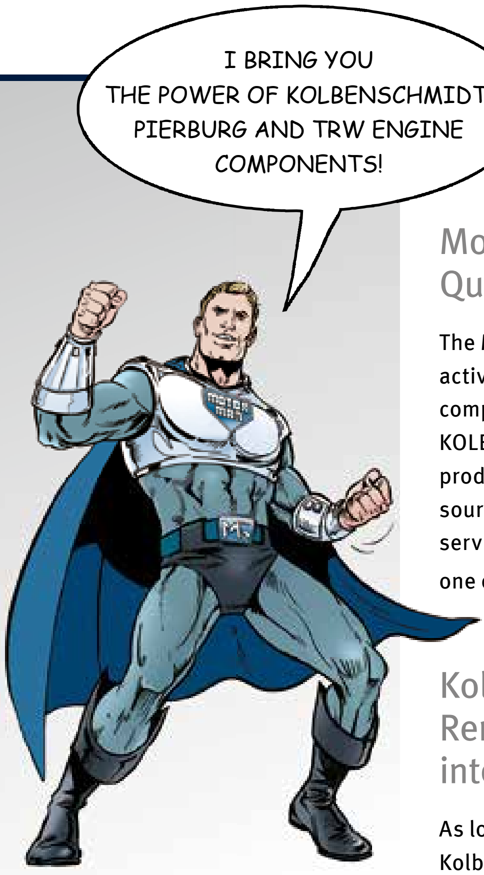
PIERBURG

Emission control and OBD

SERVICE
TIPS & INFOS



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The extent to which the technical methods and repair information described here will apply to future engine generations cannot be predicted and must be verified in individual cases by the engineer servicing an engine or the workshop operator.

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2 | On-Board-Diagnosis

In this brochure we offer simple information on the complex subject of "self diagnosis in motor vehicles". Known as "On-Board-Diagnosis" (OBD), this self diagnosis has become an internationally recognised term. It serves to monitor the running of the engine and is used for emission control.

OBD II and the European version, EOBD, are discussed here.

This brochure is intended for use by automotive specialists.

It is intended to help you in your daily work, especially in the error diagnosis of automobiles with OBD systems.

In addition to information on the structure and functioning of the systems, possible errors and the interdependencies between fault codes and causes are discussed.

Furthermore we offer practical instructions for diagnosing and correcting errors in emissions-relevant components.

Laws for the environment

s the number of motor vehicles and amount of traffic increases, the impact of exhaust gas emissions on the environment has also increased. Since 1968 toxic emissions have been restricted for motor vehicles in western industrialised nations. The United States played a leading role in this legislation.

As the years went by, these legal limits for toxic emissions have been lowered continuously. To ensure compliance with these limits during daily operation, diagnostic systems for monitoring exhaust gas relevant systems and components ("On-Board-Diagnosis"), among other things, were required. For this reason, all newer vehicles are equipped with On-Board diagnostic systems that detect, record and display errors.

In the event of a malfunction, or during regular service checkups in the workshop, fault codes and error relevant data can be read out of the fault code memory. The fault code memory is read out for the corresponding vehicles for exhaust gas inspections (EGI). This way, errors that could cause damage to the engine or increased negative impact on the environment can be detected early and remedied before damage occurs.

OBD = a solution to all problems?

OBD does indeed detect a malfunctioning part or a function that is not working altogether properly, but not always the actual cause of the failure or error.

This requires the expertise of a specialist with knowledge of the system.

Our experience for you

PIERBURG is an active developer and manufacturer of components, especially in the field of emissions control.

Because all exhaust gas relevant components are monitored by OBD, here we have extensive experience in questions related to application and service.

By presenting this brochure it is our desire to share this experience with you. For this reason, in the description of systems and diagnostic instructions we concentrate on PIERBURG products.

Because it is only since 2003 that EOBD also applies to passenger vehicles and light utility vehicles with diesel engines, emphasis is placed on vehicles with petrol engines.

2.1

2.1 Development of On-Board-Diagnosis (OBD, OBD II and EOBD)

In conjunction with emission control, since 1970 the number of mechanical and electric components in the engine environment has increased.
These new components have made it increasingly difficult for workshops to diagnose errors in cases of malfunctions.
To solve these problems, at the end of the seventies, the first, still very elementary, vehicle integrated diagnostic systems were introduced.
This was made possible by the development of increasingly more proficient electronic control units. At the same time, increasing numbers of new or further developed sensors and actuators were being used.
This also required an increase in the number of on-board power supply networks and plug-in connections.
But another consequence of this development was that, in the event of a malfunction or breakdown, uncertainty frequently reigned in diagnosing the error.
In order to improve the situation, since about 1984, increasing numbers of vehicles were being equipped with improved systems for error detection, with fault code memories and self diagnosis.
There were very different philosophies regarding the scope and use of these On-Board diagnostic systems. The result was a multitude of system variants, interfaces, adapters, data scan tools and fault codes. As a result, in many cases an error diagnosis was possible only in the respective contracted workshops.

California in the leadership role
In the United States this problem was recognised early and addressed by legislation in 1984. With this legislation, the On-Board-Diagnosis (OBD) was introduced for California from 1988 and for the entire USA from 1989.
This was a simplified On-Board diagnostic system.
It required the registering, recording and displaying of errors in exhaust gas relevant components of the vehicle. In this first version only components directly associated with the control unit were monitored. Errors were indicated by a malfunction indicator lamp. Readings were taken by interpreting blinking codes.

OBD II
As of January 1, 1996, OBD II was required for passenger cars and light utility vehicles in the United States. As a result a diagnostic system with considerably expanded functions was introduced. In addition to exhaust gas relevant components, further systems and functions were now monitored during operation. Malfunctions and deviations were entered in a “nonvolatile” (permanent) memory. Furthermore, as a help in error diagnosis, operating conditions that were present when an error occurred were registered and recorded.
An additional, essential improvement was the establishment of standardised interfaces, data transfer protocols, scan tools, diagnostic sockets and fault codes. This made it possible for the fault code memory to be read using conventional OBD compatible instruments.
Furthermore it was determined that the vehicle manufacturer should make the data necessary for service available to all those who have a legitimate interest.

The EURO III emissions standard
At the same time as the EURO III emissions standard, the European version, “EOBD”, was introduced in Europe as of January 1, 2000.
It applies to passenger vehicles and light utility vehicles with petrol engines.
As of 2003 it also applies to passenger vehicles and light utility vehicles with diesel engines.
The EOBD essentially corresponds to the American OBD II. It has, however, been “eased” in some points.

- A leak test of the fuel system is not required.
- For exhaust gas recirculation, secondary air and fuel tank ventilation, only the functioning and the electric connections of the individual components are tested.

A test of the effectiveness of these systems is not required by the EOBD.
There are, however, vehicle manufacturers that comply with the “OBD II” standard worldwide.

2.2 Requirements of OBD systems

OBD systems must perform the following functions:

Monitoring
of all exhaust gas relevant components and functions in the drive train of vehicle.

Detection
of deviations and errors.

Recording
of errors and state information.

Displaying
of errors.

Output
of fault codes and state information.

The goals of OBD systems are
- continuous monitoring of all exhaust gas relevant components and systems
- immediate detection and reporting of essential errors that produce increased emissions
- permanently low exhaust gas emissions of all vehicles over the entire product life

The following are monitored
- the current flow to earth connection, plus connection and interruption.
- the input and output signals of sensors and actuators.
- the plausibility of signals.

Depending on the OBD standard
- a simple function test (open/closed – yes/no – on/off) or
- a qualitative function check will be made. Here values (results of the function) are measured and compared to set-point values.

Important note:
Legislation does not specify the methods for monitoring a module or component. This can be done in different ways depending on the manufacturer.
What is important is that the module or component be monitored.

Responses to errors, and thus the effects, differ according to system and applicable OBD standard.

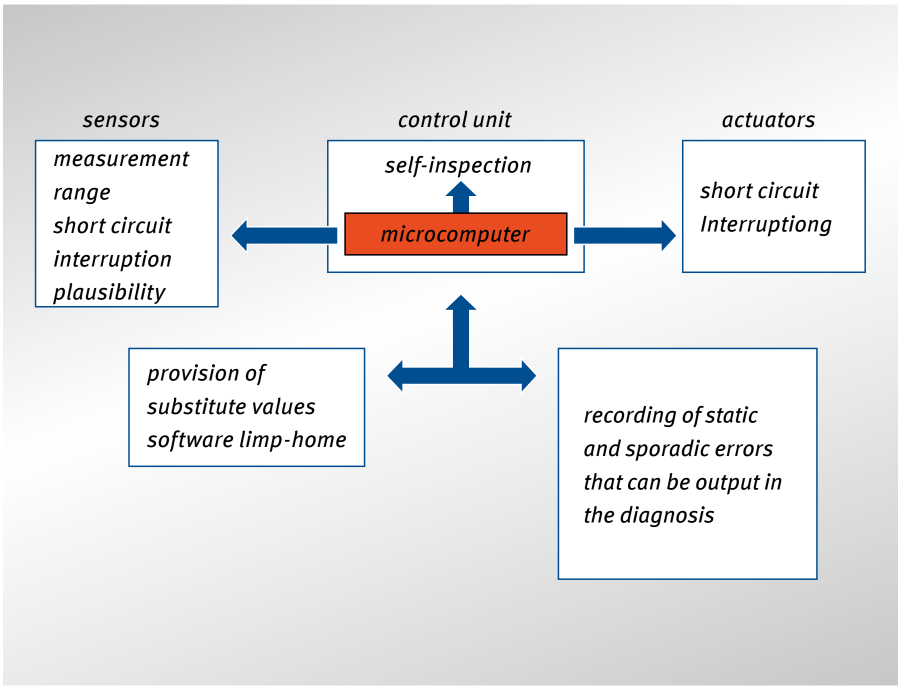

Fig. 1: self diagnosis of electronic systems (On-Board-Diagnosis)

What is relevant is the possible consequences of the errors that occur:
- deviations from the set-point
- errors that increase pollutants considerably
- errors that can cause damage to the engine or the catalytic converter

The range extends from an insignificant correction to the use of replacement values, to switching on the malfunction indicator lamp (MIL), to reduced performance, to the “limp home” function.

