Automotive electronics

What you need to know!



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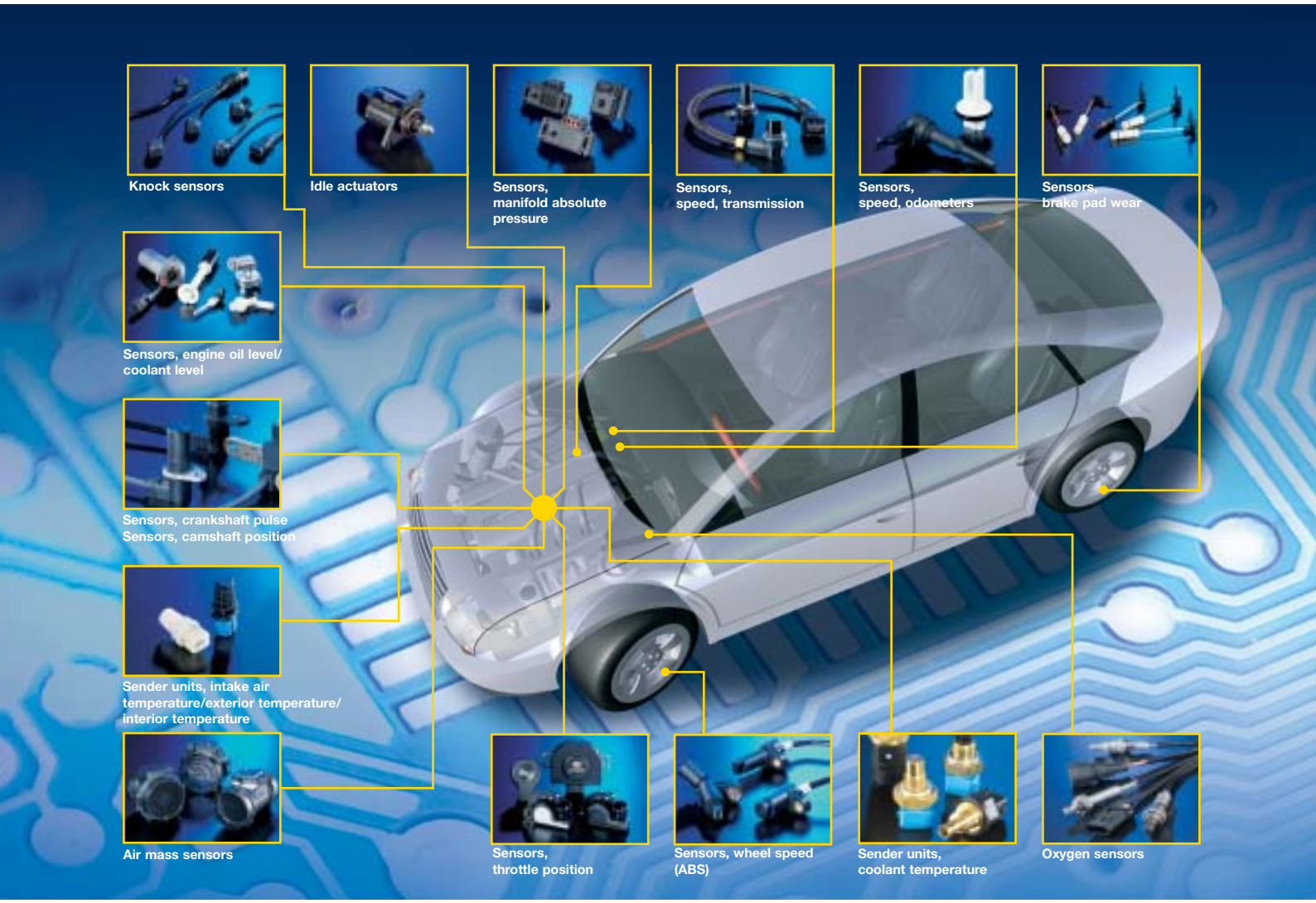
The proportion of electronics in vehicles increases constantly – it is estimated that in the year 2010, it will be approximately 30% of the entire material value of a vehicle. This poses a growing challenge to garages, and changes the original business – from the traditional maintenance service to the service-oriented high-tech garage. Hella would like to support you. Therefore, our electronics experts have put together a selection of important information on the subject of vehicle electronics.
Hella offers a vast product range for vehicle electronics:

• Air mass sensors • Air temperature sensors/sender units (intake,interior & exterior) • Brake wear sensors • Camshaft position sensors • Coolant temperature sensors/sender units • Coolant level sensors • Crankshaft pulse sensors • Engine oil level sensors • Idle actuators • Knock sensors, MAP sensors • Oxygen sensors • Speedometer sensors • Throttle position sensors • Transmission speed sensors • Wheel speed sensors (ABS)

In addition, Hella offers the possibility of continuing your education independently of location. Make use of Hella Online Training. In the electronics module you can find detailed information for use in your dailywork. Further information at www.hella.ie/OnlineTraining as well as in the advertisement on the back cover.

Have you heard about Hella's concept for independent garages? The name Hella Service Partner relates to a partnership between independent garages, participating wholesalers and Hella. By direct contact with Hella, we support partner garages in the areas of lighting, electrics, electronics and thermal management. You can find a detailed description of this opportunity for independent garages on the Internet at: http://www.hella.com/produktion/HellaDE/WebSite/Channels/Werkstatt/Konzept/HSP/HSP.jsp as well as in the advertisement on the back cover.

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We are going to inform you about testing and diagnosis units, trouble-shooting and how to obtain technical information.

Testing and diagnosis units

Let us start with the necessary testing and diagnosis units. To be able to carry out efficient troubleshooting on vehicles these days, it is important to have the right testing and diagnosis equipment available. These include:

- Multimeter
- Oscilloscope
- Diagnosis unit



Multimeter

The multimeter is probably the one measuring instrument most often used in the garage. It can be used for all quick voltage or resistance measurements. A practical multimeter should meet the following minimum requirements:

- DC V= various measuring ranges for direct voltage (mV, V)
- DC A= various measuring ranges for direct current (mA, A)
- AC V= various measuring ranges for alternating voltage
- AC A= various measuring ranges for alternating current
- Ω = various measuring ranges for resistance
- ♫ = continuity buzzer

As an additional option we recommend taking the measuring ranges for temperature and frequency into consideration as well. The input resistance should be a minimum of 10 MΩ.



Oscilloscope

An oscilloscope is required for recording and representing different sensor signals. An oscilloscope should meet the following specifications:

- 2 channels
- Minimum 20 MHz
- Store and print images

As an additional option here we recommend the possibility of automatic image sweep (recording and reproduction). A portable hand-held unit is sensible for more straightforward application at the vehicle.



Diagnosis unit

Diagnosis units are becoming more important all the time in day-to-day garage work. For these to be able to be used properly, they should also have several basic functions:

- Read out fault codes, with plain text display
- Clear fault codes
- Indicate measured values
- Actuator test

In addition there are useful options that must be taken into consideration:

- The device should be easy to transport.
- Large market-specific cover of vehicle makes and models.
- Resetting and reprogramming of service interval displays.
- The unit should have the possibility of coding e.g. control units.
- Data transfer via PC/printer should be possible.
- Updates should be able to be installed as easily as possible.

Before a decision is taken in favour of one particular diagnosis unit, it makes sense to have a look at several units from different manufacturers and perhaps to test a demonstration unit in day-to-day garage work. This is the best way to test handling and practicability aspects.

In addition, the following factors need to be considered:

What is the vehicle cover of the unit like?
Does this match the customer vehicles the garage has to deal with? Have a look at the makes of your customers' vehicles and compare these with the vehicle makes stored in the unit. If you have specialised on one make, you should definitely make sure this is stored. The complete model range of the vehicle manufacturer, including the respective engine versions, should also be available of course. Other decisive factors include the testing depth and individual vehicle systems (engine, ABS, air conditioning etc.) which can be diagnosed in individual vehicles. If there is a wide range of vehicle makes stored in the unit this does not automatically mean that the same diagnosis standard can be assumed for all vehicles.

How are updates transferred to the unit?
Again, there are different possibilities here. Updates can be carried out via the Internet, CD or memory expansion boards. In this case, every unit manufacturer has his own philosophy. What is of interest is how frequently updates take place and how comprehensive these are.

What additional information is offered?
A series of diagnosis unit manufacturers offers a wide range of additional information. This includes technical information such as circuit diagrams, installation locations for components, testing methods etc.. Sometimes information about vehicle-specific problems or customer management problems is also provided.

Support with problems?
Everyone knows what it's like when nothing seems to work. This can be linked to problems with the unit, the computer or the vehicle. In this case it is always extremely helpful if you can give a helpline a call. A lot of testing equipment manufacturers provide helplines that can help with software or hardware problems on the unit itself as well as with vehicle-specific problems. Here, too there are different possibilities of making helpline enquiries. These range from a simple telephone call through fax inquiries or e-mail queries.

Which costs have to be taken into consideration?
Alongside the actual price of the unit, there are many different ways of charging for individual additional services. Make sure you find out in detail about potential follow-on costs which could be incurred for use of the helpline, for example. Many unit manufacturers offer garages a modular structure.
This means the garage can put the software package together according to its individual requirements. These could include the extension by an exhaust emissions measuring device for carrying out the vehicle emission test.

It is not necessary to purchase all these devices separately. Sometimes they are already in the garage, an oscilloscope in the engine tester, for example, or can be purchased as a combination device, hand-held oscilloscope with multimeter. A fully equipped diagnosis unit usually also has an integrated oscilloscope and multimeter.

Vehicle diagnosis and troubleshooting

Troubleshooting begins as soon as the vehicle is brought in and details are taken. While talking to the customer and during a test drive, a lot of important information can be collected. The customer can explain exactly when and under which conditions the fault occurs. With this information you have already taken the first step towards diagnosing the fault. If there is no information available from the customer, since a test drive was not carried out and the customer was not asked to detail the problem when the vehicle was brought in, this will lead to the first problems. For example, the fault cannot be comprehended or reproduced. How can anyone find a fault that is not there?



If you know, however, exactly when and under which conditions the fault occurs, it can be reproduced again and again and initial possible solutions be found. In order to collect as much information as possible it is advisable to draw up a checklist which includes all possible conditions and vehicle states. This makes quick and effective customer questioning possible. Once the vehicle is in the garage, the first thing to do is read out the fault code. This is where the diagnosis unit is used for the first time. If there is a fault code recorded, further measurements and tests have to be used to establish whether the problem is a faulty component such as a sensor, a fault in the wiring or a mechanical problem. Simply replacing the component often costs money without necessarily successfully solving the problem.

It must always be remembered that the control unit recognises a fault but cannot specify whether the problem is in the component, the wiring or in the mechanics. Reading out the data lists can provide further clues. Here, the reference and actual values of the control unit are compared.
For example: The engine temperature is higher than 80 °C, but the engine temperature sensor only sends a value of 20 °C to the control unit. Such striking faults can be recognised by reading out the data lists.

If it is not possible to read out the data lists or if no fault can be recognised, the following further tests/measurements should be carried out:

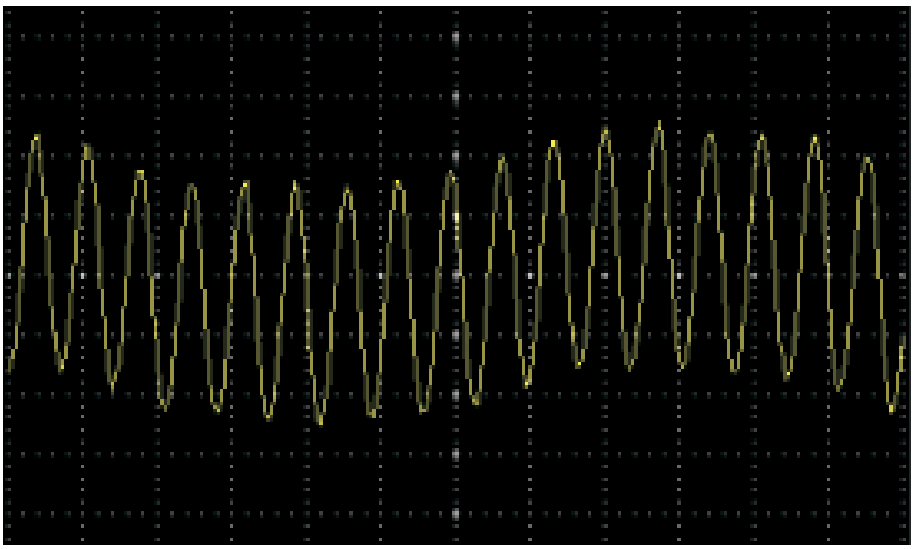
Visual inspection

A visual inspection can quickly detect transition resistance produced by oxidation or mechanical defects on connectors and/or connector contacts. Heavy damage to sensors, actuators and cables can also be detected in this way. If no recognisable faults can be found during a visual inspection, component testing must then take place.

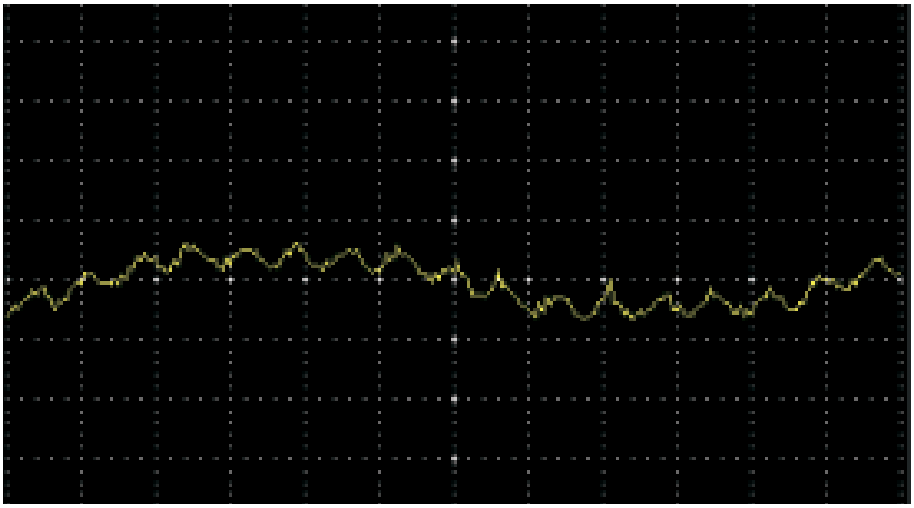
Measurements on sensors and actuators

A multimeter can be used to measure internal resistance in order to test sensors and actuators. Be careful with Hall-type sensors, these can be destroyed by resistance measurements. A comparison of reference and actual values can provide information about the state of the components. Let's use a temperature sensor as an example again. By measuring the resistance at different temperatures it can be established whether the actual values comply with the required reference values. Sensor signal images can be represented using the oscilloscope. In this case, too, the comparison of conform and non-conform images can be used to see whether the sensor provides a sufficiently good signal for the control unit or whether the fault entry is due to a different reason.

A crankshaft sensor as an example:



Oscilloscope image – intact crankshaft sensor



Oscilloscope image – faulty crankshaft sensor

For example: Heavy soiling or damage to the sensor wheel causes a poor or altered signal to be sent to the control unit. This leads to an entry in the fault store which can read: Crankshaft sensor no/false signal. In this case, replacing the sensor would not eliminate the fault. If measurement with the oscilloscope determines a faulty signal image, the sensor wheel can be tested before sensor replacement.
Actuator triggering by the control unit can also be tested using the oscilloscope, however. The triggering of the injection valves, for example. The oscilloscope image shows whether the signal image itself is OK and whether the injection valve opening times correspond to the engine's operating state.

If there is no fault code recorded, these tests become even more significant. The fact that there is no fault entry means there is no initial indication of where to look for the fault either. Reading out the data lists can provide some initial information about the data flow in this case too, however.

The mass air flow meter must be mentioned as a classical example here. Despite a perceivable fault in the engine management system no fault is recorded in the control unit. Mass air flow meter values measured during a test drive and under load reveal that the measured values do not match the engine operating state or the reference values. For the engine control unit, however, the mass air flow meter data are still plausible and it adapts the other parameters such as the amount of fuel injected to the values measured and does not record an entry as a fault code. The behaviour of other components can be similar to that of the mass air flow meter. In such cases the above-mentioned tests can be used to narrow down the possible faults.

A further possibility in addition to serial diagnosis (connection of the diagnosis unit to a diagnosis connection) is parallel diagnosis. With this kind of diagnosis the diagnosis unit is connected between the control unit and the wiring harness. Some testing equipment manufacturers offer this possibility. The advantage of this method is that each individual connection pin on the control unit can be tested. All data, sensor signals, ground and voltage supplies can be tapped individually and compared with the reference values.

In order to carry out effective system or component diagnosis it is often extremely important to have a vehicle-specific circuit diagram or technical description available. One major problem for garages is how to obtain this vehicle-specific information. The following possibilities are available:

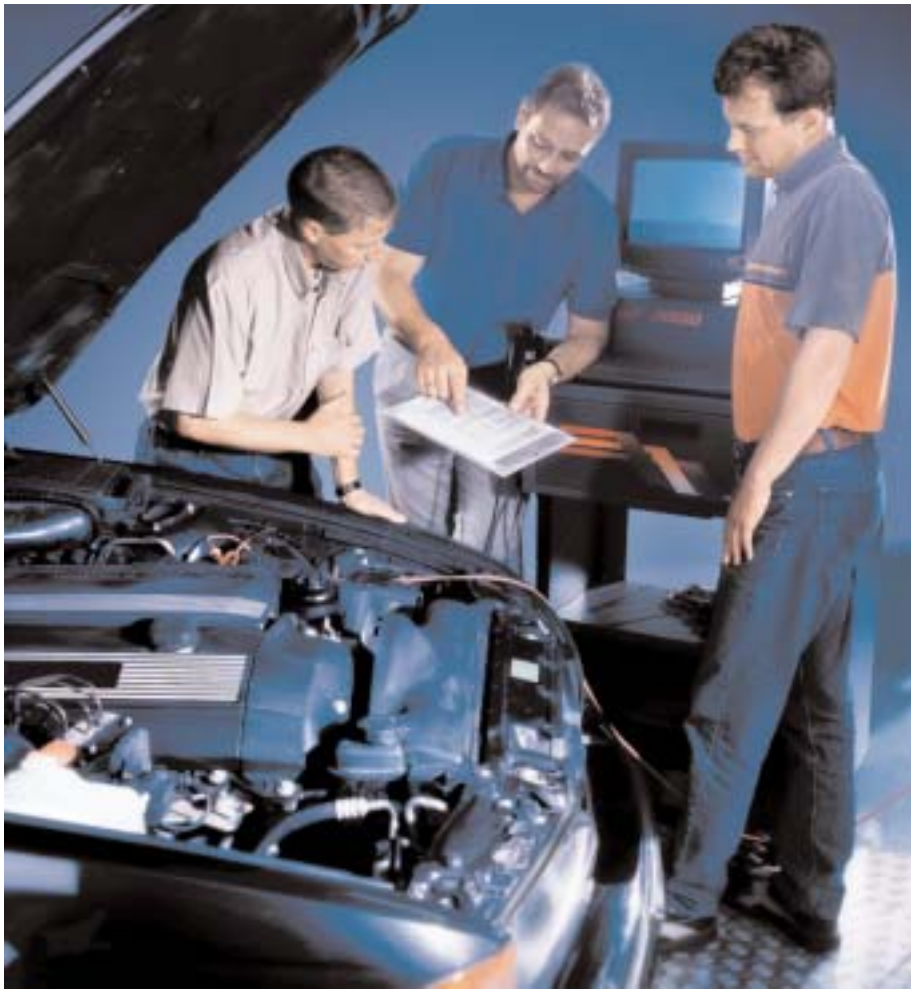
Independent data providers
There is a series of independent data providers who provide a wide range of vehicle-specific data in the form of CDs or books. These collections of data are usually very comprehensive. They range from maintenance information such as filling levels, service intervals and setting values through to circuit diagrams, testing instructions and component arrangements in different systems. These CDs are available in different versions in terms of the data included and the period of validity. The CDs are available for individual systems or as a full version. The period of validity can be unlimited or as a subscription with annual updates.

Data in connection with a diagnosis unit
Various manufacturers of diagnosis units have a wide range of data stored in their units. The technician can access this data during diagnosis or repair. As with the independent data providers, this data covers all the necessary information. The extent of information available varies from one supplier to the next. Some manufacturers prepare more data than others and thus have a better offer.

Data from the Internet

Some vehicle manufacturers offer special websites where all the relevant information is stored. Garages can apply for access clearance for these pages. The individual manufacturers have different ways of invoicing the information downloaded. Usually, costs are related to the amount of information downloaded. Downloaded documents can be filed and used over and over again. Information can be obtained not only on the vehicle manufacturers' websites, however. A lot of information is also offered and exchanged in various forums on part manufacturers' and private websites. A remark on such a page can often prove to be extremely helpful.

All these aspects are important for vehicle diagnosis. But the deciding factor is the person who carries out the diagnosis. The best measuring and diagnosis unit in the world can only help to a limited extent if it is not used correctly. It is important for successful and safe vehicle diagnosis that the user knows how to handle the units and is familiar with the system to be tested. This knowledge can only be gained through respective training sessions. For this reason it is important to react to the rapid technology changes (new systems and ongoing developments) and always be up to the optimum know-how level by encouraging employee development and training measures.



Whether as a hand-held unit or installed firmly in the engine tester – there's no way round oscilloscopes these days for day-to-day garage work. This and the following issues will provide background knowledge of how the equipment works and practical examples of the different testing and diagnosis possibilities.

Multimeter or oscilloscope?



A digital multimeter is sufficient for testing circuits in a static state. The same applies for checks where the measured value changes gradually. An oscilloscope is used when intermittent faults are to be diagnosed or dynamic tests (with the engine running) carried out.

The oscilloscope offers three advantages:

1. Measured values are recorded considerably more quickly than by even the best multimeter.
2. The signal curve can easily be presented without a great amount of specialised knowledge being necessary and interpreted easily (with the aid of comparative oscillograms)
3. It is very easy to connect up, usually two cables are all you need.

The oscilloscope's performance spectrum



The older analogue oscilloscope type was only suitable for testing high-voltage circuits in the ignition system. The modern digital oscilloscope provides additional adjustable low-voltage measuring ranges (e.g. 0-5 V or 0-12 V). It also has adjustable time measurement ranges to facilitate the best possible legibility of the oscillograms.

Hand-held devices which can be used directly on the vehicle, even during a test drive, have proved to be a good investment. These devices are able to store oscillograms and the respective data so that these can be subsequently printed or downloaded onto a PC and considered in detail.

The oscilloscope can represent vibrations, frequencies, pulse widths and amplitudes of the signal received. The working principle is simple: A graph is drawn with the voltage measured on the vertical (y) axis and the measuring time passed on the horizontal (x) axis. The quick response time allows the diagnosis of intermittent faults. In other words, the effects on the component of intervention – such as removing the multiple connector, for example – can be observed.

The oscilloscope can also be used to check the general status of an engine management system. One good example here is the oxygen sensor: The representation of the oxygen sensor can be used to determine every irregularity in the operating performance of the whole system. Correct vibration is a reliable indication that the system is working correctly.

Oscillograms

Every oscillogram contains one or more of the following parameters:

- Voltage (U)
- Signal voltage at a specified time
- Frequency – oscillation per second (Hz)
- Pulse width – scan rate (%)
- Time (t) during which the signal voltage is displayed – as a percentage (%) of the overall time
- Oscillation (change in signal)

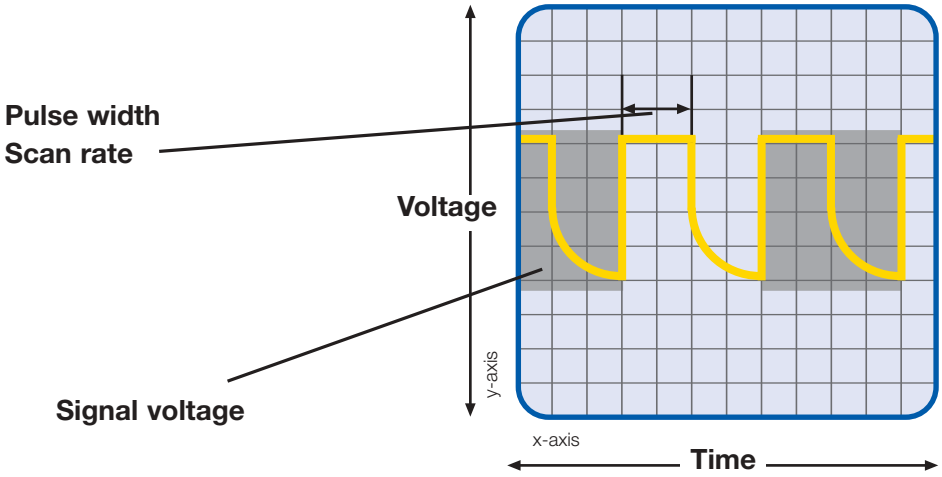


Fig. 1: Parameters

Interpreting oscillograms

Typical oscillograms (Fig. 2 and 3) depend on numerous factors and thus look very different. If an oscillogram deviates from the "typical" appearance, the following points must be heeded before diagnosis and component replacement:

1. Voltage

Typical oscillograms show the approximate position of the graph in relation to the zero axis. This graph (Fig. 2[1]), however, can be within the zero range (Fig. 2[2] and 3[1]) depending on the system to be tested. The voltage or amplitude (Fig. 2[3] and 3[2]) depends on the circuit's operating voltage. In the case of direct voltage circuits it depends on the switched voltage. Thus, for example, voltage is constant in the case of idling speed stabilisers, i.e. it does not change in relation to speed.

In the case of alternating voltage circuits on the other hand, it depends on the speed of the signal generator: The output voltage of an inductive crankshaft sensor increases with speed, for example. If the graph is too high or disappears above the top edge of the screen, the voltage measuring range has to be increased until the required presentation is achieved. If the graph is too small, the voltage measuring range has to be minimized. Some circuits with solenoids, e.g. idling speed stabilisers, produce voltage peaks (Fig. 2[4]) when the circuit is switched off.
This voltage is produced by the respective component and can usually be ignored.

With some circuits whose oscillograms have a rectangular voltage shape, the voltage can gradually drop off at the end of the switching period (Fig. 2[5]) This phenomenon is typical for some systems – it does not need to be taken into consideration either.

2. Frequency

Frequency depends on the circuit's operating speed. In the oscillograms shown, the time measurement range was defined such that the graph can be considered in detail.

In the case of direct voltage circuits the time measurement range to be set depends on the speed at which the circuit is switched (Fig. 2[6]). Thus the frequency of an idling speed stabiliser changes with engine load.

In the case of alternating voltage circuits the time measurement range to be set depends on the speed of the signal generator (Fig. 3[3]). Thus the frequency of an inductive crankshaft sensor increases with speed, for example.

If the oscillogram is compressed too greatly, the time measurement range has to be reduced. In this way, the required display will be achieved. If an oscillogram is greatly extended, the time measurement range has to be increased. If the graph is inverted (Fig. 3[4]) the components in the system to be tested have been connected with opposite polarity to the typical oscillogram illustrated. This is not an indication of a fault and can usually be ignored.

