, two fixed elements to guide the magnetic flux and the Hall sender, which is located between them. The magnetic flux depends on the angle of rotation of the rotor.



SP82_8

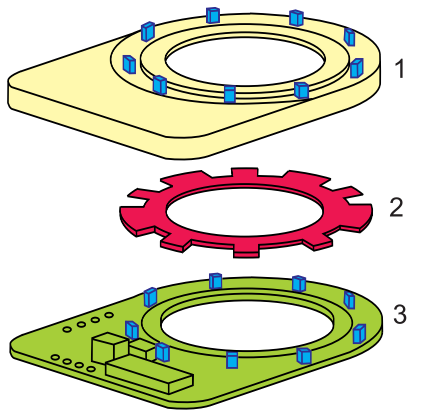
1 Motor pulley (permanent magnetic)
2 Pin attachment
3 Element for guiding the magnetic flux
4 Air gap
5 Hall sender
6 Axle (soft-magnetic)

Disadvantage:
- low shielding from external fields

Usage:
- accelerator pedal

Angle sender for the range above 180°

It consists of a fixed plate which is equipped with ***n*** Hall senders and a cover with the corresponding number of magnets. Between them there is a magnetic sensor, during the rotation ***n*** of this sensor different codewords are generated.



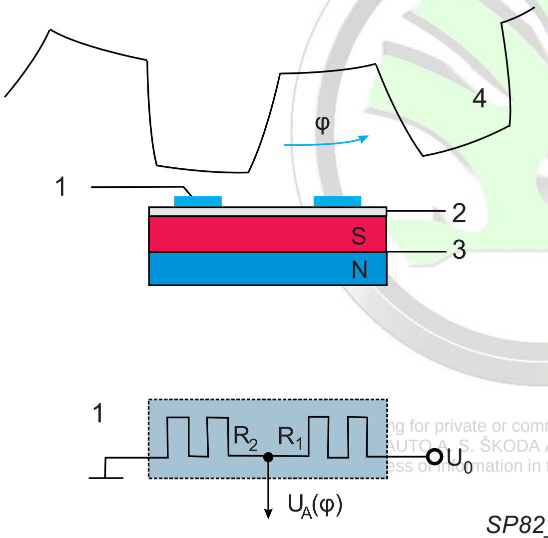
SP82_9

1 Housing with permanent magnets
2 Encoding disc
3 Board with the Hall senders

Usage:
- speed measurement
- turning angle of the steering wheel

Differential magnetoresistive sensors

The principle, on which the sensor works, describes the Gauss effect. The resistor is made of an InSb semiconductor, in short-form, so that it has a very low resistance.In order to achieve useful values (of the order of kΩ), a large number of plates must be connected in series. The operating temperature is almost 200ºC. A small conductive element, which excites both resistors of the sensor, moves via the sensor in order to sense the path or the angle.



SP82_10

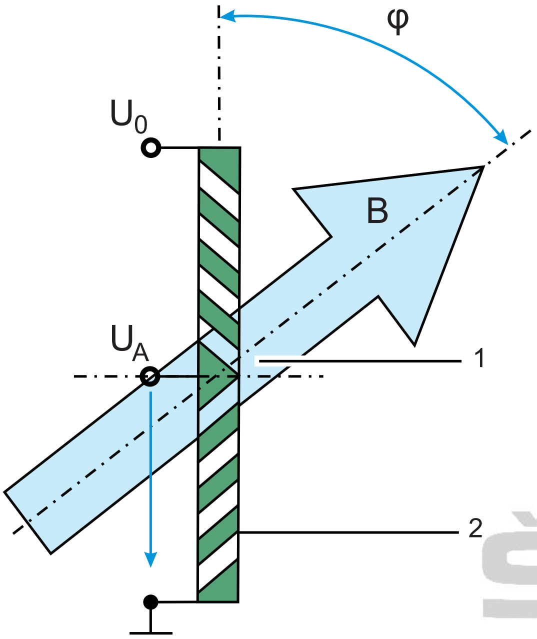
1 Magnetoresistance $R_{1,2}$
2 Soft-magnetic substrate
3 Permanent magnet
4 Toothed gear
U_A Supply voltage
U_0 Output voltage

Advantage:
- high signal level
- no evaluation electronics required
- immune to external magnetic fields

Usage:
- speed sender

Magnetoresistive (NiFe) AMR thin-film sensors (**A**nisotropic **M**agneto **R**esistive)

The electrical resistance of the thin conducting layer is "anisotropic," i.e. it is higher in the direction of the vector of magnetisation. In order to indicate this direction of magnetisation, the sensors are provided with a weak magnet. The cosine path of the resistance or the voltage results from the rotation of the vector. The control magnetic field B is formed by the rotary magnet via the sensor. A high sensitivity is achieved by forming a "bridge" made of four resistors AMR. The remaining accuracy is achieved by switching two bridges in series and by the rotation of 45°.



a Measurement principle
1 Permalloy resistors
2 Rotating permanent magnet with control induction B

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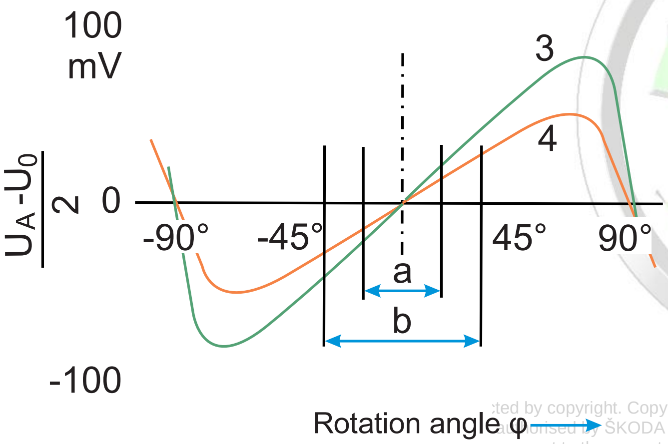

b Characteristics
3 Low operating temperature
4 High operating temperature
a Linear measuring range
b Usable measuring range
U_A Output voltage
U_0 Supply voltage (=5V)
φ Rotation angle

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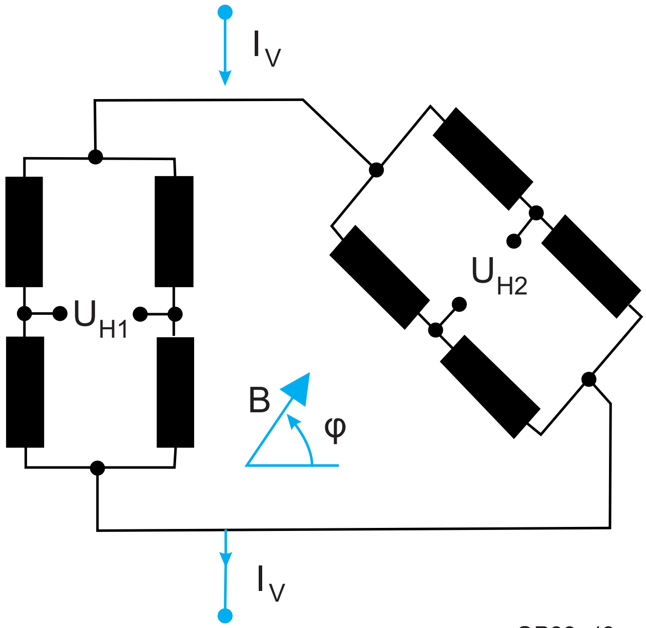

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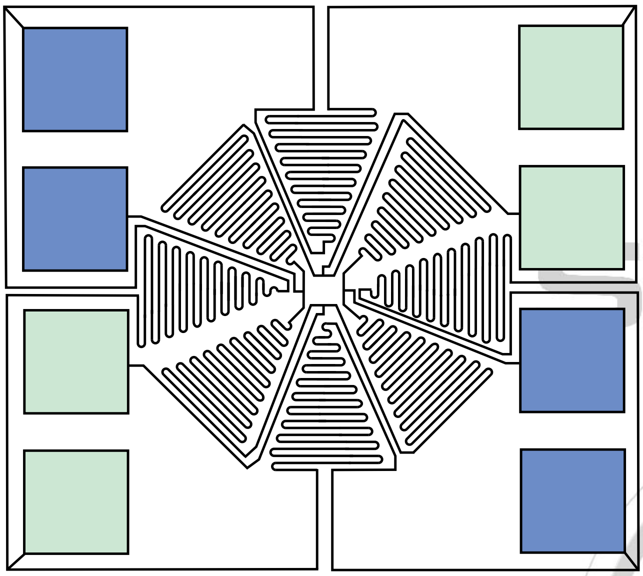
Bridge circuit

B	Control induction
I_V	Supply current
$U_{H1,H2}$	Measured voltages
φ	Rotation angle



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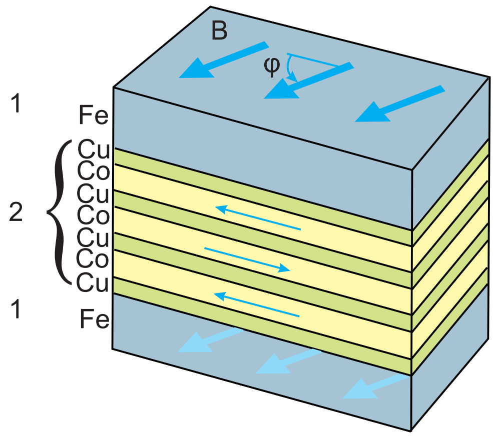
Arrangement of two bridges integrated into one another, rotated by 45°

Position sender (path/angle)

Magnetoresistive multilayer GMR sensors (**G**iant **M**agneto **R**esistance)

By applying the magnetic field, a 50% change in resistance occurs in the multiple layers, which is much larger than that of AMR sensors.



SP82_15

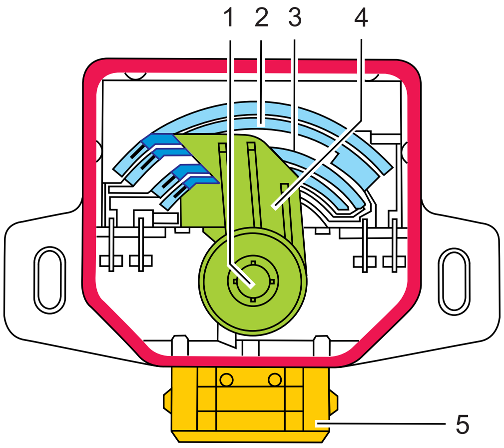
Advantage:
- much greater measuring effect
- clear identification of the rotation angle

1 Fe layers
2 Thin antiferromagnetic layers CuCo
B Control induction
φ Rotation angle

Throttle valve position sender

Structure and function principle

The fixed part consists of two resistance wires, driven by two rotors, thus forming together with the leg the rotation element which is firmly connected to the shaft of the throttle valve. The angle of rotation is directly proportional to the ratio U_A/U_V, whereby the operating voltage U_V = 5V. The characteristics of the sender is linear.



SP82_17

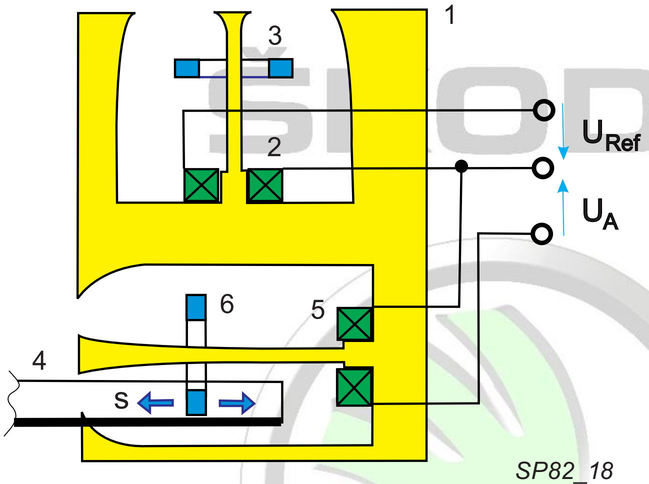
1 Throttle valve shaft
2 Resistive path 1
3 Resistive path 2
4 Leg with the rotors
5 Electrical connection (4 pin)

Usage:
The throttle valve position sender senses the rotation angle of the throttle valve of the petrol engine. On engines with the ***M-Motronic*** system, the function of recognition of the working ranges, such as idle, full load, emergency mode is used as supplementary information. The ME-Motronic system provides the required torque by means of this sender.

Control-collar position sensor HDK

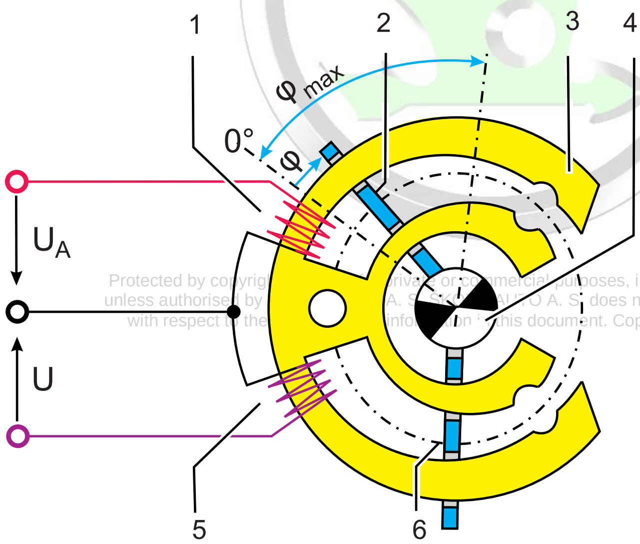
Structure and function principle

The senders have a core made of soft-magnetic iron sheets. At one end is the measuring coil and at the other end the reference coil. When the alternating current passes through the coils from the control unit, alternating magnetic fields occur. The reference ring is immobile, while the measurement ring is attached on the control rod or on the shaft of the control spool. When the measurement ring moves, the magnetic flux changes and with it the voltage. The evaluation circuit forms the ratio of the input and reference voltage U_A / U_{Ref}. The characteristics of the sender is linear.



SP82_18

1 Soft-magnetic core
2 Reference coil
3 Reference short-circuit ring
4 Control rod
5 Measuring coil
6 Measuring short-circuit ring
s Path of the control rod



SP82_19

1 Measuring coil
2 Measuring short-circuit ring
3 Soft-magnetic core
4 Shaft of control spool
5 Reference coil
6 Reference short-circuit ring
φ_{max} Angle adjustment range of the shaft for the control spool
φ Measured angle

Advantage:
- are very accurate and robust
- not subject to wear

Usage:
- position sender of the regulator for sensing the position
- angle sender in the fuel flow regulator for the rotary injection pumps.

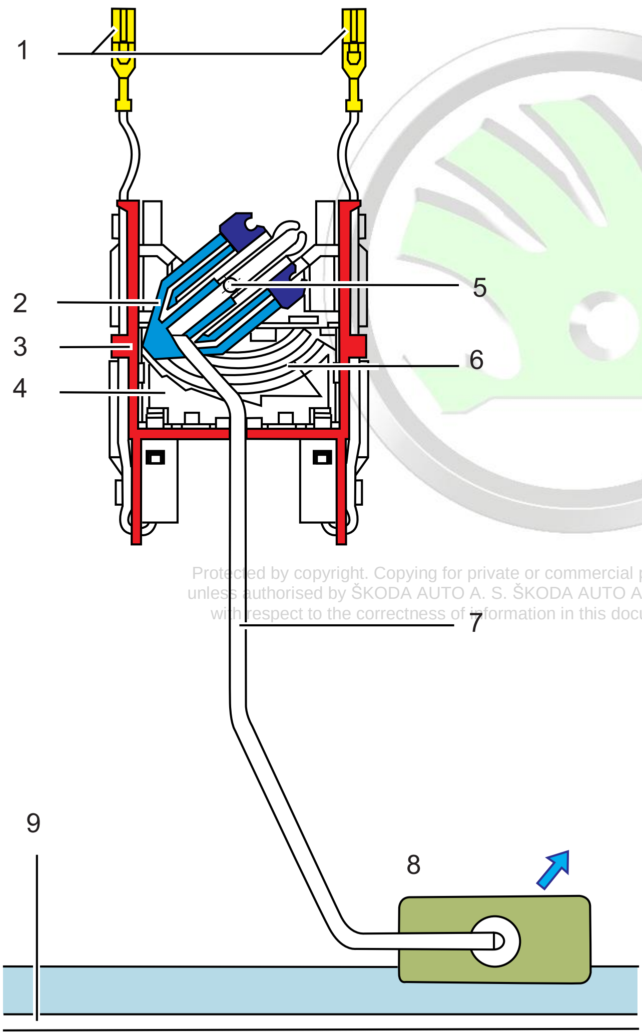
Fuel gauge sender

Structure

The sender consists of an encapsulated potentiometer, which is sealed against the penetration of fuel and used as a variable resistor. The fixed part of the potentiometer has two resistance paths, resistors and connectors. The rotating part is the shaft that connects the leg of the rotor with the float lever.