2.3
Legal requirements

The introduction of the EOBD is not directly associated with an emission standard for the European Union! Therefore the respective deadlines for introduction must be considered independently of each other.

2.3.1
OBD, EOBD, EU, EURO?

In literature and conversation there is often confusion as to the use of the different terms such as OBD, EOBD, EU and EURO.
Here a distinction must be made between the respective exhaust gas standards and the laws governing On-Board-Diagnosis.

- The "Euro I" to "Euro III" emission standards (or also referred to as "EU I" to EU III") form the legal requirements for emission control in the European Community.
- The German emission standards (e.g. D3 and D4) were introduced for tax advantages.
- On-Board-Diagnosis OBD I and II refer to the American requirements for a diagnostic system in the vehicle.
- EOBD is the European version of the American OBD II.

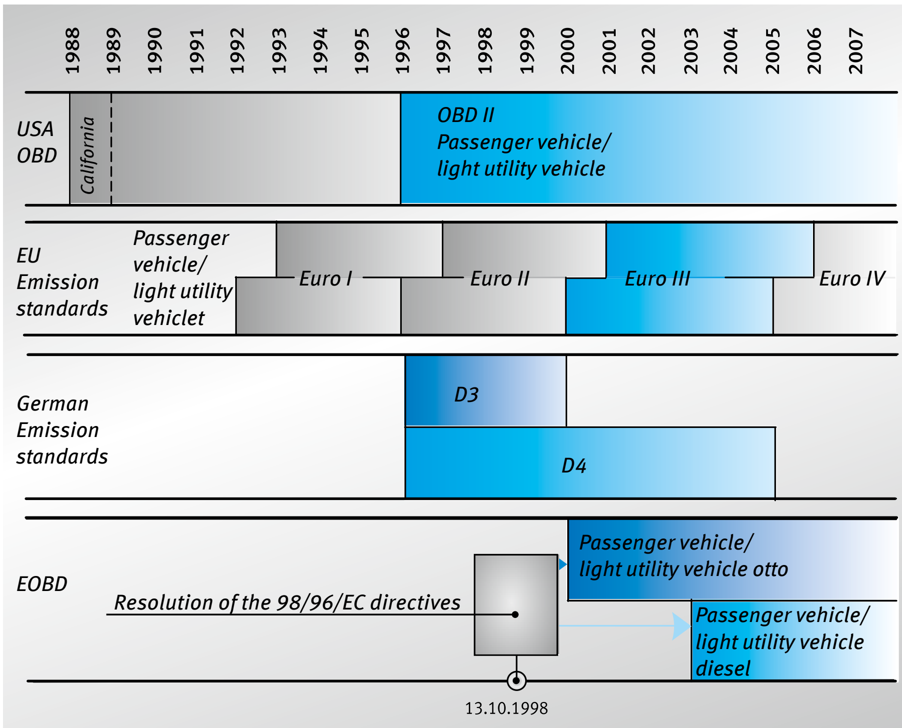

Fig. 2: chronological summary of standards and laws (excerpts)

2.3.2
EURO III – the legal basis for the EOBD

The legal basis for the EOBD is the 98/69/EC directive of the European Parliament and Council.
This directive applied the limits and requirements for EURO III.

The essential contents of EURO III are:

- more demanding test procedure for type testing
- considerably reduced emission limits
- improved durability (function stability) of all exhaust gas relevant systems and components
- increased fuel quality standards and improved fuel quality
- monitoring for compliance with limits by checking vehicles during operation ("field monitoring")
- definition of recall actions by legislation
- prescription for handling defects
- access to all information required for manufacturing or replacement of retrofit parts. Exceptions: protection of intellectual property (e.g. the data in the control units)
- determination of specifications that ensure that these parts are compatible with the OBD system
- the access to control units is to be safeguarded so that an unauthorised reprogramming (chip tuning) is essentially prevented (protection against manipulation)
- suggestions for creating an electronic standard format for repair information
- introduction of an OBD system
- further development of OBD to an On-Board measuring system (OBM)
- expansion of OBD to further systems in the vehicle

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2.3.3
EOBD

The EURO III emissions standard provides for introduction of an On-Board diagnostic system, the EOBD.

EOBD is required
- from January 1, 2000 for all new certified passenger vehicles and light utility vehicles with petrol engines
- from January 1, 2001 for all new registered passenger vehicles and light utility vehicles with petrol engines
- from January 1, 2003 for all new certified passenger vehicles and light utility vehicles with diesel engines
- from January 1, 2004 for all new registered passenger vehicles and light utility vehicles with diesel engines

Important note:
"Certified" in this sense means that the manufacturer must prove compliance with the standards and laws as part of a prototype certification test before introducing a new vehicle into the market for the first time.
The introduction of EOBD has produced the following consequences for vehicle manufacturers:
- standardised On-Board diagnostic system with fault code memory in each new registered vehicle
- unrestricted access over a standardised interface (diagnostic socket and protocol)
- an error scan tool applicable to all OBD vehicles
- uniform fault codes
- free availability of all data required for maintenance, diagnosis and repair

2.4
Scope and type of the diagnosis

The scope of the EOBD diagnosis basically corresponds to the American OBD II. It has, however, been "eased" in some points. There are some vehicle manufacturers that comply with the "OBD II" standard worldwide.

Component	Type of diagnosis
catalytic converter	• function • detection of ageing and contamination
lambda probe (pre and post catalyst probe)	• function • electric components for connection and continuity • detection of sluggishness ("ageing")
ignition system (uneven running)	• function • detection of ignition and combustion misfires
fuel supply/mixture formation	• map corrections (short and long-term adaptation)
fuel tank aeration and ventilation system ("AKF system")	• function • impermeability
fuel tank system	• impermeability by leak diagnosis[1]
secondary air system	• electric components for connection and continuity • function • effectiveness[2]
exhaust gas return system	• electric components for connection and continuity • function • effectiveness[2]
all remaining exhaust gas relevant components such as: • air mass sensor • sensors for the engine temperature • sensor for intake air temperature • sensor for intake manifold pressure • sensor for absolute pressure • actuators	• electrical components for connection and continuity (earth connection, plus connection, interruption) • signals for plausibility (comprehensive components)
engine control unit	• self monitoring

[1] Not required by EOBD if the tank seal is protected against loss.
[2] Not required by EOBD.

2.5
Monitoring process

EOBD all exhaust gas relevant components and systems are monitored.
Certain components and systems are monitored continuously ("permanent monitoring").
Other components and systems are monitored only sporadically

2.5.1
Permanent monitoring (continuously monitored systems)

- uneven running
- (combustion/ignition misfires)
- fuel system
- (mixture adaptation, injection times)
- all electric circuits for exhaust gas relevant components
- signal characteristics of the lambda probe

Permanently monitored systems are monitored irrespective of the temperature and immediately after start-up.
Function errors lead to an immediate activation of the malfunction indicator lamp.

2.5.2
Cyclical monitoring (sporadically/occasionally monitored systems)

Systems and components with functions linked to certain operating conditions will be checked only after the appropriate operating points, engine speed, load or temperature threshold, have been run through.

The following are monitored cyclically:
- catalytic converter/catalytic converter heating
- lambda probe/lambda probe heating
- secondary air system (SLS)
- tank deflation/activated carbon filter system (AKF)
- exhaust gas recirculation (EGR)

2.5.3
Driving cycle

So that the diagnosis of a certain system can be run, exactly defined conditions must apply (driving cycle). These operating conditions for carrying out a safe monitoring are referred to as the "driving cycle".
For example, if a vehicle is being used only for short distances in city traffic, it can take a while until all the systems have been checked.

Important note:
This "driving cycle" is not identical to the "New European Driving Cycle (NEFZ)" as required for the prototype certification test of a vehicle.

2.5.4
Occasional shut-off of the diagnostic function

Misdiagnoses can occur under certain operating conditions. To prevent this, the diagnostic functions can be switched off by the manufacturer, for example, under the following conditions:
- fuel level lower than 20 % of the overall volume of the tank (only for OBD II)
- high elevations over 2.500 m above NN (sea level)
- ambient temperatures below -7 °C
- low battery voltage
- operation of an auxiliary drive unit (e.g. hydraulic cable winch)
- Uneven running detection can be switched off by the engine management when the road is not level (bad road surface) so that the roughness of the road will not be misinterpreted as a misfire.

2.6
The readinesscode

The readiness code is a check of whether
- components or systems are present and
- whether diagnosis have ended.

It was created to reveal manipulations. For example, it can determine whether the fault code memory was erased by disconnecting the battery. Depending on the scan tool used, the readiness code is expressed mostly in two 12-digit numerical series.

One of these numerical series indicates whether this component or this function is checked in this vehicle.

0 Component not present/not within the scope of the test
1 Component present and within the scope of the test

The second numerical series indicates the status of the diagnosis carried out.