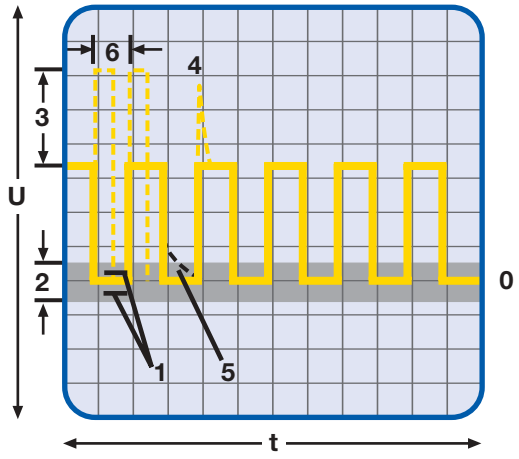


Fig. 2: Digital oscillogram

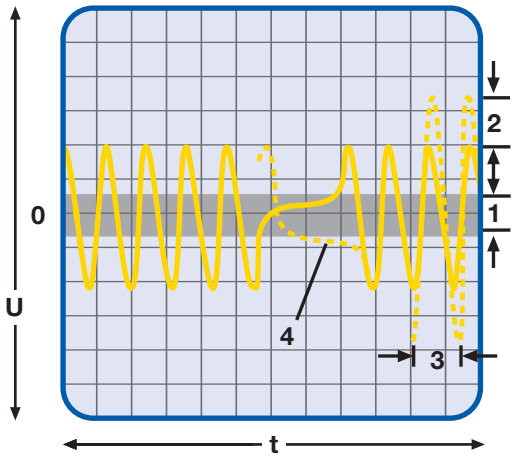


Fig. 3: Analogue oscillogram

Examples of signal shapes

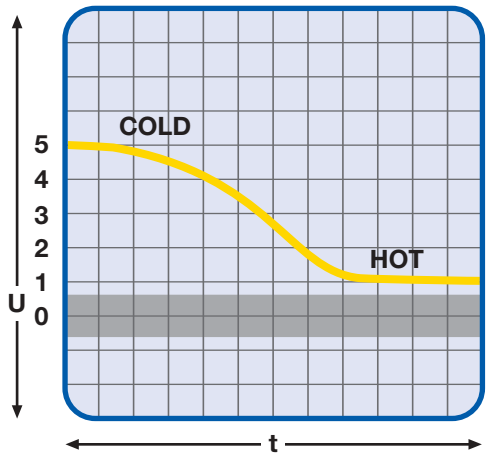


Fig. 4: Coolant temperature sensor

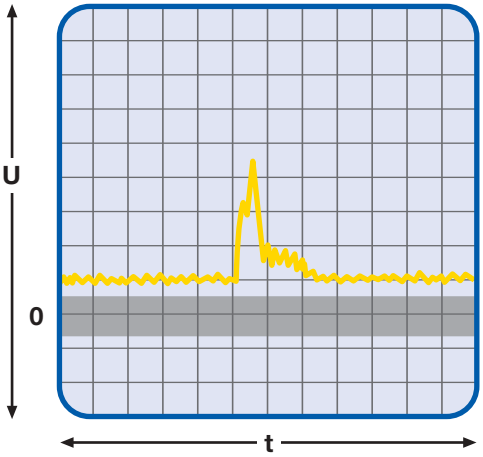


Fig. 6: Air flow sensor

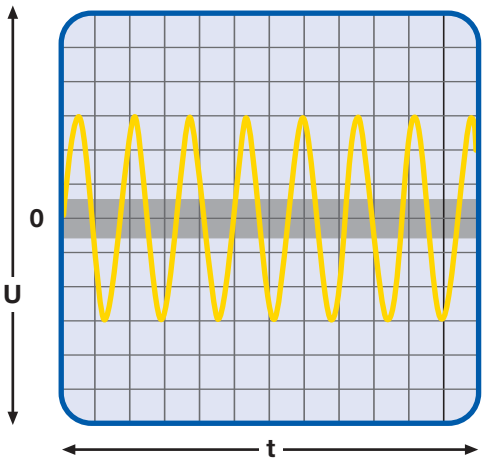


Fig. 8: Speed sensor (inductive)

Direct voltage signals

Examples for components with direct voltage signals:

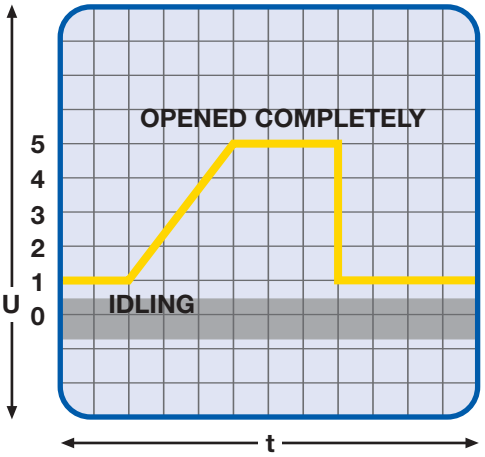


Fig. 5: Throttle potentiometer

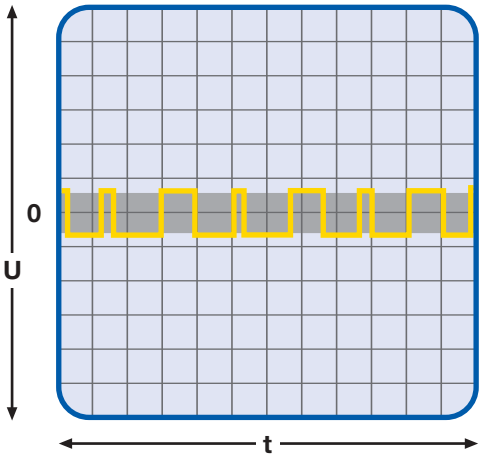


Fig. 7: Mass air flow meter (digital)

Alternating voltage signals

Examples for components with alternating voltage signals:

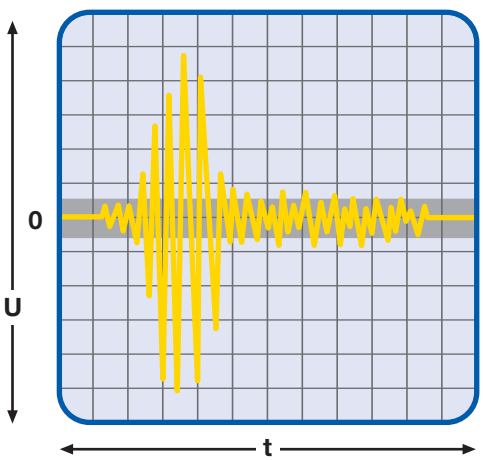


Fig. 9: Knock sensor

Examples of signal shapes

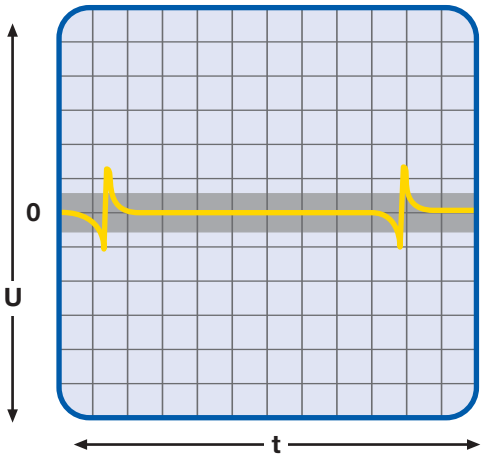


Fig. 10: Camshaft sensor (inductive)

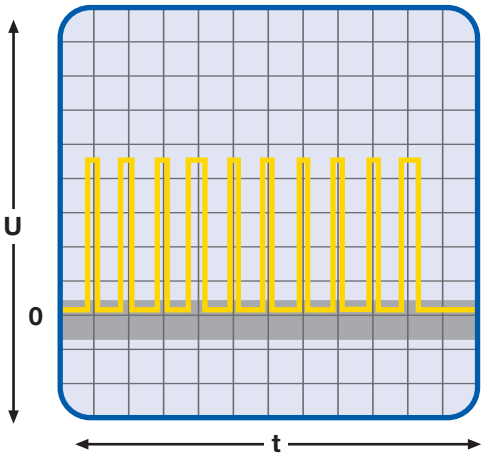


Fig. 12: Optical speed and position sensor

Frequency modulated signals

Examples for components with frequency modulated signals:

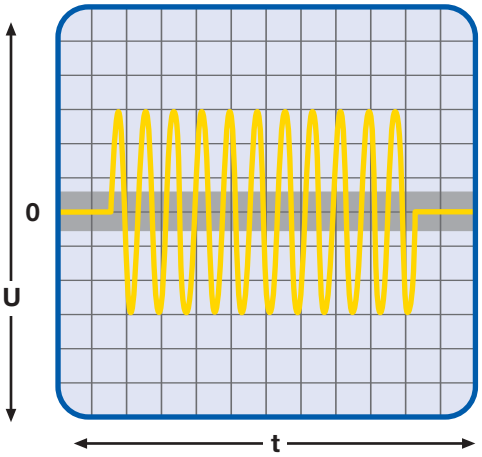


Fig. 11: Speed sensor (inductive)

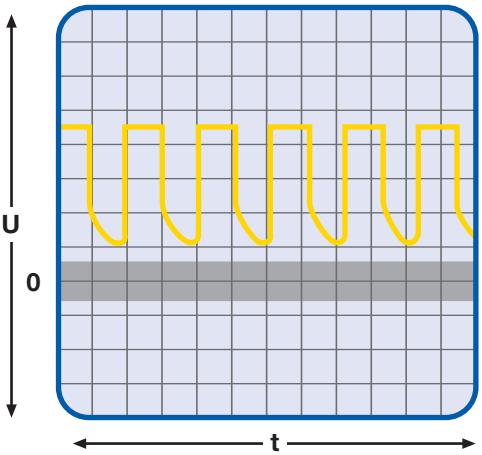


Fig. 13: Digital mass air flow sensor

There are numerous diagnosis units available which can be used to read out the fault code, display the actual value or carry out an actuator test. The most important testing and measuring device for day-to-day garage work is currently the multimeter. Basic requirements for safe fault diagnosis with the multimeter include mastering the various measuring techniques and knowledge of the reference data and circuits of the components and/or systems to be tested, of course. On the following pages we would like to explain some of the basis of electricity and the various measuring techniques in more detail.

Basics of electricity

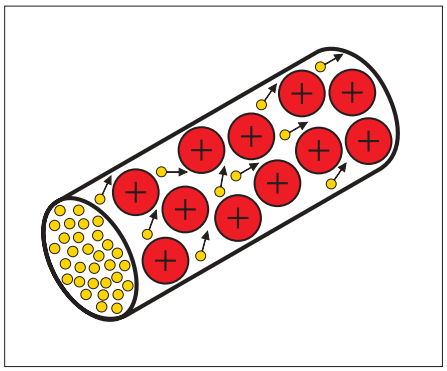


Fig. 1: Excess of electrons and lack of electrons

Voltage: Electrical voltage is produced by electrons trying to compensate the difference in potential between an electrical charge with excess of electrons (minus potential) and with a lack of electrons (plus potential) (Fig. 1). Electrical voltage has the symbol U and the measurement unit volt (V).

Current: Electrical current flows when the negative pole is connected to the positive pole via a conductor. In this case the current flow would only be of extremely short duration, however, since the potential difference would quickly be compensated. To guarantee permanent current flow a force is necessary to drive the current continually through the circuit. This force can be a battery or generator. Electrical current has the symbol I and the measurement unit ampere (A).

Resistance: Resistance results from the inhibition opposing free current flow. The size of the inhibition is determined by the kind of electrical conductor used and the consumers connected to the circuit. Resistance has the symbol R and the measurement unit ohm (Ω).

There are natural relationships between the three parameters current intensity, voltage and resistance:

Current intensity increases the greater the voltage and the smaller the resistance are.

An equation is used to calculate the individual parameters, named after the physicist Georg Simon Ohm.
Ohm's Law states:

Current intensity = $\frac{\text{Voltage}}{\text{Resistance}}$ As an equation $I = \frac{U}{R}$

Voltage = Resistance times current intensity As an equation: U = RxI

Resistance = $\frac{\text{Voltage}}{\text{Current intensity}}$ As an equation: $R = \frac{U}{I}$

Resistor circuitry

The two most simple electrical circuits for resistors (consumers) are series circuit and parallel circuit.

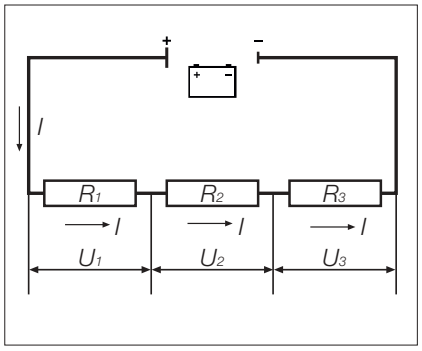


Fig. 2: Resistors in series circuit

With the **series circuit** two or more resistors (consumers) are wired in such a way that the same current flows through both (Fig. 2). When the series circuit illustrated is measured, the following results are obtained: Current intensity I is identical in all resistors. The sum of the drops in voltage on the resistors (U1…U3) is equal to the voltage applied U.

This results in the following equations:
U=U1+U2+U3+... R=Total or equivalent resistance
R=R1+R2+R3+... R1, R2…=Individual resistance

In a series circuit the total of individual resistors is equal to the total or equivalent resistance.

A series circuit is used, for example, to reduce the operating voltage at a consumer by means of a dropping resistor or to adapt the consumer to a higher mains voltage.

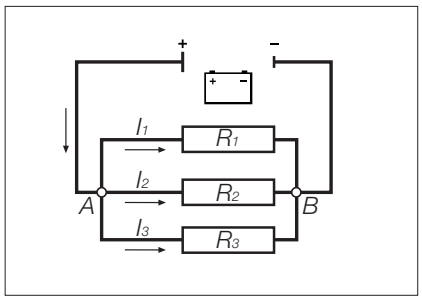


Fig. 3: Resistors in parallel circuit

With the **parallel circuit** two or more resistors (consumers) are connected parallel to one another to the same voltage source (Fig. 3). The advantage of the parallel circuit is that consumers can be switched on and off independently from one another.

In the case of parallel circuits, the sum of inflowing currents at the nodes (current junctions) equals the sum of the currents flowing out of the node (Fig. 3).
I=I1+I2+I3+...

With a parallel circuit the same voltage is applied to all the resistors (consumers).
U=U1=U2=U3=...

With a parallel circuit the reciprocal value of the overall resistance is equal to the sum of the reciprocal values of the individual resistors.

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots.$$

In a parallel circuit the total resistance is always smaller than the smallest partial resistance. This means: If a very large resistor is wired up parallel to a very small resistor, current will increase slightly at constant voltage, since the overall resistance has become slightly smaller.

The multimeter

A standard multimeter has various measuring possibilities available:

- Direct current (DCA)
- Alternating current (ACA)
- Direct voltage (DCV)
- Alternative voltage (ACV)
- Resistance (Ohm)

Optionally:
- Diode test
- Transistor test (hfe)
- Temperature
- Transmission test (buzzer, beeper)

The adjustment of the individual measuring ranges differs depending on the manufacturer of the multimeter. Adjustment is usually by means of a rotary switch. Before measurement begins, several basic points should be considered:

- The measuring leads and probes must be clean and undamaged.
- Care must be taken that the measuring leads are inserted into the correct connection jacks for the measuring range.
- If there is no measuring data available, always begin with the greatest possible setting for the respective measuring range. If nothing is displayed, select the next smaller range.

Special care must be taken when measuring current.
Some multimeters have two, others only one connection jack for current measurement. On the devices with two jacks, one is used for measuring currents up to approx. 2 ampere. This is safeguarded by a fuse in the device. The second jack up to 10 or 20 ampere is not usually fuse-protected. Care must be taken that only fuse-protected circuits up to 10 or 20 ampere are measured – otherwise the device will be destroyed. The same applies for devices with only one jack. This connection jack is not usually fuse-protected and the given maximum value must not be exceeded.

Measuring voltages

For voltage measurement the multimeter is connected parallel to the component to be measured. The test prod of the black measuring device cable should be connected with a ground point in the vehicle as far as possible. The test prod of the red cable is connected to the voltage supply cable of the component. Proceed as described above to set the measuring range. Voltage measurement should be carried out once without a load on the circuit and once under load (with consumer switched on). This shows very quickly whether the voltage collapses under load. This is then an indication of a "cold joint" or cable breakage. An example: The interior fan is not working. Voltage measurement at the respective fuse without load reveals a voltage of 12 volt. When the fan is switched on, the voltage collapses. Cause: A cold joint in the fuse box which was recognised by visual inspection after the fuse box was opened.



Measurement with an adapter cable



Measurement without adapter cable

Measuring resistance

If component resistance is to be measured, the component has to be separated from the voltage source first. The two testing cables are inserted into the respective jacks on the measuring device, the test prods connected to the component. If the approximate resistance is not known, proceed as described for voltage measurement to adjust the measuring range. The highest measuring range is set and reduced step by step until an exact display is the result.



Measurement without adapter cable

Resistance measurement can also be used to establish a short-circuit to ground and test cable transmission. This applies to both components and cables. To measure cable transmission, it must be separated from the component and at the next possible plug-type connection. The connection cables of the multimeter are connected to the ends of the cables and the measuring range "acoustic test" or "smallest resistor range" set.



Measurement with an adapter cable

If the cable is OK there will be a beeping sound or the display will show 0 Ohm. If the cable is interrupted, infinite resistance will be displayed. To establish a short-circuit to ground, measurements are made from each end of the cable to vehicle ground. If a beeping sound is heard or a resistance of 0 ohm is indicated, a short-circuit must be assumed. Tests on components, e.g. a temperature sensor, take place in the same way. The multimeter is connected to the ground pin of the component and to vehicle ground or the component housing. The measuring range is adjusted as described above. The value displayed must be infinity. If a beeping sound is heard or 0 ohm is indicated, an internal short-circuit in the component must be assumed.

Current measurement

The multimeter is wired up in series to measure the current consumption of a component. First of all, the voltage supply cable is disconnected from the component. Then the testing cables of the multimeter are connected to the ground and current jacks on the device, the test prods to the voltage supply cable and the voltage supply pin on the component. It is important that the precautionary measures described above are taken when the current is measured.

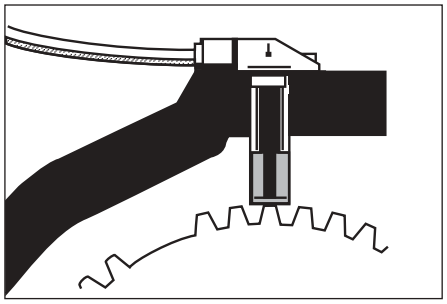


This is a small selection of the possibilities offered by the multimeter. There is no room here to describe the numerous other possibilities that are not required in day-to-day garage work. We recommend you visit a training session with a heavy practical bias, at Hella for example, to learn how to use the multimeter confidently and evaluate the measuring results correctly.

General points

The task of crankshaft sensors is to determine the speed and position of the crankshaft. They are usually installed on a gear rim near the flywheel. There are two types available: inductive sensors and Hall-type sensors. Before carrying out crankshaft sensor tests it is vital to determine what type of sensor is involved.

How it works



The rotary movement of the gear rim affects changes in the magnetic field. The different voltage signals produced by the magnetic fields are sent to the control unit. The control unit uses the signals to calculate the speed and position of the crankshaft in order to receive important basic data for fuel injection and ignition timing.

Effects of failure

The following fault symptoms could be indications of crankshaft sensor failure:

- Engine misses
- Engine comes to a standstill
- A fault code is stored

Causes of failure can be:

- Internal short-circuits
- Interrupted cables
- Cable short-circuit
- Mechanical damage to the sensor wheel
- Soiling through metal abrasion

Troubleshooting

- Read out the fault code
- Check electrical connections of the sensor cables, the connector and the sensor for correct connection, breaks and corrosion
- Watch for soiling and damage



Direct testing of the crankshaft sensor can be difficult if it is not known exactly what type of sensor is involved. Before the test it must be established whether it is an inductive or Hall-type sensor. The two types cannot be distinguished from one another on the basis of appearance. Three connector pins do not allow exact assumptions about the respective type involved. The specific manufacturer specifications and the details in the spare parts catalogue will help here. As long as it is not perfectly clear what type of sensor is involved, an ohmmeter must not be used for testing. It could destroy a Hall-type sensor!



If the sensor has a 2-pole connector, it is likely to be an inductive sensor. In this case, intrinsic resistance, a ground connection and the signal can be determined. To do this, remove the pin connection and test the internal resistance of the sensor. If the internal resistance value is between 200 and 1,000 ohm (depending on the reference value) the sensor is OK. If the reading is 0 ohm there is a short-circuit and MOhm indicates a cable interruption. The ground connection test is carried out using the ohmmeter from one connection pin to vehicle ground. The resistance value has to tend towards infinity. The test with an oscilloscope must result in a sinus signal of sufficient amplitude. In the case of a Hall-type sensor only the signal voltage in the form of a rectangular signal and the supply voltage must be checked. The result must be a rectangular signal depending on the engine speed. Once again, please remember: The use of an ohmmeter can destroy a Hall-type sensor.

Installation note
Make sure of the correct distance to the sensor wheel and sensor seat.

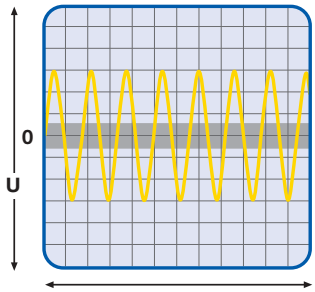


Fig. 18:
Inductive sensor
Optimum image

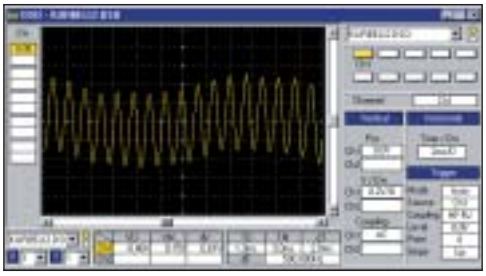


Fig. 19:
Live image OK

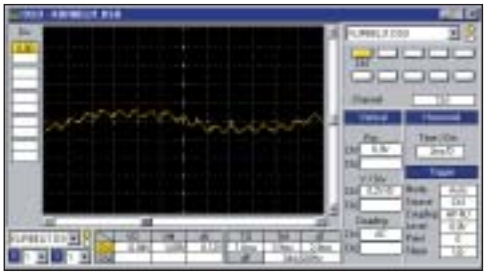


Fig. 20:
Live image with fault:
Sensor distance too great

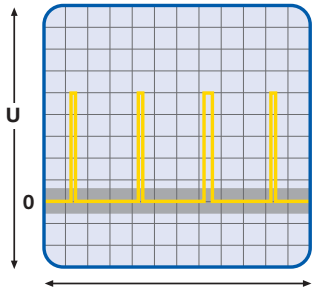


Fig. 21:
Hall-type sensor
Optimum image

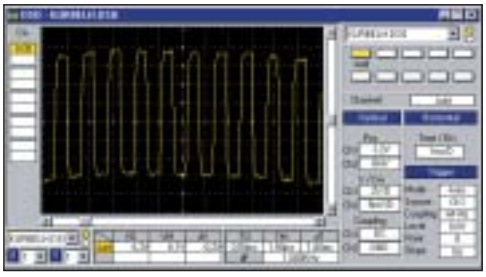


Fig. 22:
Live image OK

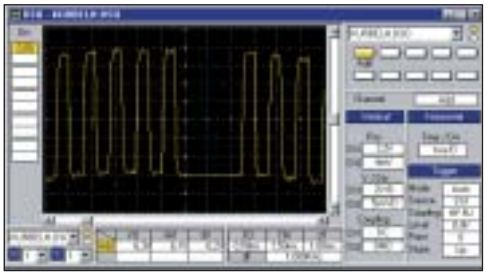


Fig. 23:
Live image with fault:
missing/damaged teeth
on the sensor wheel

To make the subject of oxygen sensors more easily understood and simplify testing in day-to-day garage work, we would like to present the function and the different testing possibilities with the oxygen sensor in this issue.
Usually, the function of the oxygen sensor is tested during the routine exhaust emissions test. Since it is subject to a certain amount of wear, however, it should be checked for perfect function regularly (approx. every 18.750 miles) – within the context of a regular service, for example.

What is the oxygen sensor for?
As a result of more stringent laws governing the reduction of exhaust emissions from motor vehicles, exhaust gas treatment techniques have also been improved. Optimum combustion is necessary to guarantee an optimum conversion rate of the catalytic converter. This is achieved when the air/fuel mixture is composed of 14.7 kg of air to 1 kg of fuel (stoichiometric mixture). This optimum mixture is described by the Greek letter λ (lambda). Lambda expresses the air ratio between the theoretical air requirement and the actual amount of air fed:

$$\lambda = \frac{\text{amount of air fed}}{\text{theoretical air amount}} = \frac{14{,}8\ \text{kg}}{14{,}8\ \text{kg}} = 1$$

Structure and function of the oxygen sensor

The principle of the oxygen sensor is based on a comparative measurement of oxygen content. This means that the residual oxygen content of the exhaust gas (approx. 0.3–3 %) is compared with the oxygen content of ambient air (approx. 20.8 %). If the residual oxygen content of the exhaust gas is 3 % (lean mixture), a voltage of 0.1 V is produced as a result of the difference to the oxygen content of the ambient air. If the residual oxygen content is less than 3 % (rich mixture) the probe voltage increases in relation to the increased difference to 0.9 V. The residual oxygen content is measured with different oxygen sensors.

Measurement using the probe voltage output (voltage leap probe)

This probe comprises a finger-shaped, hollow zirconium dioxide ceramic. The special feature of this solid electrolyte is that it is permeable for oxygen ions from a temperature of around 300 °C. Both sides of this ceramic are covered with a thin porous platinum layer which serves as an electrode. The exhaust gas flows along the outside of the ceramic, the interior is filled with reference air. Thanks to the characteristic of the ceramic, the difference in oxygen concentration on the two sides leads to oxygen ion migration which in turn generates a voltage. This voltage is used as a signal for the control unit which alters the composition of the air/fuel mixture depending on the residual oxygen content. This process – measuring the residual oxygen content and making the mixture richer or leaner – is repeated several times a second so that a suitable stoichiometric mixture (λ = 1) is produced.



Measurement using probe resistance (resistance leap probe)

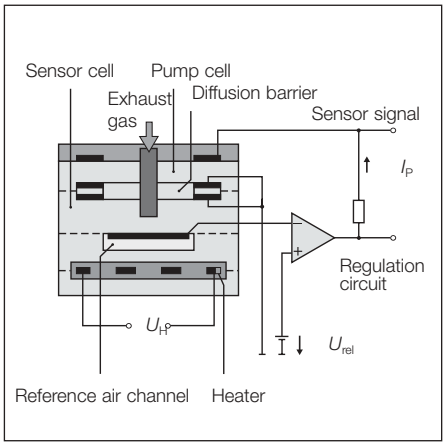


With this kind of probe, the ceramic element is made of titanium dioxide – using multi-layer thick-film technology. Titanium dioxide has the property of changing its resistance proportional to the concentration of oxygen in the exhaust gas. If the oxygen share is high (lean mixture $\lambda > 1$) it is less conductive, if the oxygen content is low (rich mixture $\lambda < 1$) it becomes more conductive. This probe doesn't need reference air, but it has to be supplied with a voltage of 5 V via a combination of resistors. The signal required for the control unit is produced through the drop in voltage at the resistors.

Both measuring cells are mounted in a similar housing. A protective pipe prevents damage to the measuring cells which project into the exhaust gas flow.

Oxygen sensor heating: The first oxygen sensors were not heated and thus had to be installed near the engine to enable them to reach their working temperature as quickly as possible. These days, oxygen sensors are fitted with probe heating, which allows the probes to be installed away from the engine. Advantage: they are no longer exposed to a high thermal load. Thanks to the probe heating they reach operating temperature within a very short time, which keeps the period where the oxygen sensor control is not active down to a minimum. Excessive cooling during idling, when the exhaust gas temperature is not very high, is prevented. Heated oxygen sensors have a shorter response time which has a positive effect on the regulating speed.

Broadband oxygen sensors



The oxygen sensor indicates a rich or lean mixture in the range $\lambda = 1$. The broadband oxygen probe provides the possibility of measuring an exact air ratio in the lean ($\lambda > 1$) and in the rich ($\lambda < 1$) ranges. It provides an exact electrical signal and can thus regulate any reference values – e.g. in diesel engines, petrol engines with lean concepts, gas engines and gas-heated boilers. Like a conventional probe, the broadband oxygen sensor is based on reference air. In addition, it has a second electrochemical cell: the pump cell. Exhaust gas passes through a small hole in the pump cell into the measuring space, the diffusion gap. In order to set the air ratio, the oxygen concentration here is compared with the oxygen concentration of the reference air. A voltage is applied to the pump cell in order to obtain a measurable signal for the control unit. Through this voltage, the oxygen can be pumped out of the exhaust gas into or out of the diffusion gap. The control unit regulates the pump voltage in such a way that the composition of the exhaust gas in the diffusion gap is constant at $\lambda = 1$. If the mixture is too lean oxygen is pumped out through the pump cell. This results in a positive pump current. If the mixture is rich, oxygen is pumped in from the reference air. This results in a negative pump current. If $\lambda = 1$ in the diffusion gap no oxygen is transported at all, the pumping current is zero. This pumping current is evaluated by the control unit, provides it with the air ratio and thus information about the air/fuel mixture.

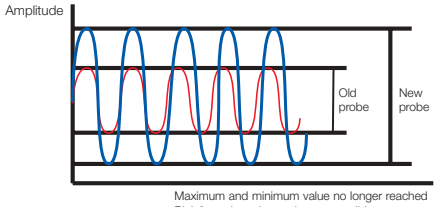
Using several oxygen sensors

In the case of V and boxer engines with double-flow exhaust systems two oxygen sensors are usually used. This means each cylinder bank has its own control cycle that can be used to regulate the air/fuel mixture. In the meantime, however, one oxygen sensor is being installed for individual cylinder groups in in-line engines, too (e.g. for cylinders 1-3 and 4-6). Up to eight oxygen sensors are used for large twelve-cylinder engines using the latest technology.

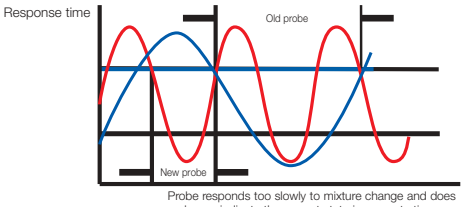
Since the introduction of EOBD the function of the catalytic converter has also had to be monitored. An additional oxygen sensor is installed behind the catalytic converter for this purpose. This is used to determine the oxygen storage capacity of the catalytic converter. The function of the post-cat probe is the same as that of the pre-cat probe. The amplitudes of the oxygen sensors are compared in the control unit. The voltage amplitudes of the post-catalytic probe are very small on account of the oxygen storage ability of the catalytic converter. If the storage capacity of the catalytic converter falls, the voltage amplitudes of the post-cat probe increase due to the increased oxygen content. The height of the amplitudes produced at the post-cat probe depend on the momentary storage capacity of the catalytic converter which vary with load and speed. For this reason the load state and speed are taken into account when the amplitudes are compared. If the voltage amplitudes of both probes are still approximately the same, the storage capacity of the catalytic converter has been reached, e.g. due to ageing.