Function principle

The spring of the rotor moves via the resistance paths of the potentiometer while the fuel level changes. This angle of rotation of the float is transmitted as voltage. The end stops define the rotation range of 100° for the minimum and maximum level while preventing the occurance of noise at the end of the path. The operating voltage is 5-13V.



SP82_20

1	Electrical supply lines
2	Rotor spring
3	Contact rivet
4	Board with resistors
5	Shaft of the potentiometer (mounted)
6	Double contact
7	Float lever
8	Float
9	Fuel tank bottom

Usage:
It is the task of the sender for the fuel supply in the tank to monitor the current status and transmit the appropriate signal to the control unit. It is installed in the tank as a built-in module together with the fuel pump, the filter, etc. In this version, it is supplied for petrol engines as well as for diesel engines.

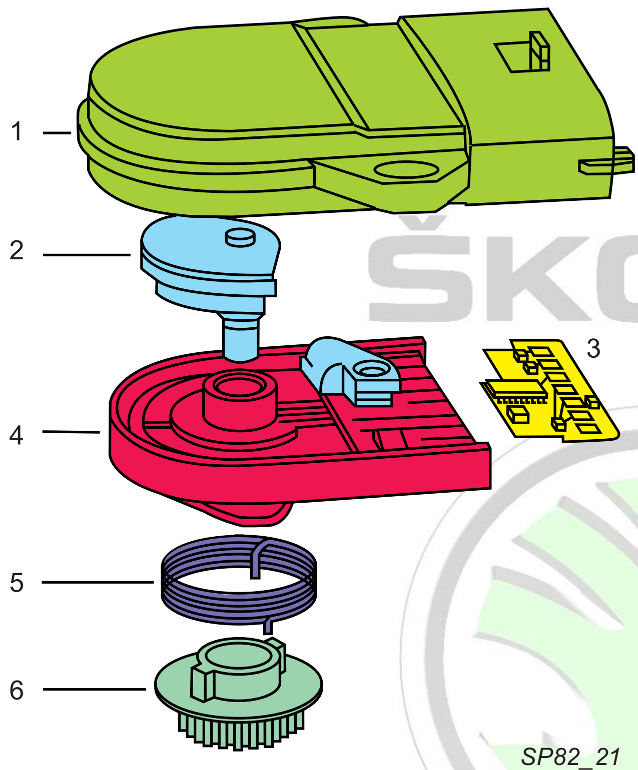
Accelerator pedal sender

Structure and function principle

Potentiometric accelerator position sender
The main component is the potentiometer, on which the voltage is set depending on the position of the pedal. The control unit then converts this voltage into the relative path, possibly into the angle position. For diagnostic purposes, a redundant (dual) sender is integrated, which transmits two independent signals.

Hall angle sender

It is derived from the principle of the moving magnet and has a range of 90°. The magnetic flux of the rotor, shaped as a magnetic disc, flows through the pin attachment (2), two other elements for guiding the magnetic flux (3) between which the Hall sender ASR1 is located, as well as the axle (6) and back to the rotor. The magnetic flux is dependent on the angular position φ. The type ASR2 does not have two magnetic elements for directing the magnetic flux.



1 Housing lock
2 Rotor pulley (permanent magnetic)
3 Evaluation electronics with Hall sender
4 Lower part of housing
5 Return spring
6 Control element (e.g. toothed gear)

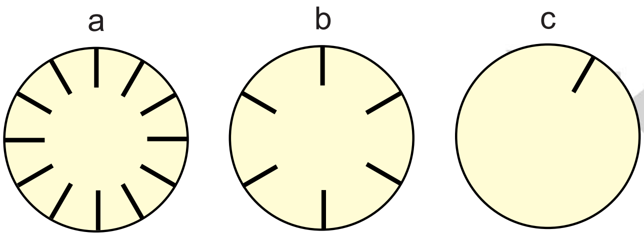
SP82_21

Usage:
The driver operates the throttle valve of the petrol engine or the injection pump of the diesel engine mechanically via a control cable or a tie rod when actuating the accelerator pedal.
In electronic systems of the engine management, the accelerator pedal position sender takes over the function of the mechanical connection.

Rev counter and speedometer

Measured properties, measurement principles

The rev counter and speedometer measure the angle or the path per unit time. If the motion of the vehicle compared to the basic reference system, which is the area, is measured, we get "absolute variables". In the event that we follow the motion of two systems located in this area, we measure the "relative variables". The senders of the relative rotational speed can be divided according to the number of sensed markings on the periphery of the rotor, as follows:



SP82_22

a) Incremental sender - with a fine pitch for precise immediate sensing.
b) Segment sender - where the division corresponds to the number of controlled elements.
c) Ordinary senders - which sense the mean speed of rotation with the single marking.

Usage:
- speed of the crankshaft and camshaft
- speed of the wheels (ABS / TCS / ESP)
- speed of the injection pump
- measurement by means of senders directly integrated in the bearings (at the wheel or at the crankshaft)
- speed in relation to the ground
- rotational speed of the vehicle in relation to the tilt or pitch axis (protection against overturning)

For practical reasons, senders which work on magnetic principles are preferred and are divided according to their form as follows:

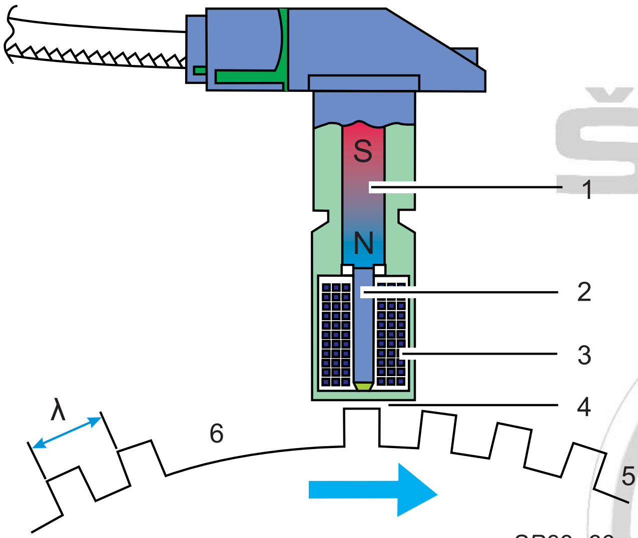
- rod-shaped sensors
- bifurcated sensors
- circular sensors

Thus the rotor is of critical importance when measuring the speed and exists in practice usually in the form of gear wheels. A tooth which has been removed partially or entirely is used as a "reference marking". In addition to the gear wheels, pressed discs with openings or wavy rings are used.
Pioneering was the introduction of senders, which are directly integrated in the bearing, whereby the rotor consists of wheels with a small number of poles. These are then sensed by means of Hall senders.

Relative measurement of the speed and the acceleration

Inductive sensors

The basic principles are described in chapter 2.1. They consist of a rod magnet (1) with pin attachment (2), at which an induction coil (3) with two outputs is located. If a ferromagnetic rotor (5), which is provided with a marking (6), rotates in front of the sender, a directly proportional voltage is induced in the coil on the basis of the change in magnetic flux relating to this change.



SP82_23

1	Rod magnet
2	Soft-magnetic pin attachment
3	Induction coil
4	Air gap d_L
5	Ferromagnetic toothed gear (or rotor, if necessary, pulse wheel)
6	Peripheral or reference marking
λ	Tooth spacing

Advantages:
- low production costs
- resistance to external magnetic fields
- dynamic measurement principle
- wide temperature range

Disadvantages:
- problem with the miniaturisation
- dependence of the output signal from the speed
- sensitivity to the variations in air gap

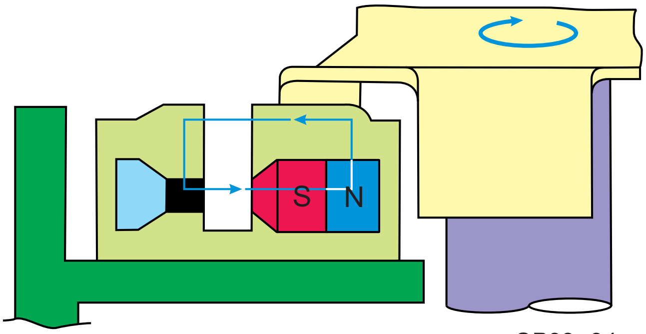
Usage:
- inductive engine speed sender (the crankshaft)
- inductive wheel speed sender
- needle movement sender (diesel injection)

Magnetostatic sensors

The basic principles are described in chapter 2.1. The output signal from these senders is not dependent on the speed of the rotor, but only on the intensity of the field. An advantage is the miniaturisation and a disadvantage is the low resistance of the electronics to high temperatures.

Hall barriers

The "integrated Hall circuit" is designed for temperatures ≤ 150°. It is located in a closed magnetic circuit, which consists of the magnet and the pin attachments. The rotor forms a ***magnetically passive*** bezel, located in the air gap. This interrupts the magnetic flux at the appropriate time, whereby the voltage is also interrupted, and subsequently the signal is evaluated.



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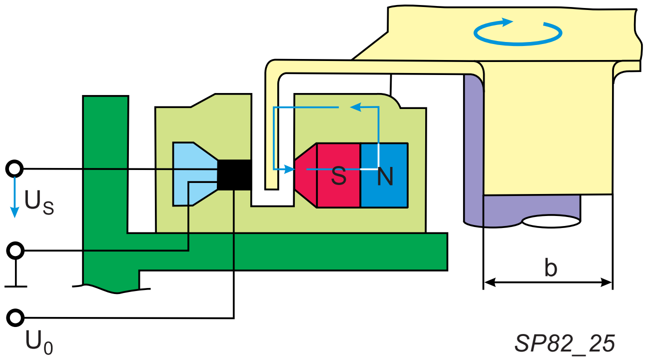

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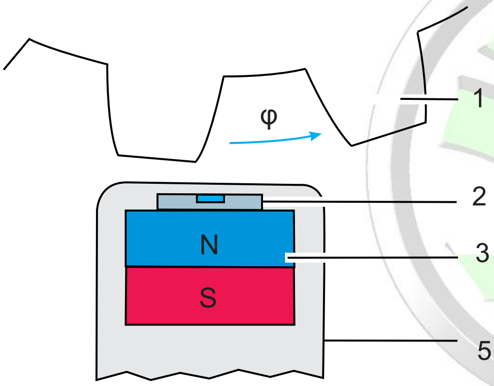
Tubular Hall sender

Once again, the sensed element is the rotor, which can be either ***magnetically active*** or **passive** (magnet wheel). In the passive version, the magnetisation depends on the air gap, which can cause erroneous pulses.



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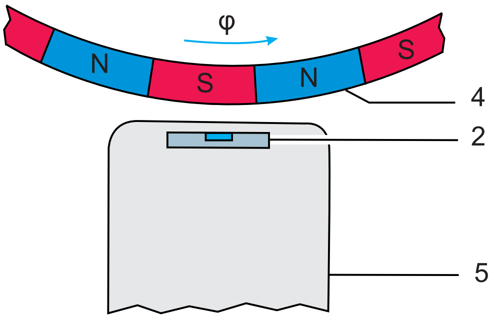
Passive rotor
1 Incremental rotor
2 Integrated Hall circuit
3 Permanent magnet
5 Housing
φ Rotation angle



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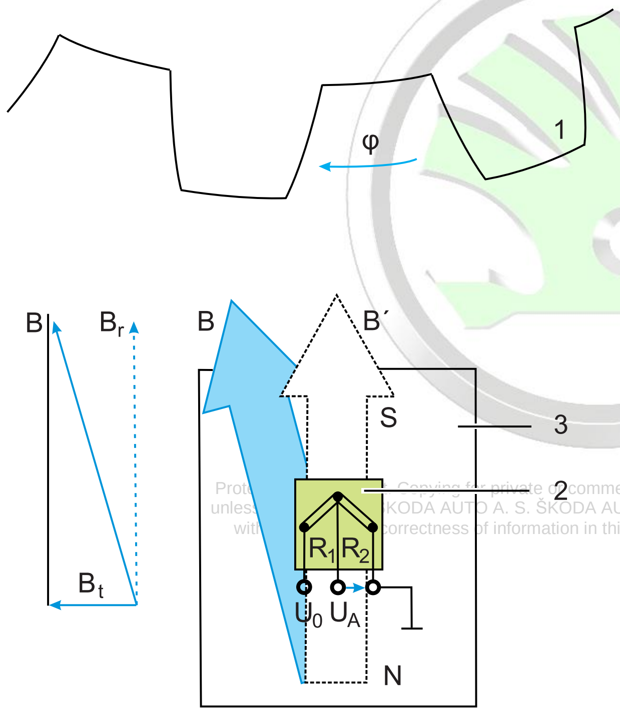
Active rotor
2 Integrated Hall circuit
4 Magnet wheel
5 Housing
φ Rotation angle

Gradient sensor

They are created on the basis of differential Hall senders or magnetoresistive differential senders and are much more suitable for sensing ***magnetically passive*** rotors than Hall senders. The basic principles are described in chapter 2.1. The sender measures the difference in the intensity of the field in two points. The first point is located directly under the tooth and the second point in the gap.

Tangential sensors

They are either produced with thin-film technology AMR (Section 2.1) or as simple permalloy resistors with full or half bridge circuit. However, they require an integrated amplifier.



1	toothed gear (Fe)
2	Permanent magnet
3	Sender
B	Intensity of the control field with tangential-component B_t and radial component B_r
φ	Rotation angle
U_0	Supply voltage
U_A	Measured voltage

SP82_28

Sensing elements GMR

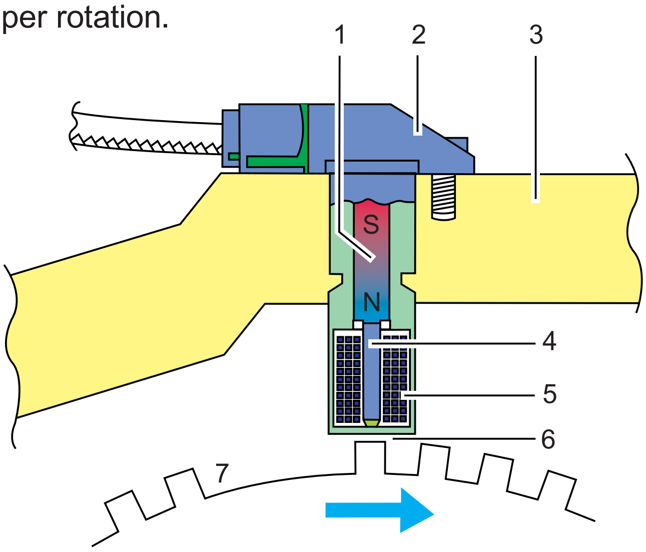
The basic principles are described in chapter 2.1.

Usage:
- Hall sender (transistorised ignition TZ-H)
- Hall phase sensor (of the camshaft)
- Hall sender at the gearbox
- Active Hall speed sender
- Active speed sender AMR
- Magnetoresistive sensor (for the injection pumps of diesel engines with radial piston)

Inductive engine speed sender

Structure and function principle

The pulse wheel (7) is exposed to magnetic field via the pin attachment (4) which is connected to the magnet (1).
The attachment also forms the core of the coil (5). The intensity of the magnetic flux through the coil is dependent on whether there is a tooth or a gap in front of the Hall sender. These changes in magnetic flux induce an output voltage in the coil, which then is directly proportional to the changes in speed. The pulse wheels for petrol engines usually have 60 teeth, two of which are omitted. Another version used in diesel engines is a wheel that has all around one tooth for each cylinder. In the case of the PD engines (pump-nozzle) the markings are made depending on the type of engine. There are four teeth in a four-cylinder engine, i.e. four pulses per rotation.