0 Diagnosis carried out
1 Diagnosis not carried out or aborted

The arrangement of the numerical series (next or below each other, or in succession) is based on the scan tool used. Most offer a help feature in the display with information on what is being displayed.

The following is displayed:

Position*	monitored range
1	not used
2	remaining components
3	fuel system
4	combustion misfire
5	EGR-system
6	lambda probe heating
7	lambda probes
8	air conditioning
9	secondary air system
10	tank ventilation system
11	catalytic converter heating
12	catalytic converter

* from left to right

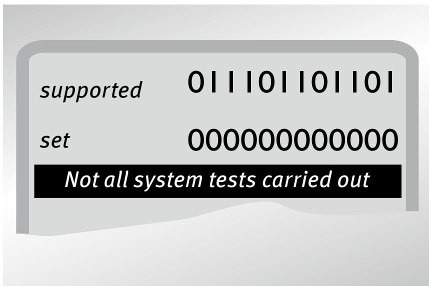


Fig. 3: readiness code when readiness is not reached (example)

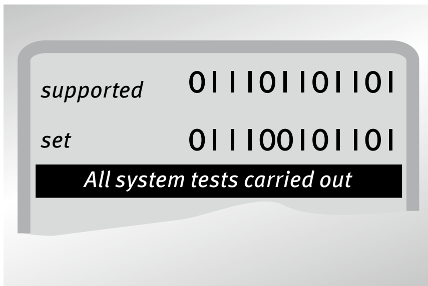


Fig. 4: readiness code after successful test (example)

Because not all vehicles have a secondary air system, for example, or an exhaust gas recirculation system, the scope of the test for the readiness code is based on the vehicle.

The readiness code is read out when an exhaust gas inspection (EGI) is being performed.It provides information on whether there has been a diagnostic result since the last time the fault code memory was erased or the control unit for all the individual systems was replaced.

The readiness code does not provide information on whether there are errors in the system.
It indicates only whether certain diagnosis were ended by the system (bit set to 0), or were not yet carried out or were aborted (bit set to 1).

The arrangement of the numerical series (next or below each other, or in succession) is based on the scan tool used.
Most offer a help feature in the display with information on what is being displayed.

So that the diagnosis of a certain system can be run, exactly defined conditions must apply (driving cycle).
For example, if a vehicle is being used only for short distances in city traffic, it can take a while until all the systems have been checked.
To "erase" the readiness code quickly, i.e., to set all the bits to 0, a driving cycle should be carried out.
The boundary conditions of such a driving cycle differ depending on the vehicle manufacturer.

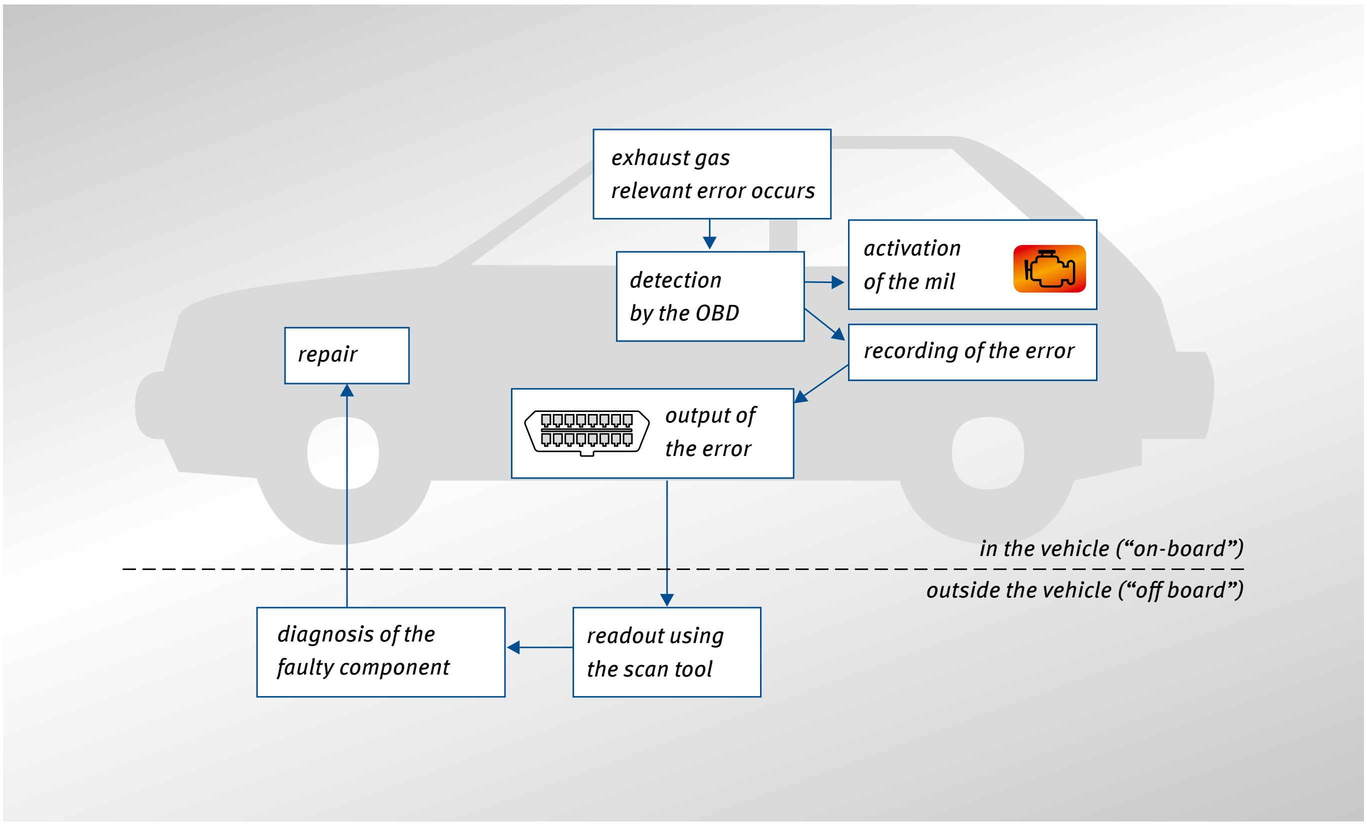


Fig. 5: OBD diagnostic concept in the vehicle

2.7 Diagnostic concept in the vehicle

In OBD it is not the quality of the exhaust gas itself that is checked, but rather the function of the exhaust gas relevant components.

- The engine control unit is expanded to include the "OBD diagnosis" function field.
- Depending on the component, diagnosis are carried out permanently or cyclically.
- The status of the diagnosis performed is maintained as a readiness code (please refer to Section 2.6).
- Errors that affect emissions are detected and recorded as unconfirmed (not "debounced") errors.
- If the same error occurs again during the following driving cycles under the same conditions or over a certain time period, it will be labelled as "debounced" (confirmed) and recorded as an OBD error. The malfunction indicator lamp will be activated.
- In addition to the error, further operating data and ambient conditions that were present when the error occurred are registered and recorded ("freeze frames").
- If deviations that cause the exhaust gas limits to be exceeded, or that cause damage to the catalytic converter, are determined during this monitoring, the malfunction indicator lamp will be activated.
- The recorded data can be read out over the diagnostic socket (interface) by the scan tool.
  Errors are recorded as fault codes, freeze frames, other error relevant data and vehicle data, for example.

2.8
The malfunction indicator lamp ("MIL")

The malfunction indicator lamp is also referred to as an MIL. It indicates that exhaust gas relevant errors have occurred.

Activation is done by the control unit. Three states are possible for the malfunction indicator lamp: "OFF", "ON" and "BLINKING".

Fig. 6: malfunction indicator lamp (MIL)

The law specifies the following requirements for the malfunction indicator lamp, among others:

- Errors can be displayed only visually or alternatively, both visually and acoustically.
- In an activated state it shows the ISO 2575 standard symbol of an engine.
- It has to be visible to the driver (normally on the instrument panel).
- The lamp goes on when the ignition is switched ON to check the function (for protection against manipulation). Activation occurs according to specially defined requirements:

The malfunction indicator lamp will be lit continuously

- if the ignition is ON (lamp function check).
- if an error is detected during a self test of the control unit.
- in the case of exhaust gas relevant errors if the admissible exhaust gas values are exceeded 150% in two consecutive driving cycles.

The MIL will blink (1/s) if errors, such as a misfire, occur that would lead to cylinder shut-off or cause damage or destruction to cylinders.

The MIL will go out if the exhaust gas relevant error no longer occurs in three consecutive driving cycles.

	Cycle 1			Cycle 2			Cycle 3			Cycle 4			Cycle 5			…	Cycle 43		
	check	fault code set ?	status of mil ?	check	fault code set ?	status of mil ?	check	fault code set ?	status of mil ?	check	fault code set ?	status of mil ?	check	fault code set ?	status of mil ?		check	fault code set ?	status of mil ?
1.	yes	yes	off													…			
2.	yes	yes	off	yes	yes	to										…			
3.	yes	yes	off	no	no	off	yes	yes	to							…			
4.	yes	yes	off	yes	no	off	yes	no	off	yes	yes	off	yes	yes	to	…			
5.	yes	yes	off	yes	yes	to	yes	no	to	yes	no	to	yes	no	off	…			
6.	yes	yes	off	yes	yes	to	yes	no	to	yes	no	to	yes	no	off	…	yes	code erased	off

Fig. 7: activation of the malfunction indicator lamp during the driving cycle

Explanation of the illustration

1. If an exhaust gas relevant error is detected during a driving cycle (here the first driving cycle), it will be recorded as a "non-debounced" error (mode 7, see Section 2.11) but the malfunction indicator lamp will not go on. An exception to this is combustion misfires that cause the cylinder to be switched off. As long as an error is present with cylinder shut-off, the malfunction indicator lamp will blink.
2. If the exhaust gas relevant error is detected again in the next driving cycle the error will be considered confirmed ("debounced", mode 3, see Section 2.11). The error map will go on after the system check[3] is finished.
3. If the second driving cycle is not sufficient to finish checking all the components, the third driving cycle will be evaluated as the following driving cycle. If the error is dete cted here as well, the malfunction indicator lamp will go on.
4. In the case of sporadically occurring errors, the malfunction indicator lamp will go on only if the same error is detected in two consecutive driving cycles.
5. The malfunction indicator lamp will go out if the exhaust gas relevant error does not occur in three consecutive driving cycles.
6. A simple error entry will be erased from the memory if the error no longer occurs under the same operating conditions in 40 further consecutive driving cycles.
   The error will also be erased without running through the same operating conditions if it no longer occurs in 80 consecutive driving cycles.