Diagnosis and testing oxygen sensors

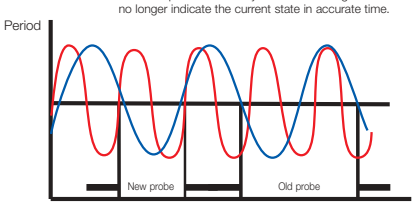
Vehicles which have a self-diagnosis system can recognise faults in the control cycle and store them in the fault store. This is usually indicated by the engine warning light coming on. The fault code can be read out using a diagnosis unit in order to diagnose the fault. However, older systems are not in a position to establish whether this fault is due to a faulty component or a faulty cable, for example. In this case further tests have to be carried out by the mechanic.



Maximum and minimum value no longer reached
Rich/lean detection no longer possible



Probe responds too slowly to mixture change and does no longer indicate the current state in accurate time.



The frequency of the probe is too slow, optimal regulation no longer possible

Within the course of EOBD, monitoring of oxygen sensors was extended to the following points: closed wire, stand-by operation, short-circuit to control unit ground, short-circuit to plus, cable breakage and ageing of oxygen sensor. The control unit uses the form of signal frequency to diagnose the oxygen sensor signals. For this, the control unit calculates the following data: The maximum and minimum sensor voltage values recognised, the time between positive and negative flank, oxygen sensor control setting parameters for rich and lean, regulation threshold for lambda regulation, probe voltage and period duration.

How are maximum and minimum probe voltage determined?
When the engine is started up, all old max./min. values in the control unit are deleted. During driving, minimum and maximum values are formed within a given load/speed range predefined for diagnosis.

Calculation of the time between positive and negative flank.
If the regulation threshold is exceeded by the probe voltage, time measurement between the positive and negative flanks begins. If the regulation threshold is short of the probe voltage, time measurement stops. The time between the beginning and end of time measurement is measured by a counter.

Recognising an aged or poisoned oxygen sensor.
If the probe is very old or has been poisoned by fuel additives, for example, this has an effect on the probe signal. The probe signal is compared with a stored signal image. A slow probe is recognised as a fault through the signal duration period, for example.

Testing the oxygen sensor using an oscilloscope, multimeter, oxygen sensor tester, exhaust emissions measuring device

A visual inspection should always be carried out before every test to make sure the cable and connector are not damaged. The exhaust gas system must be leak-proof. We recommend the use of an adapter cable for connecting the measuring devices. It must also be noted that the oxygen sensor control is not active during some operating modes, e.g. during a cold start until the operating temperature has been reached as well as at full load.

Testing with the exhaust emissions tester



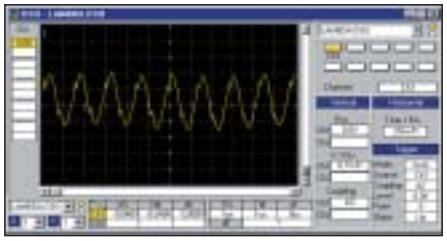
One of the quickest and easiest tests is measurement using a four-gas exhaust emissions measuring device. The test is carried out in the same way as the prescribed exhaust emissions test (AU). With the engine at operating temperature secondary air is added as a disturbance variable by removing a hose. The change in composition of the exhaust gas causes a change in the lambda value calculated and displayed by the exhaust emissions tester. From a certain value onwards the fuel induction system has to recognise this and settle this within a given time (60 seconds as with the AU). When the disturbance variable is removed, the lambda value has to be settled back to the original value. The disturbance variable specifications and lambda values of the manufacturer should always be taken into account. This test can only be used to establish whether or not the oxygen sensor control is working. An electrical test is not possible. With this method there is the danger that modern engine management systems control the air/fuel mixture through exact load recording in such a way that $\lambda = 1$ even if the oxygen sensor control is not working.

Testing with the multimeter



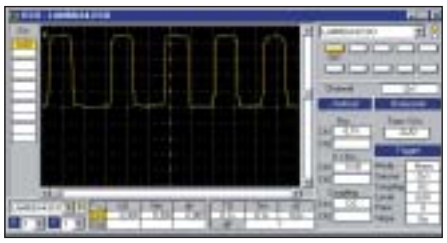
Only high-impedance multimeters with digital or analogue display should be used for the test. Multimeters with a small internal resistance (usually with analogue devices) place too great a load on the oxygen sensor signal and can cause this to collapse. On account of the quickly changing voltage the signal can be best represented using an analogue device. The multimeter is connected in parallel to the signal cable (black cable, refer to circuit diagram) of the oxygen sensor. The measuring range of the multimeter is set to 1 or 2 volt. After the engine has been started a value between 0.4-0.6 volt (reference voltage) appears on the display. When the operating temperature of the engine or the oxygen sensor has been reached, the steady voltage begins to alternate between 0.1 and 0.9 volt. To achieve a perfect measuring result the engine should be kept at a speed of approx. 2,500 rpm. This guarantees that the operating temperature of the probe is reached even when systems with non-heated oxygen sensors are being tested. If the temperature of the exhaust gas is too low during idling, the non-heated probe could cool down and not produce any signal at all.

Testing with the oscilloscope



Oscilloscope image voltage leap probe

The oxygen sensor signal is best represented using the oscilloscope. As with the multimeter, the basic requirement when using the oscilloscope is that the engine or oxygen sensor are at operating temperature. The oscilloscope is connected to the signal cable. The measuring range to be set depends on the oscilloscope used. If the device has automatic signal detection this should be used. Set a voltage range of 1-5 volt and a time of 1-2 seconds using manual adjustment.



Oscilloscope image resistance leap probe

Engine speed should again be approx. 2,500 rpm. The AC voltage appears as a sinus wave on the display. The following parameters can be evaluated using this signal: The amplitude height (maximum and minimum voltage 0.1-0.9 volt), response time and period (frequency approx. 0.5-4 Hz, in other words fi to 4 times per second).

Testing with the oxygen sensor tester



Various manufacturers offer special oxygen sensor testers for testing purposes. With this device the function of the oxygen sensor is displayed by LEDs. As with the multimeter and oscilloscope, connection is to the probe signal cable. As soon as the probe has reached operating temperature and starts to work, the LEDs light up alternately – depending on the air/fuel mixture and voltage curve (0.1–0.9 volt) of the probe. All the details given here for measuring device settings for voltage measurement refer to zirconium dioxide probes (voltage leap probes). In the case of titanium dioxide probes the voltage measuring range to be set changes to 0-10 volt, the measured voltages change between 0.1--5 volt. Manufacturer's information must always be taken into account. Alongside the electronic test the state of the protective pipe over the probe element can provide clues about the functional ability:



The protective pipe is full of soot: Engine is running with air/fuel mixture too rich. The probe should be replaced and the reason for the rich mixture eliminated to prevent the new probe becoming full of soot.



Shiny deposits on the protective pipe: Leaded fuel is being used. The lead destroys the probe element. The probe has to be replaced and the catalytic converter checked. Use lead-free fuel instead of leaded fuel.



Bright (white or grey) deposits on the protective pipe: The engine is burning oil, additional additives in the fuel. The probe has to be replaced and the cause for the oil burning be eliminated.



Unprofessional installation: Unprofessional installation can damage the oxygen sensor to such an extent that perfect functioning is no longer guaranteed. The prescribed special tool must be used for installation and care must be taken that the correct torque is used.

Testing the oxygen sensor heating

The internal resistance and voltage supply of the heating element can be tested. To do this, separate the oxygen sensor connector. Use the ohm-meter to measure the resistance on the two heating element cables at the oxygen sensor. This should be between 2 and 14 Ohm. Use the voltmeter to measure the voltage supply on the vehicle side. A voltage of > 10.5 volt (on-board voltage) has to be present.

Various connection possibilities and cable colours

Non-heated probes

No. of cables	Cable colour	Connection
1	Black	Signal (ground via housing)
2	Black	Signal Ground

Heated probes

No. of cables	Cable colour	Connection
3	Black 2 x white	Signal (ground via housing) Heating element
4	Black 2 x white Grey	Signal Heating element Ground

Titanium dioxide probes

No. of cables	Cable colour	Connection
4	Red White Black Yellow	Heating element (+) Heating element (-) Signal (-) Signal (+)
4	Grey White Black Yellow	Heating element (+) Heating element (-) Signal (-) Signal (+)

(Manufacturer-specific instructions must be taken into consideration.)

There are a number of typical oxygen sensor faults that occur very frequently. The following list shows diagnosed faults and their causes:

Diagnosed fault	Cause
Protective pipe or probe body blocked by oil residue.	Non-burnt oil has got into the exhaust gas system, e.g. due to faulty piston rings or valve shaft seals
Secondary air intake, lack of reference air	Probe installed incorrectly, reference air opening blocked
Damage due to overheating	Temperatures above 950 °C due to false ignition point or valve play
Poor connection at the plug-type connectors	Oxidation
Interrupted cable connections	Poorly laid cables, rub marks, rodent bites
Lack of ground connection	Oxidation, corrosion on the exhaust system
Mechanical damage	Torque too high
Chemical ageing	Very frequent short-distance trips
Lead deposits	Use of leaded fuel

If an oxygen sensor is replaced, the following points must be observed when installing the new probe:

- Only use the prescribed tool for dismantling and installation.
- Check the thread in the exhaust system for damage.
- Only use the grease provided or special oxygen sensor grease.
- Avoid allowing the probe measuring element to come into contact with water, oil, grease, cleaning and rust-treatment agents.
- Note the torque of 40-52 Nm for M18x1.5 threads.
- When laying the connection cable make sure this does not come into contact with hot or movable objects and is not laid over sharp edges.
- Lay the connection cable of the new oxygen sensor according to the pattern of the originally installed probe as far as possible.
- Make sure the connection cable has enough play to stop it tearing off during vibration and movement in the exhaust system.
- Instruct your customers not to use any metal-based additives or leaded fuel.
- Never use an oxygen sensor that has been dropped on the floor or damaged in any way.

General points

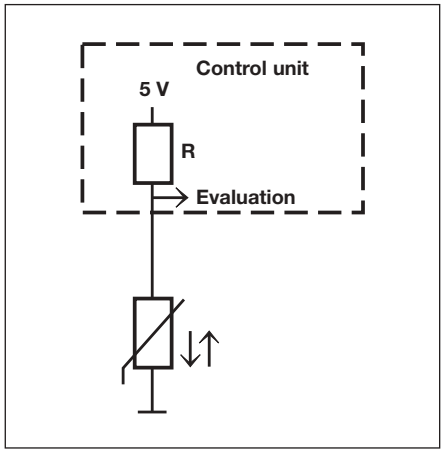
The intake air temperature sensor determines the temperature in the intake pipe and sends the voltage signals produced by the effect of temperature to the control unit. This evaluates the signals and influences the fuel induction and the ignition angle.

Function



The resistance of the temperature sensor changes depending on the intake air temperature. As the temperature increases the resistance decreases – and with it the voltage at the sensor. The control unit evaluates these voltage values, since they are in direct relation to the intake air temperature (low temperatures result in high voltage values at the sensor and high temperatures in low voltage values).

Effects of failure



A faulty intake air temperature sensor can become noticeable in different ways through the fault recognition of the control unit and the resulting limp-home running strategy.

Frequent fault symptoms are:
- Storing of a fault code and possible lighting up of the engine warning light
- Start-up problems
- Reduced engine performance
- Increased fuel consumption

There can be a number of reasons for sensor failure:
- Internal short-circuits
- Interrupted cables
- Cable short-circuit
- Mechanical damage
- Soiled sensor tip

Troubleshooting

- Read out the fault code
- Check electrical connections of the sensor cables, the connector and the sensor for correct connection, breaks and corrosion

Testing takes place using the multimeter.







1st test step
The internal resistance of the sensor is determined. The resistance depends on temperature: when the engine is cold, resistance is high and when the engine is warm, resistance is low.

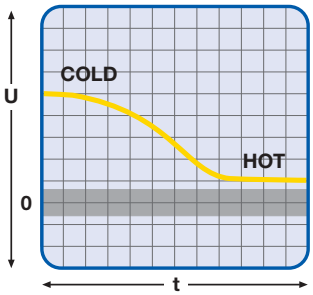
Depending on the manufacturer:
25 °C 2,0 – 5,0 KOhm
80 °C 300 – 700 Ohm
Note special reference value specifications.

2nd test step
Check the wiring to the control unit by checking every single wire to the control unit connector for transmission and connection to ground.

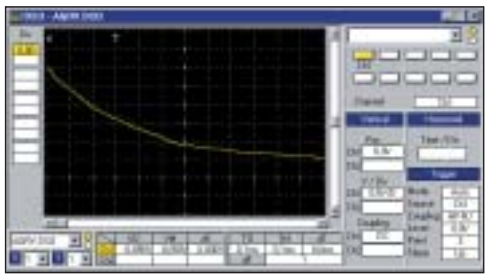
1. Connect the ohmmeter between the temperature sensor connector and the removed control unit connector. Ref. value: approx. 0 ohm (circuit diagram necessary for pin allocation on the control unit).
2. Use the ohmmeter to test the respective pin at the sensor connector and removed control unit connector to ground. Ref. value: >30 MOhm.

3rd test step
Use the voltmeter to test the supply voltage at the removed sensor connector. This takes place with the control unit inserted and the ignition switched on. Ref. value: approx. 5 V.

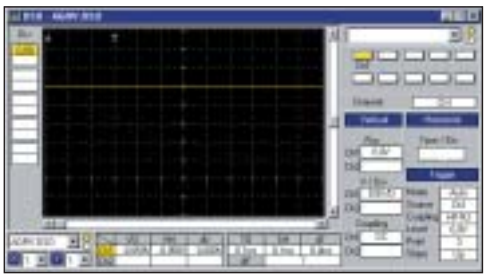
If the voltage value is not reached, the supply voltage of the control unit including ground supply must be checked against the circuit diagram. If this is OK, a faulty control unit must be considered.



Temperature sensor
Optimum image



Live image temperature sensor OK



Live image temperature sensor with fault: voltage remains constant despite change in temperature

General points

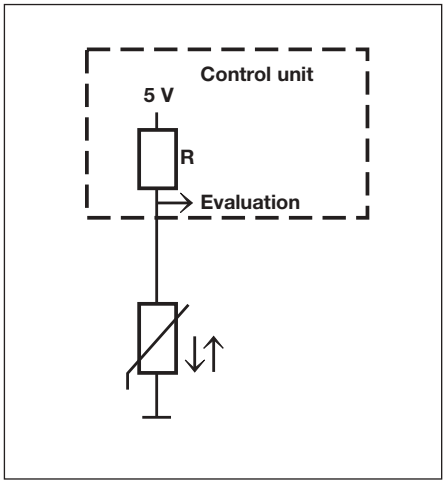
The coolant temperature sensor is used by the fuel induction system to record the engine operating temperature. The control unit adapts the injection time and the ignition angle to the operating conditions depending on the sensor information. The sensor is a temperature sensor with negative temperature coefficient: As temperature increases, internal resistance decreases.

Function



The resistance of the temperature sensor changes depending on the coolant temperature. As the temperature increases the resistance decreases and with it the voltage at the sensor. The control unit evaluates these voltage values, since they are in direct relation to the coolant temperature (low temperatures result in high voltage values at the sensor and high temperatures in low voltage values).

Effects of failure



A faulty coolant temperature sensor can become noticeable in different ways through the fault recognition of the control unit and the resulting emergency running strategy.

Frequent fault symptoms are:

- Increased idling speed
- Increased fuel consumption
- Poor start-up behaviour

In addition there could be problems with the vehicle emission test cycle due to increased CO values or the lambda regulation missing.

The following faults can be stored in the control unit:

- Ground connection in the wiring or short-circuit in the sensor
- Plug connection or interrupted cables
- Implausible signal changes (signal leap)
- Engine does not achieve the minimum coolant temperature

This last fault code can also occur with a faulty coolant thermostat.

Troubleshooting

- Read out the fault code
- Check electrical connections of the sensor cables, the connector and the sensor for correct connection, breaks and corrosion.

Testing takes place using the multimeter.



1st test step
The internal resistance of the sensor is determined. The resistance depends on temperature: when the engine is cold, resistance is high and when the engine is warm, resistance is low.

Depending on the manufacturer:
25 °C 2.0 – 6 KOhm
80 °C ca. 300 Ohm
Note special reference value specifications.



2nd test step
Check the wiring to the control unit by checking every single wire to the control unit connector for transmission and connection to ground.

1. Connect the ohmmeter between the temperature sensor connector and the removed control unit connector. Ref. value: approx. 0 ohm (circuit diagram necessary for pin allocation on the control unit).
2. Use the ohmmeter to test the respective pin at the sensor connector and removed control unit connector to ground. Ref. value: >30 MOhm.



3rd test step
Use the voltmeter to test the supply voltage at the removed sensor connector. This takes place with the control unit inserted and the ignition switched on. Reference value approx. 5 V.

If the voltage value is not reached, the supply voltage of the control unit including ground supply must be checked against the circuit diagram.

General points

Transmission sensors record the gear speed. This is required by the control unit to regulate the transmission pressure during gear shifting and to decide when to switch to which gear.

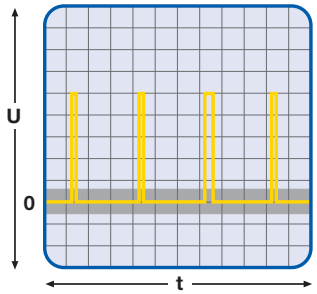
Function



There are two types of transmission sensor designs:
Hall-type sensors and inductive sensors.
The rotary movement of the gear rim affects a change in the magnetic field which changes the voltage. The transmission sensor sends these voltage signals to the control unit.

Effects of failure





Optimum image, hall-type sensor

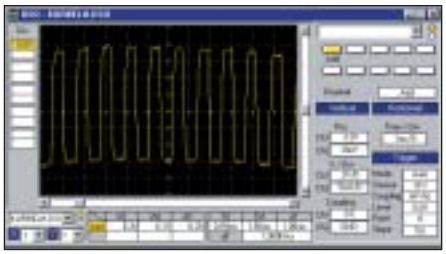
A faulty transmission sensor can become noticeable as follows:

- Failure of the transmission control, control unit switches to limp-home programme
- Engine warning light comes on

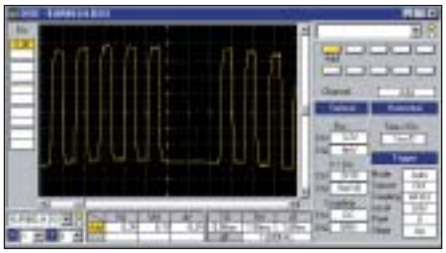
Causes of failure can be:

- Internal short-circuits
- Interrupted cables
- Cable short-circuits
- Mechanical damage to the sensor wheel
- Soiling through metal abrasion

Troubleshooting



Live image Hall-type sensor OK



Live image Hall-type sensor with fault:
Teeth missing on the sensor wheel

The following test steps should be taken into account during troubleshooting:

1. Check the sensor for soiling
2. Check the sensor wheel for damage
3. Read out the fault code
4. Measure the resistance of the inductive sensor using the ohmmeter, reference value at 80 °C approx. 1000 ohm.
5. Test the supply voltage of the Hall-type sensor using the voltmeter (circuit diagram for pin assignment necessary).

   Note: Do not carry out resistance measurement on the Hall-type sensor since this could destroy the sensor.
6. Check the sensor connection cables between the control unit and sensor connector for transmission (circuit diagram for pin assignment necessary). Ref. value: 0 ohm.
7. Check the sensor connection cables for ground connection, use the ohmmeter to measure against ground at the sensor connector with the control unit connector removed. Ref. value: >30 MOhm.

General points

Wheel speed sensors are located near wheel hubs or differentials and are used to determine the speed of the outer wheel rim. They are used in ABS, ASR and GPS systems. If the systems are combined the anti-blocking system provides the wheel rim speeds via data cables to the other systems. There are Hall-type sensors and inductive sensors. Before testing, it is essential to find out which type of sensor is involved (technical data, parts catalogue).

Function

The rotary movement of the sensor ring mounted on the drive shafts causes changes in the magnetic field in the sensor. The resulting signals are sent to the control unit and evaluated. In the case of the ABS system, the control unit determines the speed of the wheel rim which is used to determine the wheel slip, thus achieving an optimum braking effect without the wheels locking.

Effects of failure

When one of the wheel speed sensors fails, the following system features are noticeable:



- Warning light comes on
- A fault code is stored
- Wheels lock during braking
- Failure of further systems



There can be a number of reasons for sensor failure:

- Internal short-circuits
- Interrupted cables
- Cable short-circuit
- Mechanical damage to the sensor wheel
- Soiling
- Increased wheel bearing free play

Troubleshooting

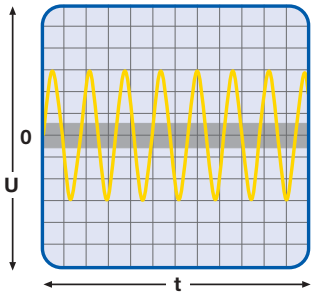
- Read out the fault code
- Check electrical connections of the sensor cables, the connector and the sensor for correct connection, breaks and corrosion.
- Watch for soiling and damage

Troubleshooting with wheel speed sensors is difficult with regard to distinguishing between Hall-type and inductive sensors, since these cannot always be distinguished from one another on the basis of what they look like. Three connector pins do not allow exact assumptions about the respective type involved. The specific manufacturer specifications and the details in the spare parts catalogue have to be consulted here.

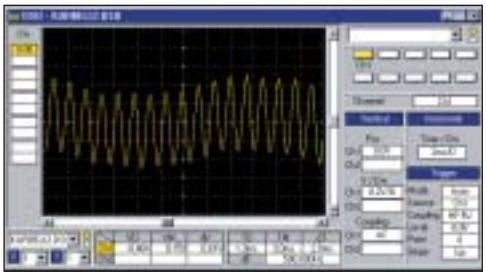
As long as it is not absolutely clear what type of sensor is involved, an ohmmeter must not be used for testing, since this could destroy a Hall-type sensor. If the sensors have a 2-pin connector fitted, they will probably be inductive sensors. In this case, intrinsic resistance, a ground connection and the signal can be determined. To do this separate the connector and test the internal resistance of the sensor using an ohmmeter. If the internal resistance value is 800 to 1200 ohm (depending on the reference value) the sensor is OK. If the reading is 0 ohm there is a short-circuit and MOhm indicates a cable interruption. The ground connection test is carried out using the ohmmeter from once connection pin to vehicle ground. The resistance value has to tend towards infinity. The test with an oscilloscope must result in a sinus signal of sufficient amplitude. In the case of a Hall-type sensor only the signal voltage in the form of a rectangular signal and the supply voltage must be checked. The result must be a rectangular signal depending on the wheel speed. The use of an ohmmeter can destroy a Hall-type sensor.

Installation note

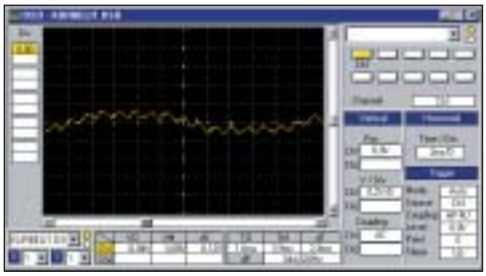
Make sure of the correct distance to the sensor wheel and sensor seat.



Inductive sensor
Optimum image



Live image inductive sensor OK



Live image inductive sensor with fault:
Sensor distance too great

General points

The knock sensor is on the outside of the engine block. It is used to record knocking sounds in the engine during all operating states in order to avoid engine damage.

Function



The knock sensor "monitors" the structure-borne vibrations on the engine block and transforms these into electrical voltage signals. These are filtered and evaluated in the control unit. The knock signal is assigned to the respective cylinder. If knocking occurs, the ignition signal for the respective cylinder is retarded as far as necessary until knocking combustion ceases.

Effects of failure

A sensor can become noticeable in different ways through the fault recognition of the control unit and the resulting emergency running strategy.

Frequent fault symptoms are:
- Engine warning light comes on
- fault code is stored
- Reduced engine performance
- Increased fuel consumption

There can be a number of reasons for sensor failure:
- Internal short-circuits
- Interrupted cables
- Cable short-circuit
- Mechanical damage
- Faulty attachment
- Corrosion

Troubleshooting

- Read out the fault code
- Check correct fit and torque of the sensor
- Check electrical connections of the sensor cables, the connector and the sensor for correct connection, breaks and corrosion.
- Check the ignition timing (older vehicles)

Testing with the multimeter

Check the wiring to the control unit by checking every single wire to the control unit connector for transmission and connection to ground.



Fig. 1

1. Connect the ohmmeter between the knock sensor connector and the removed control unit connector. Ref. value: <1 ohm **(Fig. 1)** (circuit diagram for the pin allocation of the control unit is necessary).

2. Use the ohmmeter to test the respective pin at the wiring harness connector and removed control unit connector to ground. Ref. value: at least 30 MOhm.
   Note: A connection pin can serve as a shield and show a transmission to ground.

Testing using the oscilloscope with the engine hot

1. Connect the test probes of the oscilloscope between the control unit pin for the knock sensor and ground.

2. Briefly open the throttle valve. The oscillogram must show a signal with a considerably increased amplitude (Fig. 2).

3. If the signal is not absolutely clear, knock lightly against the engine block near the sensor.

4. If the signal is still not detected this is an indication of a faulty sensor or circuit.

Installation note

Refer to manufacturer's torque setting during installation. Do not use spring washers or any other washers.

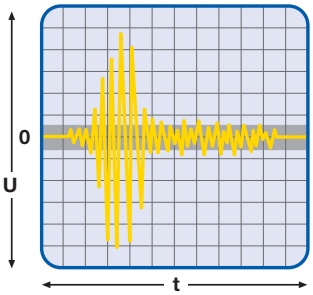
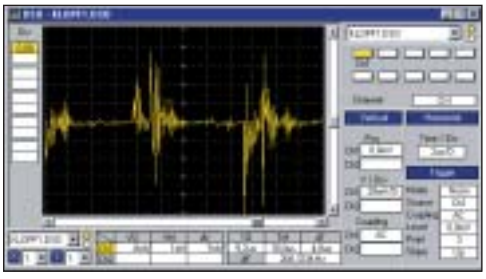
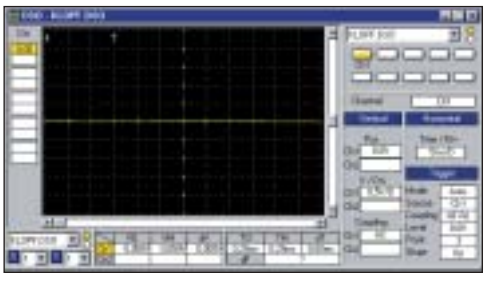


Fig. 2: Knock sensor
Optimum image



Live image knock sensor OK



Live image knock sensor with fault

General points

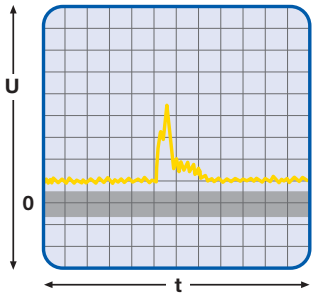
The mass air flow sensor is used to determine the intake air flow. It comprises of a pipe-shaped housing with flow rectifier, sensor protection and a sensor module screwed onto the outside. It is installed in the intake pipe between the air filter housing and the intake manifold.

Function



There are two temperature-dependent metal film resistors attached to a glass membrane arranged in the air flow. The first resistor (RT) is a temperature sensor and measures the air temperature. The second resistor (RS) is used to record the air throughput. Depending on the amount of air intake, the resistor RS cools down to a greater or lesser extent. In order to compensate the constant temperature difference between resistors RT and RS again, the flow through the resistor RS has to be controlled dynamically by the electronics. This heat flow serves as a parameter for the respective quantity of air intake by the engine. This measured value is required by the engine management control unit to calculate the amount of fuel required.

Effects of failure



Mass air flow sensor optimum image

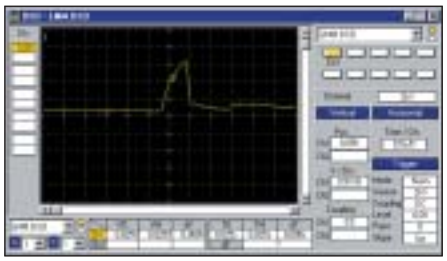
A faulty mass air flow sensor can become noticeable as follows:

- The engine comes to a standstill or the engine management control unit continues to work in limp-home mode.
- Engine warning light comes on

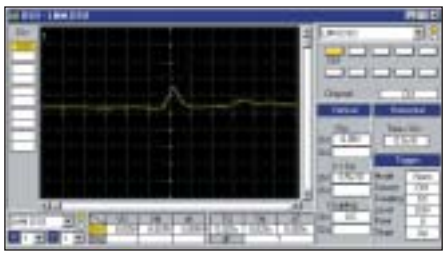
Reasons for failure of the mass air flow sensor can be:

- Contact fault at the electrical connections
- Damaged measuring elements
- Mechanical damage (vibrations, accident)
- Measuring element drift (exceeding the measuring framework)

Troubleshooting



Live image mass air flow sensor OK



Live image mass air flow sensor with fault

The following test steps should be taken into account during troubleshooting:

- Check connector for correct fit and good contact
- Check the mass air flow sensor for damage
- Check the measuring elements for damage
- Check voltage supply with the ignition switched on (circuit diagram for pin assignment is necessary). Ref. value: 7.5 -14 V
- Check output voltage with the engine running (circuit diagram for pin assignment is necessary). Ref. value: 0 -5 V
- Check the connection cables between the removed control unit connector and sensor connector for transmission (circuit diagram for pin assignment necessary). Ref. value: approx. 0 ohm.
- Electronic test of the mass air flow sensor by the engine management control unit. If a fault occurs, a fault code is stored in the control unit and can be read out using a diagnosis unit.