SP82_29

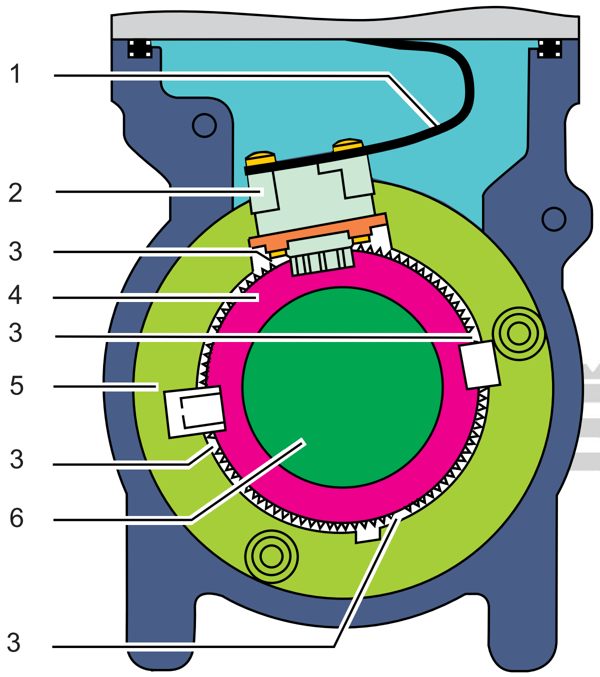
1 Permanent magnet
2 Sender housing
3 Engine housing
4 Pin attachment
5 Winding
6 Air gap
7 Pulse wheel with reference marking

Usage:
The senders are used for measuring the engine speed as well as to determine the position of the crankshaft.
The speed is calculated based on the time interval of the signals of the sender.

Speed sender and incremental turning angle sensor DWS

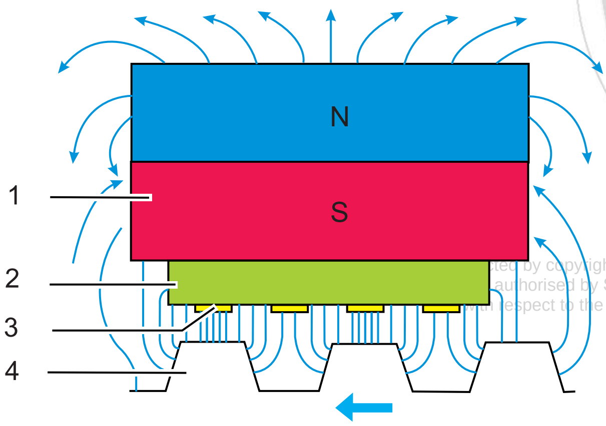
Structure and function principle

The rotor consists of the toothed pulse wheel with 120 teeth, which is mounted on the drive shaft of the pump. The tooth gaps correspond to the number of cylinders of the engine.
A double magnetoresistive differential sender is used for sensing.
It is a magnet type sender with its pole face homogenised with a thin ferromagnetic wafer.
On this there are four magnetic resistors that withstand temperatures of up to 170°C.
Two of them are alternately located opposite the teeth and two opposite the gap.
They are electrically connected to a full bridge.



SP82_30

1 Elastic film with transmitters
2 Speed sender / turning angle sensor
3 Tooth gap
4 Toothed pulse wheel
5 Rotating bearing ring
6 Drive shaft



SP82_31

1 Magnet
2 Homogenised wafers (Fe)
3 Magnetoresistance
4 Toothed pulse wheel

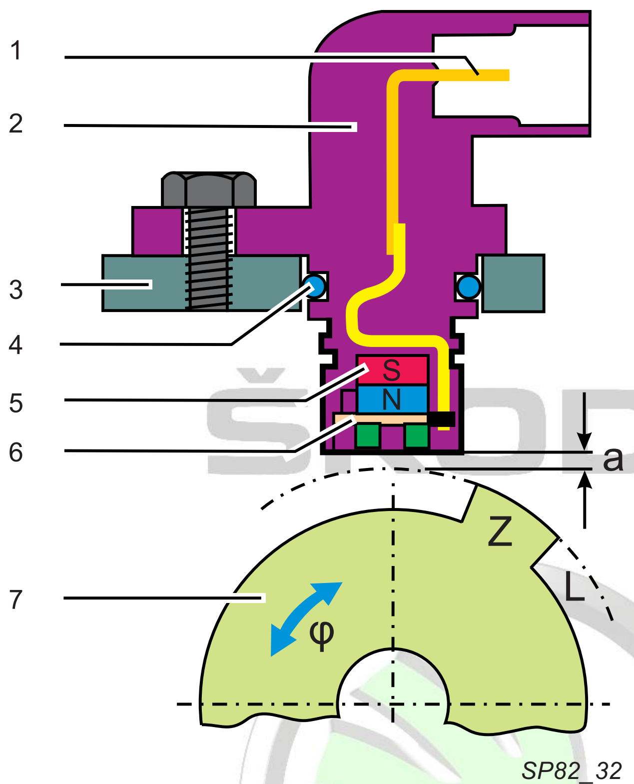
Hall phase sensor

Structure and function principle

Rod-shaped Hall sensor

The principles are described in chapter 2.1. The integrated Hall circuit (6) is located between the rotor made of ferromagnetic material (7) and the magnet (5), which forms the magnetic field. If a tooth approaches a semiconductor wafer, the intensity of the field changes and a Hall voltage of a size of several mV occurs.

The integrated evaluation electronics, itself integrated in the Hall circuit, processes the signal and transmits a rectangular pulse to the output.

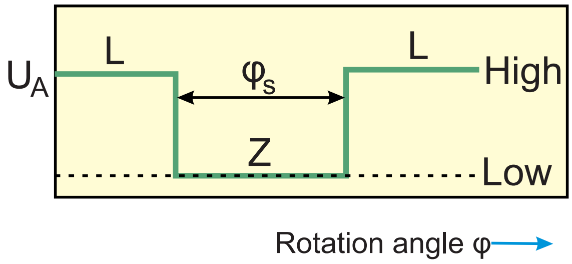


SP82_32

A Position of the sender and the unidirectional pulse wheel

1 Electrical connection (connector)
2 Sender housing
3 Engine housing
4 Sealing ring
5 Permanent magnet
6 Integrated Hall circuit
7 Pulse wheel with teeth (Z) and gap (L)
a Air gap
φ Rotation angle

B Curve of output voltage U_A



SP82_33

Usage:
The position of the camshaft specifies whether the moving piston located in the upper turning point is in the compression stroke or in detent. The sender of the camshaft, which is also called "phase sensor" transmits this information to the control unit.

Gearbox speed sensor RS (Rotational Speed Sensor)

Structure and function principle

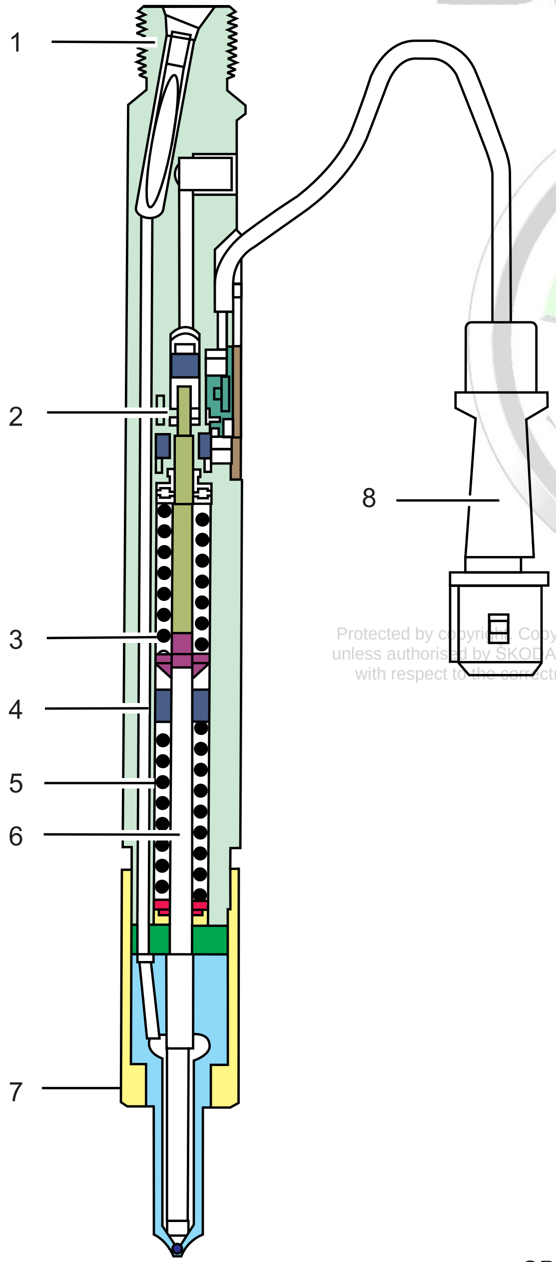
The active speed sender has an integrated differential Hall circuit, which must be connected to the voltage source U_V.
The rotor can be a toothed gear, a magnet wheel or a pressed sheet metal. The senders are available in two versions. The first provides a rectangular speed signal. In the second version, the signal is extended by additional information relating to the rotation direction, the detection of the idle state, the reserve of the air gap and the mounting position.

Usage:
These senders are designed so that they can resist the working environment, in this case oil, in which they are immersed, as well as higher temperatures, ranging from -40 to +150°C. The supply voltage U_V is 4.5 – 16.5V.

Needle lift sender

Structure and function principle

The permanent magnetic pressure bolt is pushed into the coil, which induces a directly proportional voltage to the moving speed as a result of the change in the magnetic flux.



1 Body of the holder
2 Needle movement sender
3 Pressure spring
4 Guide ring
5 Pressure spring
6 Pressure spindle
7 Nut for clamping the nozzle
8 Port for the evaluation circuit

SP82_37

Usage:
The start of the injection is an important variable for the optimal functioning of diesel engines. Its sensing allows the conversion of the injection, depending on the load and speed.
The holder of the nozzle with the needle lift sender NBS serves this purpose, for standard injection pumps as well as for rotary pumps. By lifting the needle on the nozzle, the sender transmits a signal that is further processed.

Inductive sensor for transistorised ignition

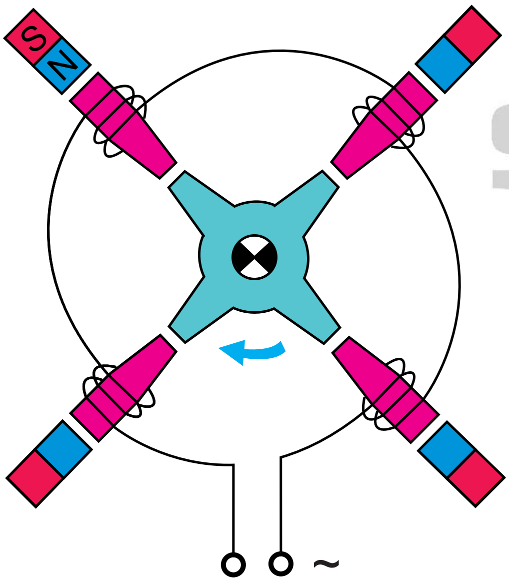
Structure

The sensor is located in the body of the distributor. The soft-magnetic (conductive) core of the coil with the winding, has the shape of a circular disc and is called "pole plate". Together with the magnet they form a complex, the so-called stator. The pulse wheel, known as the rotor and made of soft-magnetic steel, is fitted on the shaft of the distributor. The core and the rotor have attachments in the form of teeth, whose number correspond with the number of cylinders in the engine.

Function principle

During the rotation of the rotor, the width of the air gap between both attachments changes periodically, which leads to a change in magnetic flux. This change induces an AC voltage in the coils whose magnitude is directly proportional to the speed.

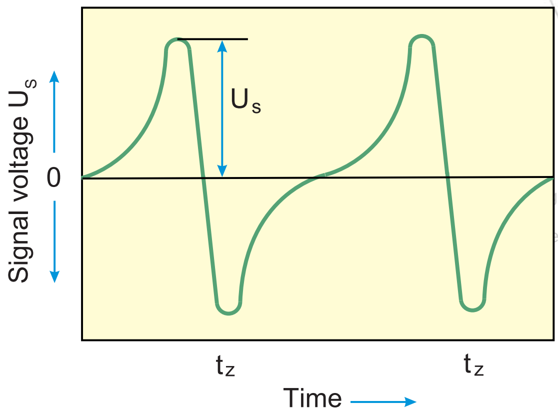
The voltage frequency ***f*** corresponds to the number of sparks per minute.



SP82_38

$f = z \cdot n/2$

f - frequency (min-1)
z - number of cylinders
n - engine speed (min-1)



SP82_39

Usage:
The sensor serves to initiate the spark for the transistorised ignition. It is an electrical AC generator.

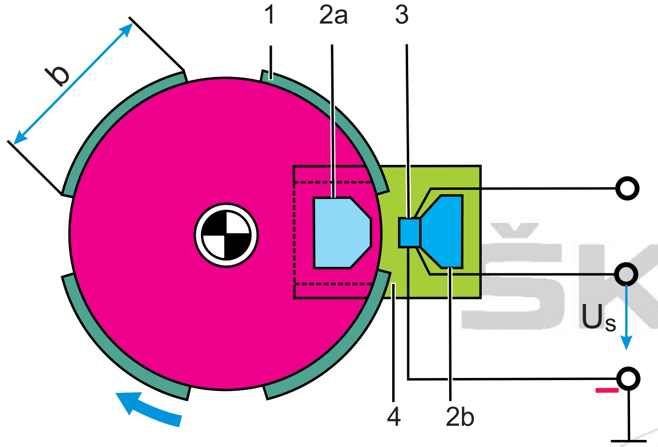
Hall sender for transistorised ignition

Structure

The Hall sender is in the distributor and its integrated circuit is cast in plastic, for reasons of humidity, mechanical damage and contamination. Magnetically conductive elements and the rotor with the bezels are made of soft-magnetic material. The number of bezels correspond to the number of cylinders of the engine.

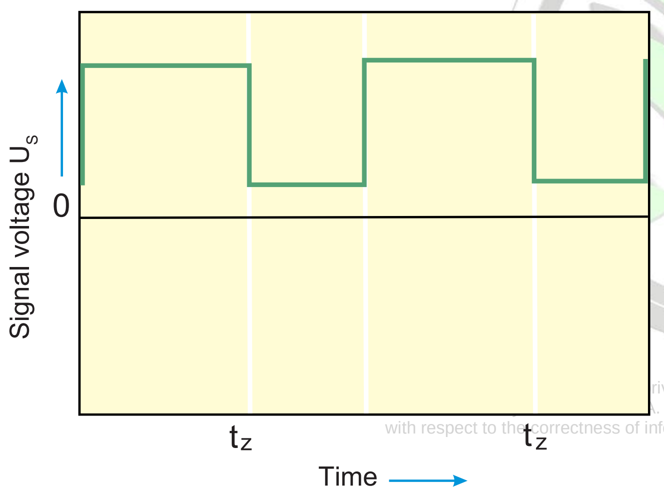
Function principle

The bezels of the rotor move without contact in the air gap. If the air gap is free, the magnetic field passes through the integrated Hall circuit and the voltage reaches its maximum, whereby the integrated circuit is connected. If one of the bezels penetrates the gap, it prevents the passage of the magnetic field and thus the voltage reaches its minimum.



1 Aperture with width b
2a Permanent magnet
2b Elements for guiding the magnetic flux made of soft-magnetic material
3 Integrated Hall circuit
4 Air gap
U_S Signal voltage (adapted Hall voltage)

SP82_40



SP82_41

Usage:
The "Hall barrier" serves to initiate the spark for the transistorised ignition TZ-H.

Measured properties, measurement principles

Vibration sensors are suitable for controlling the knocking in internal combustion engines. Vibration sensors work according to the same principle as acceleration senders. The measured property is thus the acceleration **a**, which is given as a multiple of gravitational acceleration **g** (g = 9.81 ms-2).
The measurement is based on the fundamental law of mechanics:

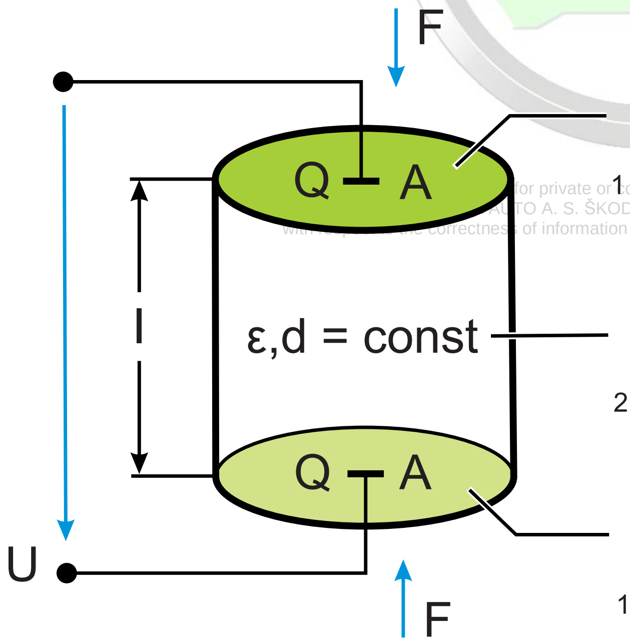
$F = m \cdot a$

This has the result that the acceleration of the body **a** depends on its mass **m** and the force **F**, acting on it. Depending on the nature of the measured property, vibration sensors can be divided into two systems:

- systems for measuring the path
- systems for measuring the mechanical tension

Systems for measuring the mechanical tension

Piezoelectric materials create charges on their surfaces **Q** under the influence of mechanical stresses caused by external forces **F**. Electrodes are attached to the surface. Natural crystalline materials exhibit this property naturally. Man-made materials must be polarised by means of an electric field for this purpose.
As a result of the influence of the environment, "depolarisation" can occur which changes the structure of the material and this principle does no longer work. One of the possibilities may be if the "Curie temperature" of 160°C is exceeded or a mechanical influence, such as intense vibrations. Another negative characteristic which present all man-made materials is the "pyroelectric effect" which produces charges in the materials due to the change in temperature. These charges are independent of the duration of the effect of the external force and are diverted over time via the measuring circuit or they discharge. Thus the sensors cannot measure statically, but dynamically.