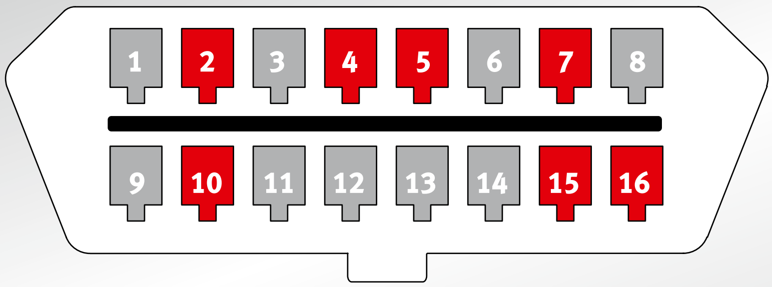
[3] Check of all exhaust gas relevant components and functions.

2.9
Diagnostic connection

The diagnostic socket in the vehicle is the interface between the OBD system (engine control unit with fault code memory) and the workshop scan tool.
Both the connection and the data transfer are standardised according to ISO 9144-2 or SAE 1962, i.e., the plug assignment and protocol are the same for all manufacturers.
This makes it possible for the first time to read out the fault code memory from vehicles of different manufacturers using an OBD-compatible scan tool.

Assignment of connections
The diagnostic socket has 16 pins. Seven connections (see Fig. 8, marked in red) are used by EOBD to check exhaust gas relevant components.
The remaining connections can be used by the vehicle manufacturer for other purposes.

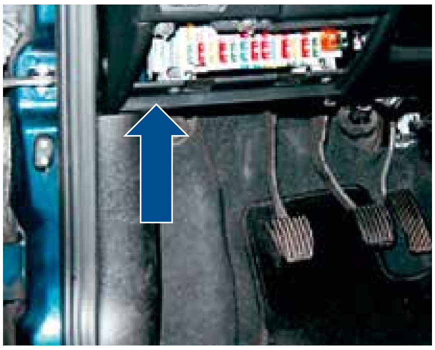
Locations
The diagnostic socket is installed in a location inside the vehicle interior that is easy for service staff to reach and is protected from accidental damage.



pin 7 +15	data transfer according to ISO 9141-2
pin 2 + 10	data transfer according to SAE J 1850
pin 4	vehicle weight
pin 5	signal measurement
pin 16	battery plus (terminal 30 or 15)

Fig. 8: diagnostic socket with assignment of connections

Fig. 9: examples of locations where diagnostic sockets are installed


Opel Astra


VW Passat


Citroën Berlingo / Peugeot Partner


Audi A6

2.10

Reading out the fault code memory – diagnostic process

connection of the scan tool to the diagnostic connection in the vehicle

Attention: *connection only when ignition is OFF!*

↓

switch ignition on

automatic detection of the type of transmission used by the control unit

↓

communication setup

After successful communication setup the system identified will be displayed with the system identification and address.

↓

selection of the desired test mode

please refer to section 2.11

↓

reception of the data requested

2.11 Scan tool modes (test modes)

An OBD-compatible scan tool according to ISO 15 031-5 has a minimum of 9 functions (modes).

Important note:
According to the new OBD directive the term “mode” is replaced by “service”.

mode 1	reads out the current operating data (actual data) such as engine speed, lambda probe signal, readiness code
mode 2	reads out the operating data in which an error occurred (“freeze frame”) such as engine speed, coolant temperature, engine load
mode 3	reads out the exhaust gas relevant errors that caused the malfunction indicator lamp (MIL) to go on such as P0101 combustion misfire Only “debounced”, i.e., confirmed errors are displayed (see Sections 2.7 and 2.8)
mode 4	erases the fault code memory of all systems Erases the fault codes, the “freeze frame” values and the readiness codes Attention: admissible only if followed by a repair and a new driving cycle
mode 5	displays the lambda probe signals (current voltage) Attention: the engine must be running and at an operating temperature
mode 6	displays the measured values of the systems that are not monitored permanently such as blowing in of secondary air, which varies according to vehicle manufacturer
mode 7	reads out “sporadic errors” reads out errors that have not yet caused the malfunction indicator lamp (MIL) to go on Only “non-debounced”, i.e., non-confirmed errors are displayed (see Sections 2.7 and 2.8)
mode 8	system and component test status indicating whether the test is finished (component test, readiness code)
mode 9	displays information on the vehicle such as the engine code, chassis number

2.12
Fault codes

Fault codes are assigned to the stored errors.When the fault code memory is being read out, these fault codes are shown in the "scan tool" display.
The fault codes are five-digit.

There are two types of fault codes:
- Fault codes standardised according to SAE J 2012/ISO 9141-2 are identified by a "0" in the second position.
- Manufacturer-specific fault codes are identified by a "1" in the second position.

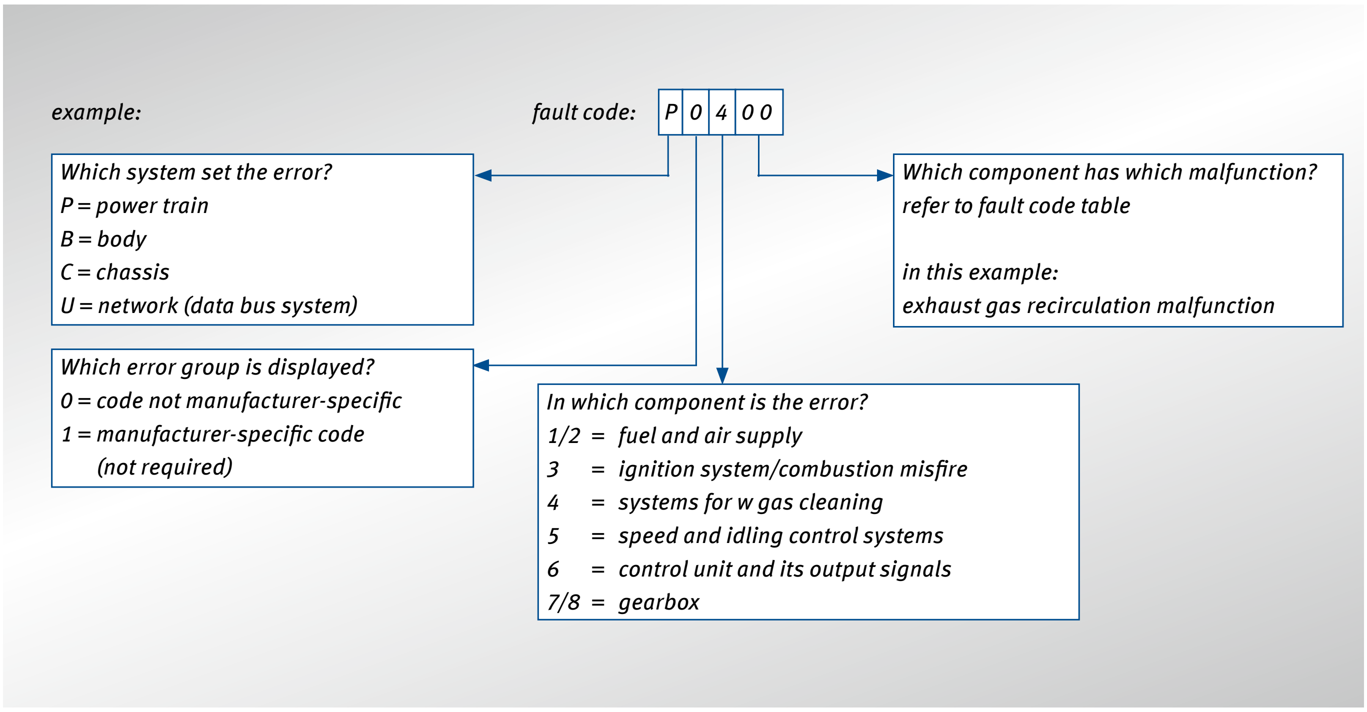


Fig. 10: structure of the fault codes

Manufacturer	Manufacturer-specific code	(E)OBD
Audi	16706	P0320
BMW	67	
Citroen/Peugeot	41	
Ford	227	
Mercedes-Benz	045	
Opel	19	
Toyota	6	
Volkswagen	00514	
Volvo	214	

Fig. 11: P0 fault code, one for many

Thanks to standardisation, uniform fault codes are now assigned to errors that are recorded for the first time since there have been fault code memories.
The various fault codes of the individual manufacturers for an error are now replaced by a P0 code.

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Important note:
For standard P0 fault codes see Sections 6.4; [9].