General points

In coordination with the crankshaft sensor, camshaft sensors have the task of exactly defining the first cylinder. This information is required for three purposes:

1. for initial injection in the case of sequential injection,
2. for the control signal for the solenoid in the case of the unit injector system and
3. for cylinder-selective knock control.

Function



The camshaft sensor works according to the Hall principle. It scans a gear rim located on the camshaft. Due to the rotation of the gear rim, the Hall voltage of the Hall-IC in the sensor head changes. This change in voltage is sent to the control unit and evaluated there in order to establish the required data.

Effects of failure

A faulty camshaft sensor can become noticeable as follows:

- Engine warning light comes on
- A fault code is stored
- Control unit works in limp-home programme

Reasons for failure of the camshaft sensor can be:

- Mechanical damage
- Break in the sensor wheel
- Internal short-circuits
- Interruption in the connection to the control unit

Troubleshooting

- Check the sensor for damage
- Read out the fault code
- Check electrical connections of the sensor cables, the connector and the sensor for correct connection, breaks and corrosion

1. Check the connection cable from the control unit to the sensor using the ohmmeter. Remove the connectors from the control unit and the sensor, check the individual cables for throughput. Circuit diagram for pin assignment is necessary. Ref. value: approx. 0 ohm.

2. Test connection cables for ground connection. Measurement between sensor connector and vehicle ground, control unit connector is removed. Ref. value: >30 MOhm.

3. Test the supply voltage from the control unit to the sensor. Insert the control unit connectors, switch on the ignition. Ref. value: approx. 5 V (refer to manufacturer's information).

4. Testing the signal voltage. Connect the oscilloscope measuring cable and start the engine. The oscilloscope display must show a rectangular signal (Fig. 1).

Installation note

Make sure of the correct distance to the sensor wheel and the seal is seated correctly.

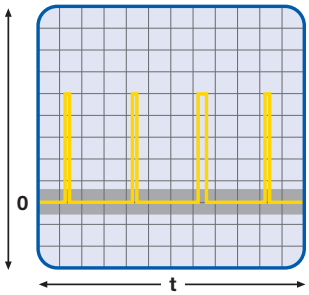
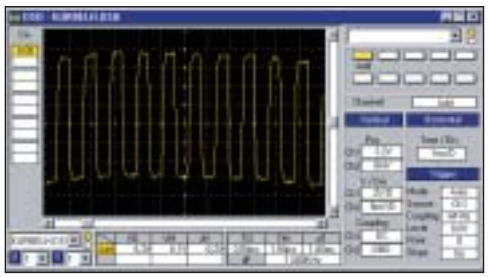
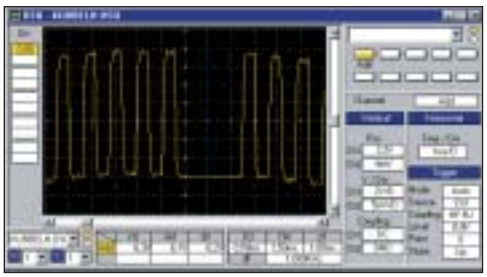


Fig. 1: Hall-type sensor Optimum image



Live image Hall-type sensor OK



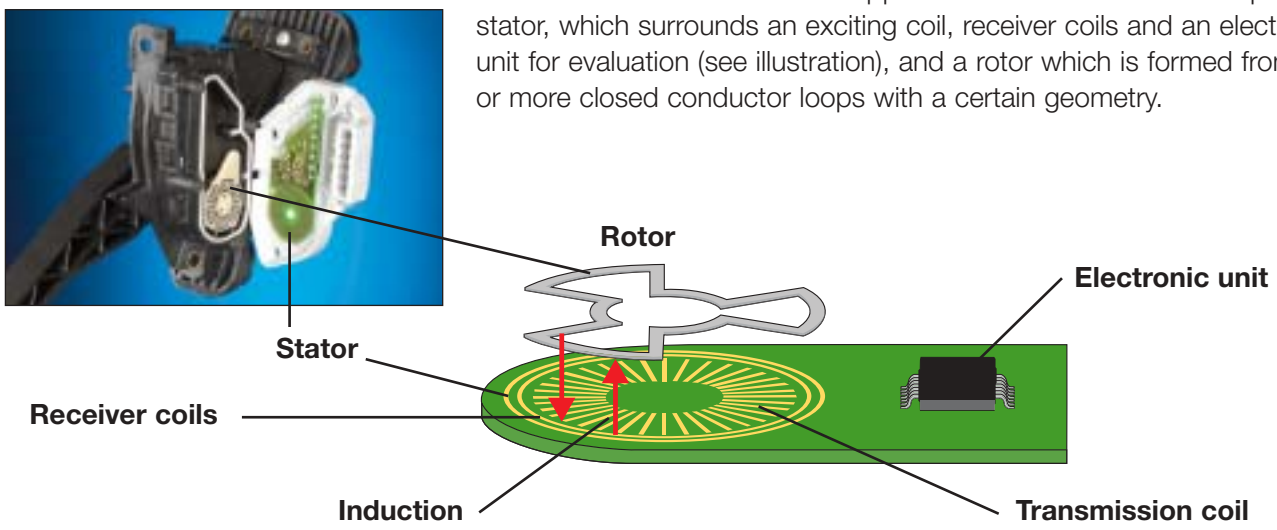
Live image Hall-type sensor with fault: teeth damaged on the sensor wheel

General points

In modern vehicles, the share of electronic components is increasing all the time. Reasons include legal regulations e.g. in the field of emission and fuel consumption reduction. Electronic components are also taking over more and more functions which increase active and passive safety as well as driving comfort. One of the most important components is the accelerator pedal sensor.

Design

Non-contact sensors based on an inductive principle are being used more and more often for automotive applications. These sensors comprise a stator, which surrounds an exciting coil, receiver coils and an electronic unit for evaluation (see illustration), and a rotor which is formed from one or more closed conductor loops with a certain geometry.



Function

The application of alternating voltage to the transmission coil produces a magnetic field which induces voltages in the receiver coils. A current is also induced in the rotor conductor loops which in turn influences the magnetic field of the receiver coils. Voltage amplitudes are produced depending on the position of the rotor relative to the receiver coils in the stator. These are processed in an electronic evaluation unit and then transmitted to the control unit in the form of direct voltage. The control unit evaluates the signal and forwards the respective pulse to the throttle valve actuator, for example. The characteristic of the voltage signal depends on how the accelerator pedal is activated.

Effects of failure

The following fault symptoms can occur

if the accelerator pedal sensor fails:

- Engine only shows increased idling
- Vehicle does not react to accelerator pedal movements
- Vehicle switches to "limp-home" mode
- Engine warning light comes on

There can be various reasons for failure:

- Damaged cables or connections at the accelerator pedal sensor
- Lack of voltage and ground supply
- Faulty evaluation electronics in the sensor

Troubleshooting

The following test steps should be taken into account during troubleshooting:

- Read out fault code
- Visual inspection of the accelerator pedal sensor for mechanical damage
- Visual inspection of the relevant electrical connections and cables for correct fit and potential damage
- Testing of the sensor with the aid of oscilloscope and multimeter

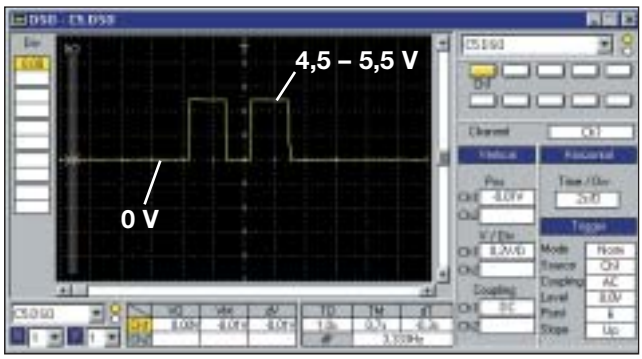
The test steps, technical data and illustrations listed below to explain troubleshooting are based on the example of a MB A-Class (168) 1.7.

Technical data: pin allocation/cable colours

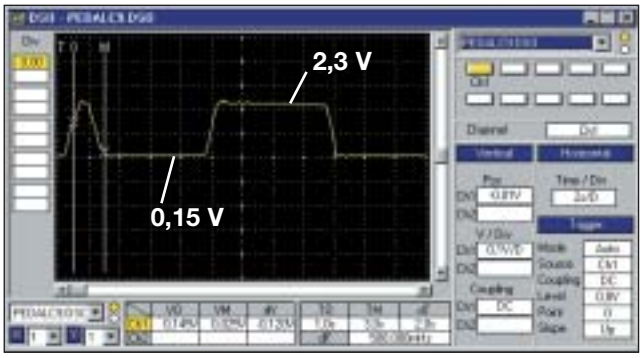
Control unit pin	Signal	Test conditions	Reference value
C5 blue-yellow	⇨	Driving current off	0 V
C5	⇨	Driving current on	4.5 – 5.5 V
C8 violet-yellow	⊥	Driving current on	0 V
C blue-grey	←	Driving current on Accelerator pedal released	0.15 V
C9	←	Driving current on Accelerator pedal pressed	2.3 V
C10 violet-green	←	Driving current on Accelerator pedal released	0.23 V
C10	←	Driving current on Accelerator pedal pressed	4.66 V
C23 brown-white	⊥	Driving current on	0 V

⇨ **Output signal** ← **Input signal** ⊥ **Control unit ground**

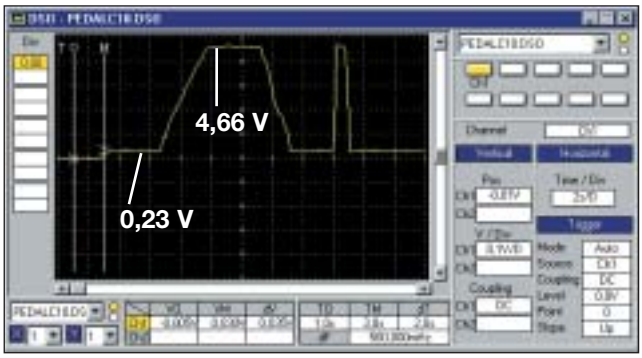
Signal recorded from pin C5:
This measurement is used to check the sensor voltage supply.
Ignition on/off.



Signal recorded from pin C9:
Ignition on, press pedal and release again.
The increase and decrease in signal depends on the speed at which the pedal is pressed and released again.



Signal recorded from pin C10:
Ignition on, press pedal and release again.
The increase and decrease in signal depends on the speed at which the pedal is pressed and released again.

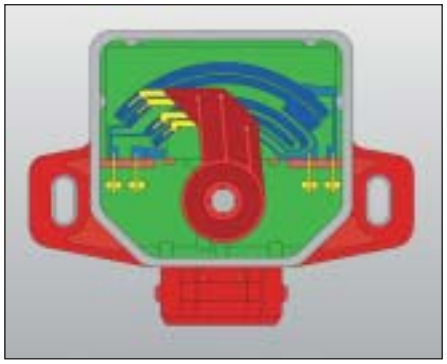


Recommendation:
The measurements should be carried out by two people. The tapping of the signals at the sensor, carrying out of various test cycles and diagnosis at the oscilloscope is possible for one person, but is much more difficult and requires significantly more time.

General points

The throttle potentiometer is used to determine the opening angle of the throttle valve. The information gained is sent to the control unit and is one of the factors used to calculate the amount of fuel required. It is attached directly to the throttle valve axis.

Function



The throttle potentiometer is an angle sensor with a linear characteristic. It transforms the respective opening angle of the throttle valve into a proportional voltage ratio. When the throttle valve is actuated, a rotor connected to the throttle valve axis moves with its contacts over resistor paths, which transforms the position of the throttle valve into a voltage ratio.

Effects of failure

A faulty throttle potentiometer can become noticeable as follows:

- Engine judders and/or stutters
- Fuel feed to engine is poor
- Poor start-up behaviour
- Increased fuel consumption

Reasons for failure of the throttle potentiometer can be:

- Contact fault at the pin connection
- Internal short-circuit caused by soiling (humidity, oil)
- Mechanical damage

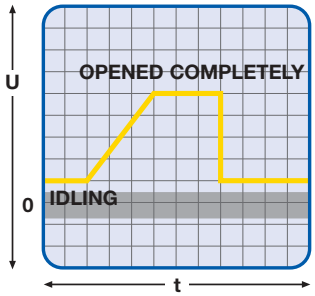
Troubleshooting

The following test steps should be taken into account during troubleshooting:

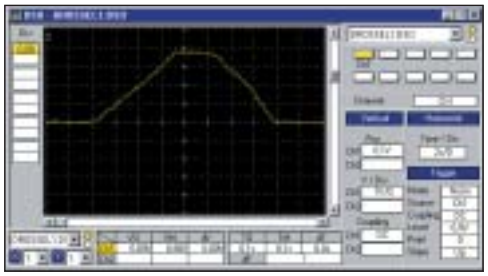
- Check the throttle potentiometer for damage
- Check pin connection for correct fit and soiling
- Check voltage supply of the control unit (circuit diagram for pin assignment is necessary). Ref. value: approx. 5 V (refer to manufacturer's information).

- Resistance measurement at the throttle potentiometer (circuit diagram for pin assignment is necessary). Connect the ohmmeter and test the resistance with the throttle valve closed, slowly open the throttle valve, observe changes in the resistance (during measurement an interruption of the loop contact can be established). Test the resistance with the throttle valve fully open (refer to manufacturer's instructions).

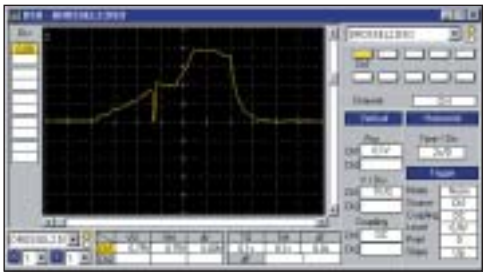
- Check the cable connections to the control unit for continuity and ground connection (circuit diagram for pin assignment is necessary). Test the individual cables and the component connector for continuity with the control unit connector removed, reference value: approx. 0 ohm. Test each cable for a ground connection against vehicle ground, reference value: approx. 30 MOhm.



Throttle potentiometer optimum image



Live image throttle potentiometer OK

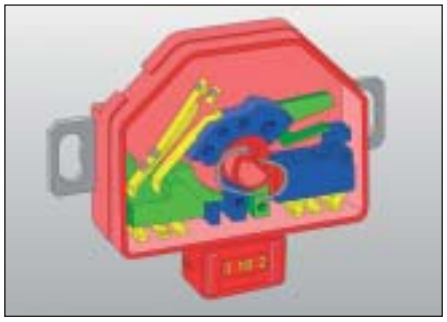


Live image throttle potentiometer with fault:

General points

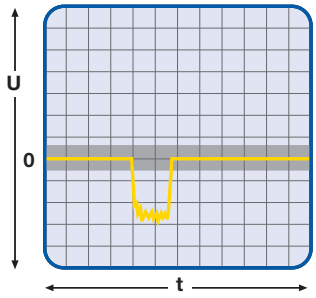
Throttle valve switches are used to determine the position of the throttle valve. They are attached directly to the throttle valve axis. The respective switch positions are transmitted to the engine management control unit and contribute to the calculation of the required fuel quantity.

Function



There are two switches in the throttle valve switch which are actuated via a switching mechanism. The two switches provide the engine management control unit with the information it requires about the engine operating states idling and full load in order to guarantee accurate calculation of the required fuel quantity.

Effects of failure



Throttle valve switch optimum image

A faulty throttle valve switch can result in the following:

- Engine dies during idling
- Engine is bumpy at full load

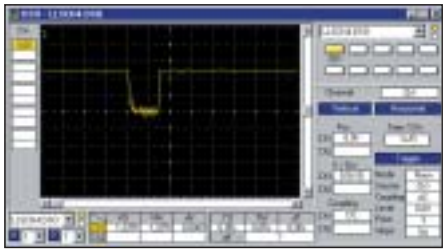
Reasons for a faulty throttle valve sensor can be:

- Mechanical damage (e.g. due to vibrations)
- KContact fault at the electrical connection (corrosion, humidity)
- Contact fault at the inner switching contacts (humidity, soiling)

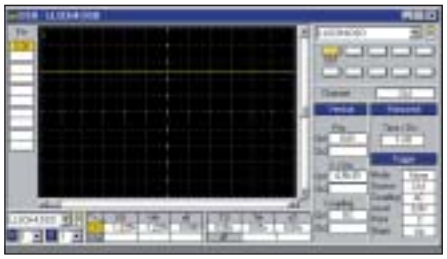
Troubleshooting

The following test steps should be taken into account during troubleshooting:

1. Check the throttle valve switch to make sure it has been installed properly
2. Check whether the switching mechanism is actuated by the throttle valve shaft (with the engine at a standstill move the throttle valve from the idling stop to full load stop position to hear whether the switches are actuated)
3. Check pin connection for a correct fit and any soiling
4. Test the switching contacts using a multimeter:
   - Idling switch closed: Measurement between pin 1 and 3. Measuring value = > 30 MOhm.
   - Idling switch opened: Measurement between pin 1 and 3 (note: open the throttle valve slowly during measurement until the idling switch opens). Measuring value = 0 ohm.

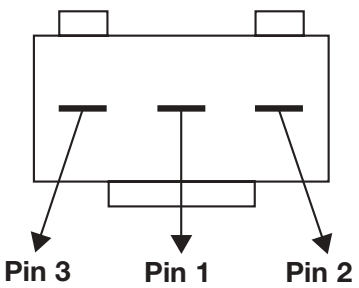


Live image throttle valve switch OK



Live image throttle valve switch with fault

- Full load switch opened: Measurement between pin 1 and 2. Measuring value = > 30 MOhm.
- Full load switch closed: Measurement between pin 1 and 2. Measuring value = > 0 Ohm.



General points

Fuel injectors have the task of injecting the exact amount of fuel calculated by the control unit during every engine operating state. To achieve good fuel atomisation with low condensation loss, a certain distance and injection angle must be kept, depending on the particular engine involved.

Function



Fuel injectors are actuated electro-magnetically. The control unit calculates and controls the electrical pulses to open and close the injection valves on the basis of the current sensor data related to the engine operating state. Fuel injectors are made up of a valve body containing a magnet winding and guide for the valve needle and a valve needle with magneto inductor. When the control unit applies a voltage to the magnet winding, the valve needle is lifted from its seat and reveals a precision bore hole. As soon as the voltage is removed, the valve needle is pushed back onto the valve seat by a spring, closing the bore hole. The flow quantity with the injection valve open is exactly defined by the precision bore hole. In order to inject the fuel amount calculated for the operating state, the control unit calculates the opening time of the injection valve aligned to the flow quantity. This guarantees that the exact fuel amount is always injected. The design of the valve seat and the precision bore hole means that optimum fuel atomisation is achieved.

Effects of failure



A faulty injection valve or one not working properly can result in the following fault symptoms being found:

- Start-up problems
- Increased fuel consumption
- Loss of power
- Unsteady idling speed
- Impaired exhaust behaviour (e.g. exhaust emission analysis)
- Later damage as a result: reduction of the engine service life, damage to the catalytic converter



A fault or limited function could be caused by:

- A blocked filter sieve in the injection valve caused by soiled fuel.
- Poor closing of the needle valve caused by tiny soiling particles from the inside, combustion residue from the outside, additive deposits.
- A blocked, closed drain hole.
- A short-circuit in the coil.
- A cable interruption to the control unit.

Troubleshooting

Troubleshooting can be carried out with the engine running or switched off.

Troubleshooting with the engine running

1. Using a cylinder comparison measurement and simultaneous exhaust emission measurement the amount of fuel injected can be compared on the basis of drop in speed, HC and CO values of the individual cylinders. In the most favourable case the values are identical for all the cylinders, if the values fluctuate greatly this could mean that too little fuel is being injected (a lot of non-combusted fuel = high HC and CO values. little non-combusted fuel = low HC and CO values). The cause can be a faulty injection valve.

2. The injection valve signal can be represented using the oscilloscope. To do this, the measuring cable is connected to the control cable of the injection valve control unit, the other cable to a suitable ground point. The voltage and pulse duration (opening time) can be read off on the signal image with the engine running. When the throttle valve is opened the pulse duration must increase during the acceleration phase and then at constant speed (approx. 3,000 rpm) drop again to or just below the idling value. The results of the individual cylinders can be compared and could provide clues about possible faults, e.g. poor voltage supply.

3. Further important tests are fuel pressure measurement, in order to detect other possibly faulty components (fuel pump, fuel filter, pressure regulator) and a leak test for the intake and exhaust systems in order to prevent the measuring results being corrupted.

Troubleshooting with the engine/ignition switched off

1. Test the cable connection between the injection valves and the control unit for continuity (circuit plan for pin assignment is necessary). For this measurement remove the control unit connector and test the individual cables of the injection valve connectors to the control unit. Ref. value: approx. 0 ohm.

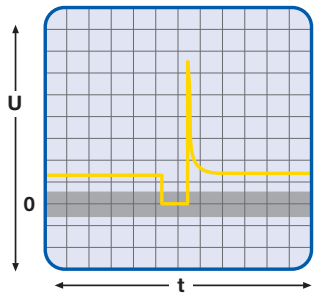
2. Test the cable connection between the injection valves and the control unit for ground connection. With the control unit connectors removed, measure the cables from the injection valves to the control unit against vehicle ground. Ref. value: >30 MOhm.

3. Check the injection valve coils for continuity. To do this, connect the ohmmeter between the two connection pins. Ref. value: approx. 15 ohm (refer to manufacturer's information).

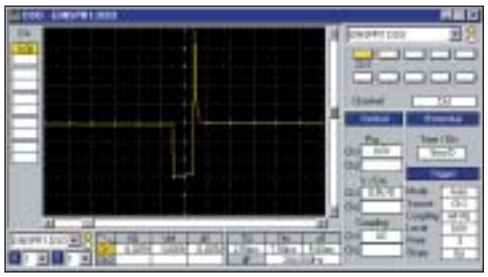


4. Check the injection valve coils for ground connection. To do this test each individual connection pin for continuity against the valve housing. Ref. value: >30 MOhm.

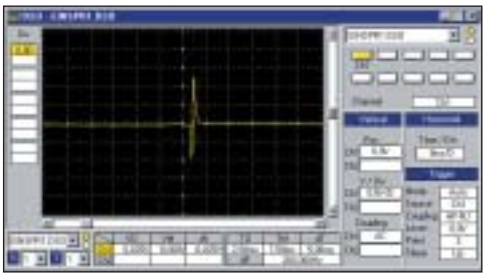
A special testing device can be used to test the injection pattern of the injection valves when they are not installed in the vehicle. In addition, it is possible to use this tester to clean the injection valves.



Injection valve
Optimum image



Live image injection valve OK



Live image injection valve with fault

General points

The idling speed stabiliser is a bypass air valve. The idling speed stabiliser example illustrated is made up of a closed cast housing with a solenoid servo unit flanged onto it. Attached to this is a nozzle rod which releases different air cross-sections by moving the servo unit and can thus control the mass air flow with the throttle valve closed.

Function



The idling speed stabiliser is responsible for regulating the engine speed within the context of the complete idling regulation of the engine management system. If there is a sudden change in engine load status during idling (air conditioning is switched on, creeping speed in 1st gear or additional consumers are switched on), additional air and fuel are required to prevent the engine from stalling. If the engine speed falls below such a critical value which is stored as a constant in the control unit memory, the solenoid is activated and achieves increased air flow. At the same time the opening time of the injection valves is extended and adapted to the engine requirements.

Effects of failure

A faulty idling speed stabiliser can become noticeable as follows:

- Idling speed too high
- Engine dies out at idling speed
- Engine dies out at idling speed when an additional consumer is switched on
- Engine warning light comes on

Reasons for failure of the idling speed stabiliser can be:

- Heavy soiling/gumming
- A short-circuit in the coil
- Blocking of the electrical magnetic drive
- No voltage supply from the engine management control unit

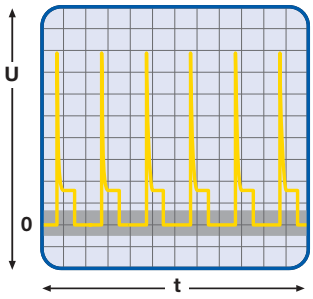
Troubleshooting

The following test steps should be taken into account during troubleshooting:

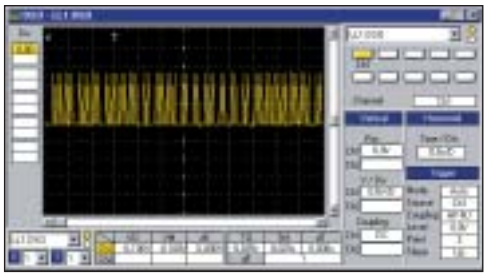
1. Test the voltage supply with the ignition switched on. Measuring value: 11 – 14V.
2. Use the multimeter to measure the coil resistance between the two connection pins on the idling speed stabiliser. Reference value = approx. 10 Ohm (refer to manufacturer's information).
3. Test the coil for a winding short-circuit between the two connection pins. Reference value = 0 ohm.
4. Test the coil for a winding interruption between the two connection pins. Measuring value = > 30 Mohm.
5. Test the coil for ground connection – between pin 1 and component housing as well as pin 2 and component housing. Measuring value = > 30 Mohm.
6. Mechanical test: Unscrew the servo unit from the housing. Visual test as to whether the bypass opens and closes when the valve rod is actuated.
7. Read out fault code

Installation note

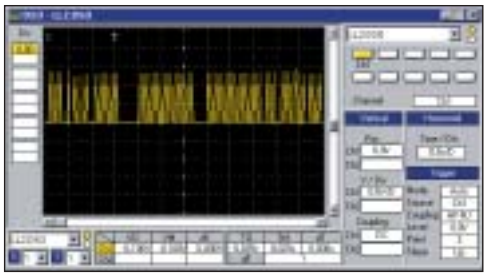
A flange seal is required. The attachment screw torque is 12 – 15 Nm.



Idling speed stabiliser optimum image



Live image idling speed stabiliser OK



Live image idling speed stabiliser with fault

In this issue we would like to explain the most important component of the engine control to you in more detail. The engine control unit.

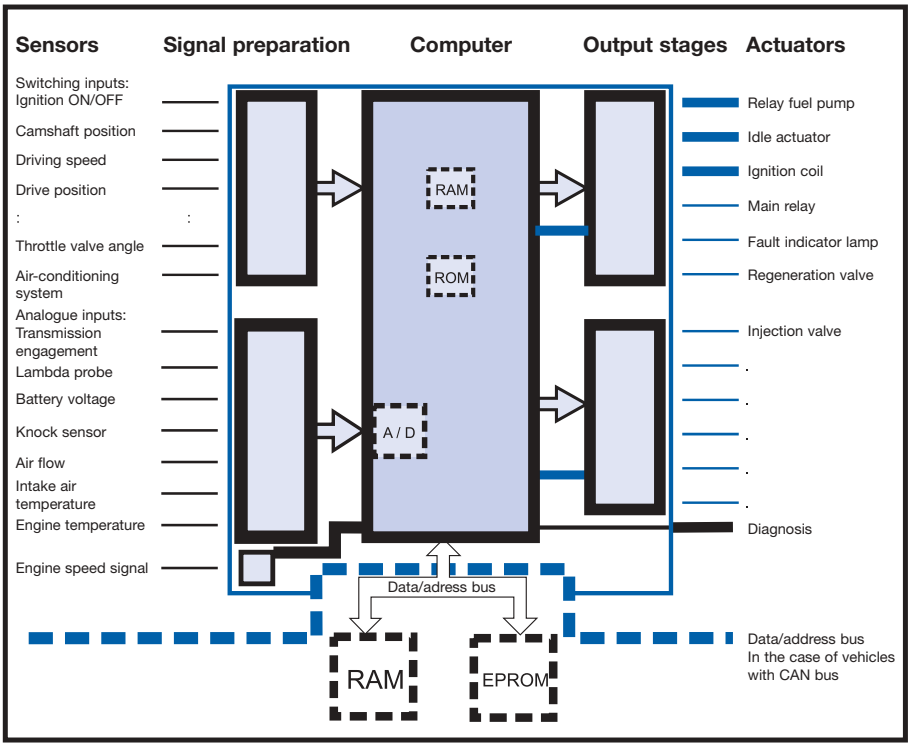
The story of the engine control unit began in 1967 with the introduction of the D-Jetronic. It was the first electronic injection system to be mass-produced. When it was introduced, the control unit was the size of a shoe box. It comprised around 30 transistors and 40 diodes. The most important input parameters were intake pipe pressure and engine speed. As development of the injection systems advanced – L-Jetronic and K-Jetronic – the demands made of the system control also changed. More and more data had to be recorded, processed and outputted. Requirements continued to increase, the performance ability of the control units was steadily increased.