SP82_42

1	Electrodes
2	Piezoelectric model
l	Length
A	Cross-sectional area of the model
F	Force
Q	Charge
U	Voltage
ε	Dielectric constant
d	Piezoelectric charge constant

The electrical behaviour of these sensors is described by the "piezoelectric charge constant **d**" or by the **"piezo module K"**. Here are the following relations:

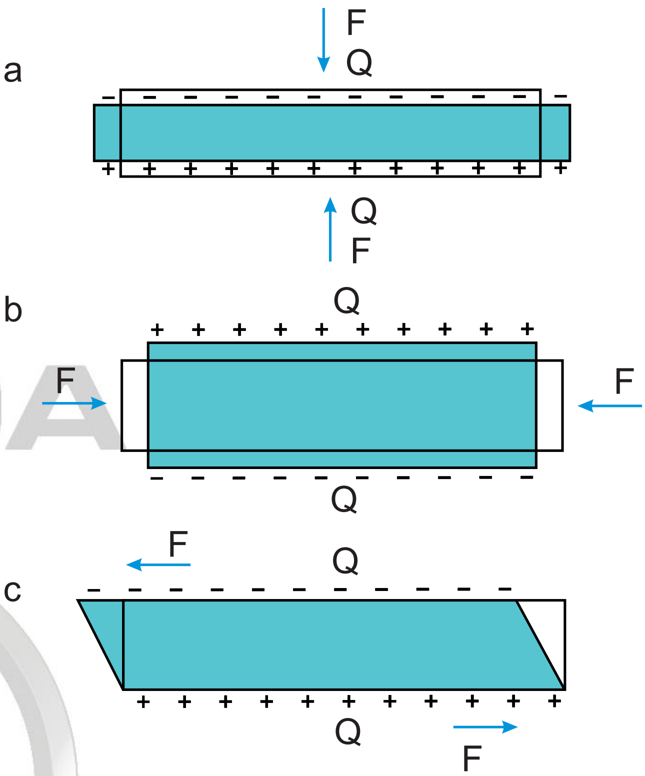
Mechanical tension $\sigma = F / A$ (N/m2)

Variable of the charge $Q = d \cdot F$ (C)
Sender voltage $U = g \cdot L \cdot \sigma$ (V)
Intensity of the electric field $E = g \cdot \sigma$ (V/m)

Piezoelectric voltage constant $g = d / \varepsilon$

F - force (N)
A - cross section of the body (m2)
L - length of the body (m)
ε - dielectric constant

Depending on the type of stress, the piezo-electric effect can further be divided into the longitudinal effect (a), the longitudinal sliding effect (b) and the lateral sliding effect. Each of them finds here its application in practice.



SP82_43

Thin PVDF films

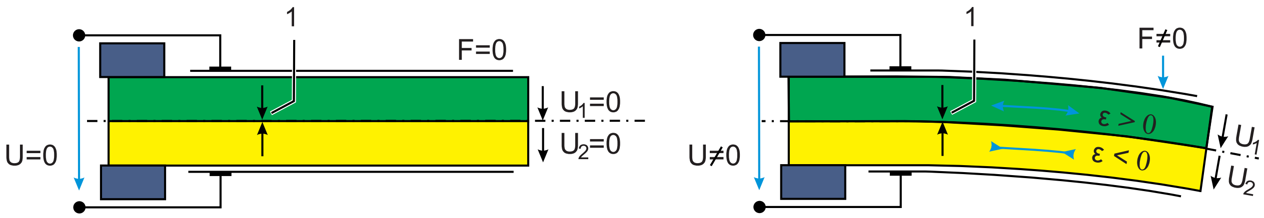
They are among the most widely used, man-made materials in the automotive industry.

Advantages:
- very low cost

Disadvantages:
- poor measurement properties
- pyroelectric effect

Bimorph wafers

They consist of two piezoelectric ceramic wafers with opposite polarisation sense.
While bending, one layer will be stretched ($\varepsilon > 0$) and the other is compressed ($\varepsilon < 0$).
The resulting voltage equals the sum of the partial voltages of both layers. If one of the ends is firmly anchored, the curvature can be measured. If they are soldered or glued to a metal diaphragm, they also measure the deflexion.



SP82_44

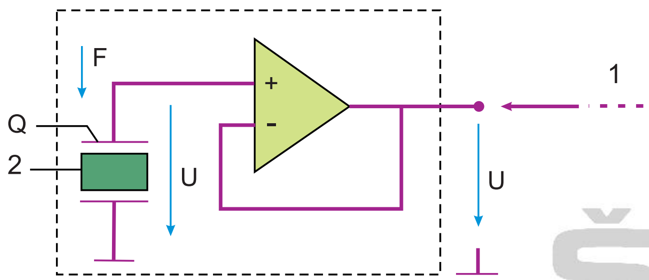
At rest

When bending,stretching above ($\varepsilon > 0$), pressing below ($\varepsilon < 0$)

1	Polarisation direction
F	Measured force
U	Total voltage
$U_{1,2}$	Partial voltage

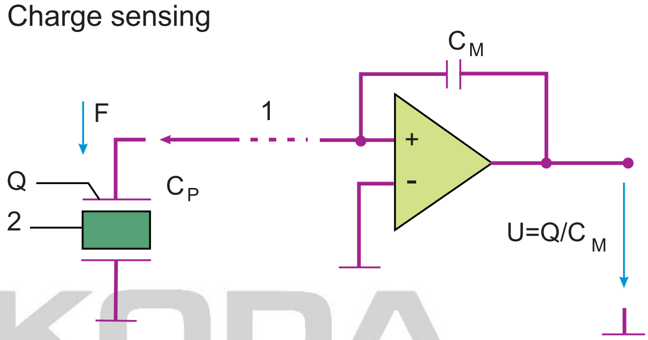
Electrical signal evaluation

Voltage sensing



SP82_45

Charge sensing



SP82_46

1	Power cable
2	Piezoelectric model with capacity Cp
Cm	Measured capacity
F	Measured force
Q	Charge
U	Voltage

Usage:
- Hall-acceleration sender
- Piezoelectric acceleration sender (bimorph bending elements, longitudinal elements as knock sensor)
- Micromechanical acceleration sensor

Vibration sensors

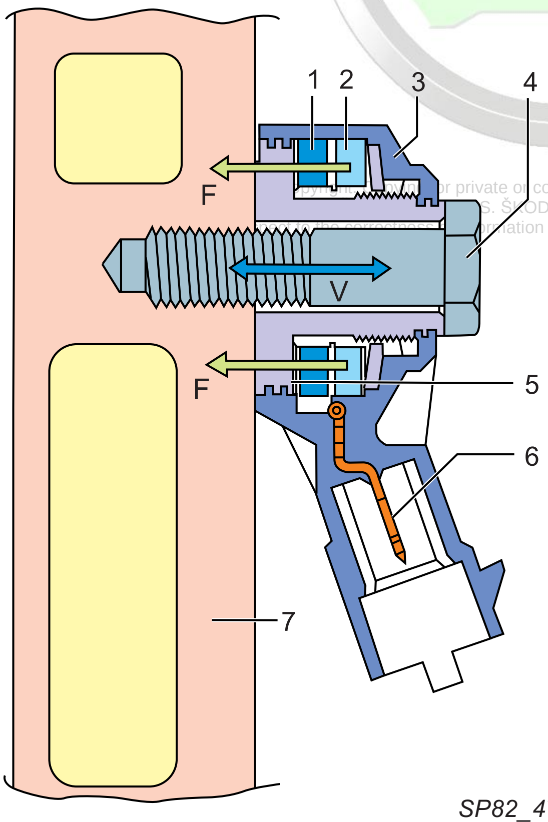
Piezoelectric knock sensors

Structure

On account of its inertia, the mass exerts compressive forces on a circular piezoceramic element in the same rhythm as the vibrations causing them. As a result of the deformation, charge transfer occurs within the ceramic element. A voltage is generated between the upper and lower sides of the ceramic element, this voltage is increased with an AC amplifier and is further processed in the control unit of the ignition.

Installation

The following conditions must be observed so that the resulting signals can be directed from the measuring site to the sender which is mounted with one screw:
- The screw must be tightened to relevant tightening torque.
- The mounting surface and the thread opening in the engine must have the required quality.
- No balancing or spring washers must be used for mounting.



SP82_47

1	Piezoceramic
2	Seismic mass with pressure forces F
3	Housing
4	Screw
5	Port
6	Electrical connection
7	Engine block
V	Vibration

Usage:
Regarding their principle of functionality, knock sensors are basically vibration sensors and are suitable for detecting structure-borne acoustic oscillations. The sensor converts the deflections into electrical signals.

Measured properties, measurement principles

The pressure is measured directly by means of the diaphragm deformation or by a force sensor.
For the measurement, sensors are used which are suitable for measuring ***static***, as well as ***dynamic*** systems, that are not only in gaseous or liquid state, but also thoses which are made of soft gel-like substances.

Diaphragm sensors

The most common method of pressure measurement uses a thin diaphragm as a mechanical intermediate stage, which is exposed on the one side to the pressure to be measured, as a result of which it flexes.

Capacitive sensors

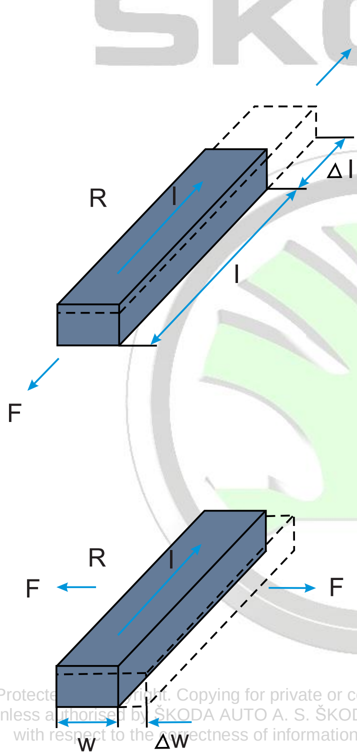
Direct contact with the medium to be measured is necessary. It requires expensive technical measures to separate the sensor from this medium. A measuring element of the capacity may be a capsule.

SGS measurement (**S**train**G**auge**S**trip)

Depending on the type of the diaphragm, the ***SGS measurement*** can be divided into the following measurement techniques.

- bonded films
- thick layer
- metal sheeting
- thin siliceous layer
- diffused resistors

Their properties differ substantially depending on their size and measuring effect. The size of the measuring effect characterises the "coefficient **K**", which indicates the relative change of resistance **R** in terms of relative value of its length **l**.



Coefficient K	$K=\frac{\Delta R/R}{\varepsilon} = 1 + 2 \bullet \nu + \frac{\Delta\rho/\rho}{\varepsilon}$
Resistance	R (Ω)
Poisson constant	ν
Electrical conductivity	ρ (S) Siemens
Longitudinal extension	$\varepsilon = \frac{\Delta l}{l}$ (ppm)
Transverse extension	$\varepsilon = \frac{\Delta w}{w}$ (ppm)

SP82_48

The materials used for the diaphragms are either ceramic, metallic or made of quartz (silicon). The deflection of the diaphragm is established by different strengths of pressure forces on both sides. The fundamental division of pressures for the senders, are:

- absolute pressure
- reference pressure
- barometric pressure
- differential pressure (pressure difference)

Return to the force sensor

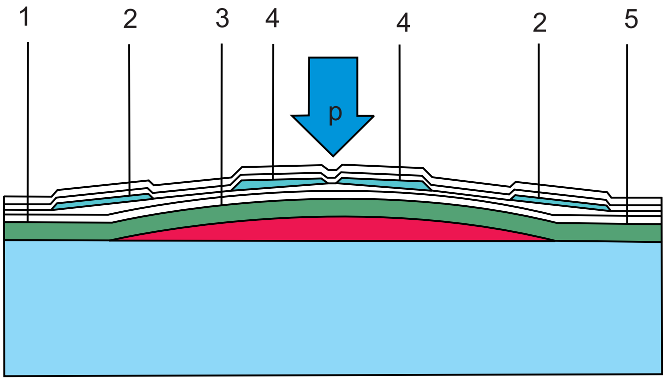
These sensors are designed so that the force resulting from the bending of the diaphragm is transmitted to the force sensor by means of an extension rod.

Usage:
- thick-film pressure sensors
  micromechanical pressure sensors
- silicon pressure sensor in the combustion chamber
  high pressure sender with metal diaphragm

Thick-film pressure sensors

Structure and function principle

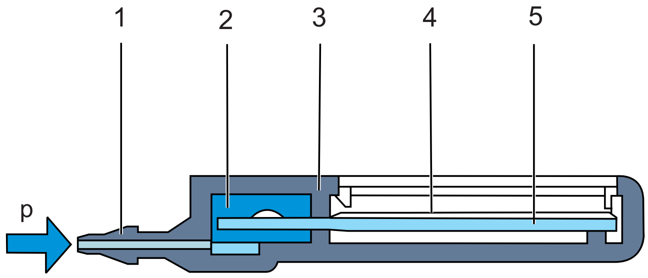
The sensor is divided into a measuring cell and the space for the evaluation circuit. Both parts are arranged on a common ceramic substrate. The measuring cell consists of a thick-layered diaphragm, near which are four resistances in the bridge circuit. Two active resistors change their conductivity according to the mechanical tension and two passive resistors serve as temperature compensation. The deflection of the diaphragm causes a change in the balance of the bridge circuit and the measured voltage U_A, which is fed into the control unit, and corresponds to the measured pressure **p**.



SP82_49

1 Thick-layered diaphragm
2 Passive reference tenacity
3 Reference pressure chamber (blister)
4 Active tenacity
5 Ceramic substrate
p Measured pressure

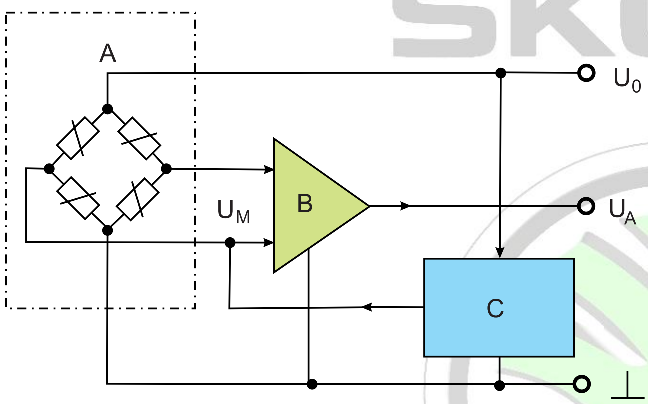
Pressure sender



SP82_50

Measuring section:
1 Pressure port for the measured pressure p
2 Measuring cell
3 Sealing partition

Signal processing:
4 Evaluation circuit
5 Thick-layer hybrid circuit on ceramic substrate



SP82_51

A Measuring cell SGS
B Amplifier
C Temperature compensation circuit
U_0 Supply voltage
U_M Measured voltage
U_A Output voltage

Usage:
Thick-film pressure sensors are used occasionally as an alternative to micro-mechanical senders.

- pressure sender in intake manifold and charge pressure sender (20 - 400 kPa)
- ambient pressure sender (60 - 115 kPa)

Micromechanical pressure sensors

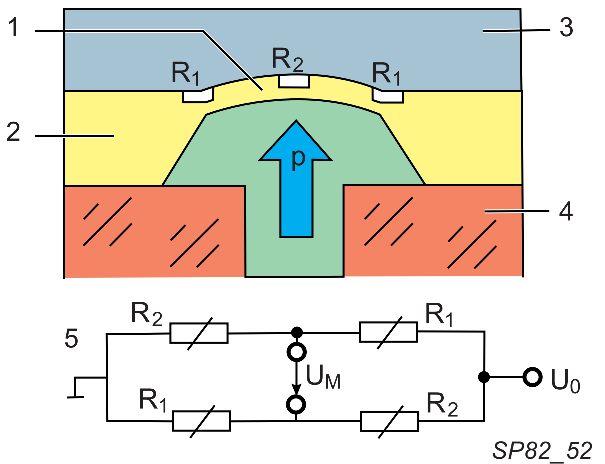
Version with reference vacuum on the structure side

Structure

The measuring cell consists of a silicon chip. A thin diaphragm, on which four resistors are diffused, is etched micromechanically into the chip. Its electrical resistance changes depending on the mechanical tension of the diaphragm. The reference vacuum is located under the cap. A temperature sensor is often integrated in the housing of the sender, its signal is evaluated independently.