The fault code names the component involved and the type of error. A distinction is made between two types of errors:

Errors that are the result of malfunctions
In specific diagnosis, for example, are registered:
- malfunction
- quantity too small/too great
- rate too low/too high
- leak
- insufficient effect
- lean/rich control limit

Errors in component monitoring (comprehensive components).
Here all exhaust gas relevant sensors and actuators are monitored.

Examples of sensors are:
- air mass sensor
- pressure sensors
- speed sensor
- phase sensor
- temperature sensors
- position potentiometer

Examples of actuators are:
- valve actuators
- electric switch-over valves
- EGR valves
- electropneumatic transducer

P01/2xx	(fuel and air supply)	
P0117	coolant temperature sensor	signal too low
P0171	cylinder row 1	mixture too lean
P0213	cold start valve	malfunction in electrical circuit
P0234	turbocharging	limit exceeded
P03xx	(ignition system or combustion misfire)	
P0301	cylinder 1	misfire determined
P0325	knock sensor	malfunction in electric circuit
P0350	ignition coil	malfunction in electric circuit
P04xx	(additional system for emission control)	
P0400	exhaust gas recirculation	malfunction
P0411	injection system secondary air	incorrect flow rate
P0444	solenoid valve activated carbon filter	open electrical circuit
P0473	exhaust gas pressure sensor	signal too high
P05xx	(vehicle speed and idling control systems)	
P0506	idling control	engine speed below set-point
P0510	idle switch	malfunction in electrical circuit
P06xx	(control unit and its output signals)	
P0642	control unit	knock control defective
P07/8xx	(gearbox)	

Fig. 12: excerpt from the list of P0 fault codes

Examples of actuators are:
In component monitoring a distinction is made between electric errors and range errors (deviations from the set-point):

Examples of electric errors are:
- short circuit to earth
- short circuit to the supply voltage (plus connection)
- interruption/no signal

Examples of range errors are:
- signal/voltage
- not plausible (implausible operating range)
- outside the range
- too high or too low
- too little or too great
- lower/upper limit exceeded

Important note:
Please note that the wording of the text describing the fault code indicated can differ depending on the manufacturer of the scan tool.

Example: text display of different scan tools for fault code P0191

P0191	fuel rail pressure sensor	measuring range or power problem
P0191	fuel distribution pressure sensor	range/function error
P0191	pressure sensor circuit	fuel rail range operating behaviour
P0191	fuel pressure sensor G247	implausible signal

The following sections are intended to give you an overview of the individual systems and diagnosis of an On-Board-Diagnosis.

The diagnostic instructions at the end of the respective system are intended to be a help in determining the causes of errors for the system described.
They contain practical hints for error diagnosis and correction for emissions-relevant components. Many of these instructions are the result of customer queries and technical consultations with our Service Department.

Therefore this brochure concentrates on PIERBURG products.

Important note:
Because it is only since 2003 that EOBD also applies to passenger vehicles and light utility vehicles with diesel engines, emphasis is placed on vehicles with petrol engines.

3.1 System knowledge required

(E)OBD is a device that detects, records and displays errors.
The intention is to prevent severe damage to engine components and thus to avoid negative impact on the environment.
The diagnostic system can indeed detect a faulty component or a function that is not working properly, but often not the cause of the damage or the component causing the damage.
When there is a malfunction, error diagnosis is made easier by reading out the fault code and by putting out error relevant data for the workshop, but it is not always the case that a component that is indicated by the scan tool as faulty is actually the cause of the damage as well.

The actual cause can often be several components.
This requires the expertise of a specialist with knowledge of the system.

When the error is being diagnosed, the fault code should first be read out by a scan tool, and the component indicated as faulty should be checked.

The fault codes that are output give important indications of possibly faulty modules or components.
But often they also do not give any indications of simple causes such as buckled or leaky vacuum lines, stuck or leaky valves etc.

Depending on the vehicle manufacturer and scan tool, components can be activated in an actuator diagnosis.
It is practical to read out the fault code memory first and then to run the actuator diagnosis according to the manufacturer data of the scan tool.
A component activated by the actuator diagnosis is actuated in intervals so that it will be connected audibly or tangibly.
If it is connected audibly or tangibly, the voltage supply and the component must be OK electrically. This does not, however, determine leakage or internal soiling.
Electrical errors in the wiring harness or component itself are recorded in most applications as errors. Just like mechanical errors such as leaks, stuck valves etc., they also have to be tracked using conventional testing equipment.

In troubleshooting, attention should also be given to
- leaks in hose lines
- bad contacts in plug connections
- smooth running of actuators ("pressure boxes", actuators etc.)

The fault code memory must be erased after a test and if replaced.

3.2
Safety instructions

This brochure was designed exclusively for automotive specialists.

Each of the applicable conditions and relevant safety instructions must be observed, especially when handling fuel and fuel vapours.

Plug-in connections must not be disconnected or connected when the ignition is ON. Voltage peaks resulting from such action could damage the electronic components.
The resistance of components may be measured only after disconnecting the plug, as this could otherwise damage interior circuits. Safety devices must not be switched off or bypassed.
The manufacturer's specifications must be observed.

3.3
Further possibilities for diagnosis

In addition to the diagnostic instructions listed below there is an abundance of information sources that offer you assistance in diagnosing errors.
You will find a selection in Section 6.4 "Sources and further reading".

3.4 PIERBURG and OBD

As specialist in mixture formation, fuel and vacuum supply, air control and emissions control, Pierburg is very involved in the development and production of today's components.

Statistically there are 3.2 PIERBURG components in every passenger vehicle that is manufactured in Europe.
The majority is monitored directly or indirectly by OBD.

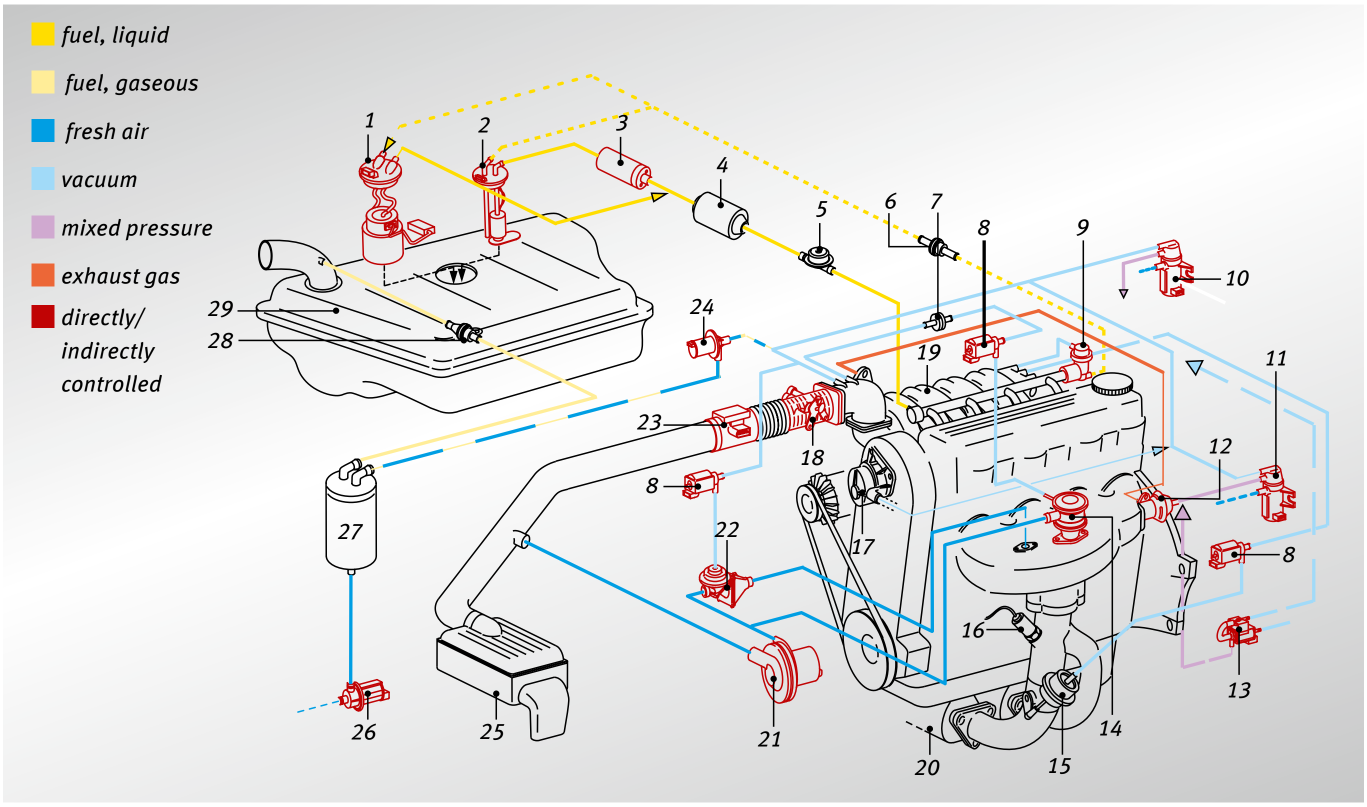

Fig. 13: exhaust gas relevant Pierburg products (petrol and diesel), schematic

PIERBURG products

1 fuel in-tank module
2 in-tank/presupply pump
3 in-line pump
4 fuel filter
5 pulsation damper
6 fuel check valve
7 non-return valve
8 electric switch-over valve (EUV)
9 pressure regulator
10 electropneumatic pressure transducer (EPW) for actuation turbocharger (VTG)
11 electropneumatic pressure transducer (EPW) for actuation EGR valve
12 EGR valve/exhaust gas recirculation valve
13 electric transducer (EDW)
14 cut-off secondary air valve (ARV)
15 exhaust gas flap
17 vacuum pump
18 throttle body (with attachments such as throttle switch,idling actuator, idle speed actuator etc.)
19 intake manifold (with attachments electromotive drive module EAM-i)
21 electric secondary air pump (SLP)
22 combi valve
23 air mass sensor (LMS)
24 canister purge valve/regeneration valve
26 canister purge valve
28 tank pressure valve –Water circulating pump (WCP not shown)

External product

16 lambda probe (pre-catalyst probe)
20 catalytic converter
25 air filter[4)]
27 activated carbon filter (AKF)
29 fuel tank
• turbocharger (not shown)

The individual systems and components are explained in the following section in greater detail.