Control unit structure



The control unit itself, a PCB with all electronic components, is mounted in a metal or plastic housing. Connection of sensors and actuators is via a four-channel plug-type connection. The necessary power components for direct actuator control are installed on heat sinks in the housing to dissipate the heat produced. Further requirements had to be taken into account during design. These concern the ambient temperature, mechanical load and humidity. Just as important is the resistance to electro-magnetic noise and the limiting of the radiation of high-frequency interfering signals. The control unit has to work perfectly at temperatures of –30 °C to +60 °C and voltage fluctuations from 6 V-15 V.

How it works



The control unit is supplied with a constant voltage of 5 V for the digital circuits through an internal voltage regulator. The input signals of the sensors reach the control unit in different forms. For this reason they are forwarded via protective circuits and, if necessary, via amplifiers and signal transformers and then processed directly by the micro-processor. Analogue signals, e.g. from the engine and intake air temperature, the intake air quantity, battery voltage, oxygen sensor etc. and transformed into digital values by an analogue/digital transformer in the micro-processor. To prevent interfering pulses, signals from inductive sensors (e.g. speed mapping and reference mark sensors) are processed in a part circuit.

ROM / EPROM / RAM

The micro-processor requires a program to process the input signals. This program is stored on a read-only memory (ROM or EPROM). This read-only memory also contains the engine-specific characteristic diagrams and curves required for engine control. In order to realise the function of some vehicle-specific features or engine versions, variant coding is carried out by the vehicle manufacturer or the garage. This is required if the control unit is replaced as a spare part or if individual sensors or actuators are replaced. To keep the number of different control units at the vehicle manufacturers to a minimum, the complete sets of data are not read into the EPROM until the end of the production line for some unit types.

Alongside ROM or EPRON, a read/write memory (RAM) is also required. This has the task of storing calculated values, adaptation values and any faults that may occur in the system in such a way that they can be read out with a diagnosis device. This RAM memory requires a permanent current supply. If the current supply is interrupted, e.g. if the battery is disconnected, the stored data are lost. In this case all adaptation values have to be re-established by the control unit. To avoid the loss of variable values, these are stored in an EPROM instead of in a RAM in some unit types.

The signal output to trigger the actuators takes place via output stages. They have sufficient power for direct connection of the individual actuators and are controlled by the micro-processor. These output stages are protected in such a way that they cannot be destroyed by short-circuits to ground and battery voltage or by excess electrical load.

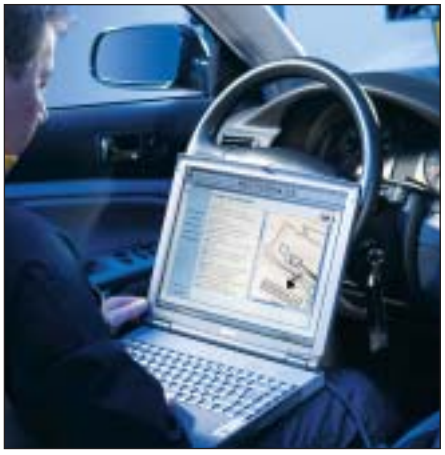
Thanks to self-diagnosis, faults which occur at some output stages can be detected and the output switched off if necessary. This fault is then stored in the RAM and can be read out in the garage using a diagnosis unit. To allow the program to be completed with some unit types, the main relay is held by a hold circuit until the end of the program after the ignition has been switched off.

The central task of the engine control unit is to adapt the air/fuel mixture and ignition timing to the respective load state of the engine. This includes closing angle control, ignition timing adjustment, fuel injection, knock control, oxygen sensor control, load pressure regulation, idling speed stabilisation and exhaust gas recirculation control. More recent systems also include monitoring and service functions which monitor the complete system, detect any faults which occur and record them as a fault code. In addition, the interval between necessary servicing jobs is coordinated. Control units which are integrated in a CAN bus provide other control units (e.g. transmission and ESP control unit) with additional information. To calculate the output signals respectively required, all information recorded by the sensors is compared with the stored characteristic diagrams, calculated and outputted to the required actuators.

Fault diagnosis

Faults which occur can be caused by different reasons. It is possible that the fault is caused by a false input signal, output signal or the faulty execution of a signal. If the fault is caused by a false input signal, a sensor or the respective wiring could be the cause. If an output signal is false, it must be assumed that an actuator or wiring are faulty. If the input signals are OK but false signals are outputted by the control unit, a fault in the control unit must be considered.

In many cases fault diagnosis is very difficult. With vehicles that have a diagnosis connection, the fault store can be read out using a diagnosis unit. If there is no suitable unit available, the possibilities specified by various manufacturers can be used to read out the fault store using a flash code. Here, manufacturer's instructions must always be taken into consideration as well as those of the various test unit manufacturers. If a stored fault has been read out, further tests may have to be carried out to confirm a component fault rather than damage to the connector or cable.

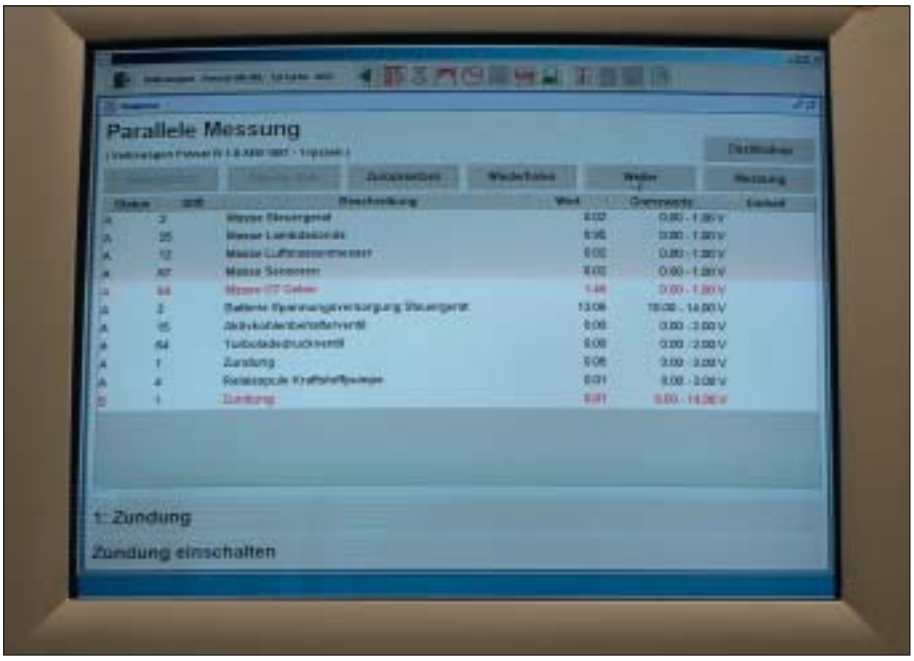


It must be noted that a stored fault does not have to have been caused directly by the component indicated, but that it can also have been caused by another faulty component. A classic example of this phenomenon is the fault stored "oxygen sensor voltage too low", caused by a faulty temperature sensor. The faulty temperature sensor continually sends the information "engine cold" to the control unit although operating temperature has been reached. The control unit continues to enrich the air/fuel mixture and the oxygen sensor remains at 0.1 V on account of the rich mixture, which is of course evaluated as a fault by the control unit. This also applies to faults on actuators. If there is a fault in the system that is not recorded in the fault store, a suitable diagnosis unit could be used to read out the measured value blocks. During this process a comparison of reference and actual values is carried out.

The actual values displayed are compared with the reference values stored in the diagnosis unit and can provide clues about faulty values. **There is a classic example available here too**: The values forwarded by the mass air flow meter to the control unit do not correspond to the engine load state but are still plausible for the control unit. The engine no longer works at full power. This fault can be diagnosed very quickly by reading out the respective measured value block and comparing these values with the reference values under various load states.

When must a control unit fault be assumed?
This question is extremely difficult to answer, as practical garage work often shows. Basically, it can be said that: If despite the fact that all the voltage and ground connections to the control unit and all the input signals have been tested one (or more) actuators cannot be triggered at all or triggered properly, a fault within the control unit must be assumed. It is important that not only the actuators are triggered by the control unit but relays, too (e.g. ground supply from the fuel pump relay). Vehicle-specific circuit diagrams and reference values should always be taken into account during all work. They provide an accurate summary of all components and cables that are connected to the control unit. Problems occur if the diagnosis unit does not build up a connection to the control unit. If the connection between the diagnosis unit and the vehicle is OK and the correct vehicle has been selected, this fault source can be excluded. It should be checked whether all voltage and ground connections on the control unit are OK and whether the voltage values correspond to the reference values. If no faults can be found, it must be assumed that damage has occurred within the control unit and destroyed the unit.

As well as serial diagnosis (testing using the diagnosis connection) some test unit manufacturers offer the possibility of parallel diagnosis. In this case the diagnosis unit is connected to the control unit by means of a vehicle-specific adapter cable. With parallel diagnosis, all values and signals of the individual pins on the control unit can be tested and compared. This diagnosis possibility provides a solution for vehicles which do not have a serial diagnosis connection yet.



Screen presentation, parallel diagnosis



Connection, parallel diagnosis

A further diagnosis possibility is to use a test box (brake out box). With this test method, the test box is connected parallel to the control unit using the respective adapter cables. The individual sensors, cables, ground and voltage supplies can be tested at the test box sockets using the multimeter or oscilloscope. With this test it is very important that the pin assignments and reference values prescribed by the manufacturer are available.



Testing using the test box

Testing without diagnosis unit or test box

If neither diagnosis unit nor test box are available, troubleshooting is extremely difficult. Measurements can be carried out with the multimeter or oscilloscope using the necessary vehicle-specific circuit diagrams and reference values. It is important that the connectors and cables are not damaged when the test prods of the testing unit are connected. Quite frequently, the connector contacts are bent by the test prods and no longer contact properly. These "self-inflicted faults" are very difficult to discover later.

Which precautionary measures have to be considered?
Be extremely careful when carrying out measurements on the control unit. Inverse polarity or voltage peaks can destroy sensitive electronic components in the control unit. For this reason, do not use a conventional test lamp. Use a multimeter, oscilloscope or diode test lamp. To delete the fault store follow the manufacturer's instructions only. With new systems, stored data can be lost when the battery is disconnected. It can then be necessary to re-adapt or code some components or systems to enable them to function perfectly and be detected by the control unit. This is also necessary when the control unit or certain component are replaced. Adaptation or coding is only possible using a diagnosis unit.
If the control unit is replaced it must be noted that in some unit types the plug-in program memories (EPROM) have to be taken over in the new unit. New control units that have to be adapted and coded in the vehicle can only be used in this one vehicle. Installation in a different vehicle for trial purposes is not possible.
If you are not certain in your diagnosis, it is possible to have the control unit checked for a reasonable price. If the control unit is faulty it may be possible to repair it. If the fault is irreparable, it is possible to exchange the unit 1:1. If no fault is found, the control unit can be reinstalled without any problems. You can find more information on this subject on the Internet under:
www.hella.com.

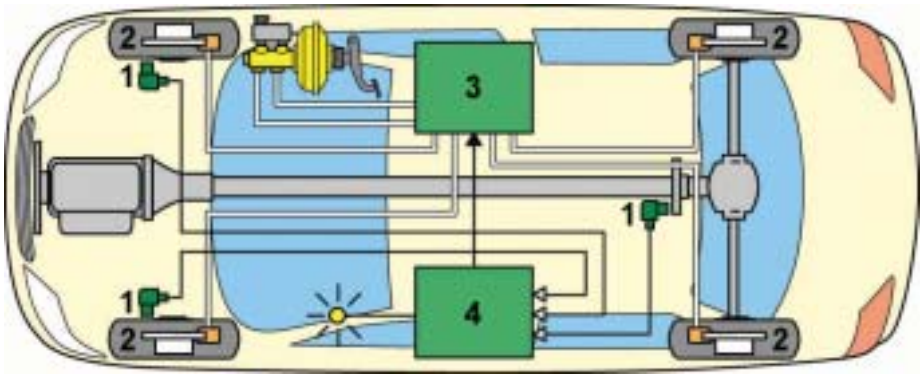
In this issue we would like to explain the ABS braking system and possible faults and diagnosis possibilities in the electronic system in detail. The main focus is not on design and function but rather on diagnosis and troubleshooting.

At the end of the 1970s developments were so far advanced that the first ABS braking system was ready for series production. The ABS braking system made it possible to increase safety during critical braking situations. Different road conditions (wet, icy) or sudden obstacles led to the wheels locking on vehicles without ABS in emergency braking situations. This resulted in drivers no longer being able to steer their vehicle. When vehicles are equipped with ABS, wheel locking is prevented and the vehicles can be steered at all times, even in hard stop or emergency braking situations.

ABS system components

The ABS system comprises the following components:

- Control unit
- Hydraulic power unit
- Speed sensors
- Wheel brakes



1 Speed sensors

2 Wheel brakes

3 Hydraulic power unit

4 Control unit

The control unit is the centrepiece of the system. It receives and evaluates the speed signals from the wheel speed sensors. These are used to calculate brake slip and wheel slowing or wheel acceleration. This information is processed in a digital controller comprising two independent, parallel micro-controllers for two wheels each. The control signals produced are sent to the solenoids of the hydraulic power unit as actuating commands.

The hydraulic power unit contains the solenoids which carry out the actuating commands of the control unit. Even if the pressure applied to the brake pedal by the driver is significantly higher during emergency braking, the solenoids provide optimum control for the pressure to the wheel brake cylinders. The hydraulic power unit is installed between the main brake cylinder and the wheel brake cylinders.

The control unit determines the wheel rim speed from the signals mapped by the wheel speed sensors. These sensors are usually inductive sensors. With more recent systems, however, active speed sensors are also used. The braking pressure transferred to the wheel brakes by the hydraulic power unit produces an elastic force which presses the brake pads onto the brake discs or brake drums.

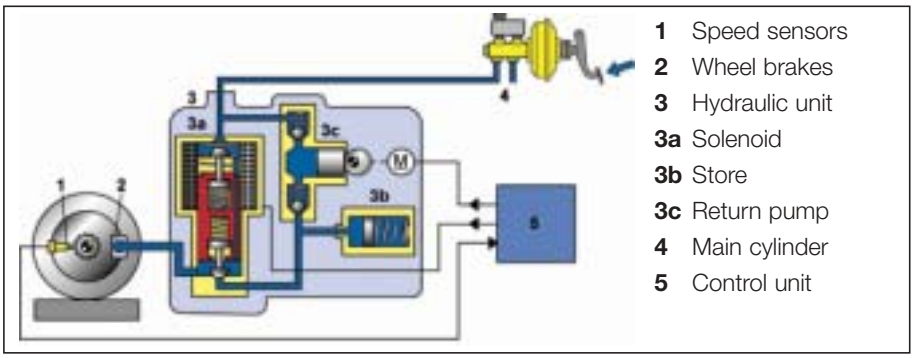
How does the ABS system work?

In the case of a hard stop the ABS system controls the braking pressure that has to be applied in the service braking system. This takes place for each individual wheel cylinder depending on wheel slowing or wheel acceleration and wheel slip.

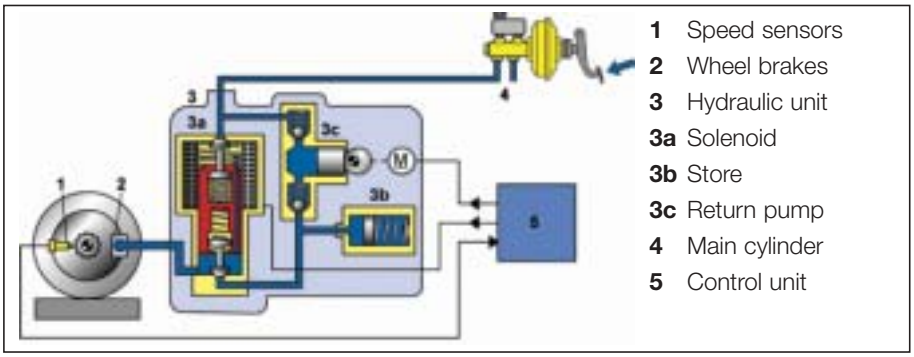
The speed the control unit requires to calculate the wheel rim speed is determined on the front wheels and the rear axle differential or on the rear wheels through the speed sensors. If the control unit detects that one or more wheels will tend to lock, the solenoids and the return pump of the wheels involved will be triggered. Each of the front wheels is influenced by the respective solenoid in such a way that it achieves the best possible braking effect. Independent of the other wheels. In the case of vehicles which only have one speed sensor on the rear axle differential, the wheel with the greatest locking tendency determines the braking pressure on the two wheels. This means the wheel with the better friction coefficient will be braked somewhat less than possible and the braking distance is somewhat longer, but vehicle stability is better. With vehicles which have a speed sensor on each of the rear wheels the control system is the same as on the front wheels.

The control unit triggers the solenoids of the individual wheels in three different switching states:

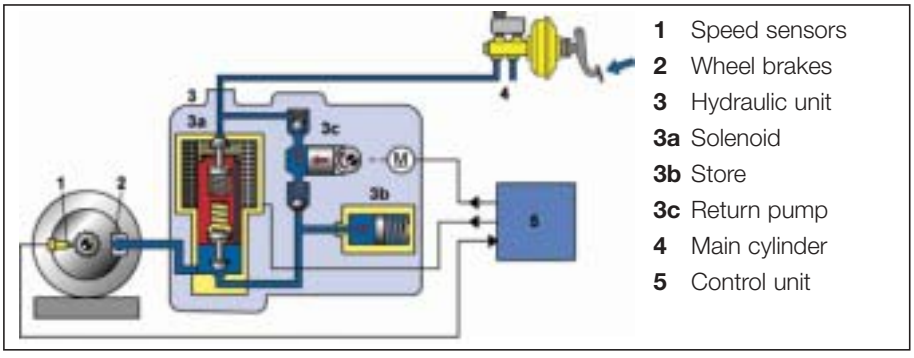
In the first switching state (pressure build-up) the master cylinder and the wheel cylinder are connected to one another. This means that the inlet valve is opened and the outlet valve closed. Braking pressure can increase without hindrance.



In the second switching state (pressure maintenance) the connection between the master cylinder and the wheel cylinder is interrupted. The braking pressure remains constant. This means that the inlet valve has current supplied and is thus closed. The outlet valve is also closed.



In the third switching state (pressure reduction) the braking pressure is reduced. This means that the outlet valve has current supplied and is thus opened. At the same time the pressure is reduced by the return pump. The inlet valve is closed.



Thanks to these different switching states it is possible to build up or reduce braking pressure in stages through cyclic triggering of the solenoids. When the ABS system is used these control processes run 4-10 times every second depending on the roadway structure.

What happens if there is a fault in the ABS system?

As soon as a fault occurs in the system, the system becomes inactive. In this case the vehicle's service braking system continues to work without restrictions. The driver is informed of the ABS system failure by the ABS warning light coming on.

Troubleshooting in the ABS system

If there is a fault in the ABS system and the warning light comes on, there are various troubleshooting or diagnosis possibilities depending on the age and type of ABS system involved. You should always begin with the most straightforward possible faults.

Faulty fuses:
A quick look at the operating instructions and in the fuse box can exclude the first potential source of fault if all the fuses connected with the ABS system are OK.

Visual inspection:
- Are all connectors and cables OK?
- Are the connectors locked in place correctly?
- Are there visible chafe marks on the cables which could lead to a short-circuit?
- Are all the ground connections OK?
- Are the speed sensors and/or the sensor wheel soiled or damaged?
- Are all the tyres OK and the right/same size?



Sensor and sensor wheel

Wheel bearing and suspension mounting:
Are the wheel bearings and the suspension mounting (balls and joints) OK and without play?

Testing the service braking system:
The test of the service braking system on the brake test bench and a leak test are also necessary.
The filling level in the brake fluid tank must be correct.

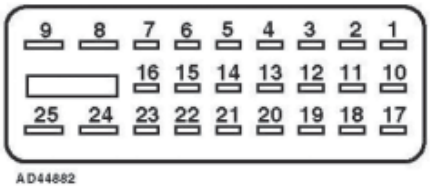
If no faults are found during these tests, further measurements must be carried out. There are various possibilities available here. These depend on the vehicle age/type, for example, and the test units available.
If the ABS system can be diagnosed, a suitable diagnosis unit can be used to read out the fault code and scan the measured values and parameters. If there is no suitable test unit available or the system is not suitable for diagnosis, further measurements can be carried out using an oscilloscope or multimeter. It is always important to remember that a circuit diagram must be available for the system to be tested.



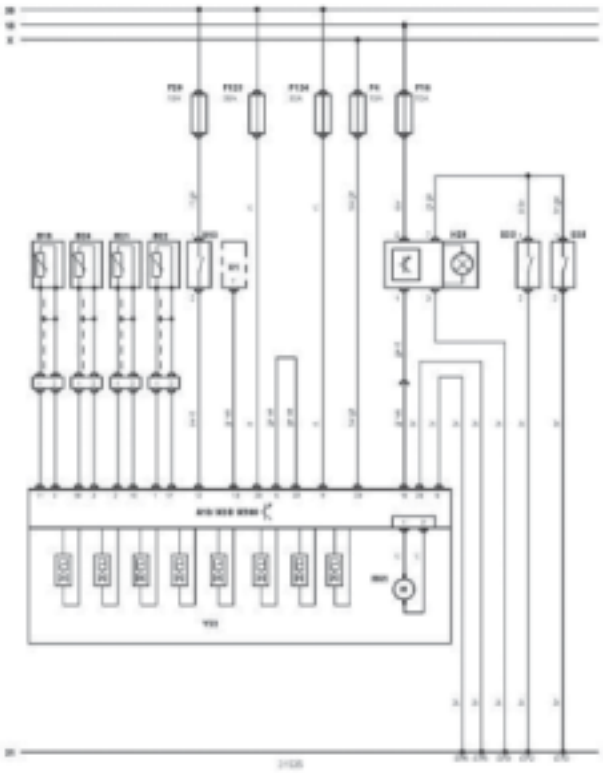
Experience has shown that most faults are caused by faulty connectors, broken cables or poor ground connections. These faults can usually always be found using a multimeter or oscilloscope.

Testing with the multimeter/oscilloscope

All the measurements listed here were carried out on a VW Golf 3 as an example. It is important for the battery voltage to be OK so that any drops in voltage at the cables/connectors can be recognised during measurement.



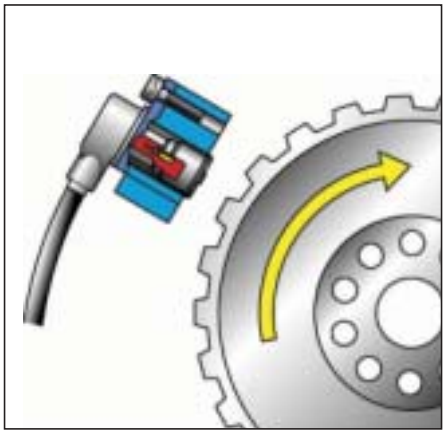
Control unit pin pattern



ABS circuit diagram

Measuring the voltage and ground supply at the control unit

To do this the connector has to be removed from the ABS control unit. Then read off the pin assignment on the circuit diagram and connect the red measuring cable of the multimeter to the respective pin of the voltage supply and the black measuring cable with any ground point on the vehicle. Make sure that the ground cable is clean and the measuring cable is well contacted. Be very carefully when connecting the control unit connector in order to avoid damage to the plug-type contacts. Carry out voltage measurement to check whether battery voltage is available. Use resistance measurement to test the ground connection of the control unit. To do this, look for the respective ground pins in the circuit diagram and connect the multimeter measuring cable. Connect the measuring cable to vehicle ground again. The resistance value should not exceed around 0.1 Ω (approximate value which can vary with cable cross-section and length).
If faults occur during voltage or resistance measurement, i.e. if there is no voltage supply or resistance is too high or infinite, the cables have to be traced back to the next connection. Existing connections are found in the circuit diagram. Separate these connections and test the cables for continuity and/or ground connection with the aid of resistance measurement. To do this, connect the measuring cables of the multimeter with the ends of the cables. The measured value should again be around 0.1 Ω. If the resistance is significantly higher or infinite, the cable is interrupted or connected to ground. This method can be used to determine a cable interruption or ground connection between every individual connection.



Testing the wheel speed sensors

To make the interpretation of the measured values easier, here is a brief explanation of inductive wheel sensor design and speed mapping.

Wheel speed sensors are attached directly above the trigger wheel which is connected to the wheel hub or drive shaft. The pole pin which is surrounded by a winding, is connected to a permanent magnet, the magnetic effect of which extends as far as the pole wheel. The rotary movement of the trigger wheel and the alternation of tooth and tooth gap linked with this has the effect of changing the magnetic flow through the pole pin and winding. This changing magnetic field induces a measurable alternating voltage in the winding. The frequency and amplitudes of this alternating voltage are in relation to the wheel speed.

Testing with the multimeter



Resistance measurement: Disconnect the sensor connector and use an ohmmeter to measure the internal resistance at the two connection pins. Important: Only carry out this measurement if you are sure it is an inductive sensor you are dealing with. Resistance measurement will destroy a Hall-type sensor.

The resistance value should be between 800 Ω and 1200 Ω (heed reference values). If the value is 0 Ω there is a short-circuit and if resistance is infinite this means there is an interruption in the cable. A ground connection test, from the respective connection pin to vehicle ground, has to result in an infinite resistance value.



Voltage test: Connect the multimeter to the two connection pins. The multimeter measuring range has to be set to alternating voltage. If the wheel is turned by hand, the sensor produces an alternating voltage of approx. 100 mV.



Testing with the oscilloscope: Using the oscilloscope it is possible to visualise the signal produced by the sensor in a graphic representation. To do this, connect the measuring cable of the oscilloscope to the sensor signal cable and the ground cable to a suitable ground point. The oscilloscope setting should be around 200 mV and 50 ms. When the wheel is turned – and the sensor is intact – a sinus signal will appear on the oscilloscope. The frequency and output voltage change depending on the wheel speed.



Testing the brake light switch: The brake light switch can be tested using a continuity test or voltage measurement. For the transmission test, the multimeter is set to a low resistance value or to acoustic test.
Disconnect the connector from the brake light switch and connect the measuring cables to the connector pins of the switch. When the brake pedal is activated, a resistance of approx 0 (Ohm symbol) must be indicated or a beep be heard, depending on the setting.
During the voltage test with the multimeter check the input voltage at the switch (value = battery voltage). With the brake pedal activated the battery voltage must also be present at the second connection pin.





Testing the high-pressure pump: Remove the connector from the high-pressure pump. Use two self-made cables to supply battery voltage briefly to the high-pressure pump. If the pump begins to work it can be assumed that it is OK.

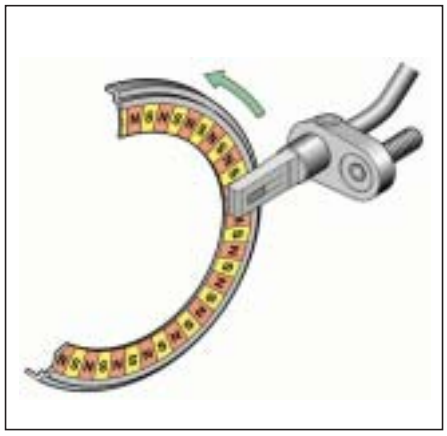
Testing with the diagnosis unit: If the ABS system can be diagnosed, a suitable diagnosis unit can be used to read out the fault store and scan the data lists.



There are great differences in how comprehensive the data lists are and also the range of components to be tested. The depth of testing possible is dependent on the diagnosis unit and the testing capabilities of the system manufacturer.

Active wheel speed sensors

Finally in this section, brief information on the subject of "active sensors". Active sensors are becoming more important all the time. They have several advantages in comparison to passive sensors. Their signals are much more accurate and they can measure speeds in both directions up to 0.1 km/h. The accurate measured data is useful for other systems such as the navigation system, hill-holder lock etc.. Furthermore, they also take up much less space thanks to their compact design.



Their design differs from passive sensors as follows:
The trigger wheel is no longer designed like a toothed wheel, it can be integrated in the sealing ring on the wheel bearing instead, for example. Magnets are inserted in the sealing ring which are arranged in alternating polarity around the circumference. This makes the sealing ring into a multi-pole ring. As soon as the multi-pole ring begins to rotate, the magnetic flow through the measuring cell changes constantly in the sensor. The magnetic flow influences the voltage produced in the sensor. The sensor is connected to the control unit by a two-wire cable. The speed information to the control unit is transmitted as current. The current frequency (similarly to the frequency in inductive sensors) is the comparison to the wheel speed. The voltage supply of the active sensor – another difference to the passive sensor – is between 4.5 V and 20 V.

The exhaust gas recirculation system

Ever more stringent laws have made it necessary to reduce exhaust emissions further. This is applicable both for diesel and petrol engines. Nitrogen oxide emissions are reduced with the aid of the so-called exhaust gas recirculation method. In the case of petrol engines, the fuel consumption is also reduced in the part-load range.