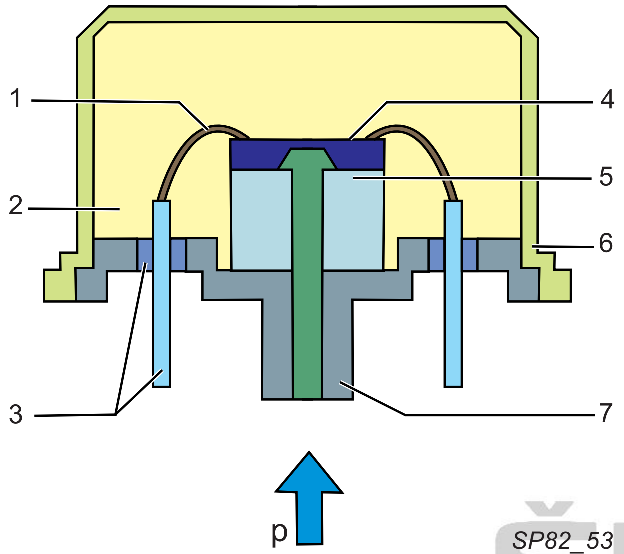
Function principle

The measuring resistors are connected as a bridge. By changing the resistors, the ratio of the electrical voltage changes on the resistors. The measured total voltage U_M is the standard of the pressure on the diaphragm.



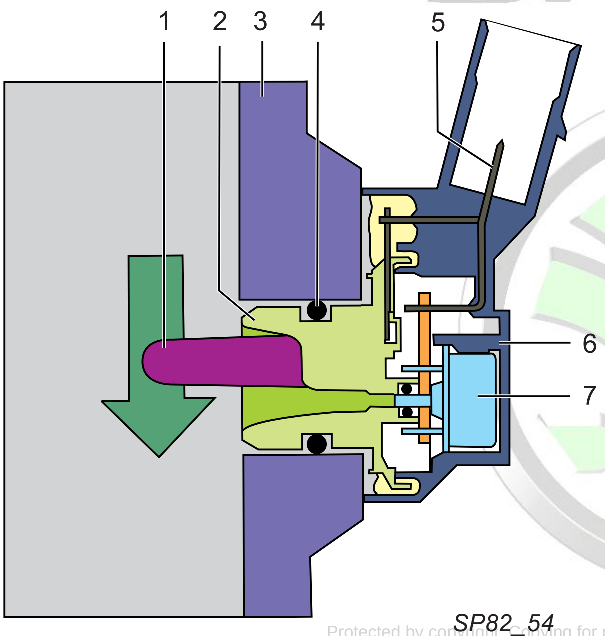
SP82_52

1 Diaphragm
2 Silicon chip
3 Reference vacuum
4 Glass base (Pyrex)
5 Bridge circuit
p Measured pressure
U_0 Supply voltage
U_M Measured voltage
R_1 Tenacity (pressed)
R_2 Tenacity (stretched)



SP82_53

1.3 Electrical supply lines with glass bushing
2 Reference vacuum
4 Measuring cell (chip) with evaluation electronics
5 Glass base
6 Cap
7 Supply line of the measured pressure p



SP82_54

1 Temperature sensor (NTC)
2 Lower part of housing
3 Intake manifold wall
4 Sealing rings
5 Electrical connection (connector)
6 Housing lock
7 Measuring cell

Pressure sender

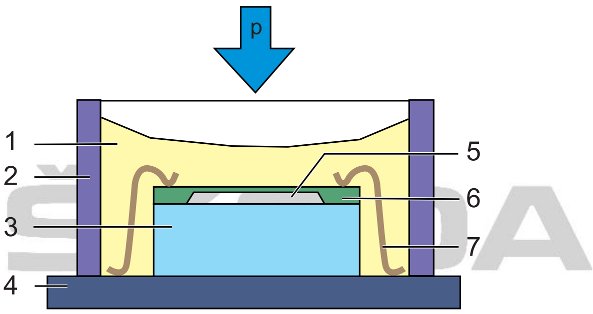
Version with reference pressure in the hollow space

Structure

The silicon chip is located on the glass base and the measured pressure is applied directly to that side, where you will find the evaluation electronics. For this reason, this side is protected by a special gel. The reference vacuum is present in the hollow space between the chip and the glass base.
A temperature sensor is often integrated in the housing of the sender which protrudes into the cavity of the flowing air. It reacts very quickly to temperature changes and its signal is evaluated independently.

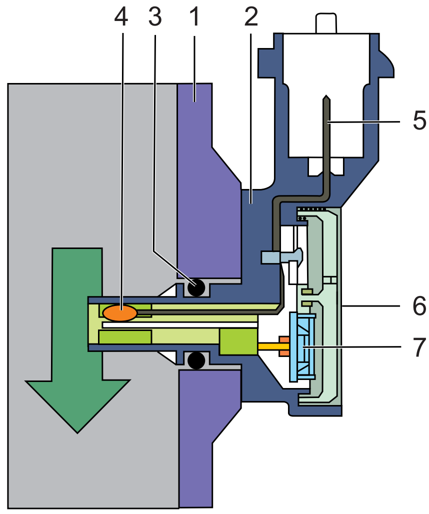
Function principle

The operating principle is identical to the version with the reference vacuum on the structure side. The only difference is that the diaphragm of the measuring cell is deformed in the opposite direction.



SP82_55

1 Protective gel
2 Gel frame
3 Glass base
4 Ceramic hybrid substrate
5 Hollow space with reference vacuum
6 Measuring cell (chip) with evaluation electronics
7 Outputs welded on
p Measured pressure



SP82_56

1 Intake manifold wall
2 Housing
3 Sealing ring
4 Temperature sensor (NTC)
5 Electrical connection (connector)
6 Housing lock
7 Measuring cell

Usage:
Pressure sender in intake manifold and charge pressure sender (250 kPa)
This sender measures the ***absolute pressure*** in the intake manifold between the charger and the engine in relation to the reference vacuum. This allows the precise air mass to be determined.

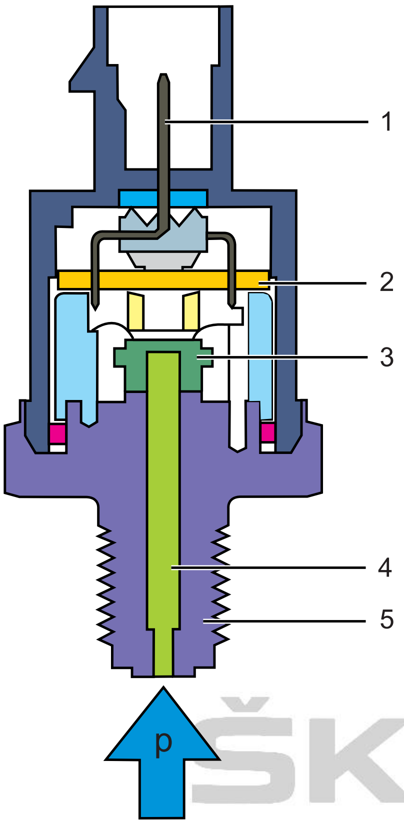
Ambient pressure sender (60 - 115 kPa)
This sender measures the ***absolute pressure*** and is located directly in the control unit or the engine compartment. The signal is used to correct the values, with which the control loops operate, depending on the altitude e.g. exhaust gas recirculation or charge pressure control.

Oil pressure sender (50 - 1000 kPa)
This sender measures the ***absolute pressure*** of the oil and is mounted on the oil filter.
The measuring cell is used for measuring the pressure in the low pressure part of the fuel tank. The sender is mounted on the fuel filter, possibly inside it.

High-pressure sender

Structure and function principle

The core of the sender consists of a steel diaphragm on which resistors are vacuum-metallised in the bridge circuit. The measuring range of the sender depends on the strength of the diaphragm. The pressure and the strength are directly proportional. The measured pressure acts on the diaphragm, its deflection changes the tension of two resistances. The resulting measuring voltage in the bridge (80 mV) is conducted into the evaluation circuit, which amplifies the signal (5 V) and forwards it to the control unit.



SP82_57

1 Electrical connection (connector)
2 Evaluation circuit
3 Steel diaphragm with vacuum-metallised
- resistors
4 Pressure port
5 Mounting thread

Usage:
High-pressure senders are used in motor vehicles for measuring the pressure of the fuel and the brake fluid.

Pressure sender for diesel in the pressure vessel (180 MPa)
This sender measures the pressure in the distributor pipe (rail) in the Common Rail diesel injection system.
The pressure is also controlled by the circuit and is independent of the engine speed.

Pressure sender for petrol in the pressure vessel (5 - 15 MPa)
This sender measures the pressure in the distributor pipe (rail) of the MED system - Motronic with direct fuel injection. The pressure depends on the speed.

Pressure sender for brake fluid (25 - 35 MPa)
The sender measures the pressure of the brake fluid in the hydraulic unit of the system to ensure safety.

Measured properties, measurement principles

In the vehicle, flow meters are used for measuring the amount of fuel delivered or the intake air volume to be combusted. Measuring the fuel flow was carried out in internal combustion engines without electronic control, e.g. to display the fuel consumption for a given distance.

Measurement of the air flow

In the chemical process of fuel combustion, the mass ratios of the intake and charge air are taken into account. In petrol engines, the air mass flow is the most important variable for the pollution, whereby the senders which measure the quantity of gas flow are called anemometers. The maximum measured mass flow is in the range of 400-1200 kg/h for engines and the ratio between the minimum and maximum flow at idle is 1:90-1:100 with an accuracy of 1-2% of the measured value. The air flow senders are very curved so that the measured signals have to be linearised prior to evaluation. The flow through the pipeline can be either laminar or turbulent. This depends on the factor of the Reynolds number $R_{e.}$

$$R_e = v \bullet \frac{E}{\eta}$$

v - flow velocity
D- cross-sectional dimension
η - kinematic viscosity of the medium

If the value R is greater than 1200, a turbulent flow occurs, which can be assumed for vehicles (v = constant). If it is lower, there is a laminar flow.
The flow can then be calculated as follows:

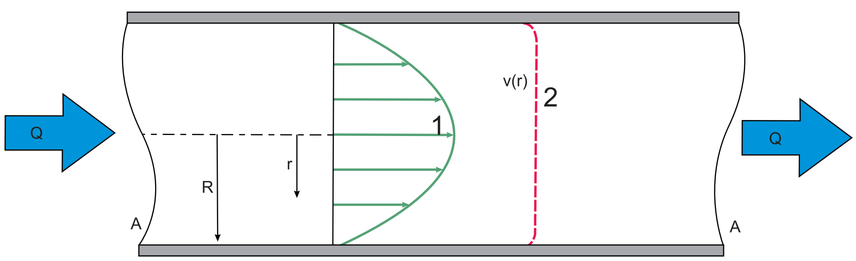
Volume flow: $Q_V = v \bullet A$
Mass flow: $Q_M = \rho \bullet v \bullet A$

ρ - density of the homogeneous medium
A - measurement cross-section

In practice, the measurement is made at the point where there is a narrow cross-section by measuring the mean value of the flow rate:

$$Q_{Str} = const \bullet \sqrt{Q_V \bullet Q_M}$$

The drop in pressure at the flow meter must not exceed the value of 20-30 mbar.



SP82_66

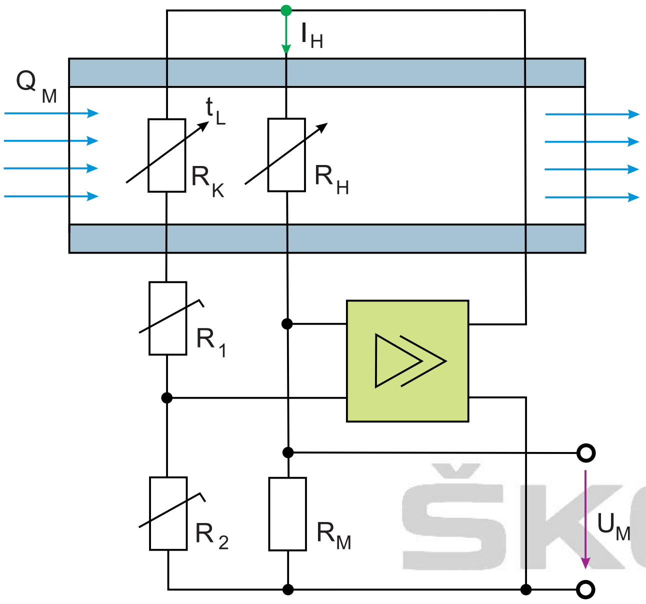
1 Laminar flow
2 Turbulent flow
A Cross-sectional area of the pipe
Q Passage
R Radius of the pipe
r Distance from the centre
v(r) Flow profile

Flow meter

Hot-wire air-mass meter HLM

Structure and function principle

The sender consists of a measuring tube through which flows the intake air. Inside runs a thin filament made of platinum with a diameter of 70 microns and a resistance R_H. A resistor R_k for the temperature compensation is present against the direction of flow. The control circuit ensures that the temperature of the wire is higher by a constant difference. The heater current I_H generates a voltage U_M that is proportional to the air mass flow based on the resistance measurement R_M.



SP82_71

RK	Resistor for the temperature compensation
R_H	Resistance filament
R_M	Measuring resistance
$R_{1.2}$	Resistors for the bridge balance
U_M	Measured voltage
I_H	Heater current
t_l	Air temperature
Q_m	Air flow

Usage:

The hot-wire air-mass meter HLM is located between the air purifier and the throttle valve. It measures the intake air mass flow Q_M through the engine and is the fastest of all flow meters.

Hot-wire- / hot-film anemometer

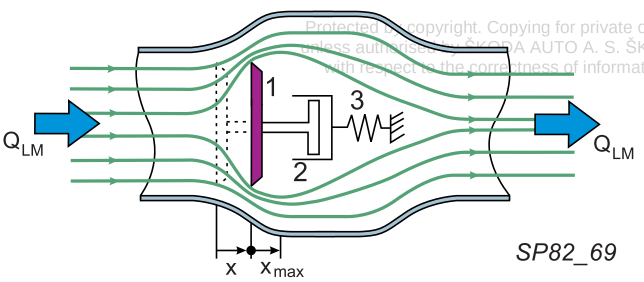
If a current I_H flows through a thin wire with the electrical resistance R, the wire heats up. If a medium with the density p and the speed u flows around it, a balance results between the forwarded electric power p_{el} and the pneumatic secondary power p_v.