[4)] Air filter inserts are part of the scope of delivery of MS Motor Service (for further reading: please refer to Section 6.4).

4.1
Fuel system

operate vehicles and machines with combustion engines, normally petrol or diesel fuel is required.
The components used for this purpose are classified under the term “fuel system”.

Fig. 14: fuel pumps and fuel in-tank modules, different versions

The fuel tank ventilation system (also referred to as “AKF system”) and the fuel tank leakage diagnosis are handled separately in the following sections (see Sections 4.2 and 4.3).

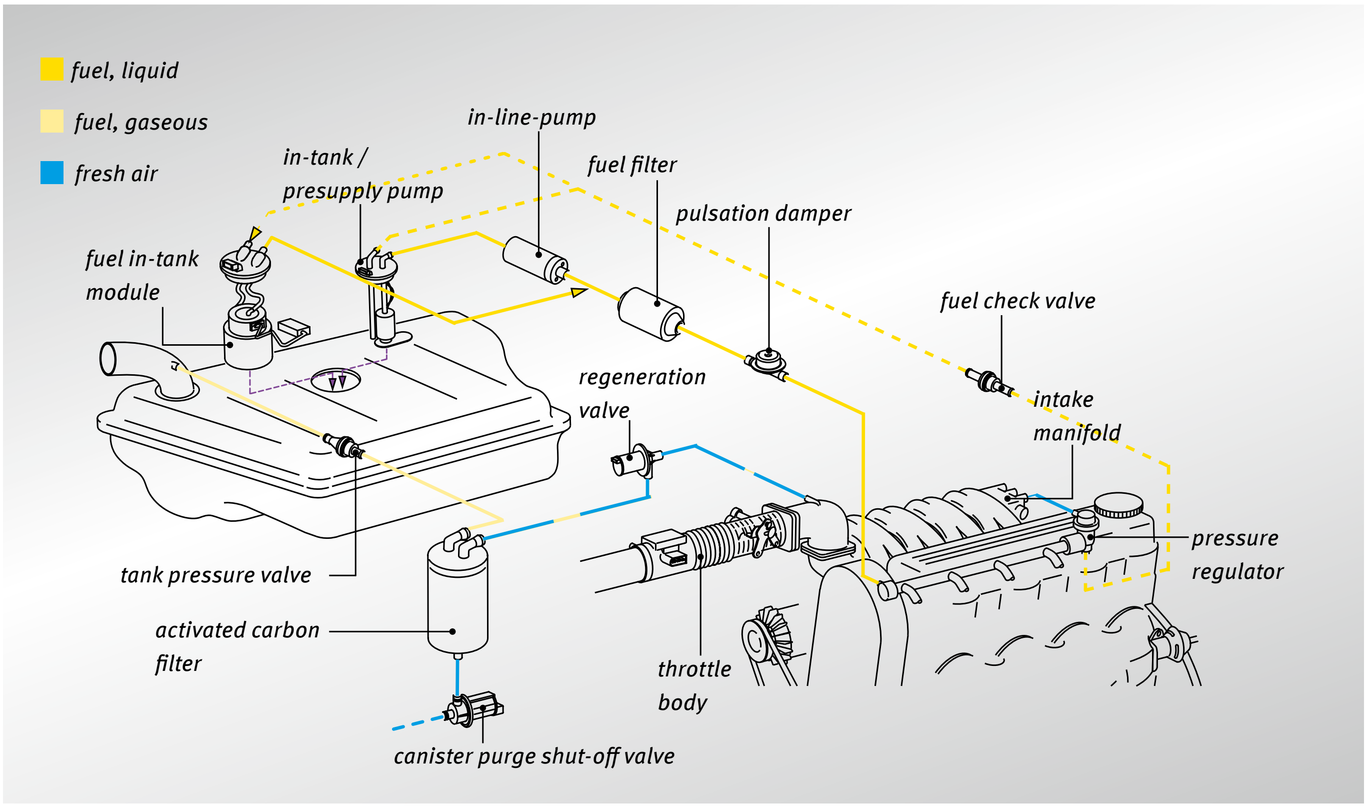

Fig. 15: fuel system, schematic

4.1.1 Monitoring

When there are greater deviations in the fuel system, similar malfunctions can occur, as described under combustion misfire or uneven running detection (please refer to Section 5.3.3):

- lack of power, jerking
- misfires until the uneven running detection responds
- oil dilution

Malfunctions or component errors that affect the mixture in such a way that they are exhaust gas relevant are detected by the lambda probe control position.

If an error is detected, a correction will be made by an adjustment of the injection times by the control unit. This correction is a short-term adjustment that is recalculated for each operating point.

The self adjustment of the mixture formation allows for an independent fine adjustment of the measured fuel quantities.

Short-term adjustment
When there are changes to the lambda value (e.g. “leaner” mixture) an immediate mixture correction will be made (in this case, for example, in the direction of “richer” mixture) so that the fuel/air ratio will again match that of the set-point.

Long-term adjustment
If corrections are necessary in the same direction over a longer time period, the control unit will apply a permanent correction value to the operating data memory. A long-term adjustment, also referred to as “adaptive precontrol”, will be made. Examples of such changes are changed leak air rates in the intake air system or changes to the air density when there are extreme changes in the elevation (mountain/valley driving).

This map, and therefore the average, are shifted so that the lambda control range for the short-term adjustment is fully retained in the “rich” as well as the “lean” direction.

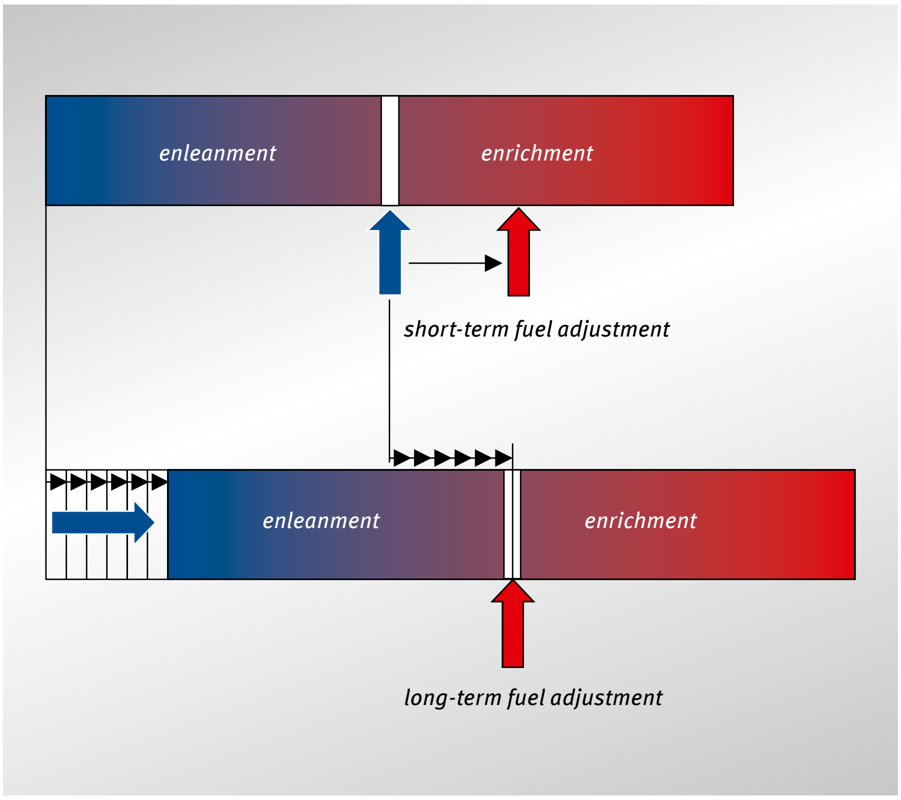

Fig. 16: self adjustment of the fuel system (mixture adjustment)

A shifting of the map, however, is possible only within specific limits (adjustment limits). If the adjustment limit is exceeded, an error will be recorded and the malfunction indicator lamp will be activated.

Possible flaut codes

P0170	volume control (bank 1)	malfunction
P0171	volume control (bank 1)	system too lean
P0172	volume control (bank 1)	system too rich
:		
P0175	volume control (bank 2)	system too rich
P0176	fuel composition measuring probe	malfunction
P0177	fuel composition measuring probe	measuring range or power problem
:		
P0178	measuring probe fuel composition	low input
P0179	measuring probe fuel composition	high input
:		
P0263	injection cylinder 1	contribution or synchronisation problem
P0266	injection cylinder 2	contribution or synchronisation problem
:		
P0296	injection cylinder 12	contribution or synchronisation problem
P0301	cylinder 1	ignition misfire
:		
P0312	cylinder 12	ignition misfire
P0313	ignition misfire detected	when fuel is too low
P0314	single cylinder (cyl. not defined)	ignition misfire

Important note:
Further reading:
please refer to Section 6.4.