At high combustion temperatures nitrogen oxides are produced in the engine combustion chamber. Recirculating part of the exhaust gas to the fresh air charge reduces the combustion temperature in the combustion chamber. The lower combustion temperature prevents nitrogen oxides being produced.

The exhaust gas recirculation rate in diesel and petrol engines is made clear by the following table:

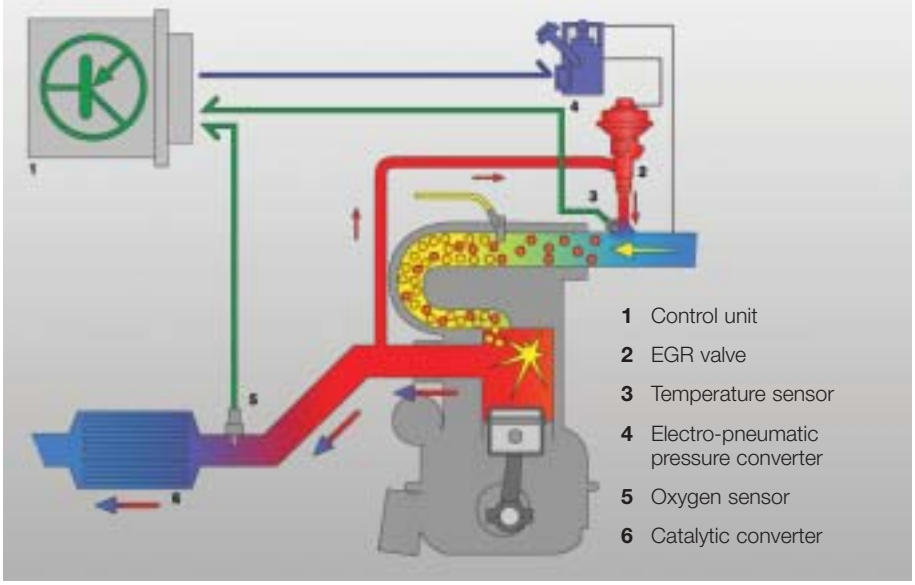
	Diesel	Petrol	Petrol (direct injection)
EGR rage (max.)	50 %	20 %	Up to 50 % (depending on engine operation, homogeneous or layered load)
Exhaust temperature when the EGR system is active	450 °C	650 °C	450 °C to 650 °C
Why is an EGR system used?	Reduction of nitrogen oxides and noise	Reduction of nitrogen oxides and consumption	Reduction of nitrogen oxides and consumption

How does exhaust gas recirculation take place?

A distinction is made between two kinds of exhaust gas recirculation: "inner" and "outer" exhaust gas recirculation.

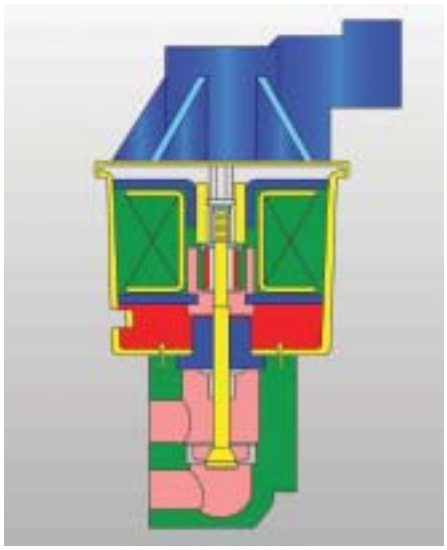
With inner exhaust gas recirculation, exhaust gas and fresh air/fuel mixture are mixed within the combustion chamber. In all four-stroke engines this is achieved by means of system-specific valve overlap of inlet and outlet valve. On account of the design the exhaust gas recirculation rate is extremely low and can only be influenced to a limited extent. It is only since the development of variable valve control that active influence on the recirculation rate has been possible, depending on load and speed.

EGR system



Outer exhaust gas recirculation takes place via an additional line between the exhaust manifold/pipe and the intake manifold as well as the EGR valve.
The first systems were controlled by a poppet valve which is opened or closed by a vacuum advance unit (pneumatic drive). The intake pipe pressure served as a control parameter for the vacuum advance unit. This meant that the position of the poppet valve depended on the engine's operating state.
To gain more influence on the exhaust gas recirculation rate, pneumatic check valves and pressure control valves as well as delay valves were installed. Some systems also take the exhaust backpressure into account as regulating pressure for the vacuum advance unit. In some operating states exhaust gas recirculation is switched off completely. This is made possible by installing electrical changeover valves in the control line.
Despite these possibilities of influencing the system, it was always dependent on the engine load state and the vacuum in the intake pipe linked to this to control the vacuum advance unit.

To meet the requirements of modern engines and become independent of intake pipe vacuum, electrical drives were developed for exhaust gas recirculation valves. At the same time sensors were integrated which detect valve position.
These developments made exact control with short adjustment times possible. Today, direct current motors are also used as electrical drives alongside stepper motors, lifting and rotary magnets. The actual control valve itself has also been changed with time. Alongside needle and poppet valves with different sizes and dimensions, rotary and flap valves are now also used.



Electrical EGR valve

Exhaust gas recirculation system components



Installed EGR valve



Pressure converter

Exhaust gas recirculation valve:
The exhaust gas recirculation valve is the most important component in the system. It is the connection between the exhaust pipe and the intake tract. Depending on the control command, it releases the valve opening and allows exhaust gas to flow into the intake manifold.
There are various versions of the exhaust gas recirculation valve available: Single or double diaphragm versions, with and without position feedback or temperature sensor and of course electrically controlled.
Position feedback means that a potentiometer is attached to the exhaust gas recirculation valve and provides the control unit with signals indicating the valve position. This makes it possible to accurately map the amount of exhaust gas recirculated in every load state. A temperature sensor can be used for self-diagnosis on the exhaust gas recirculation valve.

Pressure converter:
Pressure converters have the task of controlling the necessary vacuum for the exhaust gas recirculation valve. They adapt the vacuum to the respective engine load state in order to achieve an exactly specified recirculation rate. They are triggered either mechanically or electrically.

Thermal valves:
They have a similar task to the pressure converters but work depending on temperature. Pressure converters and thermal valves can also be combined.

Faults which occur and their causes

On account of the high loads involved the EGR valve is the greatest fault source of course. Atomised fuel oil and soot from the exhaust gas soots the valve and reduces the cross-section of the valve opening with time until it is completely blocked. This leads to a continual reduction in the amount of exhaust gas recirculated which is reflected in the exhaust gas behaviour.
The high thermal load further favours this process. The vacuum hose system is also a frequent cause of system faults. Leaks reduce the vacuum required for the EGR valve and the valve no longer opens.
An EGR valve which is not working on account of a lack of vacuum can of course also be caused by a faulty pressure converter or a thermal valve not working properly.

There are various possibilities of checking the exhaust gas recirculation system. These depend on whether the system can carry out self-diagnosis or not. Systems that cannot carry out self-diagnosis can be tested using a multimeter, a manual vacuum pump and a digital thermometer.

Before complicated tests are started, however, a visual inspection of all system-related components must be carried out.
This means:

- Are all the vacuum lines airtight, connected correctly and laid without any kinks?
- Are all the electrical connections on the pressure converter and change-over switch connected properly? Are the cables OK?
- Are there any leaks in the EGR valve or the connected lines?

If the visual inspection does not reveal any faults, further tests and measurements must be used to test the system.

Testing vacuum-controlled EGR valves on petrol engines:

The following procedure must be used when testing vacuum-controlled EGR valves:

Valves with one diaphragm
With the engine switched off, remove the vacuum line and connect the manual vacuum pump. Produce a vacuum of approx. 300 mbar. If the valve is OK, the pressure must not drop within 5 minutes. Repeat the test with the engine running and at operating temperature. At a pressure difference of approx. 300 mbar the idling speed has to fall or the engine die. If the valve is equipped with a temperature sensor, this can also be tested. To do this remove the temperature sensor and measure the resistance. The approximate resistance values for the individual temperatures are listed in the following table:

Temperature	Resistance
20°C	> 1000 k Ω
70°C	160 - 280 k Ω
100°C	60 - 120 k Ω

Use a heat gun or hot water for heating. Use the digital thermometer to test the temperature and compare the measured values with the reference values.

Valves with two diaphragms
Valves with vacuum connections offset at the side are only opened by one connection. These can be arranged above one another or side by side on one level. Valves which have vacuum connections arranged above one another work in two stages. The valve is opened partly over the upper connection and completely over the lower connection. Valves with vacuum connections offset at the side are only opened by one connection. The connections are colour coded. The following combinations are possible:

- Black and brown
- Red and brown
- Red and blue

The vacuum supply is connected to the connection marked red or black.

Leak tests are carried out under the same conditions as for valves with one diaphragm but must be carried out at both vacuum connection points. To check the vacuum supply to the valve, the manual vacuum pump can be used as a manometer. It is connected to the supply line to the EGR valve. The vacuum present is displayed with the engine running. In the case of valves with connections arranged above one another, the hand vacuum pump must be connected to the line of the lower connection, in the case of side by side connections to the line to the red or black connection.

EGR valves on diesel engines

EGR valves on diesel engines can be tested in the same way as on petrol engines.
A vacuum of approx. 500 mbar must be produced by the manual vacuum pump with the engine switched off. This vacuum must be retained for 5 minutes and must not fall. A visual inspection can also be carried out. To do this, use the hand vacuum pump again to produce a vacuum via the vacuum connection. Observe the valve rod (connection between diaphragm and valve) through the openings. It has to move proportionally to the activation of the manual vacuum pump.

Leak test on an EGR valve



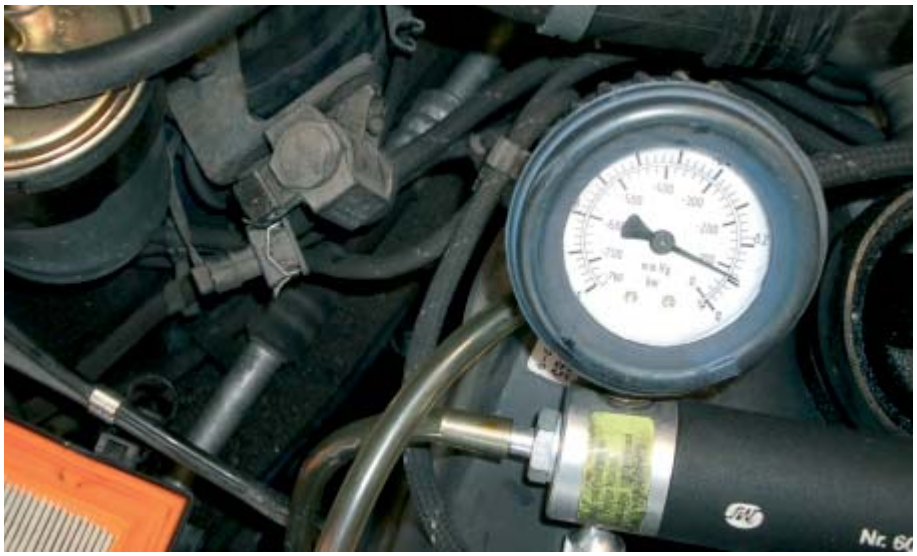
EGR valves with potentiometer
Some EGR valves have a potentiometer for valve position feedback. The EGR valve is tested as described above. Proceed as follows when testing the potentiometer:
Remove the 3-pin connector and use a multimeter to measure the overall resistance at pin 2 and pin 3 of the potentiometer. The value measured must be between 1500 Ω and 2500 Ω. To measure the resistance of the loop track the multimeter has to be connected to pin 1 and pin 2. Slowly open the valve using the manual vacuum pump. The value measured starts at approx. 700 Ω and increases to 2500 Ω.

Testing pressure converters, changeover valves and thermal valves

Testing mechanical pressure converters:
In this test the manual vacuum pump is not used to produce a vacuum but rather as a manometer. Remove the vacuum hose from the pressure converter to the EGR valve at the pressure converter and connect the vacuum pump. Start the engine and slowly move the pressure converter rods. The manometer display of the vacuum pump has to move accordingly.

Testing a pressure converter

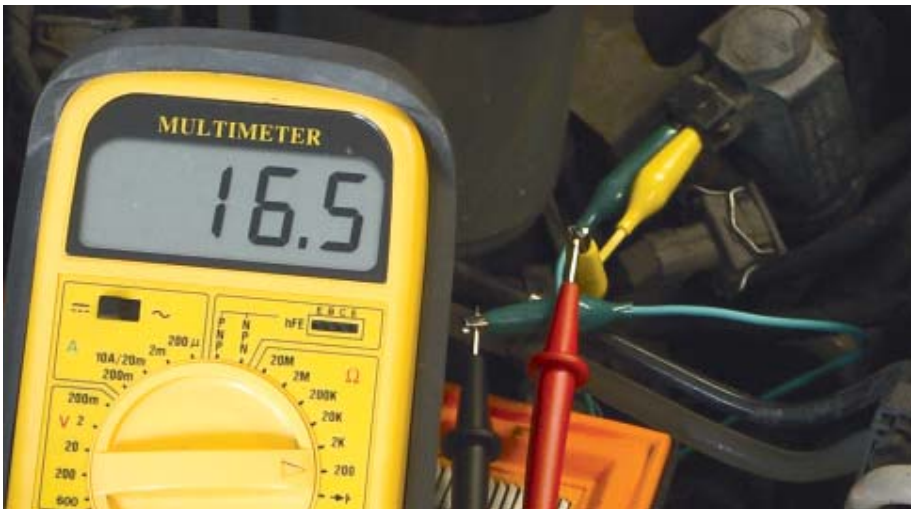
Testing electro-pneumatic pressure converters:
Here, too, the manual vacuum pump is again used as a manometer. The connection at the electro-pneumatic pressure converter is again to the vacuum connection which leads to the EGR valve. Start the engine and remove the connector from the electronic pressure converter connection. The vacuum displayed on the manometer must not exceed 60 mbar. Replace the connector and increase the engine speed. The value displayed on the manometer must increase at the same time.



To test the resistance of the pressure converter winding, remove the electrical connector again and connect a multimeter to the two connector pins. The resistance value should be between 4 Ω and 20 Ω.

In order to test the triggering of the pressure converter, connect the multimeter to the pin connections and observe the voltage value displayed. This has to change with engine speed.

Measuring resistance at the pressure converter



Testing electrical pressure converters:
The method for testing electrical pressure converters is identical to the test for electrical changeover valves.

Testing electrical changeover valves:
Electrical changeover valves have three vacuum connections. If only two of the connections are occupied, the third has a sealing cap fitted which must not be airtight.

For the test, an operation test can be carried out at the output lines of the changeover valve using the manual vacuum pump. To do this connect the valve pump to an output line. If a vacuum can be produced, voltage must be supplied to the changeover valve. Important: If polarity (+ and -) is specified at the changeover valve connection, this must not be confused. When voltage is applied to the changeover valve, it has to change over and the vacuum produced is reduced. Repeat the test for the other connection.

Testing thermal valves
The vacuum hoses have to be removed for testing thermal valves. Connect the manual vacuum pump to the central connection. When the engine is cold the thermal valve must not be open. If the engine is at operating temperature, the valve has to open. To be independent of the engine temperature, the thermal valve has to be removed and heated in a water bath or using a hot air blower. The temperature must be monitored continually in order to find out the switching points.

All the testing values listed here are approximate values. To receive exact values, vehicle-specific circuit diagrams and testing values must be available.

Testing with a diagnosis unit:

EGR systems capable of diagnosis can be tested using a suitable diagnosis unit. Here again, the testing depth of the unit used and the system to be tested may vary. Sometimes it is only possible to read out the fault store, sometimes the measured value blocks can be read out and an actuator test carried out.

EGR data list



EGR actuator test



In this context it is important that components that only have an indirect influence on the EGR system are also tested.
The mass air flow meter or engine temperature sensor, for example.
If the control unit receives an incorrect value from the mass air flow meter, the amount of exhaust gas recirculated will also be calculated incorrectly. This can lead to worsening of the exhaust values and serious engine running problems.
In the case of electrical EGR valves it is possible that no faults are indicated during diagnosis and that an actuator test does not provide any clues to the problem. In this case the valve can be heavily soiled and the valve opening no longer opened to the cross-section requested by the control unit.
In such cases it is advisable to remove the EGR valve and check it for soiling.

Evaporative emission control and recirculation system

General points

When vehicles are parked up, fuel evaporates and escapes into the atmosphere via the fuel tank vent line. To avoid this pollution, vehicles with controlled carburation systems have an evaporative emission control and recirculation system. An important component in this system is the activated carbon canister.

Function



Activated carbon canister

The activated carbon canister is connected to the tank fuel tank vent line. The activated carbon stores the evaporated fuel. When the engine is started up, the stored fuel is integrated in the carburation process. There is a stroke valve located in the line connecting the intake pipe and the activated carbon canister. As soon the oxygen sensor control is active, the stroke valve is triggered and releases the line between the intake pipe and the activated carbon canister. The vacuum in the intake pipe causes ambient air to be taken in through an opening in the activated carbon canister. This flows through the activated carbon and carries the stored fuel along with it. Since the system influences the composition of the air/fuel mixture, it does not become active until the oxygen sensor control starts to work.

Effects of failure



Stroke valve

A failure of the system can be expressed as follows:

- A fault code is stored
- Poor engine performance
- Smell of petrol due to escaping fuel fumes

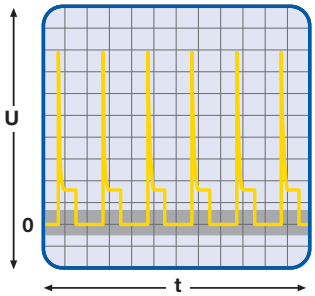
A non-functioning system can have various causes:

- Not triggered by the control unit
- Faulty stroke valve
- Mechanical damage (accident)
- Faulty lines

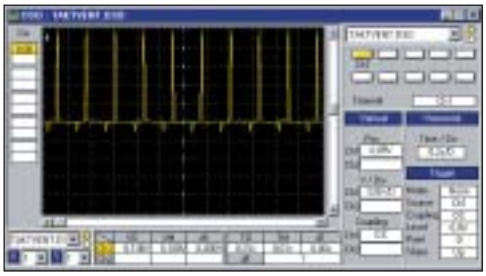
Troubleshooting

The following should be taken into account during troubleshooting:

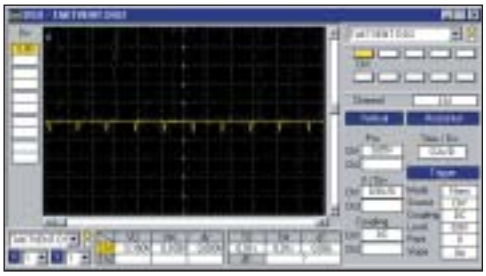
- Check the activated carbon canister for damage
- Check the hoses, lines and connections for damage and correct fit/installation.
- Check the stroke valve for damage
- Check the electrical connections of the stroke valve for damage and correct installation.
- Test the ground and voltage supplies. To do this remove the connector on the stroke valve. With the engine at operating temperature, a voltage of approx. 11 – 14 V must be applied (engine must be warm for the oxygen sensor control to be active – otherwise the stroke valve cannot be triggered).
- Testing with the oscilloscope: Connect the measuring cable from the oscilloscope to the ground cable of the stroke valve. Adjust the measuring range, x-axis = 0.2 seconds, y-axis = 15 V. Signal see image.



Stroke valve
optimum image



Live image stroke valve OK



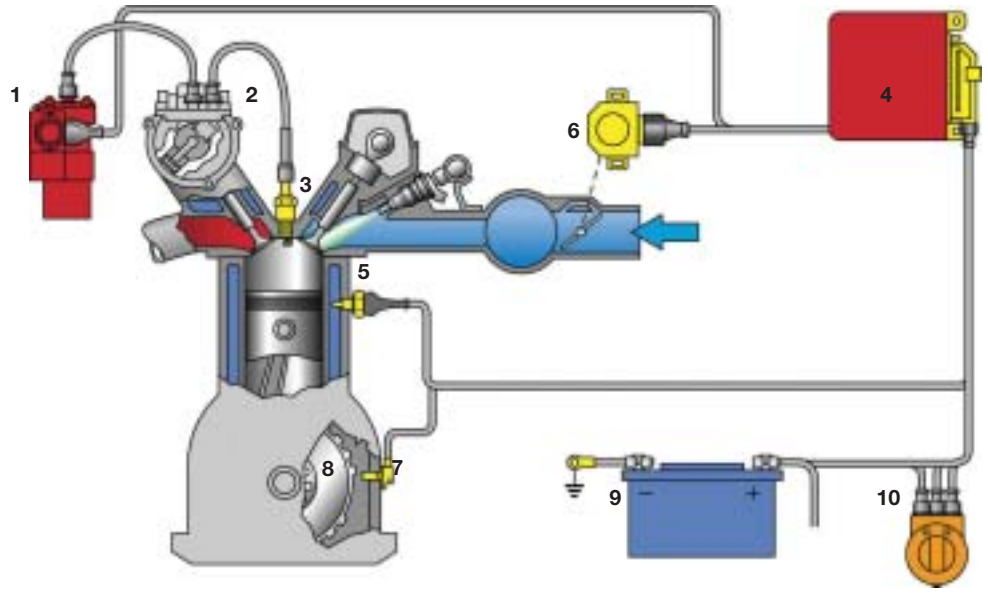
Live image stroke valve with fault

This issue will explain the more recent ignition system developments
- electronic ignition (EZ) and
- y electronic ignition (VZ).
It will go into the structure and function of these systems, and possible faults and diagnoses will also be illustrated.

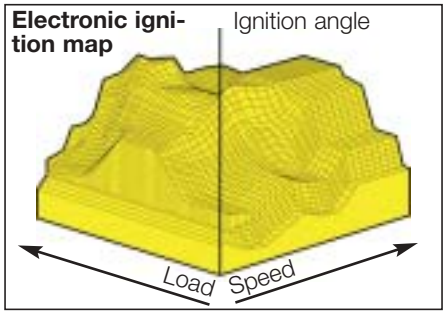
Electronic ignition

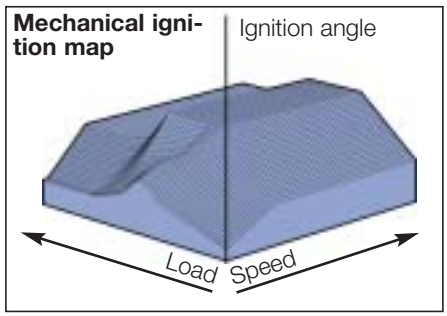
The straightforward adjustment curves of centrifugal and vacuum control of a conventional distributor are no longer sufficient to meet the requirements of optimum engine operation.

For this reason, sensor signals are used with electronic ignition to determine the ignition point. These make mechanical ignition timing a thing of the past. A speed signal and additional load signal are evaluated in the control unit to trigger the ignition. These values are used to calculate optimum ignition timing and then forwarded to the switching unit via the output signal.



1 Ignition coil with mounted ignition output stage
2 High-voltage distributor
3 Spark plug
4 Control unit
5 Engine temperature sensor
6 Throttle valve sensor
7 Speed and reference mark sensor
8 Toothed wheel
9 Battery
10 Ignition start switch





The signal produced by the vacuum sensor is used by the ignition as a load signal. This signal and the speed signal are used to produce a three-dimensional ignition map. This map makes it possible to program the best possible ignition angle for every speed and load state. A map contains up to 4000 different ignition angles, resulting in different curves for certain operating states. If the throttle valve is closed, a curve for idling/overrun is chosen. This makes it possible to stabilise idling and take driving behaviour and exhaust emission values into account in overrun. At full load the most favourable ignition angle is selected taking the knock limit into account.

Input signals

The two important parameters for determining the ignition point are speed and intake pipe pressure. There are various other signals too, however, which are recorded and evaluated by the control unit to correct the ignition point.



Crankshaft sensor

Speed and position of the crankshaft
An inductive sensor which scans a gear rim on the crankshaft is often used to map the speed and position of the crankshaft. The change in magnetic flow produced induces an alternating voltage which is evaluated by the control unit. This gear rim has a gap to allow the position of the crankshaft to be determined. This is detected by the control unit on the basis of the change in signal.

Intake pipe pressure (load)
An intake pipe pressure sensor is used to map the intake pipe pressure. This is connected to the intake pipe by a hose. Alongside this "indirect intake pipe pressure measurement", intake air mass or quantity of air per time unit are also particularly suitable for determining the load. For this reason the signal used by the fuel injection system in engines with electronic fuel injection systems can also be used by the ignition system

Position of the throttle valve
The position of the throttle valve is determined through the throttle valve switch. This provides a switching signal at idling or full load.

Temperature
A temperature sensor installed in the engine cooling circuit is used to record engine temperature and transmit the signal to the control unit. In addition, or in place of the engine temperature, the intake air temperature can be recorded by a further sensor.

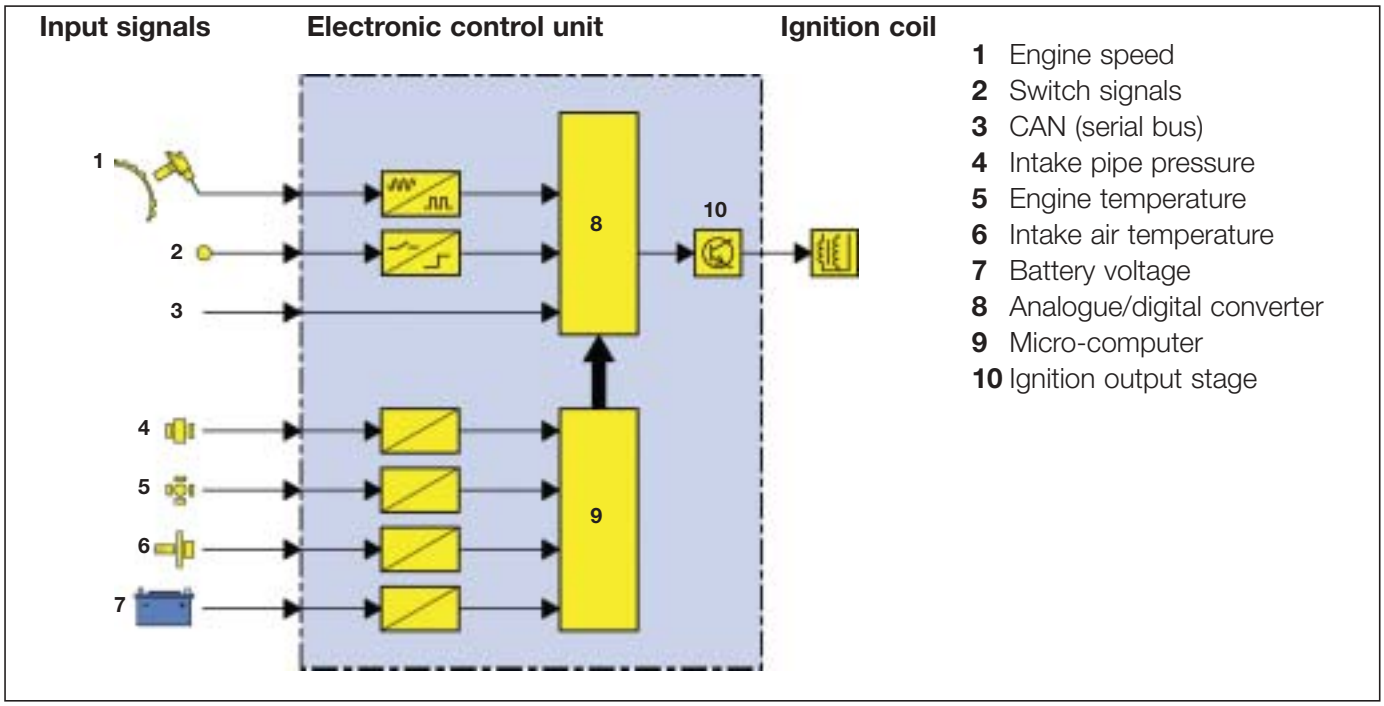
Battery voltage
Battery voltage is also taken into account as a correction parameter by the control unit.

Processing the signals

The digital signals of the crankshaft sensor (speed and position of the crankshaft) as well as the throttle valve switch are processed directly by the control unit. The analogue signals from the intake pipe pressure and temperature sensors as well as the battery voltage are transformed into digital signals in the analogue/digital converter. The control unit calculates and updates the ignition point for every ignition process in every operating state of the engine.

Ignition output signal

The primary circuit of the ignition coil is switched by a power output stage in the control unit. The secondary voltage can be kept almost constant by controlling the contact time. Independent of the engine speed and battery voltage.



In order to determine a new contact time and/or contact angle for every speed and battery voltage point, a further map is required: the contact angle map.
It is built up in a similar way to the ignition map. A three-dimensional net is spread across the axes – speed, battery voltage and contact angle – and is then used to calculate the respective contact time. Using such a contact angle map makes it possible to apportion energy in the ignition coil as accurately as with contact angle control.