$P_{el} = P_V$

$I_H^2 \bullet R = c_1 \bullet \lambda \bullet \Delta v$

Here, the thermal conductivity: $\lambda = \sqrt{Q_{LM} + c_2}$ Then: $I_H = c_1 \bullet \sqrt{(\sqrt{Q_{LM}}) + c_2} \bullet \sqrt{\frac{\Delta v}{R}}$

c2 - heat loss



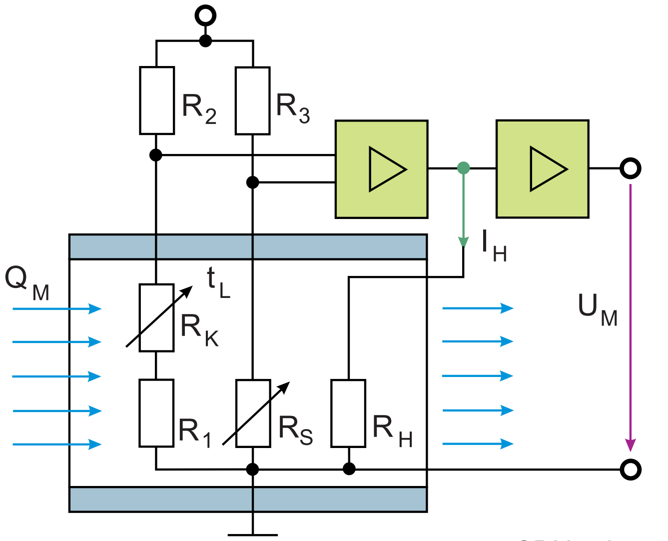
SP82_69

1	Bezel
2	Damping system
3	Soft return spring
Qlm	Air mass flow
x	Position of the disc shutter depending on the flow

Hot-film air-mass meter HFM2

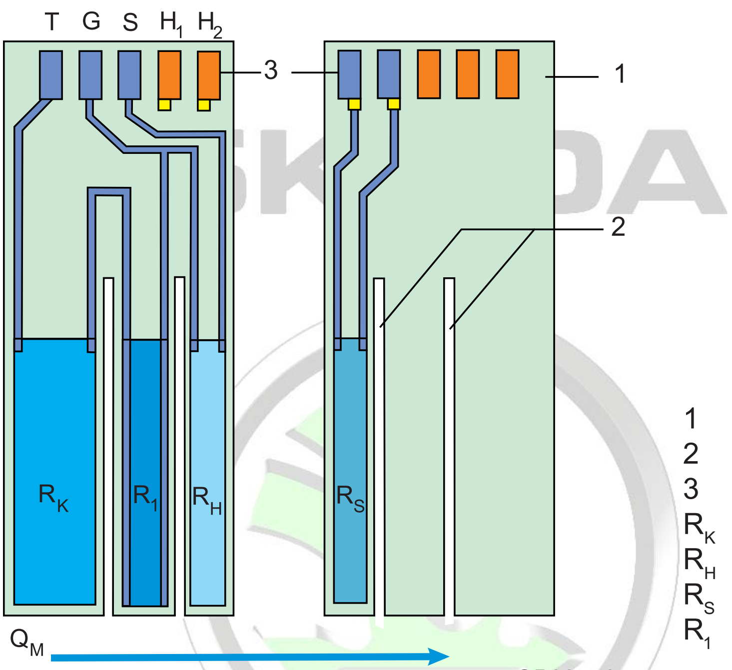
Structure and function principle

The temperature of the electrically heated platinum resistance R_H is measured by the resistor R_S. The heater element and the resistor for the temperature compensation R_g are thermally separated by a slot. All of these resistors are located on a silicon wafer. The operating principle is similar to the sender HLM.



R_K	Sender for temperature compensation
R_H	Heating resistor
R_S	Sensor resistor
$R_{1,2,3}$	Bridge resistors
U_M	Measured voltage
I_H	Heater current
t_L	Air temperature
Q_M	Air flow

SP82_72



1	Ceramic substrate
2	Two waste strips
3	Contacts
R_K	Sender for temperature compensation
R_H	Heating resistor
R_S	Sensor resistor
R_1	Bridge resistor

SP82_73

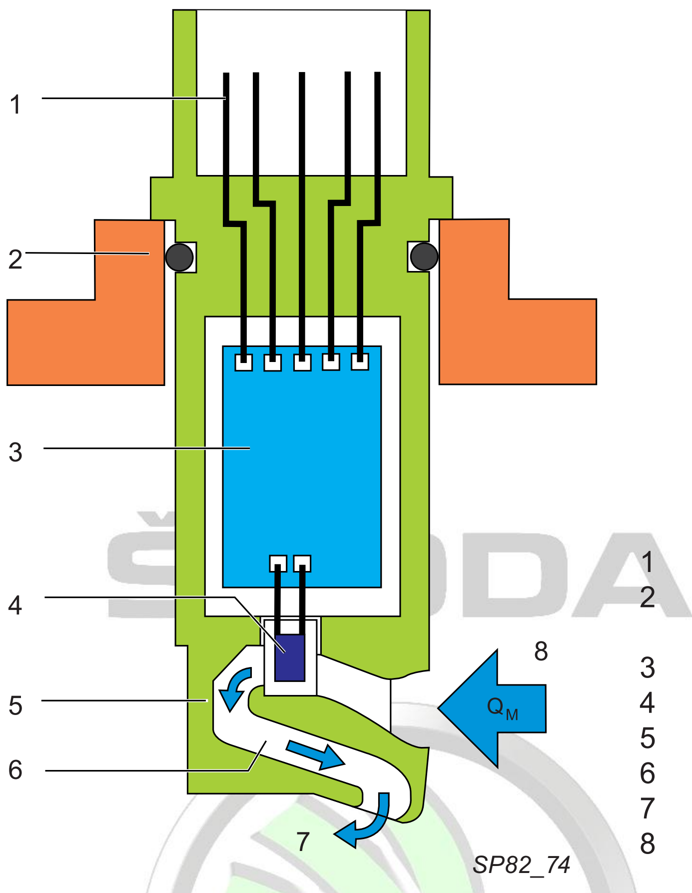
Usage:

On petrol engines, the hot-wire air-mass meter HFM2 is located between the air purifier and the throttle valve. It measures the intake air mass flow Q_M through the engine with high accuracy.

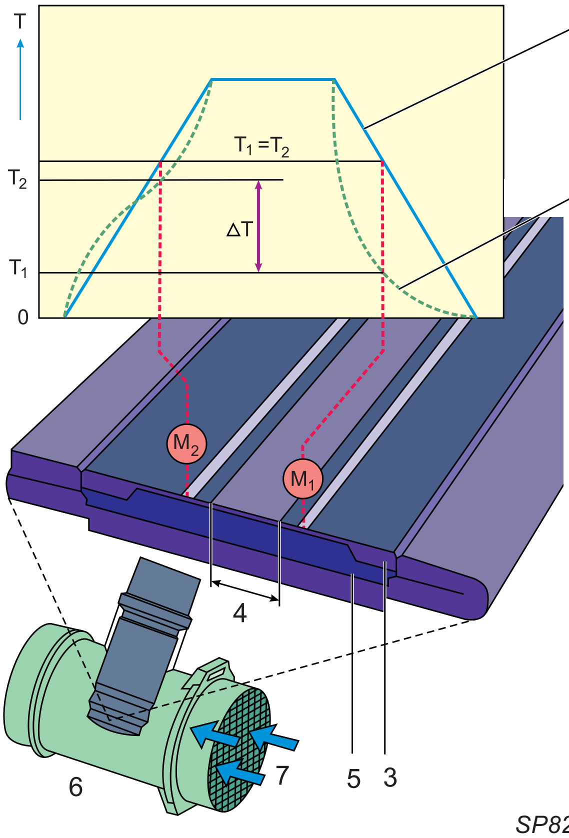
Hot-film air-mass meter HFM5

Structure and function principle

The air mass meter HFM5 is inserted into the suction pipe line behind the air purifier. The sensor consists of the member (4), around which flows the supplied air from the inlet chamber (8), as well as the evaluation electronics (3). The measuring elements are vacuum-metallised on the semiconductor substrate and the evaluation electronics on the ceramic substrate. The measuring channel (6) is shaped in such a way that eddy currents are prevented, thereby improving the stability against pulsating currents. This sender is the only one which detects a return flow.



1 Electrical connection (connector)
2 Measuring tube or wall lining of the air purifier
3 Evaluation electronics (hybrid circuit)
4 Measuring element of the sender
5 Sender housing
6 Measuring channel for the partial flow
7 Output of the measured partial flow Q_M
8 Input of the measured partial flow Q_M



SP82_75

1	Temperature profile without flow
2	Temperature profile with flow
3	Measuring element of the sender
4	Heating zone
5	Diaphragm of the sender
6	Measuring tube with air-mass meter
7	Intake air flow
$M_{1,2}$	Measuring points
$T_{1,2}$	Temperature values in the measuring points $M_{1,2}$
Δ_T	Temperature difference

Principle:

The resistor located in the middle of the measuring element (3) heats the micro-mechanical diaphragm of the sender (5) and keeps it at a constant temperature. The temperature drops outside of this controlled zone (4).
Two resistors at the points $\mathbf{M_1}$ and $\mathbf{M_2}$ detect the temperature distribution on the diaphragm. In the idle state, the temperatures are the same (1). When the air flows via the measuring element, the temperatures (2) change, whereby on the intake side, the curve is steeper due to the cooling and on the other side, it flows better due to the measuring element that heats the air. The difference in temperatures at the points $\mathbf{M_1}$ and $\mathbf{M_2}$ is proportional to the resistance at the resistors. The corresponding voltage is finally converted in the control unit to the value of the air mass flow (kg/h) according to the stored characteristics.

Usage:
This sender is used for very accurate measurement of the partial air flow based on the total current that flows through the measuring tube or through the air purifier. Changes in the temperature of the intake air do not affect the measurement accuracy.

Measured properties, measurement principles

The concentration of the substance indicates the mass ratio of the individual elements or mixtures of other substances. The concentration meter detects only one element, possibly a substance, the others will be ignored. The following variables are measured on vehicles:

- oxygen content in the exhaust gases
- carbon monoxide and nitrogen oxide content
- humidity in air brake systems
- humidity of the outside air
- soot concentrations in the exhaust gases on diesel engines

The humidity generally indicates the water content in a substance. In the case of gaseous substances, it is water vapour. If moist gas is isobarically cooled, it reaches a certain temperature at a certain saturation level. This temperature limit is called the dew point T. Two terms were introduced for measuring the humidity:

Absolute humidity
It expresses the mass of water contained in the unit volume of air

$$X = \frac{m_W}{m_{tr}} = \frac{M_W}{M_{tr}} \bullet \frac{p_W}{p-p_w} \text{ (v\%)}$$

m_w	Mass of water
m_s	Mass of water in the saturated state
m_{tr}	Mass of dry gas
M_w	Molar mass of water
M_{tr}	Average molar mass of dry gas
p	Total pressure of the gas mixture
p_w	Partial pressure of water vapours

Relative humidity
It indicates the ratio between the amount of water vapour in the air and the amount of saturated vapour at the same temperature and pressure.
Saturated steam is a state in which the number of molecules leaving the liquid surface is equal to the number of (after liquefaction) returning molecules.

In the automotive industry, only resistance and capacitive sensors are used for measuring the humidity.

Capacitive sensors

As the dielectric of the capacitor, a hygroscopic water vapour absorbent layer is used, whereby these vapours pass through one of the electrodes. With increasing humidity, the dielectric absorbs water whereby the capacitance of the sensor is increased significantly.

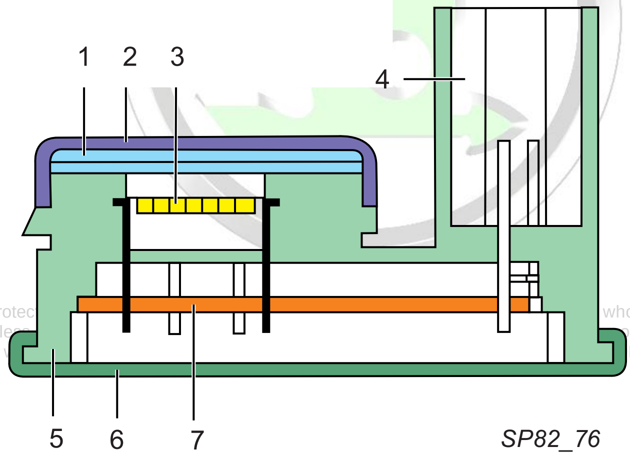
Resistance sensors

Between the pair of electrodes there is hygroscopic salt, its conductivity varies significantly depending on the *relative humidity*. This change of resistance is highly dependent on the temperature, so that a compensation must be made. If the temperature is measured at the same time, the dew point and hence the *absolute humidity* can be determined.

Air quality sensors

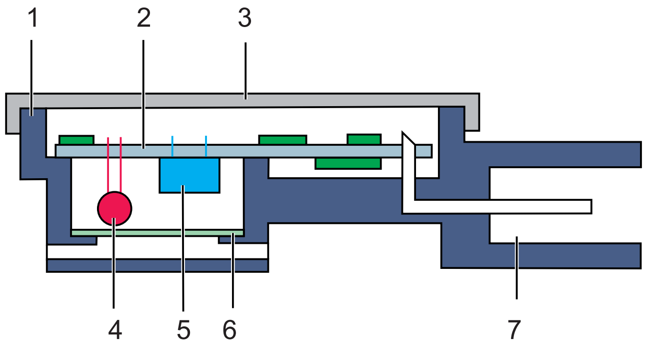
Structure and method of use

The sensors are built directly into the control units and consist of thick-layer resistors containing stannic oxide. Here, the elements to be measured settle through the flow and the resistors change significantly their resistance. The ceramic substrate on which are the resistors, is heated by a conductor to the operating temperature of 330°C.
As soon as the concentration of harmful gases exceeds the safety limit, the control unit shuts off the supply of fresh air.



1 Teflon diaphragm
2 Hood (gas permeable)
3 Measuring cell NO_2/CO
4 Connector
5 Housing
6 Cover with seal
7 Board

SP82_76



1 Housing
2 Board
3 Cover with seal
4 Temperature sender
5 Humidity sensor
6 Teflon diaphragm
7 Connector

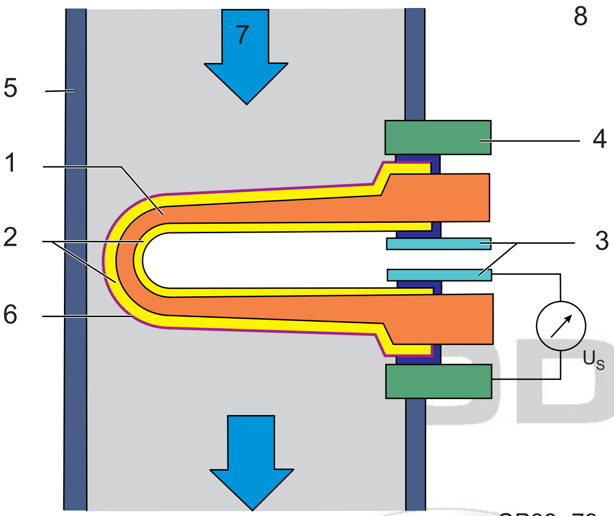
SP82_77

Usage:
These sensors measure the long-term air quality in the inlet area of the ventilation.
They respond to the harmful elements of the exhaust gases CO and NOx. They are also used to measure the water vapour content in the air in order to prevent window fogging.

Snap-action lambda probe

Rod probes

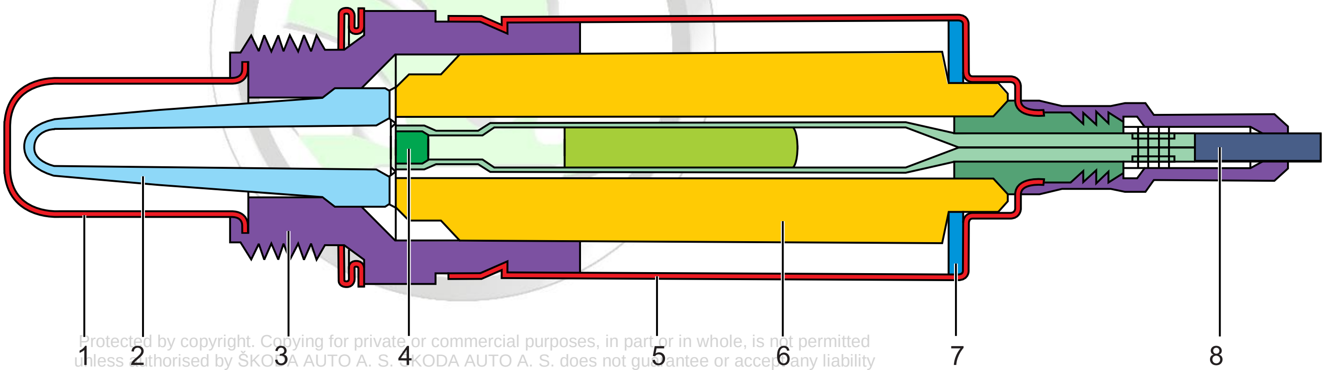
The electrolyte consists of a ceramic body closed at one end, where no gas can penetrate. The surface on both sides have electrodes made of a porous thin platinum coating.
The electrode on the outside operates like a small catalyst, where the forwarded exhaust gases are brought into the stoichiometric equilibrium (λ = 1). In addition, there is a porous protective layer on the side of the exhaust gases. A metal tube protects the ceramic body from mechanical damage and thermal shock. Inside, there is the reference gas.