Diagnostic instructions

Component	Possible causes/errors	Possible solutions/actions
Fuel system/mixture formation		
fuel	• defective fuel quality, fuel deficiency • soiling, blending with external substances such as diesel in the petrol fuel	• visual inspection, odour check • cleaning of the fuel systems • replacement of the fuel • replace the fuel filter and possibly the injection valves
fuel pumps	• fuel pump delivery rate (prefeeder and main pump) too low • fuel pressure too low	• measure pressure and delivery rate if present as well in the prefeeder pump • replace faulty pump
pressure regulator	• pressure controller defective, pressure too high/too low – thus injection quantity deviating	• check pressure and regulation function • replace faulty pressure controller • check fuel system
fuel filter	• clogged fuel filters; flow too low	• measure delivery rate behind the filter • replace filter
fuel lines	• fuel lines broken off • in the flow – fuel supply insufficient • in the return – fuel pressure too high	• when delivery rate is insufficient and pressure deviates, visual inspection • align lines and replace if necessary

Component	Possible causes/errors	Possible solutions/actions
Fuel system/mixture formation		
injection valves	• function errors • incorrect injection times • incorrect injection direction • leaky injection valves	• when the engine is off use a suitable instrument to check the HC value in the intake manifold • check injection times, injection signal and impermeability • clean valves or replace if necessary
AKF system	• AKF system leaking or not functioning • valves stuck • fuel overflow	• please refer to Section 4.2.3
Secondary air system		
secondary air system	• damage to the secondary air pump, the lines or the shut-off valve causing leak air in the exhaust manifold	• please refer to Sections 4.4.2 and 4.4.3
Engine control		
air mass sensor (LMS)	• wrong signal • sensor soiled or damaged	• check with scan tool (measure voltage signal) • replace defective lms
air mass sensor	• wrong signal • sporadic error (especially at high elevations)	test with scan tool: • check lines and plug-in connections • replace defective sensor if necessary
coolant sensor	• wrong signal • sporadic error	test with scan tool: • check lines and plug-in connections • replace defective sensor if necessary
air supply		
throttle body and attachments	• leak air • sensor for throttle valve position gives faulty signal • limit switch gives faulty signal or no signal	• check for leaks, replace damaged seal if necessary • check closing and end position and adjust if necessary, otherwise replace throttle body • check potentiometer signal, if necessary replace throttle body • check for wear, if necessary replace throttle body
intake manifold	• leak air in intake manifold • leak air behind the air mass sensor • leak air	• check for leaks, replace damaged seal if necessary • check closing position and adjust if necessary, otherwise replace wear parts, if necessary variable intake manifold • check for wear, if necessary replace variable intake manifold

Important note:
Modern engine control units have adaptive "storage modules", i.e. some of the map data required for operation must be "learned". If the power supply to the engine control unit is removed, it may be required to "teach" the control unit again.
The map data will first be recorded during driving and stored in the memory. This may take a few minutes! For this reason a test drive should be taken and only then should the function be checked again.

4.2
The fuel tank ventilation system (AKF system)

vapours are formed above the surface of the fuel in the fuel tank. The fuel tank ventilation system prevents fuel vapours from escaping into the environment with the hydrocarbons (HC) they contain. They are therefore accumulated in an AKF (activated carbon filter) canister.

Important note:
Another name for the fuel tank ventilation system is the "activated carbon filter" system, or "AKF" system.

Because the storage capacity of the activated carbon in the AKF canister is limited, the accumulator must be emptied ("regenerated") regularly and the condensates recirculated back into the combustion. This is done by suctioning ambient air from the manifold vacuum into the AKF canister. It is dosed by the AKF regeneration valve. In systems with increased pressure in the fuel tank, a fuel tank pressure valve can also be added.

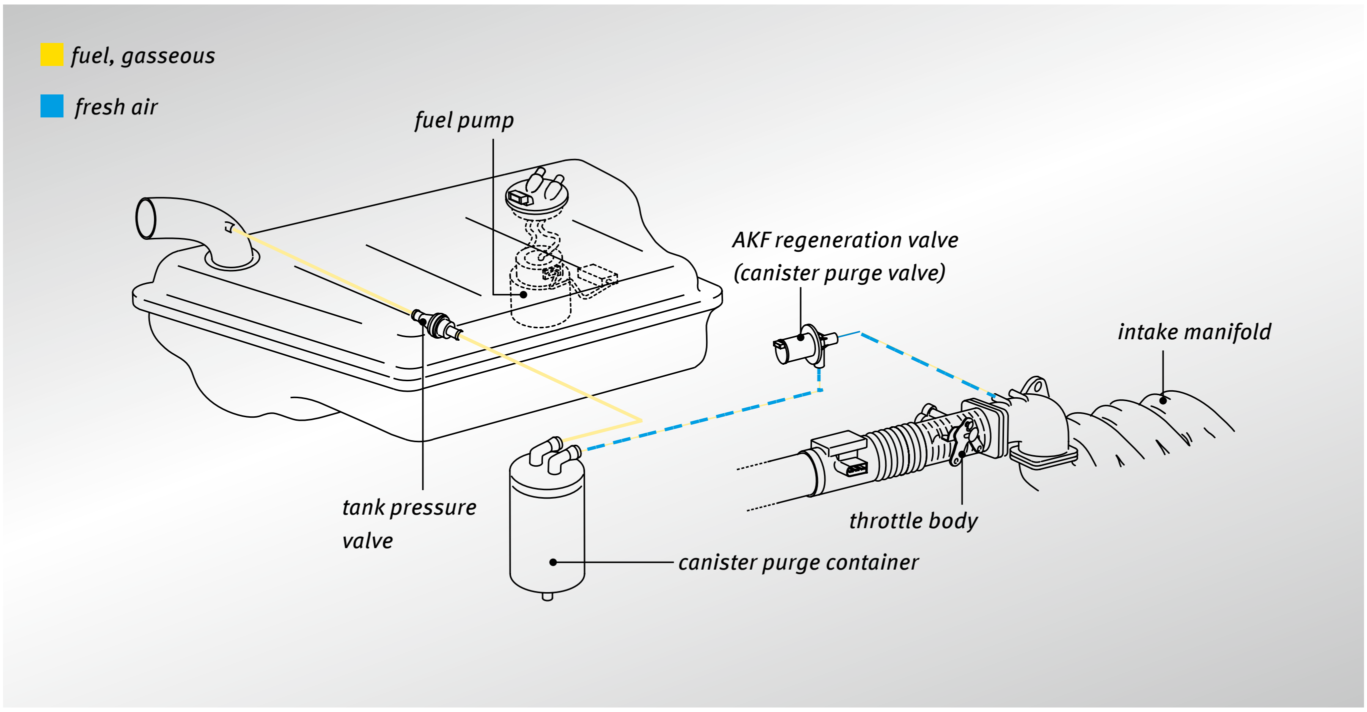

Fig. 17: fuel tank ventilation system, schematic

To "regenerate" the activated carbon filter, i.e., to rinse out the hydrocarbons accumulated in it, the AKF regeneration valve is opened by the engine control unit in certain operating states. The hydrocarbons accumulated in the activated carbon filter are introduced into the intake manifold and thus fed to the combustion.

Important note:
The AKF regeneration valve is also referred to as the canister purge valve, regeneration valve, or tank ventilation valve.

4.2.1
Monitoring

With the most common methods of monitoring, the lambda value is first measured after the AKF regeneration valve is closed. Then the AKF regeneration valve is opened.

- If many hydrocarbons are bonded in the activated carbon filter, the fuel mixture will be too rich for a brief period. The lambda control then regulates in the "lean" direction.
- If no active hydrocarbons, or only a few are accumulated in the activated carbon filter, only air or air with a low fuel content will flow when the AKF regeneration valve is open. This will produce leanness. The lambda control will then regulate in the "rich" direction.

If this adjustment does not occur within a certain time in both cases, and error will be indicated.

Lambda control will not react if a mix of lambda = 1 is produced at random when the AKF regeneration valve is opened. In this case the idle speed actuator will prevent the engine speed from increasing. During proper functioning the diagnostic threshold must also be reached within a certain time here. Here as well an error will be detected if the adjustment does not occur within a certain time.

A further method is the modulation diagnosis. In this case the AKF regeneration valve is opened and closed again by the control unit within a certain test interval. This generates pressure changes in the intake manifold that are registered by the intake manifold pressure sensor. The measured values are compared with the set-point values in the control unit. When there are deviations, an error will be detected.

Monitoring conditions
Monitoring occurs
- during idling
- at operating temperature.

Possible fault codes

P0170	fuel trim (bank 1)	malfunction
P0171	fuel trim (bank 1)	system too lean
P0172	fuel trim (bank 1)	system too rich
⋮		
P0175	fuel trim (bank 2)	system too rich
P0440	evaporative emission control system	malfunction
P0441	evaporative emission control system	incorrect purge flow
P0442	evaporative emission control system	leak detected (small leak)
P0443	evaporative emission control system	purge control valve circuit
P0444	evaporative emission control system	purge control valve circuit open
P0445	evaporative emission control system	purge control valve circuit shorted
P0446	evaporative emission control system	vent control circuit
P0447	evaporative emission control system	vent control circuit open
P0448	evaporative emission control system	vent control circuit shorted
P0449	evaporative emission control system	vent valve/solenoid circuit
P0450	evaporative emission control system	pressure sensor
P0451	evaporative emission control system	pressure sensor range/performance
P0452	evaporative emission control system	pressure sensor low input
P0453	evaporative emission control system	pressure sensor high input
P0454	evaporative emission control system	pressure sensor intermittent
P0455	evaporative emission control system	leak detected (gross leak)
P0456	evaporative emission control system	leak detected (very small leak)
P0457	evaporative emission control system	leak detected (fuel cap loose/off)
P0460	fuel level censor circuit	malfunction
⋮		
P0464	fuel level sensor circuit	intermittent
P0465	EVAP purge flow sensor circuit	malfunction
⋮		
P0469	EVAP purge flow sensor circuit	intermittent

Diagnostic instructions

In addition to electrical errors, that in any event are recorded and output as fault codes, there are other errors that can cause malfunctions. In the case of these errors the cause is not always diagnosed. The following table is intended as a help in determining the causes of such errors.