Further output signals

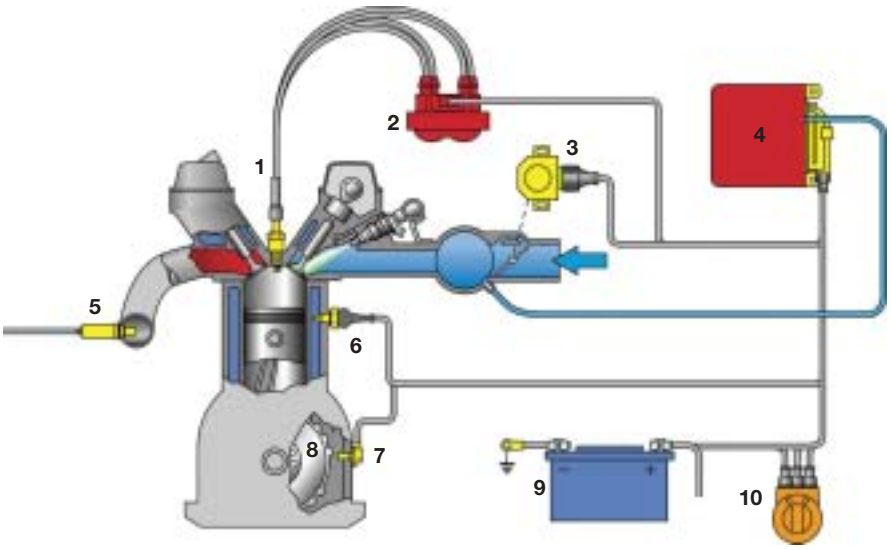
Apart from the ignition output stage, the control unit can output further signals. These can be speed and state signals for other control units – such as for fuel injection, or can be diagnosis and switching signals for relays.

The electronic ignition system is particularly suitable for combination with other engine control functions. Combined with electronic fuel injection, it results in the basic Motronic version in a control unit.

The combination of electronic ignition and knock control has also become standard, since ignition retard is the simplest, quickest and safest way to avoid engine knocking.

Fully electronic ignition

The difference between fully electronic ignition and electronic ignition is the high-voltage distribution. The electronic ignition works with a rotating high-voltage distribution – the ignition distributor – whereas the fully electronic ignition works with a static or electronic high-voltage distribution.



1 Spark plug
2 Double spark ignition coil (2x)
3 Throttle valve sensor
4 Control unit with built-in output stages
5 Oxygen sensor
6 Engine temperature sensor
7 Speed and reference mark sensor
8 Toothed wheel
9 Battery
10 Ignition start switch

This results in the following advantages:
- Rotating parts are no longer required.
- Lower noise level.
- Significantly lower disturbance levels since there are no longer any open sparks.
- The number of high-voltage cables is reduced.
- Design advantages for engine builders.

Voltage distribution with fully electronic ignition





Double spark ignition coils

n systems with double spark ignition coils two spark plugs are supplied with high voltage from one ignition coil. Since the ignition coil produces two sparks at once, one spark plug has to be in the power stroke and the other in the exhaust stroke, turned through 360°.

In a four-cylinder engine, for example, cylinders 1 and 4 are connected to one ignition coil and 2 and 3 to another. The ignition coils are triggered by the ignition output stages in the control unit. This receives the TDC signal from the crankshaft sensor in order to begin triggering the right ignition coil.

Single spark ignition coils

In the case of systems with single spark ignition coils, one ignition coil is allocated to each cylinder. These ignition coils are usually installed directly on the cylinder head above the spark plug. Triggering takes place in the sequence specified by the control unit.

The control unit of a single spark system requires a camshaft sensor as well as a crankshaft sensor in order to distinguish between the compression and charge changing TDC. Switching an individual spark coil corresponds to the switching of a conventional ignition coil.

An additional component in the secondary circuit is a high-voltage diode to suppress the so-called closing spark. This undesirable spark which is produced by a self-induction voltage in the secondary winding when the primary winding is switched on, is suppressed by the diode. This is possible since the secondary voltage of the closing spark has the opposite polarity to the ignition sparks. The diode blocks in this direction.

With single spark coils the second output of the secondary winding is connected to ground via terminal 4a. To be able to monitor the ignition, a measuring resistor is installed in the ground cable which measures the drop in voltage produced by the ignition current during spark arc-over.

Single spark coils are available in different versions. As individual ignition coils (e.g. BMW), for example, or as a coil block where the individual coils are contained in a plastic housing (e.g. Opel).

Faults which occur and their diagnosis

There are usually some faults which occur in all kinds of ignition systems and are often repeated. These faults range from the extreme, where engines do not start up or keep stalling, to skipping, juddering, backfiring or poor performance. These faults can occur under all or only certain operating conditions and external conditions, such as when the engine is hot or cold or in humid conditions.



If faults occur in an ignition system, a lengthy troubleshooting process could be necessary. To save unnecessary work, this process should again begin with a visual inspection of the system.

- Are all cables and connectors routed and connected properly?
- Are all the cables OK?
- Are the spark plugs, cables and connectors OK?
- Are the ignition distributor and the rotor in a good state?
- Are any ground cables connected/oxidised?

If no faults or defects can be detected during visual inspection, we recommend testing the ignition system using the oscilloscope. The evaluation of the primary and secondary oscillograms allows conclusions to be drawn about all parts of the ignition system.

Connecting the oscilloscope

The connection of the oscilloscope does not usually present a problem in the case of electronic ignition systems with a rotating voltage distribution. In this case all the high-voltage cables are accessible. The oscilloscope connection cable for terminal 4 and the trigger probe can be connected directly. This is also applicable for single spark coils which are not attached to spark plugs. The high-voltage cables are usually accessible here, too.



More of a problem is presented by single spark coils which are directly attached to the spark plugs. An adapter cable set makes it possible to record the primary and secondary oscillogram at the same time for all cylinders (e.g. BMW). If there is no adapter cable set available, a self-made intermediate cable can be used to create a possibility of recording the secondary oscillogram. The intermediate cable is made of a spark plug connector that fits the spark plug, a piece of ignition cable and the suitable connection to the ignition coil. Remove the ignition coil and connect the self-made cable between the spark plug and the coil.

The secondary probe can be attached to the intermediate cable. The oscilloscope image can be stored and the process repeated for all the other cylinders. It is possible to subsequently compare the stored images.

If the output stage is housed in the single spark coil (e.g. with VW FSI) primary voltage can no longer be measured. The control unit sends control pulses only to the ignition coil. In this case a current measurement probe can be used to measure the primary current at the plus or ground cable of the ignition coil. An intermediate cable for oscilloscope connection must again be used to measure the secondary voltage. These ignition systems are equipped with misfiring detection which recognises any misfiring which may occur. With vehicles which have double ignition and single spark coils (e.g. Smart), a two-channel oscilloscope can also be used to record the primary or secondary voltage.

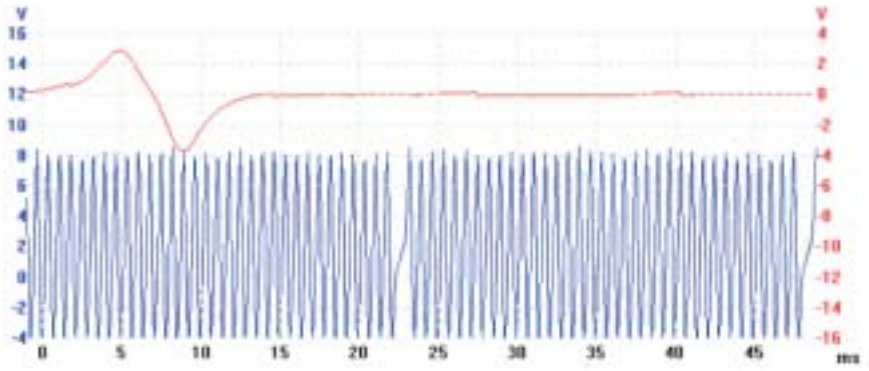
Further tests on single spark coils

A further testing possibility is to measure resistance. The problem with single spark coils with a high-voltage diode is that only measurement of the primary range is possible. Since the voltage drop on the diode in the direction of conduction is so high, no statements can be made about the secondary voltage.



In such cases, the following procedure can be used instead:
Connect a voltmeter in series to the secondary winding of the ignition coil on a battery. If the battery is connected in conduction direction of the diode, the voltmeter has to display a voltage. After the connections have been reversed in the diode blockage direction, no voltage may be displayed. If no voltage is displayed in either direction, an interruption in the secondary area can be assumed. If a voltage is displayed in both directions, the high-voltage diode is faulty.

Testing the sensors
Since the signals of the crankshaft and camshaft sensors are absolutely necessary for the function of the electronic ignition, it is very important to test them during troubleshooting. Here, too, the signal can be recorded using an oscilloscope. A two-channel oscilloscope makes it possible to record and display the two signals at the same time.



Camshaft sensor versus crankshaft sensor

A further important sensor for determining the ignition point is the knock sensor. The knock sensor can also be tested using the oscilloscope. To do this, connect the oscilloscope and use a metal object (hammer, spanner) to tap the engine block lightly near the sensor.

Tests using a diagnosis unit:



Depending on the vehicle system and diagnosis unit it is possible to recognise faults in the ignition system. Faulty sensors or a failed ignition coil – if misfiring control is available – can be recorded as a fault code.

During all testing work on the ignition system it must not be forgotten that faults determined during a test with the oscilloscope are not only due to problems with the electronics but could also be caused by mechanical engine problems. This can be the case, for example, if the compression is too low on one cylinder, leading to a lower ignition voltage being displayed by the oscilloscope for this cylinder than for the others.

Increasingly high demands are being made of vehicles today. Requirements of driving safety, comfort, eco-friendliness and economy are continually increasing.

Development times for new technologies are becoming shorter, while the objectives of development engineers are becoming more and more ambitious. This is progress - and it's a good thing. We have it to thank for such developments as ABS, airbags, fully automatic air conditioning systems … to mention only a few examples from the wide range or technical innovations to be integrated in vehicles in the last ten years.

This development has also meant an increase in the share of electronic systems. Depending on vehicle class and equipment features, modern vehicles have between 25 and 60 electronic control units, all of which need to be wired up.
If conventional wiring were used, cables, connectors and fuse boxes would take on enormous proportions which would result in complex production processes. Not to mention the problems that would occur during troubleshooting on such vehicles. Mechanics often face a difficult an arduous and lengthy troubleshooting process that works out expensive for the customer. Data exchange between the control units also reaches the limit of feasibility using this technology.

For these reasons, in 1983 the automotive industry demanded the development of a communication system that would be in a position to link the control units together and achieve the required data exchange. The system was to fulfil the following properties:

- Favourable price for series application
- Real time ability for quick processes
- High reliability
- High safety level against electromagnetic interference

The most common bus system is the CAN data bus.

History of the CAN data bus:

1983	Start of CAN development (Bosch).
1985	Start of cooperation with Intel for chip development.
1988	The first CAN series type is available from Intel. Mercedes Benz begins CAN development in the automotive field.
1991	First use of CAN in a standard vehicle model (S-Class).
1994	An international standard is introduced for CAN (ISO 11898).
1997	First use of CAN in vehicle interior (C-Class).
2001	Entry of CAN in compact vehicles (Opel Corsa) in the power train and bodywork fields.

What does CAN mean?

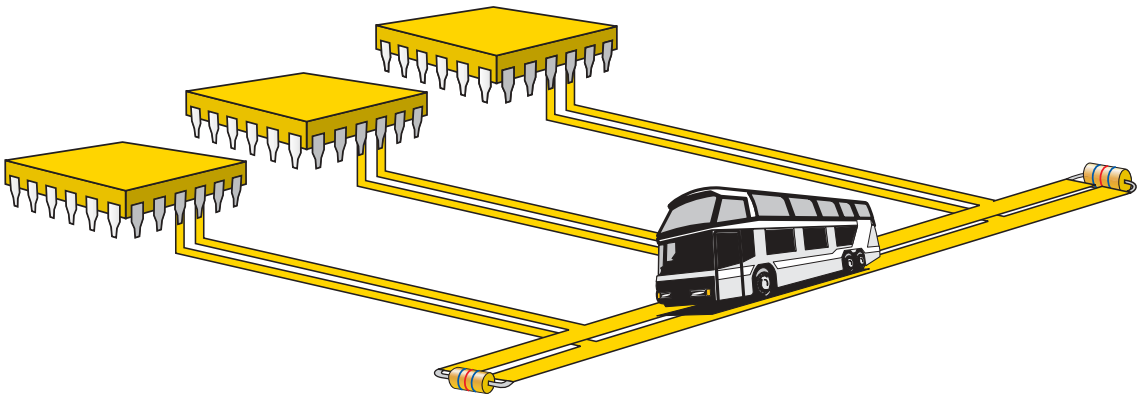
CAN stands for Controller Area Network

Advantages of the CAN data bus:

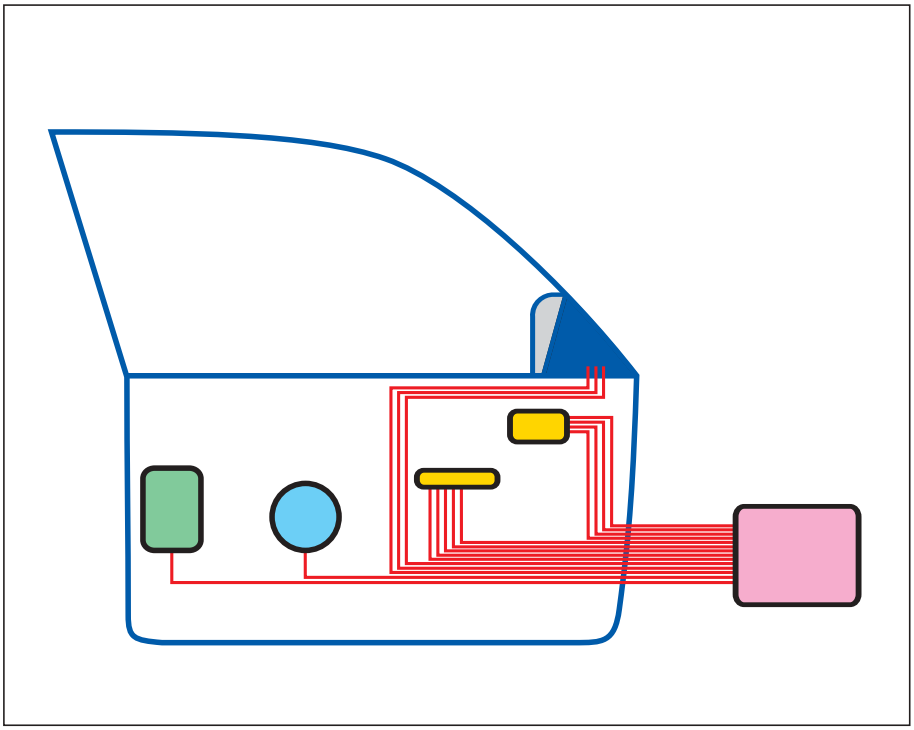
- Data exchange in all directions between several control units.
- Multiple use of sensor signals is possible.
- Extremely quick data transmission.
- Low fault rate thanks to numerous controls in the data protocol.
- Usually, software modifications alone are sufficient for extensions.
- CAN is standardised the world over, i.e. data exchange is possible between control units from different manufacturers.

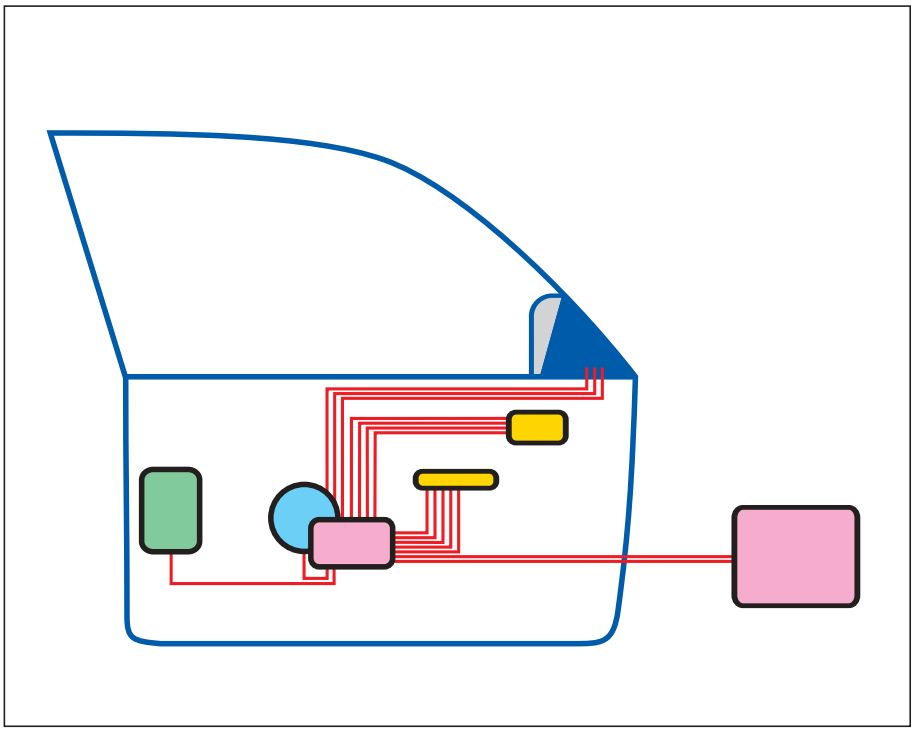
What is a CAN data bus?

A CAN bus can be compared with a normal bus. Just as a bus transports lots of people, the data bus transports large amounts of information.



Without a data bus, all the information has to be guided to the control units via a number of cables.
This means a cable exists for each individual piece of information.

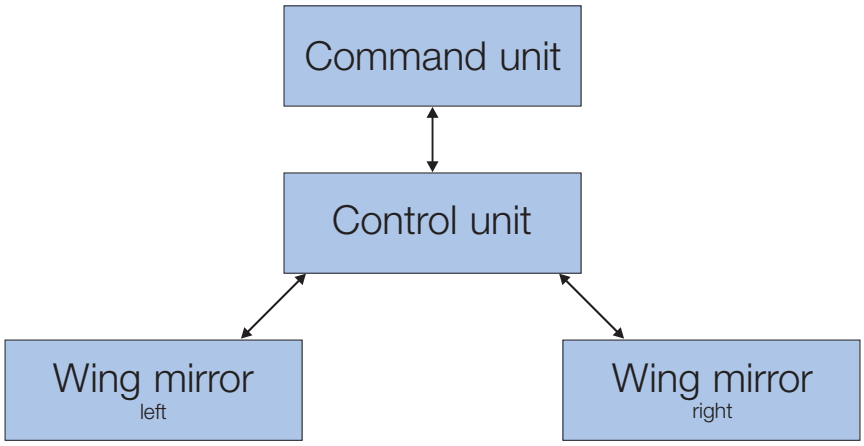




With the data bus, the number of cables is significantly reduced.
All the information is exchanged via a maximum of two cables between the control units.
There are different connection techniques (networks) used for automotive applications. A brief summary of the techniques and their properties is given below.

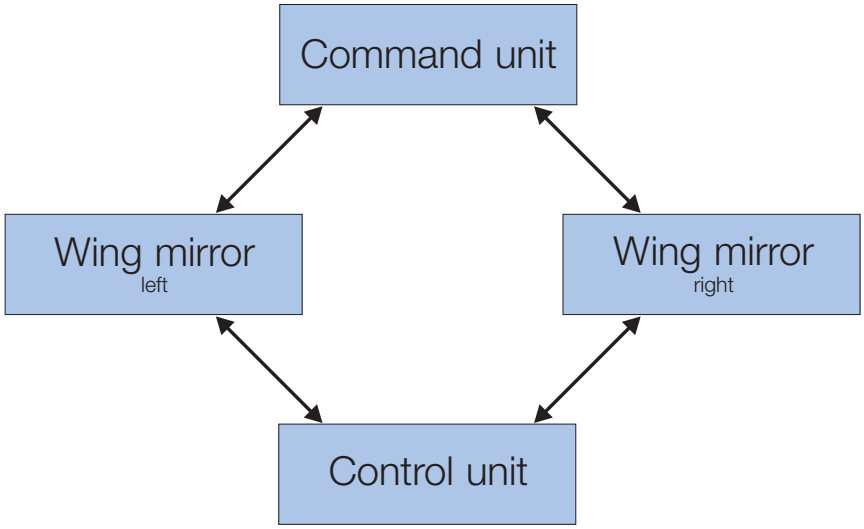
Star structure

- With the star structure, all bus participants are connected to a central unit (control unit).
- If the control unit fails, the connection is disturbed.



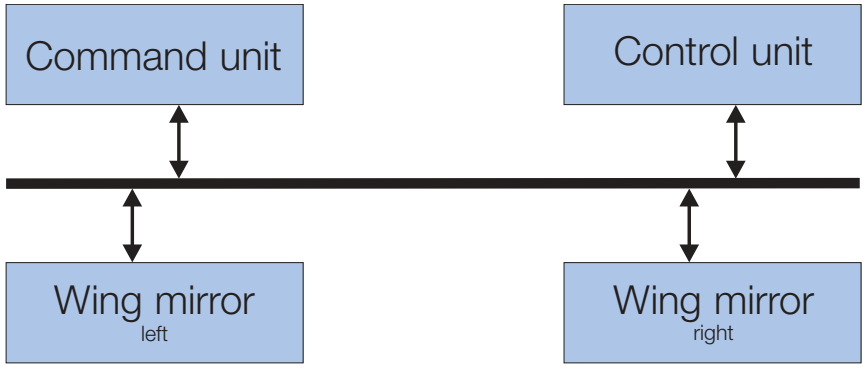
Ring structure

- With the ring structure, all participants are equal-access.
- To get from device A to device B, a piece of information usually has to travel through another device.
- If a device fails, this leads to failure of the complete system.
- Updates are easy to carry out but require operation to be interrupted.



Linear structure

- The signal is propagated by the transmitter in one or both directions.
- If one device fails, the others are still in a position to communicate with one another.



Since the linear structure is the one most frequently used in vehicles, this issue will mainly provide information about this type of CAN-bus structure.

Structure of the data bus system

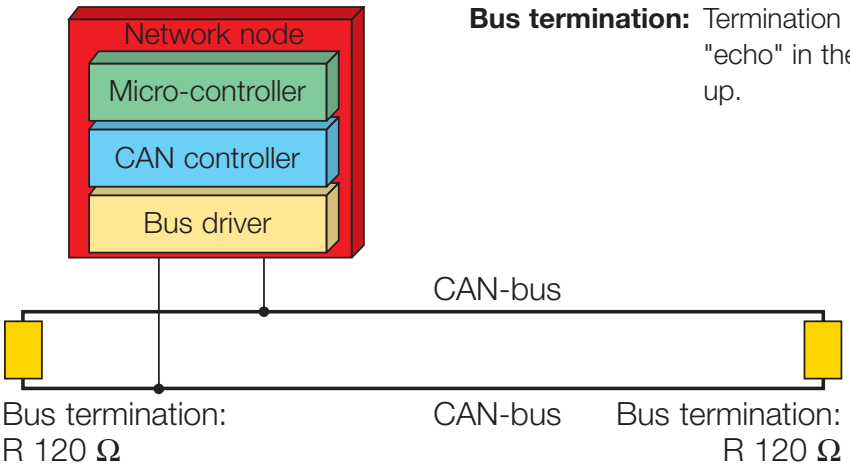
Network node: (control unit) This houses the micro-controller, the CAN controller and the bus driver.

Micro-controller: Is responsible for controlling the CAN controller and processes the transmission and received data.

CAN controller: Is responsible for transmission and receive mode.

Bus driver: Transmits or receives the bus level.

Bus cable: Is a two-wire cable (for both signals; CAN-High and CAN-Low). The cables are twisted to reduce electromagnetic interference.



Bus termination: Termination resistors with 120 Ω each prevent an "echo" in the cable ends and thus avoid signal break-up.

How does a data bus work?

Data transmission using the CAN data bus works in a similar way to a telephone conference. A participant (control unit) "speaks" its information (data) into the cable network, while the other participants "listen in" on this information. Some participants find the information interesting and use it. Others simply ignore it.

Example:
A car starts to move without the driver door being closed properly. For the driver to be warned, the check-control module, for example, requires two pieces of information.

- Vehicle is moving.
- Driver door is open.

The information is recorded or produced respectively by the door contact sensor / wheel speed sensor and converted into electrical signals. In turn, these are converted into digital information by the respective control units and then transmitted as a binary code through the data line until they are picked up by the receiver.
In the case of the wheel rotation signal, the signal is also required by other control units, e.g. the ABS control unit. This also applies to some vehicles which are equipped with an active chassis. With this system, the distance to the roadway is changed to optimise road holding depending on the vehicle speed.
Thus all the information is passed via the data bus and can be analysed by every participant.

The CAN data bus system has been designed as a multi-master system, i.e.

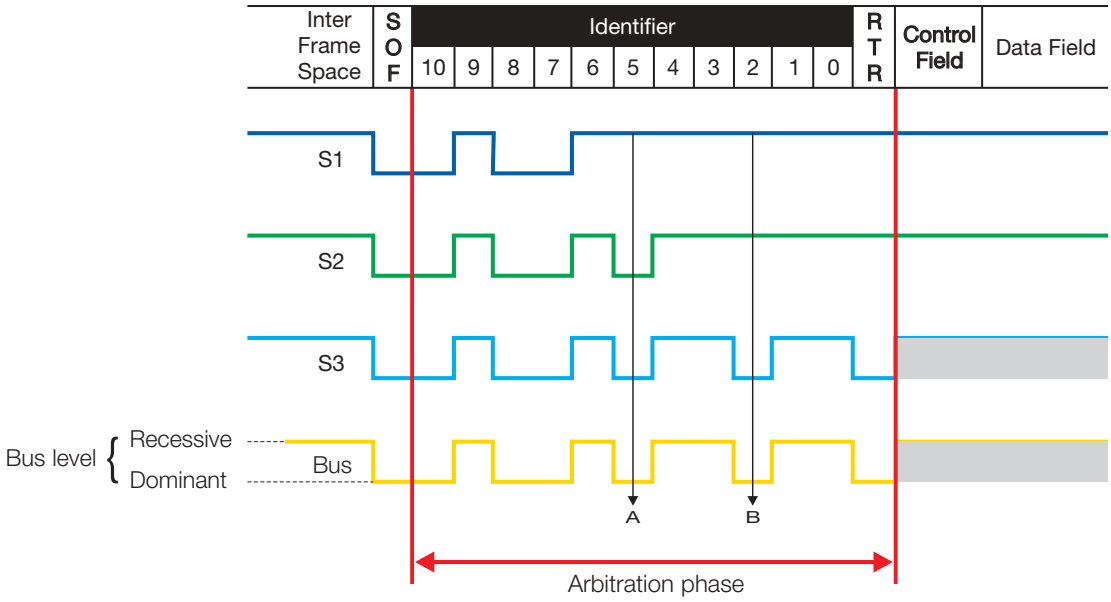
- All network nodes (control units) are equal-access.
- They are equally responsible for bus access, troubleshooting and failure control.
- Each network node has the property of accessing the joint data line independently and without the help of another network node.
- If one network node fails, this does not lead to the failure of the complete system.

With a multi-master system, bus access is not controlled, i.e. as soon as the data line is free, several network nodes can access it. If all the information were now sent down the line simultaneously, however, there would be perfect chaos.
It could lead to a "data collision". So there has to be order in data transmission. For this reason, CAN bus has a clear hierarchy, regulating who can transmit first and who has to wait. When the network nodes are programmed, the order of importance of individual data is defined. Which means a high priority message will assert itself against a low priority message. If a network node transmits with high priority, all the other network nodes automatically switch to receive.

Example:
A message which comes from a safety-related control unit such as the ABS control unit will always have a higher priority than a message from a gear control unit, for example.

How does the hierarchy (bus logic) work with the CAN bus?

With CAN, a distinction is made between dominant and recessive bus levels. The recessive level has the value 1 and the dominant level the value 0. If several control units transmit dominant and recessive bus levels simultaneously, the control unit with the dominant level is allowed to transmit its message first.



This example serves to elucidate bus access once more. In this example, three network nodes want to transmit their message via the bus. During the arbitration process, control unit S1 will prematurely abort attempted transmission at Point A since its recessive bus level is overwritten by the dominant bus levels of the control units S2 and S3.
For the same reason, control unit S2 aborts its attempted transmission at Point B. In this way, control unit S3 asserts itself over the others and is able to transmit its message.

What is a data protocol?

Data transmission is via a data protocol at very short intervals. The protocol is made up of a large number of consecutive bits.
The number of bits depends on the size of the data field. One bit is the smallest unit of information, eight bits correspond to one byte = a message. This message is digital and can only have the value 0 or 1.

What does a CAN signal look like?