SP82_78

1 Ceramic body of the probe
2 Electrodes
3 Contacts
4 Contact with the housing
5 Exhaust manifold
6 Ceramic coating
7 Exhausts
8 Outside air
U_s Probe voltage

Unheated rod probe LS21

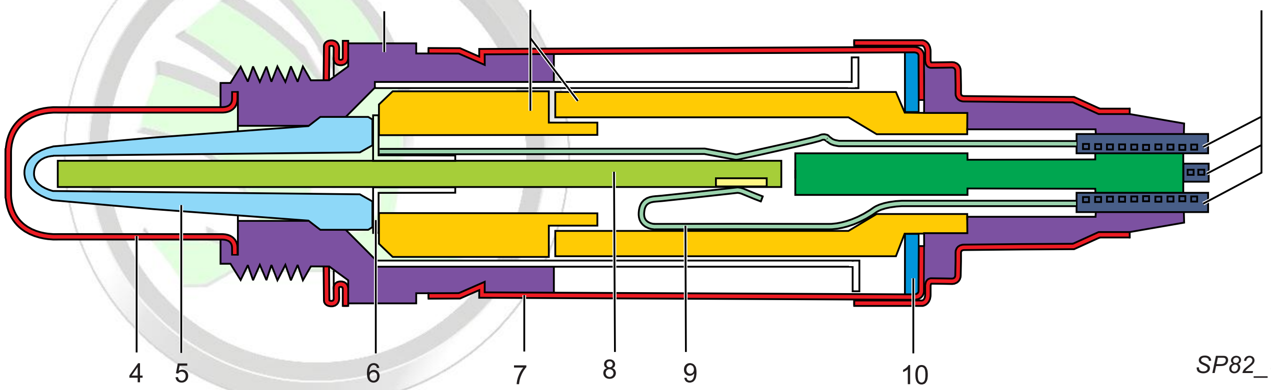


SP82_79

1 Protective tube
2 Active probe ceramic
3 Probe housing
4 Connecting part
5 Protective sleeve
6 Ceramic support tube
7 Plate spring
8 Connection cable

Heated rod probe LSH24

With this probe, the temperature of the ceramic body is determined at low load of the engine, by electrically heating, and at high load, by the temperature of the exhaust gases. This probe can be installed even at a great distance from the engine and the operating temperature can be reached very quickly under the heating effect. The lambda control can therefore operate immediately after starting.

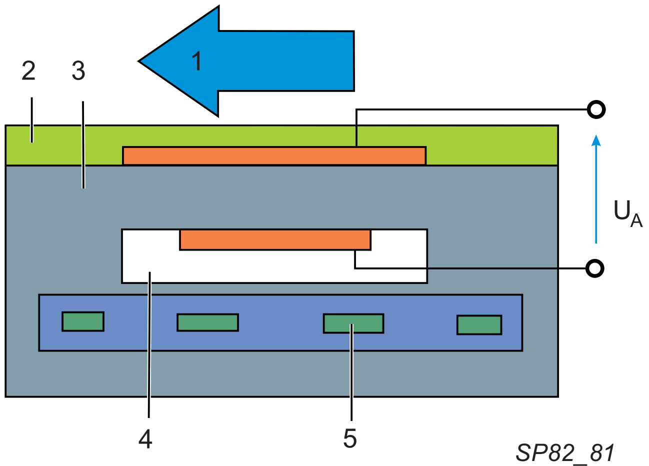


SP82_80

1 Probe housing
2 Ceramic support tube
3 Connection cable
4 Protection tube with slots
5 Active probe ceramic
6 Contact part
7 Protective sleeve
8 Heating element
9 Connection terminals
10 Plate spring

Planar probes

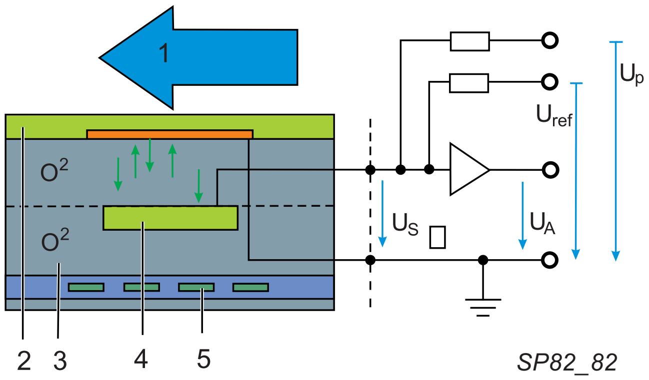
In their function, they correspond to the heated rod probes with a jump characteristic (λ = 1). The electrolyte consists of individual ceramic sheets laminated together. The planar ceramic element has the shape of an elongated plate with a rectangular cross section. The porous ceramic layer serves as protection against erosion. The heater element is a metal conductor, which is integrated into the ceramic wafer. Inside, there is either an air duct (LSF4) or a chamber with oxygen (LSF8).



SP82_81

Version LSF4

1 Exhausts
2 Porous ceramic protection
3 Measuring element with micro-porous layer of precious metal
4 Reference air duct
5 Heating element
U_A Output voltage



SP82_82

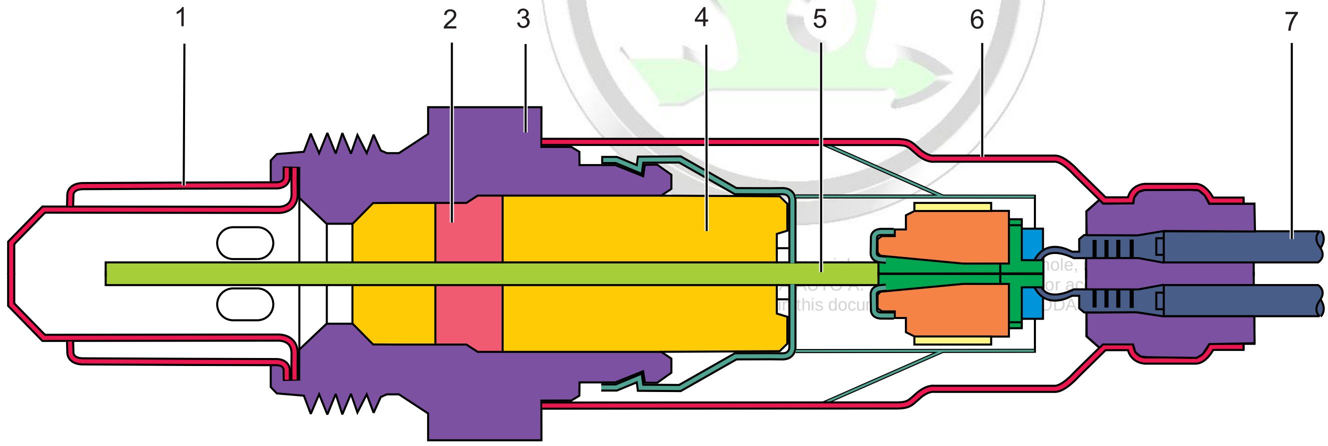
Version LSF8

1 Exhausts
2 Porous ceramic protection
3 Measuring element with micro-porous layer of precious metal
4 Reference chamber for O_2
5 Heating element
U_A Output voltage
U_S Probe voltage
U_P Petrol station
U_{Ref} Reference voltage

Function principle

The ceramic material is conductive above 350°C for oxygen ions. The charges, which are generated from the residual oxygen in the exhaust gases, are discharged through the outer electrode and the charges from the reference chamber are guided by the inner electrode. Between them is then created an electrical voltage, by means of which the proportion of oxygen in the exhaust gases as well as the ratio of the intake air and fuel can be determined. The temperature of the ceramic body affects the conductivity of oxygen ions and hence the voltage profile. High temperatures shorten the life span, so that the lambda probe must be positioned in such a way that the temperature does not exceed 350°C at full load over a longer period of time.

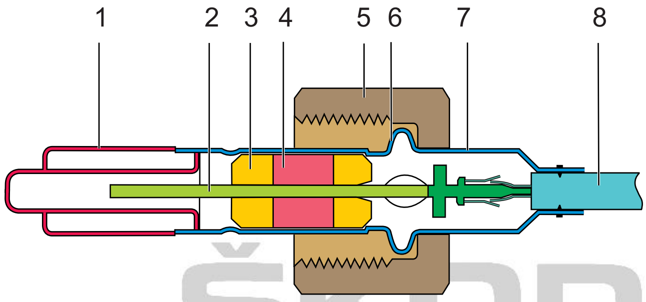
Planar lambda probe LSF4



SP82_83

1 Protective tube
2 Ceramic sealant
3 Probe housing
4 Ceramic support tube
5 Planar measuring element
6 Protective sleeve
7 Connection cable

Planar lambda probe LSF8



SP82_84

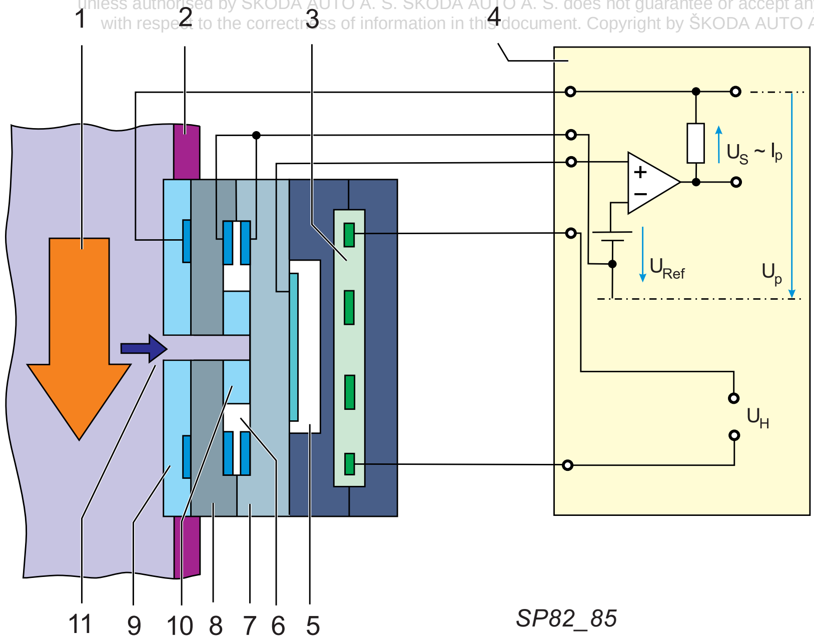
1 Protective tube
2 Planar measuring element
3 Insulating sleeve
4 Ceramic sealant
5 Union nut
6 Sealing flange
7 Probe housing
8 Metal lining

Usage:
The lambda probes determine with a two-point lambda control the oxygen concentration in the exhaust gases and from this the ratio of air and fuel for petrol engines. The lambda coefficient indicates this ratio. They protrude into the exhaust manifold and measure the exhaust flow from all cylinders. Their function is based on the principle of the Nernst galvanic oxygen concentration element with an electrolyte in solid aggregate state. The two-point probes give a signal, whether there is a rich ($\lambda<1$) or a lean mixture ($\lambda>1$) in the exhaust gases.

Planar broadband lambda probe LSU4

Structure

LSU4 is a planar dichotomous probe that uses the principle of limiting current. The measuring element is made of ceramic and comprises a combination of the Nernst concentration galvanic element (7) (two-point lambda) and an oxygen-pumping element (8). Between both elements is a channel (6) with a diameter of 10-50 microns, into which the exhaust gases enter via a diffusion barrier (11). The barrier limits the flow of oxygen from the exhaust gases. To reach the operating temperature as quickly as possible, a heater element (3) is integrated in the probe.



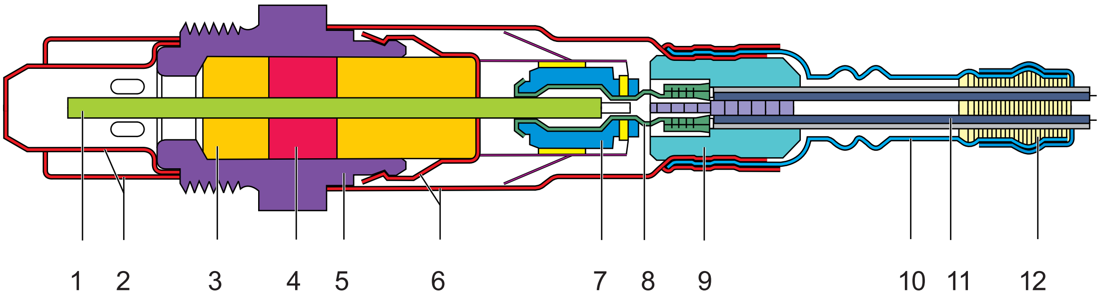
SP82_85

1 Exhausts
2 Exhaust manifold
3 Heating element
4 Control electronics
5 Reference chamber with reference air duct
6 Diffusion duct
7 Nernst concentration element
8 Oxygen pump element with inner and outer electrode
9 Porous protective layer
10 Opening for the admission of the gases
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 Probe voltage

Function principle

To set the coefficient of excess air λ in the diffusion channel, the Nernst element compares the gas with the ambient air in the reference channel.
The oxygen from the exhaust gases in the diffusion channel or vice versa can be pumped by applying the pump voltage U_p to the electrodes of the pumping element. The Nernst element regulates the voltage U_p by means of the electronics so that the gas in the diffusion channel has a constant composition with the coefficient λ = 1. In the event of poor exhaust gases, the pumping element pumps oxygen from the diffusion channel into the exhaust gases and vice versa for rich exhaust gases. The pump current is directly proportional to the oxygen concentration in the exhaust gases and represents the level of the coefficient λ.



SP82_101

1 Measuring element (combination of the Nernst concentration element and the oxygen-pumping element)
2 Double protection tube
3 Sealing ring
4 Sealant
5 Probe housing
6 Protective sleeve
7 Contact holder
8 Connecting clips
9 PTFE grommet (Teflon)
10 PTFE formed hose
11 Five power cables
12 Seal

Temperature sensor

Measured properties, measurement principles

The temperature is a scalar variable that characterises the state of the medium and is dependent on location and time.

T = T (x, y, z, t)

x, y, z Spatial coordinates
t Time
T Temperature (°C, K)

For gases and liquids, the measurement can be made at all spatial points. For solid bodies, the measurement is solely taken on the surface. The temperature is measured either directly, with a close contact of the sensor to the medium to be measured, or indirectly using the radiated energy. The mounting of the sensor should be thermally insulated.
The time it takes for the sensor to change in temperature in order to display 90% of the final value, is indicated by the time constant **t**. This time depends on the heat capacity of the sensor and the coefficient of heat transfer to the measured medium. The time constant increases with the square root of the flow velocity of the medium. When measuring the temperature, the temperature dependence of electrical resistance materials with a positive (PTC) or negative (NTC) temperature coefficient is used. The following temperatures are measured in the vehicle:

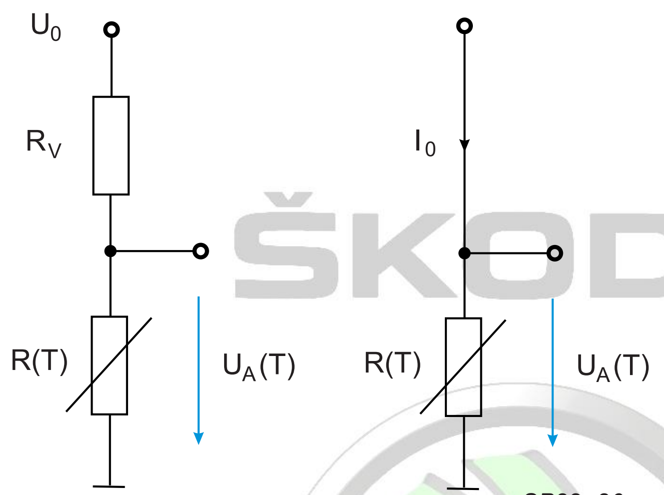
Measured temperature	Range
Intake/charge air	**-40 ... 170**
Surroundings	-40 ... 60
Cabin	-20 ... 80
Ventilation air / heating	-20 ... 60
Evaporator (air conditioning system)	-10 ... 50
Coolant	-40 ... 130
Engine oil	-40 ... 170
Battery	-40 ... 100
Fuel	-40 ... 120
Tyre air	-40 ... 120
Exhaust gases	100 ... 1000
Bracket of the disc brakes	-40 ... 2000

Contact temperature measurement

In addition to the production costs, demands are also made on the measuring methods which assume a very significant temperature effect with linear characteristics.

Resistance sensors

Electrical resistors are bipolar components whose resistance depends on the temperature. To achieve an analog signal at the output, the circuit is completed by a fixed resistor $\boldsymbol{R_V}$, which has the same resistance as the measuring resistor at a certain temperature $\boldsymbol{T_0}$.