Recessive bit

CAN-H 2,5 V

CAN-L 2,5 V

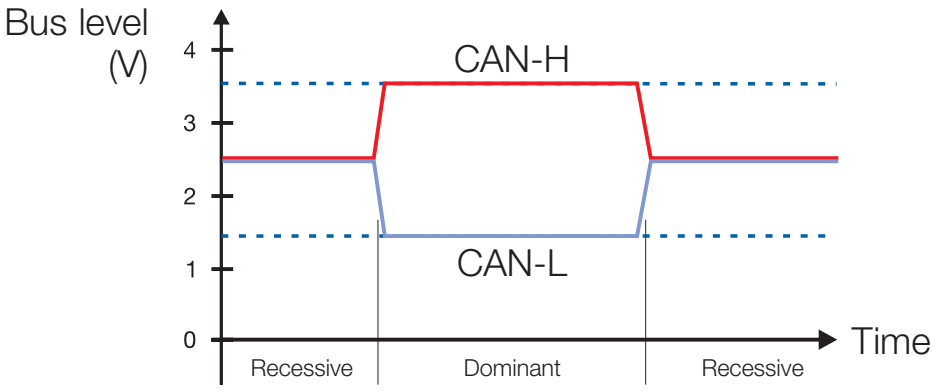
Difference 0 V

Dominant bit

CAN-H 3,5 V

CAN-L 1,5 V

Difference 2 V



High-speed bus Signal

- The signals CAN-H (high) and CAN-L (low) are on the bus.
- The two signals are mirror images of each other.

CAN data buses in passenger cars

Today, two CAN buses are used in modern vehicles.

The high-speed bus (ISO 11898)

- SAE CAN Class C
- Transmission rate 125 kBit/s - 1 Mbit/s
- Bus length up to 40 metres at 1 Mbit/s
- Transmitter output current > 25 mA
- Short-circuit proof
- Low current consumption
- Up to 30 nodes

Thanks to its high transmission speed (real-time critical information transfer in milliseconds), this bus is used in the power train where control units from the engine, gears, chassis and brakes are networked together.

The low-speed bus (ISO 11519-2)

- SAE CAN Class B
- Transmission rate 10 kBit/s - 125 kBit/s
- Max. bus length depends on the transmission rate
- Transmitter output current < 1 mA
- Short-circuit proof
- Low current consumption
- Up to 32 nodes

This bus is used in the vehicle interior where components of bodywork and comfort electronics are networked together.

CAN data bus diagnosis:

Possible faults with the CAN data bus:

- Line interruption.
- Connection to ground.
- Connection to battery.
- Connection CAN-High / CAN-Low.
- Battery / supply voltage too low.
- Lack of terminating resistors.
- Interference voltages e.g. through a defective ignition coil which can lead to implausible signals.

Troubleshooting:

- Check system function.
- Scan fault code.
- Read measured value block.
- Record signal using an oscilloscope.
- Check level voltage.
- Measure line resistance.
- Measure resistance of the terminating resistors.

Troubleshooting in the data bus

Before carrying out any troubleshooting work check whether auxiliary units are installed in the respective vehicle which have access to data bus system information. System interference could be caused by data bus intervention. Troubleshooting possibilities with the data bus depend on several factors. The possibilities prescribed by the vehicle manufacturer to garages are decisive. These can be troubleshooting with the diagnosis unit if a suitable diagnosis unit is available, or "only" using the oscilloscope and multimeter. The availability of vehicle-specific data (circuit diagrams, data bus topology etc.) is also very important in classifying vehicle networking.

Troubleshooting procedure, whether using the diagnosis unit or oscilloscope, should always be structured. This means that simple "trial and error" may be able to limit the potential fault in such a way that the subsequent measurements can be reduced to an absolute minimum. To better represent troubleshooting procedure, we shall use a particular vehicle as an example. This is a Mercedes Benz E-Class (W210).

There are complaints about the following fault:
Window lift on the passenger side is not working.

Functional test
1. Can the window lift be actuated from the driver side?

Yes:
In this case both door control units, the CAN data bus lines and the window lift motor are all OK. The fault will probably be found in the window lift switch on the passenger side.

No:
Can other functions (e.g. mirror adjustment) be operated?
If it is possible to carry out other functions it must be assumed that the door control units and the CAN data bus are OK. Possible causes of the fault are the window lift switch on the driver side or the window lift motor on the passenger side. This can be determined by carrying out a functional test from the passenger side. If the window lift works, the window lift motor can be excluded as a potential cause. The switch on the driver side must be considered as the potential source of the fault.

If no other functions can be carried out on the passenger side from the driver side, the fault could be in the CAN data bus or in the control units.

Comparison between conform and non-conform images on the oscilloscope

Conform image: Both signals CAN-H and CAN-L can be seen.



Non-conform image: Only one signal is visible.



To link the oscilloscope to the CAN data bus, connection should be made at a suitable spot. This is usually at the plug-type connection between the control unit and the CAN data bus line. In our example vehicle there is a potential distributor on the passenger side, in the cable channel beneath the sill strip (photo).



This is where the individual data bus lines from the control units meet. The oscilloscope can easily be connected to this potential distributor.



If no signals can be seen on the connected oscilloscope, the data bus has a problem. In order to find out exactly where the fault is, the individual plug-type connections can now be disconnected. The oscilloscope must be monitored during this procedure. If signals can be seen on the oscilloscope after a plug-type connection has been disconnected, the data bus is working again. The fault is located in the system belonging to the plug-type connection. All the connectors previously removed should be reinserted. The subsequent problem is to assign the plug-type connection that belongs to the faulty system to a control unit. Vehicle manufacturers provide no information about this assignment.

To make the search as simple and effective as possible, trial and error should again be used to find out which systems are not working. On the basis of vehicle-specific data about the linking and installation locations of the individual control units, the faulty system can be found. By separating the data bus plug-type connection at the control unit and connecting the plug-type connection to the potential distributor it can be established whether the fault is located within the cable connection or in the control unit. If signals can be seen on the oscilloscope, the data bus is working and the cable connection is OK. If no signals can be seen after the control unit has been connected, the control unit is faulty. If a faulty cable connection is found, resistance and voltage measurement can be used to detect a ground or plus connection or a connection between the lines.



In vehicles which do not have a potential distributor, troubleshooting is significantly more complex. The oscilloscope has to be connected to the data bus line at a suitable spot (e.g. on a plug-type connection at the control unit). Then all the control units present must be removed and the data bus plug-type connections disconnected directly at the control unit. Vehicle-specific data are necessary for this to determine which control units are installed and where in which vehicle. The oscilloscope must be monitored again before and after disconnecting the plug-type connections. The further procedure does not differ from that of our example vehicle.

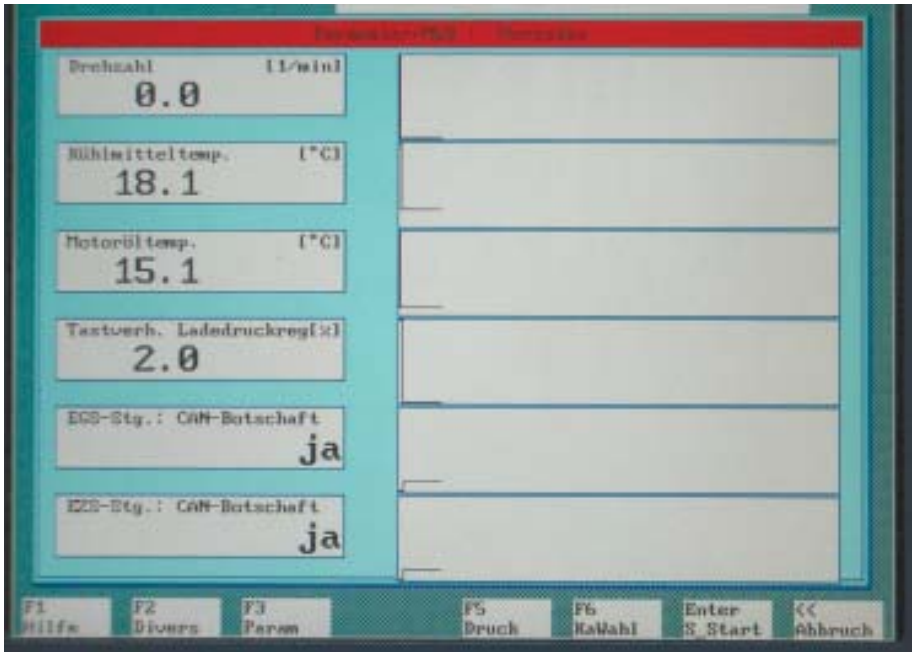
To test the termination resistors, the data bus has to be in sleep mode. The control units must be connected up during measurement. The total resistance resulting from the two 120 ohm resistors connected in parallel is 60 ohm. This is measured between the CAN-High and CAN-Low lines.

Troubleshooting with the diagnosis unit:

During troubleshooting with the diagnosis unit, testing depth is a deciding factor.
Always start by reading out the fault code. If there are faults in the CAN bus system, first indications of these could be found here.



Further functions can be tested by reading out the measured value blocks.



If a fault is established using the diagnosis unit, tests using the oscilloscope are once again required to narrow down the fault even further. One frequently occurring problem is that control units have not been recoded / adapted following replacement or having been disconnected from the voltage supply (e.g. if battery has been replaced).

In this case the control units are installed in the vehicle and connected up but do not carry out a function. This can also lead to faults in other systems in individual cases. In order to exclude these faults, make sure that control unit(s) is/are coded correctly and adapted to the vehicle following replacement or an interruption to the voltage supply.

Installing auxiliary devices

The installation of auxiliary devices e.g. navigation systems, which also require signals from the data bus, can be extremely difficult. The problem of finding a suitable location to tap the speed signal, for example, is extremely difficult without vehicle-specific documents.
There are some sites on the Internet which provide information and possibilities about connections and their installation locations. This information is always subject to change so that garages always have to bear the risk of the correctness of this information. The safest method is always to take the vehicle manufacturer's instructions into consideration.
In order to become familiar with all the possible data bus systems, find out how data transfer, structure, function and troubleshooting work, how any auxiliary devices can be installed, we strongly advise visiting a training workshop.

The correct tyre pressure is important!

Tyre pressure is a major safety factor in vehicles. The most frequent cause of tyre damage is gradual pressure loss. This is often only noticed extremely late by the vehicle's drivers. Too low tyre pressure leads to increased fuel consumption and poor vehicle performance. Linked to this are also an increase in tyre temperature and greater wear. One effect of tyre pressure being too low can be the tyre suddenly bursting. This means an enormous safety risk for all those in the vehicle. For this reason, more and more vehicle manufacturers are supplying tyre pressure control systems as a standard feature or accessory. The independent parts aftermarket also has several systems to offer for retrofitting.

Tyre pressure control systems monitor both tyre pressure and temperature. Tyre pressure control systems have been available for some years now and are already prescribed for new vehicles in the USA. In other words, it is time every garage became familiar with the subject. Because even only changing the wheels can impair the tyre pressure control system if not enough is known about it.

At the moment, there are two basically different types of tyre pressure control systems on the market – passive and active systems.

Passive systems

With the passive measuring systems, pressure monitoring is carried out with the aid of the ABS sensors on the vehicle. The ABS control unit detects the pressure loss of a tyre on account of the changed rolling circumference. A tyre with low air pressure rolls through more rotations than with the correct pressure. These systems do not work as accurately as active measuring systems, however, and require a pressure lost of around 30 % before a warning message is sent. The advantage is the relatively favourable price, since many existing vehicle components can be used. All that is required is adapted ABS software and an additional display in the instrument unit.

Active systems

Much more accurate but also more complex and thus more expensive are the active measuring systems. Here, a battery-powered sensor is housed in each of the wheels. This measures both tyre temperature and pressure and radio-transmits the measured values to the tyre pressure control system control unit or the display unit. One or more antennas are used for signal transmission. Active systems compare the tyre pressure with a reference value stored in the tyre pressure control system control unit, which has the advantage of pressure loss being able to be detected in several tyres simultaneously. This can make calibration or recoding of the sensors necessary when tyres have been changed. A further disadvantage of the active measuring systems is that the batteries have to be replaced after around 5-10 years. Depending on the manufacturer, these batteries form one unit with the sensors, which often means the sensor unit has to be replaced completely. Necessary battery replacement is indicated in good time by the display unit and can thus not lead to sudden system failure. When changing from summer to winter tyres care must be taken that additional wheel sensors have to be attached or existing sensors converted. Several important points have to be taken into consideration to prevent damage or functional problems during tyre fitting.

What particular points are important during wheel/tyre fitting?

Before starting work on wheel or tyre fitting, always find out whether or not the vehicle has a tyre pressure control system. This can be recognised by a coloured valve, coloured valve cap, symbol on the instrument cluster or additional display unit (with retrofit systems), for example. We recommend asking customers about the tyre pressure control system when they bring their vehicle into the garage and pointing out the special features. In the case of active systems, the following guidelines must be adhered to:





- When removing the tyres the forcing tool may only be applied on the opposite side to the valve on both sides ❶
- When pulling the tyre off, the insertion head must be positioned around 15 cm behind the valve ❷
- Avoid exerting any force on the sensor
- During tyre removal or fitting, tyre bead and rim flange may only be moistened using fitting spray or soapy water. The use of fitting paste can lead to the filter area of the sensor electronics becoming sticky
- The sensor may only be cleaned using a dry, fluff-free cloth. Compressed air, cleaning agents and solvents must not be used
- Before fitting a new tyre the sensor unit must be checked for soiling, damage and a tight fit
- Replace the valve insert or the valve (depending on manufacturer's instructions), note torques
- After fitting, carry out calibration/re-coding with the tyres cold
- Individual vehicle and system manufacturers' instructions must also be consulted separately.

Since there are numerous different systems from different manufacturers on the market (see table), the manufacturer-specific fitting instructions should always be taken into consideration.

Summary of tyre pressure control systems:

System	Manufacturer	Description	Used in
TSS	Beru	Tire Safety System – directly measuring tyre pressure control system with four separate antennas	Audi, Bentley, BMW, Ferrari, Land Rover, Maserati, Maybach, Mercedes, Porsche, VW, commercial vehicles
SMSP	Schrader, Distribution in Germany: Tecma	Directly measuring tyre pressure control system with one central antenna	Citroën, Opel Vectra, Peugeot, Renault, Chevrolet, Cadillac
DDS	Continental Teves	indirectly measuring tyre pressure control system	BMW M3, Mini, Opel Astra G
TPMS	Continental Teves	Tire Pressure Monitoring System – directly measuring tyre pressure control system	Opel Astra G
Warn Air	Dunlop	Indirectly measuring tyre pressure control system	BMW, Mini
Tire Guard	Siemens VDO	Directly measuring tyre pressure control system with a battery-free sensor integrated firmly in the tyre	Renault Megane
Smar Tire	Distribution: Seehase	Directly measuring tyre pressure control system for retrofitting	universal
X-Pressure	Pirelli	Directly measuring tyre pressure control system for retrofitting	universal
Road Snoop	Nokian	Directly measuring tyre pressure control system for retrofitting	universal
Magic Control	Waeco	Directly measuring tyre pressure control system for retrofitting	universal

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It is not possible to go into all special features here. Two systems are described in more detail below as examples.

1. Tire Safety System (TSS) Beru

The TSS from Beru is installed by numerous vehicle manufacturers as a standard feature but is also supplied as an accessory or for retrofitting. BMW terms the Beru system "RDC" (German Reifen Druck Control = Tyre Pressure Control), at Mercedes and Audi it is known as the "tyre pressure control system". It comprises four each (or five, if additional spare wheel monitoring is included) of aluminium valves, wheel electronics (wheel sensors), antennas and one control unit. Wheel electronics and valve are mounted on the rim. The radio receiver is in the wheel housing. When the system has been installed as standard, the display unit is integrated in the instrument cluster.

A separate display unit is installed for retrofit systems. When removing/fitting the wheels/tyres the points mentioned above must always be followed. The wheel electronics must be replaced if the housing is visibly damaged or the filter surface is soiled. The complete valve must be replaced if the

- Wheel electronics are replaced
- Self-locking (Torx) fastening screw and/or cap nut of the valve are/is loose (do not tighten)
- Support points of the wheel electronics project by more than one millimetre

Figure ❸ below illustrates the individual system components

- Wheel electronics (1)
- Wheel electronics with tyre valve (2)
- Retaining clips (3)
- Antenna (4)
- Control unit (5)



❹



Putting together and assembling the wheel electronics and the wheel valve are easy to carry out with the aid of figure (4).

- Insert the self-locking fastening screw (1) through the wheel electronics housing (2) and screw into the valve by two or three revolutions
- Push the valve (3) through the valve bore hole in the rim, insert the spacer washer (4) and screw on the cap nut (5) as far until it locates
- Insert the assembly pin (7) in the radial bore hole of the valve and tighten the cap nut using a torque of 3.5 - 4.5 Nm. Pull the assembly pin out otherwise the tyre will be damaged during subsequent fitting work.
- Press the wheel electronics slightly into the deep rim well. The support points must be flat in the deep rim well. Then tighten the fastening screw using a torque of 3.5 - 4.5 Nm.
- Screw the valve cap (6) back in place following tyre fitting

Following wheel/tyre replacement, changing of wheel positions, replacement of wheel sensors or a conscious change in tyre pressure (e.g. when the vehicle is fully loaded), the new pressures are taken over by the TSS. For this to happen, all the tyres have to be filled with the prescribed or specially selected pressure first. The values are stored by pressing the calibration button.
The system then checks whether or not the pressures are realistic (e.g. the minimum pressure or the differences between left and right). If the wheels have been transported in the boot of the vehicle, e.g. when seasonal tyres are to be changed, they are within the range of the control unit. If the wheels to be exchanged have been read into the system before, the control unit now receives eight or nine signals instead of the usual four (or five including spare wheel).
In this case the system sends the message "not available".

The same thing can happen if unloaded wheels or wheels belonging to another vehicle which also has a tyre pressure control system are nearby. Inform your customer that the system has to be recalibrated in such cases. Calibration of the standard feature TSS is vehicle-specific. Instructions for this process can be found on Beru's website.

Practical tip:
If the spare wheel is also monitored using the tyre pressure control system and is required at some point, it should be returned afterwards to exactly the position it was in before use. In the course of servicing or after checking air pressure in particular, care must be taken with the BMW E60, E65 that the tyre valve is back at the 9 o'clock position when the spare wheel has been replaced. The receiver will only detect the transmitter signal in this position.

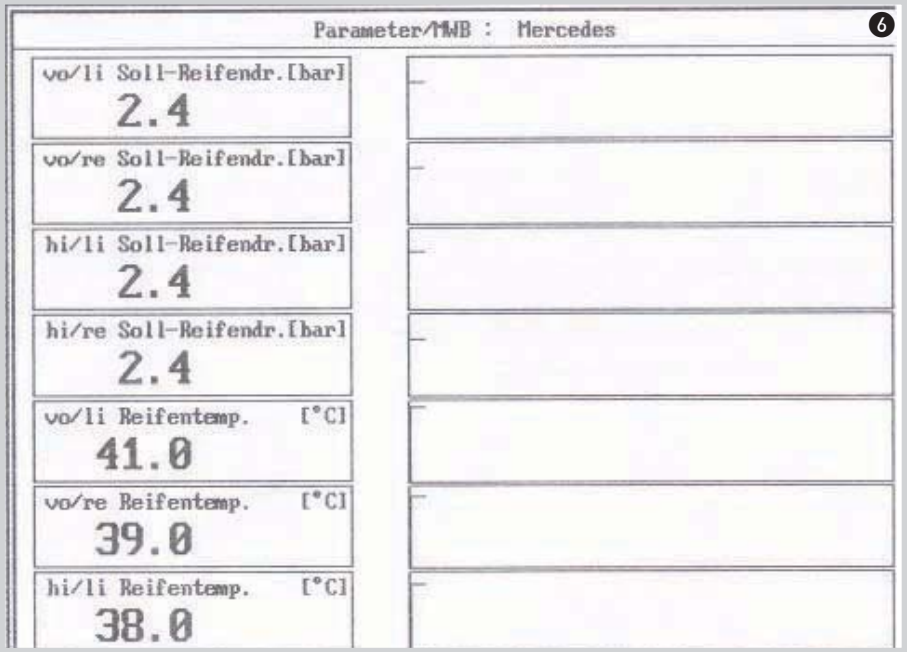
French vehicle manufacturers in particular use the SMSP system from Schrader. The difference between this system and the one described above is that it only has one radio receiver (antenna). The positions of the wheels are distinguished through coloured valve markings.

- Green ring = front left
- Yellow ring = front right
- Red ring = rear left
- Black ring = rear right

Following tyre fitting or sensor replacement, sensor coding could be necessary, since with only one antenna a difference in position of the wheels is not detected or the radio connection was interrupted. Since with this system the electronics only measure the pressure every 15 minutes when the vehicle is at a standstill and only transmits the measured values to the control unit once every hour, a so-called "valve exciter" ❺ is required for coding in addition to a diagnosis unit.

This requests the wheel electronics via a radio signal to transmit the measured values to the control unit.





Diagnosis units such as Gutmann Mega Macs 40, 44 or 55 are also in a position to read out the fault code and the actual values (Fig. 6) of the tyre pressure control system and to delete any fault codes. Coding takes place as follows:

- Connect the diagnosis unit to the vehicle
- Select program coding
- Use the valve exciter to read in the valve codes

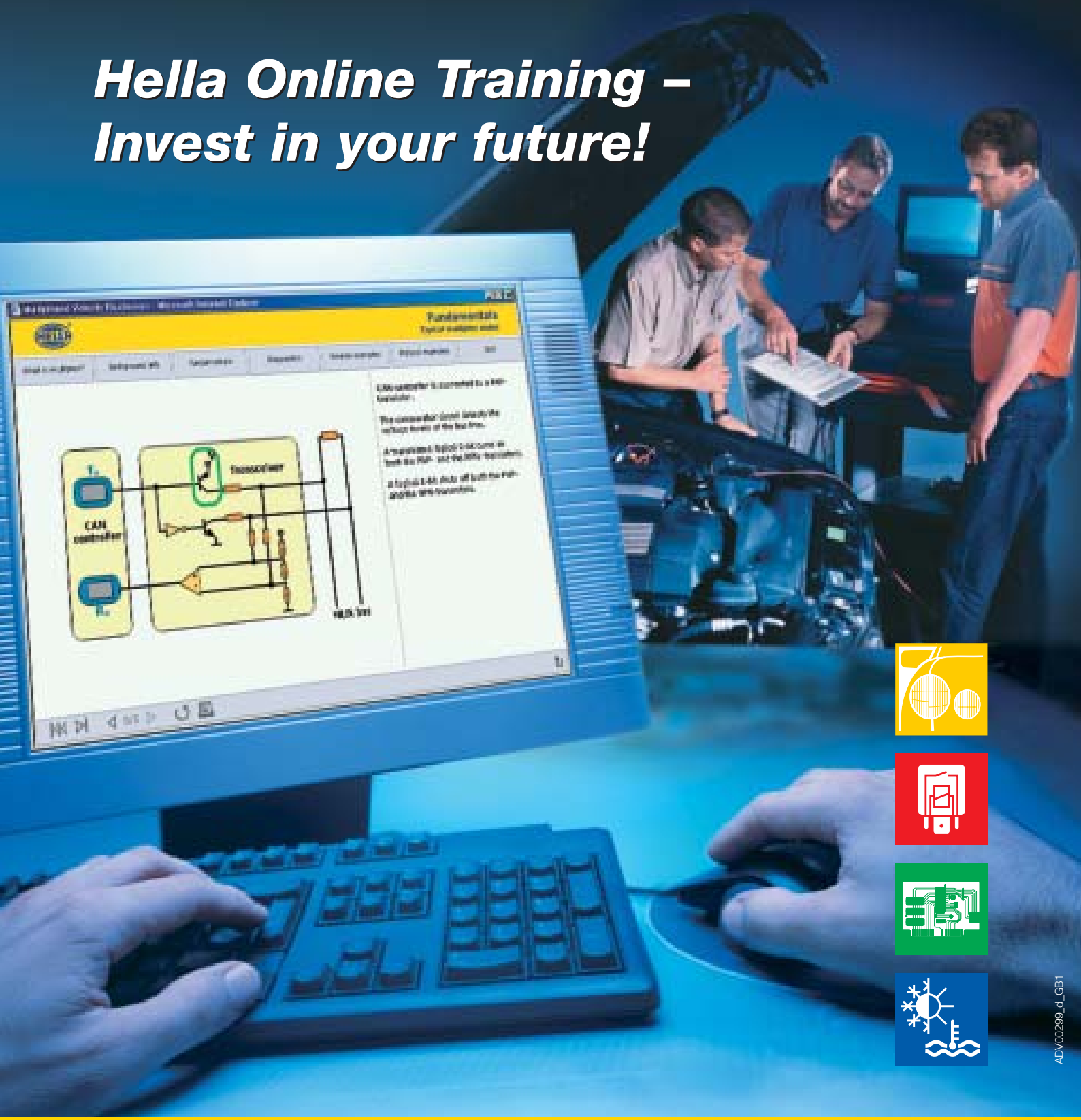
Practical tip:
When wheels have been removed (e.g. for repairs to the brake system) they have to be remounted in the position they were originally in. Otherwise this can lead to display faults in the tyre pressure control system (e.g. Renault Laguna 2).

Almost all tyre pressure control systems transmit in the frequency range 433 MHz. This frequency range is also used by radio units, radio-controlled headsets, alarm systems and garage door drives, however. Please bear this in mind if there should be problems with the tyre pressure control system. Current developments are favouring small, battery-free (transponder technology) active systems which only have to be glued into the shell or are integrated in the tyre. These systems work in a range which is not as prone to problems, 2.4 GHz, and can record further information such as road surface and wear state alongside temperature and pressure values.

In a few years time tyre pressure control systems will be just as natural a feature in new vehicles as the ABS or air conditioning systems are today. In the face of all this monitoring technology, however, one thing should not be forgotten. A tyre pressure control system does not automatically correct air pressure and does not provide any information about the age or tread depth of the tyre. Which means it will be essential in future, too, to check tyres – the most important link between the vehicle and the road – at regular intervals.

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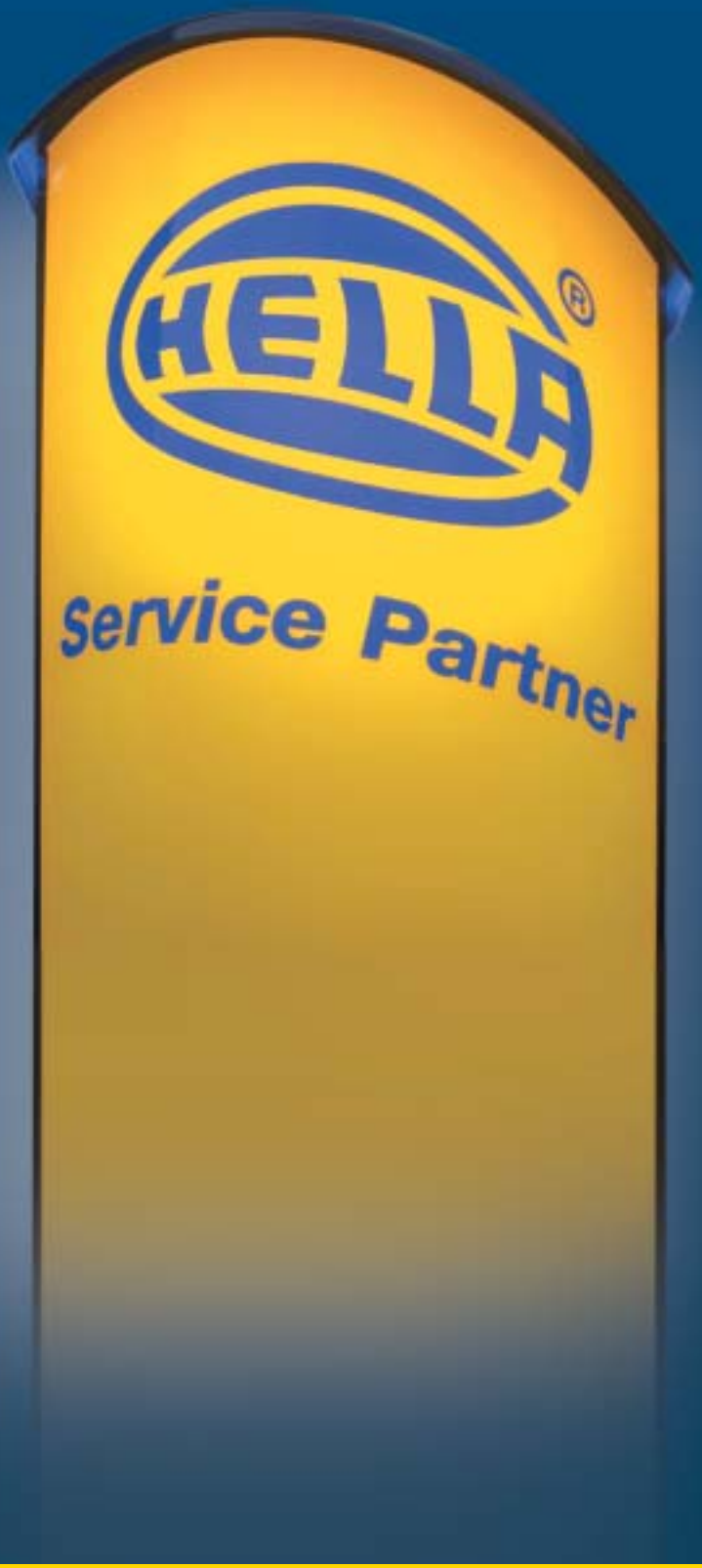
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Hella Ireland Limited
Woodford Business Park
Santry, Dublin 17
Republic of Ireland
Tel.: +353 (1) 8 62 00 00
Telefax: +353 (1) 8 62 11 33
e-mail: irlsales@hella.com
Internet: www.hella.ie

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