SP82_86

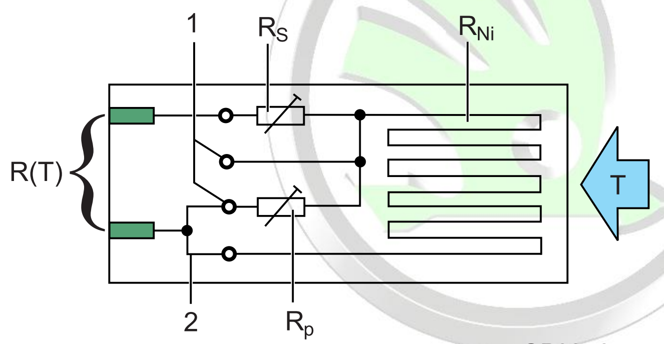
I_O Supply current
U_O Supply voltage
R_V Independent heat resistance
R(T) Independent thermal resistance measurement
UA(T) Output voltage

$R_V = R\,(T_O)$

$$U\,(T) = U_O \bullet \frac{R\,(T)}{R\,(T) + R_V}$$

or the senders are fed with a constant current I_0.

$$U\,(T) = I_O \bullet R\,(T)$$

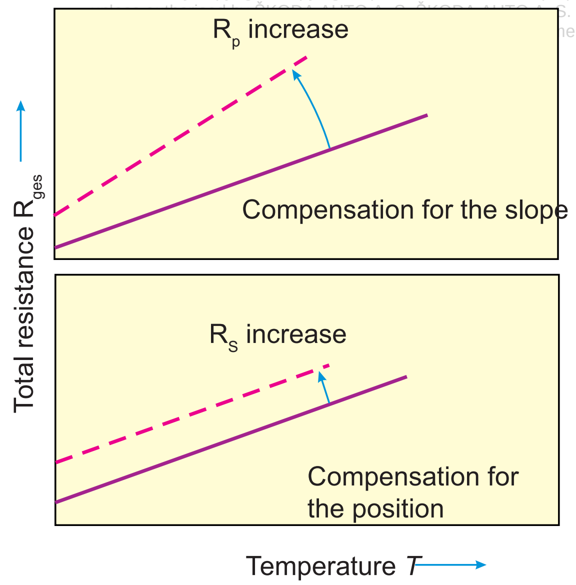


SP82_87

Resistance sensor

Characteristic of the sensor

1 Auxiliary contacts
2 Crosspiece
R_{Ni} Sheet resistance made of nickel
$R_{ges}(T)$ Total resistance in relation to the temperature T
R_p Equilibratable parallel resistance
R_s Equilibratable series resistance



SP82_88

The measured control and regulating variables are converted in the control unit into signals that are required to operate the actuators. These output signals can be analog, digital or pulsed. The processing of this signal takes place according to appropriate adaptations such as filtering, amplifying the signal, pulse shaping, etc.

Onboard computer, control unit

The onboard computer contains the central control unit (CPU) that performs arithmetic and logical operations. It also includes special function modules for the measurement and analysis of external signals. These peripheral modules carry out partial tasks in real time, thus the CPU utilisation is decreased significantly.

Types of output signals:
Digital - detecting switch positions or digital signals of senders (Hall senders).
Analog - signals of analog senders (lambda probe, pressure sender, potentiometer)
Input pulse signals - inductive speed sender, also converting to digital signal

Output signals - by means of performance switch and amplifier, these signals from the onboard computer are amplified to a level of performance required by the actuators.

Diagnostic units

Faults on the senders, sensors and actuators are stored in the fault memory, indicating the nature of the fault. The diagnostic units are able to read the faults in the form of a code and then evaluate them. The following diagnostic units are used:

- VAS 5051
- VAS 5051B
- VAS 5052
- VAS 5052A
- VAS 5053

VAS 5051

VAS 5051B

ENGINE EQUIPMENT (valid as of 12/2009)

Vehicle type	ENGINES																																				
	1,0 37kW	1,2 HTP 40kW	1,2 HTP 44kW	1,2 HTP 47kW	1,2 HTP 51kW	1,2 TFSI 77kW	1,4 44 kW	1,4 50kW	1,4 16V 55kW	1,4 MPI 55kW	1,4 16V 59kW	1,4 16V 74kW	1,4 16V 63kW	1,4 TDI PD 51kW	1,4 TDI 55kW	1,4 TDI PD 59kW	1,4 TFSI 90kW	1,4 TFSI 92kW	1,6 55kW	1,6 74kW	1,6 75kW	1,6 16V 77kW	1,6 FSI 85kW	1,6 TDI CR 77kW	1,8 92kW	1,8 110kW	1,8 TFSI 112kW	1,8 TFSI 118kW	1,8 132kW	1,9 SDI 47kW	1,9 D 47kW	1,9 SDI 50kW	1,9 TDI 66kW	1,9 TDI 74kW	1,9 TDI PD 77kW	1,9 TDI 81kW	1,9 TDI 85kW
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96kW	81kW	85kW	110kW	100 kW	103 kW	103kW	103kW	125kW	125kW	147kW	114kW	120kW	142kW	191kW	GEARBOX 5°									6°						5° 4x4	6° 4x4				4° AUTO		5° AUTO	6° AUTO		7° AUTO
1,9 TDI	2,0 TDI CR	2,0	2,0 FSI	2,0 TDI PD	2,0 TDI	2,0 TDI PD	2,0 TDI CR	2,0 TDI PD	2,0 TDI CR	2,0 TFSI	2,5 TDI	2,5 TDI	2,8	3,6 FSI	012 F	0A4	0 AF	02 T	02 R	002	02 J	02 K	01 W	01 E	0 AJ	0A2	0A8	02 Q	02 S	02 C	02 M	02 Q	02 S3	02 Y	01 M	001	01 V	09G	02 E	0 AM
															ML285	MQ250	MQ200	MQ200	MQ250	MQ150	MQ250	MQ150	ML285	C90	MQ200	ML350	MQ350	MQ350	MQ250	MQ250	MQ350	MQ350	MQ250	MQ350	AQ250	AQ150	AL250	AQ250	DQ250	DQ200
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Overview of the sensors - ENGINE (valid as of 12/2009)

DESCRIPTION OF THE SENDER																							
TYPE	DESIGNATION	CODE	1,0 37kW	1,2 40kW	1,2 44kW	1,2 47kW	1,2 51kW	1,2 TSI 77kW	1,4 44 kW	1,4 50kW	1,4 55kW	1,4 59kW	1,4 74kW	1,4 63kW	1,4 TDI 51kW	1,4 TDI 55kW	1,4 TDI 59kW	1,4 TSI 90kW	1,4 TSI 92kW	1,6 - AEE 55kW	1,6 - 1AV 55kW	1,6 74kW	1,6 75kW
SN	**Ambient pressure sender**	F96														●							
SN	Oil temperature sender	G8																					
SN	Coolant temperature sender	G27																					
SN	Engine speed sender	G28	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●			●	●
SN	Charge pressure sender	G31						●									●	●	●				
SO	Lambda probe before catalytic converter	G39	●	●	●	●	●	●	●	●	●	●	●	●			●	●	●	●	●	●	●
SN	Hall speed sender	G40			●		●	●			●	●		●	●	●	●	●	●	●	●	●	●
CI	Intake air temperature sender	G42			●		●	●			●	●		●			●	●	●	●	●	●	●
SN	Knock sensor	G61	●	●	●	●		●	●	●	●	●	●	●				●	●	●	●	●	●
CI	Coolant temperature sender	G62	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
SN	Pressure sender of the air conditioning system	G65																					
SN	Knock sensor	G66																					
SN	Throttle valve potentiometer	G69																		●			
CI	Intake manifold pressure sender	G70													●	●	●				●	●	
CI	Intake manifold pressure sender	G71	●	●	●	●	●	●	●	●	●	●		●	●	●		●	●	●			●
CI	Intake manifold pressure sender	G72	●	●		●	●		●	●	●		●		●	●							
SN	Accelerator pedal sender	G79	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●				●
SN	Needle lift sender	G80																					
SN	Fuel temperature sender	G81													●	●	●						
SN	Radiator outlet coolant temperature sender	G83						●			●	●						●	●				
SN	Brake pedal position sender	G100						●															
SO	Lambda probe 2 before catalytic converter	G108																					
SO	Lambda probe after catalytic converter	G130	●	●	●	●	●	●			●	●	●	●				●	●				●
SO	Lambda probe 2 after catalytic converter	G131																					
SN	Control-collar position sensor	G149																					
SN	Hall sender for camshaft position	G163	●	●		●			●	●	●		●										
SN	Fuel level sender 2	G169																	●				
SN	Accelerator pedal sender	G185	●	●	●	●	●	●	●	●	●	●	●	●			●	●	●				●
SN	Throttle valve drive angle sender	G187	●	●	●	●	●	●	●	●	●	●	●	●				●	●				●
SN	Throttle valve drive angle sender	G188	●	●	●	●	●	●	●	●	●	●	●	●				●	●				●
SN	Rotation angle sensor	G208																					
SN	Fuel shortage sender	G210																					
SN	Control valve position sender	G212				●					●						●						
SN	Exhaust position sender 1	G235															●						
SN	Fuel pressure sender (low pressure)	G247						●										●	●				
SN	Oil level and oil temperature sender (WIW sensor)	G266		●	●	●	●	●			●	●		●	●	●	●	●	●				●
SO	Lambda probe 3 after catalytic converter	G287																					
SN	Brake servo pressure sensor	G294						●										●	●				
SN	NOx sender	G295																					
SN	Intake air temperature sender 2	G299						●										●	●				
SN	Variable intake manifold position sender	G336																					
SN	Fuel pressure sender (high pressure)	G410																					
SN	Exhaust gas temperature sender 2	G448															●						
SN	Pressure sender 1 in the exhaust manifold	G450															●						
SN	Clutch position sender	G476						●				●						●	●				
SN	Exhaust gas temperature sender 3	G495																					
SN	Additive level sender	G504																					
SN	Temperature sensor before solid particle filter	G506																					
SN	Temperature sensor before turbocharger	G507																					
SN	Temperature sensor of intake manifold switch 2	G513																					
SN	Temperature sensor after solid particle filter	G527															●						
SN	Position sender for charge pressure regulator	G581																					
SN	Exhaust gas temperature sender 4	G648																					

ENGINE

77kW 1,6	85kW 1,6	77kW 1,6 TDI CR	92kW 1,8	110kW 1,8 - AWT	110kW 1,8 - AGU	110kW 1,8	132kW 1,8	118kW 1,8 TSI	47kW 1,9 D	50kW 1,9 SDI	66kW 1,9 TDI	74kW 1,9 TDI - ATD	74kW 1,9 TDI - AVB	74kW 1,9 TDI	77kW 1,9 TDI	77kW 1,9 TDI (DPF)	81kW 1,9 TDI	85kW 1,9 TDI	96kW 1,9 TDI	85kW 2,0 - AZJ	85kW 2,0 - AZM	85kW 2,0 - AQY	110kW 2,0 FSI - BLX	110kW 2,0 FSI - BLR	110kW 2,0 FSI - BLY	100 kW 2,0 TDI	103 kW 2,0 TDI - BKD	103 kW 2,0 TDI - BSS	103kW 2,0 TDI - BMP(DPF)	103kW 2,0 TDI CR	125kW 2,0 TDI CR	147kW 2,0 TSI	114kW 2,5 TDI	142kW 2,8	191kW 3,6 FSI V6
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Overview of the sensors - GEARBOX (valid as of 12/2009)

DESCRIPTION OF THE SENDER		INCORPORATION					
		GEARBOX					
		4° AUTO		5° AUTO	6° AUTO	6° AUTO	7° AUTO
DESIGNATION	CODE	001	01 M	01 V	09 G	DSG - 02 E	DSG - 0AM
Speedometer sender	G22						
Engine speed sender	G28		●				
Gearbox speed sensor	G38	●	●				
Speed sender	G68	●	●				
Accelerator pedal sender	G79	●					
Oil level sender in the gearbox	G93	●	●	●	●	●	
Gearbox input speed sensor	G182			●	●	●	●
Accelerator pedal position sender 2	G185	●					
Throttle valve drive angle sender 1	G187	●					
Oil pressure sender 1 for automatic gearbox	G193					●	
Oil pressure sender 2 for automatic gearbox	G194					●	
Gearbox output speed sensor	G195			●	●	●	●
Gearbox input speed sensor 2	G196					●	●
Hydraulic pressure sensor of the gearbox	G270						●
Linear sender 1 of the gearshift	G487					●	●
Linear sender 2 of the gearshift	G488					●	●
Linear sender 3 of the gearshift	G489					●	●
Linear sender 4 of the gearshift	G490					●	●
Input shaft speed sender 1	G501					●	
Input shaft speed sender 2	G502					●	
Oil temperature sender in the multi-plate clutch	G509					●	
Temperature sensor in the control unit	G510					●	●
Gearbox input speed sensor 2	G612						●
Clutch travel sensor 1	G617						●
Clutch travel sensor 2	G618						●
Gearbox input speed sensor 1	G632						●

Overview of the previously edited self-study programmes

No.	Designation
1	Mono-Motronic
2	Central locking
3	Vehicle alarm
4	Working with wiring diagrams
5	ŠKODA FELICIA
6	Safety of the ŠKODA vehicles
7	Principles of ABS - were not published
8	ABS - FELICIA
9	System for safe start-up with transponder
10	Air conditioning in the vehicle
11	Air conditioning FELICIA
12	1.6 engine - MPI 1AV
13	Four-cylinder diesel engine
14	Power-assisted steering
15	ŠKODA OCTAVIA
16	1.9 ltr. TDI diesel engine
17	ŠKODA OCTAVIA Convenience electronic system
18	ŠKODA OCTAVIA Manual gearbox 02K, 02J
19	1.6 ltr. and 1.8 ltr. petrol engines
20	Automatic gearbox - fundamentals
21	Automatic gearbox 01M
22	1.9 ltr./50 kW SDI, 1.9 ltr./81 kW TDI diesel engines
23	1.8 ltr./110 kW and 1.8 ltr./92 kW petrol engines
24	OCTAVIA, CAN BUS
25	OCTAVIA - CLIMATRONIC
26	OCTAVIA - safety of the vehicle
27	OCTAVIA - 1.4 ltr./44 kW engine and gearbox 002
28	OCTAVIA - ESP - fundamentals, design, function
29	OCTAVIA 4 x 4 - all-wheel drive
30	2.0 ltr. 85 kW and 88 kW petrol engines
31	Radio navigation system - design and functions
32	ŠKODA FABIA - technical information
33	ŠKODA FABIA - electrical systems
34	ŠKODA FABIA - electro-hydraulic power-assisted steering
35	1.4 ltr. - 16 V 55/74 kW petrol engines
36	ŠKODA FABIA - 1.9 ltr. TDI Unit injection
37	Manual gearbox 02T and 002
38	ŠkodaOctavia; model 2001
39	Euro-On-Board-Diagnosis
40	Automatic gearbox 001
41	6-Speed gearbox 02M
42	**Škoda**Fabia - ESP
43	Exhaust emissions
44	Extended service intervals
45	Three-cylinder petrol engines 1.2 ltr.
46	**Škoda**Superb; Vehicle presentation; part I
47	**Škoda**Superb; Vehicle presentation; part II
48	**Škoda**Superb; 2.8 ltr./142 kW V6 petrol engine
49	**Škoda**Superb; 2.5 ltr./114 kW TDI V6 diesel engine
50	**Škoda**Superb; automatic gearbox 01V
51	2.0 ltr./85 kW petrol engine with balancing shafts and two-stage intake manifold
52	**Škoda**Fabia; 1.4 ltr. TDI engine with unit injection system
53	**Škoda**Octavia; Vehicle presentation
54	**Škoda**Octavia; Electrical Components
55	FSI petrol engines; 2.0 ltr./110 kW and 1.6 ltr./85 kW
56	Automatic gearbox DSG-02E
57	Diesel engine; 2.0 ltr./103 kW TDI with pump-nozzle units, 2.0 ltr./100 kW TDI with pump-nozzle units
58	**Škoda**Octavia, Chassis and electromechanical power-assisted steering
59	**Škoda**Octavia RS, 2.0 ltr./147 kW FSI turbo engine
60	2.0 ltr./103 kW 2V TDI diesel engine; particle filter with additive
61	Radio navigation systems in the **Škoda**
62	**Škoda**Roomster; Vehicle presentation part I
63	**Škoda**Roomster; Vehicle presentation part II
64	**Škoda**Fabia II; Vehicle presentation
65	**Škoda**Superb II; Vehicle presentation part I
66	**Škoda**Superb II; Vehicle presentation part II
67	Diesel engine; 2.0 ltr./125 kW TDI with Common Rail injection system
68	1.4 ltr./92 kW TSI petrol engine with turbocharger
69	3.6 ltr./191 kW FSI petrol engine
70	All-wheel drive with Haldex coupling of the IV. generation
71	**Škoda**Yeti; Vehicle presentation part I
72	**Škoda**Yeti; Vehicle presentation part II
73	LPG system in Škoda vehicles
74	1.2 ltr./77 kW TSI petrol engine with turbocharger
75	7-speed dual-clutch automatic gearbox 0AM
76	Green Line vehicles
77	Geometry
78	Passive safety
79	Additional heating
80	2.0 ltr., 1.6 ltr., 1.2 ltr. diesel engines with Common Rail injection system
81	Bluetooth in Škoda vehicles
82	Sensors in Škoda vehicles – engine

S00.2002.82.20 (GB) Technical status 11/2010

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