Component	Possible causes/errors	Possible solutions/actions
activated carbon filter	• fuel tank aeration and ventilation (external aeration) insufficient (soiled, clogged) • activated carbon filter flooded by fuel overflow • filling in activated carbon filter ineffective (granulates have disintegrated)	• visual inspection • clean or replace defective components • examine fit of AKF regeneration valve and check lines for deposits (dust/grime). This is an indication of disintegrated granulates
AKF regeneration valve	• idling problems • idle control has reached the control limit • valve stuck • valve partially blocked/leaking • noticeable smell of petrol especially at higher temperatures	• check non-return valve for functioning with vacuum hand pump • run self/actuator diagnosis • check electric resistance of the valve • clean valve, if necessary, replace defective valve
lines (to AKF regeneration valve or intake manifold)	• fuel tank aeration and ventilation (external aeration) insufficient (soiled, clogged) • lines soiled, broken off or no longer connected • drooping lines plugged by condensates	• clean or replace defective components • check lines

4.3
Fuel tank leakage diagnosis

When there is leakage in the fuel system or a missing fuel tank cap, harmful hydrocarbons (HC) would be emitted into the environment by the evaporation of fuel. The fuel tank leakage diagnosis (also referred to as "fuel tank diagnosis" or "leakage diagnosis") monitors the fuel tank system for leakage.

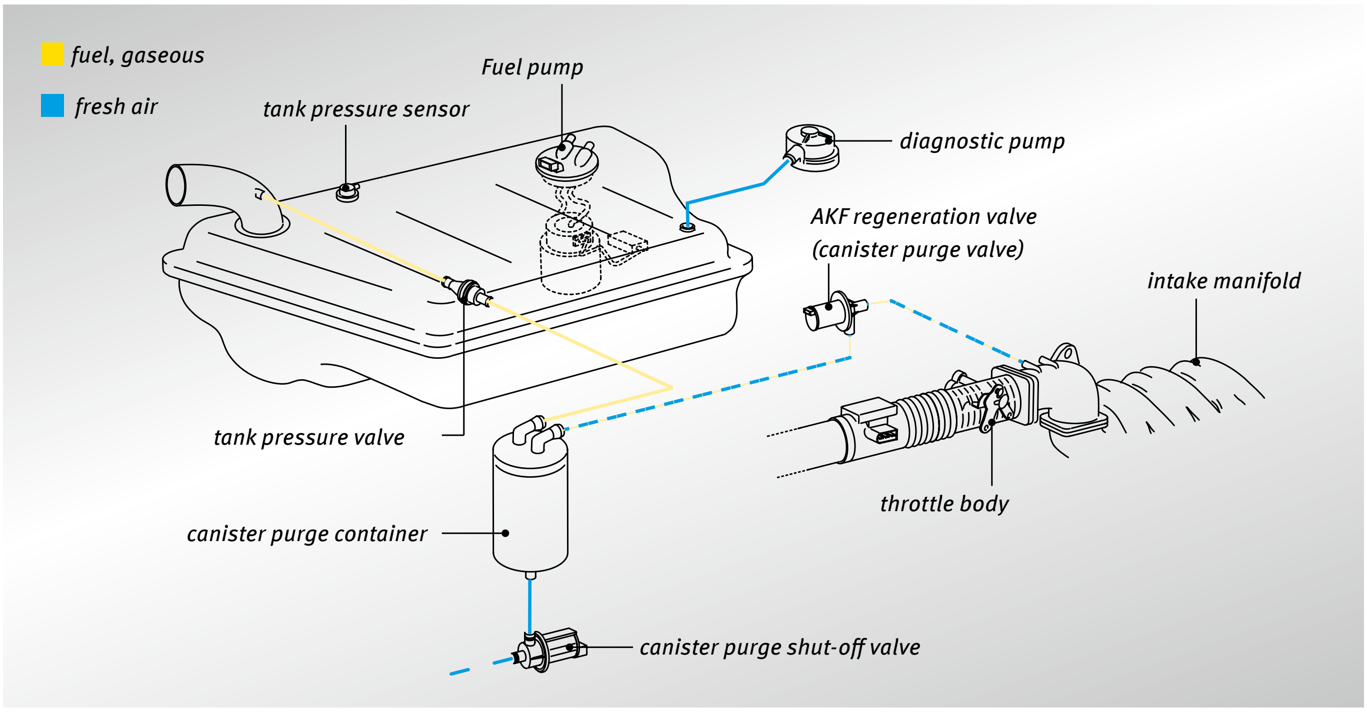

Fig. 18: fuel tank leakage diagnosis

Fig. 19: different valves (AKF-system)

For the tank leakage diagnosis, in addition to the components of the tank ventilation system (see Section 4.2), a canister purge shut-off valve and, depending on the test procedure, either a fuel tank pressure sensor or a diagnostic pump are necessary.

Important note:
The AKF regeneration valve is also referred to as the canister purge valve or regeneration valve.

4.3.1
Monitoring

For the test, two different procedures are used.

Only OBD II (USA) requires both types of fuel tank leakage diagnosis described. For EOBD (Europe) a tethered fuel tank cap to prevent loss and an electric component monitoring system are sufficient.

Testing with vacuum
The canister purge shut-off valve is closed. The AKF regeneration valve is open. This creates a vacuum in the intake manifold. If no vacuum is formed within a certain time, a leak (large leak up to approximately 1 mm) will be detected as an error.

If a specified vacuum is achieved within a specified time period, the AKF regeneration valve will close. If the pressure difference in this now closed system drops faster than specified, a small leak (up to approximately 0.5 mm) will be detected as an error.

Important note:
The AKF regeneration valve is also referred to as the canister purge valve, regeneration valve or tank ventilation valve.

Testing with overpressure
The canister purge valve and AKF regeneration valve are closed.
A diagnostic pump with integrated shut-off valve, required here, will create a defined pressure. If this pressure is reached, the pump will shut off automatically. If this pressure drops below a certain value, the pump will switch back on. Depending on the size of the leak, this will occur in shorter or longer intervals. When there are large leaks, no pressure can be built up. Depending on the procedure, the leak will be evaluated either by the power consumed or by the delivery time of the diagnostic pump.

Possible fault codes

P0440	evaporative emission control system	malfunction
P0441	evaporative emission control system	incorrect purge flow
P0442	evaporative emission control systeml	eak detected (small leak)
P0443	evaporative emission control system	purge control valve circuit
P0444	evaporative emission control system	purge control valve circuit open
P0445	evaporative emission control system	purge control valve circuit shorted
P0446	evaporative emission control system	vent control circuit
P0447	evaporative emission control system	vent control circuit open
P0448	evaporative emission control system	vent control circuit shorted
P0449	evaporative emission control system	vent valve/solenoid circuit
P0450	evaporative emission control system	pressure sensor
P0451	evaporative emission control system	pressure sensor range/performance
P0452	evaporative emission control system	pressure sensor low input
P0453	evaporative emission control system	pressure sensor high input
P0454	evaporative emission control system	pressure sensor intermittent
P0455	evaporative emission control system	leak detected (gross leak)
P0456	evaporative emission control system	leak detected (very small leak)
P0457	evaporative emission control system	leak detected (fuel cap lost/off)
P0460	fuel level sensor circuit	malfunction
⋮		
P0464	fuel level sensor circuit	intermittent
P0465	EVAP purge flow sensor circuit	malfunction
⋮		
P0469	EVAP purge flow sensor circuit	intermittent

Diagnostic instuctions

n addition to electrical errors, that in any event are recorded and output as fault codes, there are other errors that can cause malfunctions. In the case of these errors the cause is not always diagnosed.

The following instructions are intended as a help in determining the causes of such errors.

If the OBD indicates a leak:

- Check the entire fuel tank system with all the connections to the fuel tank segments (for saddle tanks) and to the activated carbon filter for leaks.
- Especially the shut-off valve must be checked for leaks and for functioning.
- Other possible errors are stuck or soiled AKF regeneration valves and canister purge shut-off valves.
  If this soiling of the valves is due to the activated carbon filter, it must be replaced. If the valves become stuck repeatedly, the entire system may have to be cleaned.

Important note:
An error message can also be triggered by a loose or missing fuel tank cap!

4.4
Secondary air system

For a certain cold start a mixture with excess fuel (rich mixture) is needed. Because the mixture is too rich in the cold start phase, there will be a greater amount of unburned hydrocarbons (HC) and carbon monoxide (CO) in the exhaust gas. Blowing oxygen-rich ambient air (secondary air) into the exhaust manifold will produce a post-oxidation (catalytic post-combustion) of pollutants. Although the secondary air system is switched on for only a maximum of 90 seconds after a cold start, this will reduce the HC and CO emissions considerably during the cold start phase. At the same time the warm-up time of the catalytic converter is shortened considerably by the heat that is released during the post-oxidation.

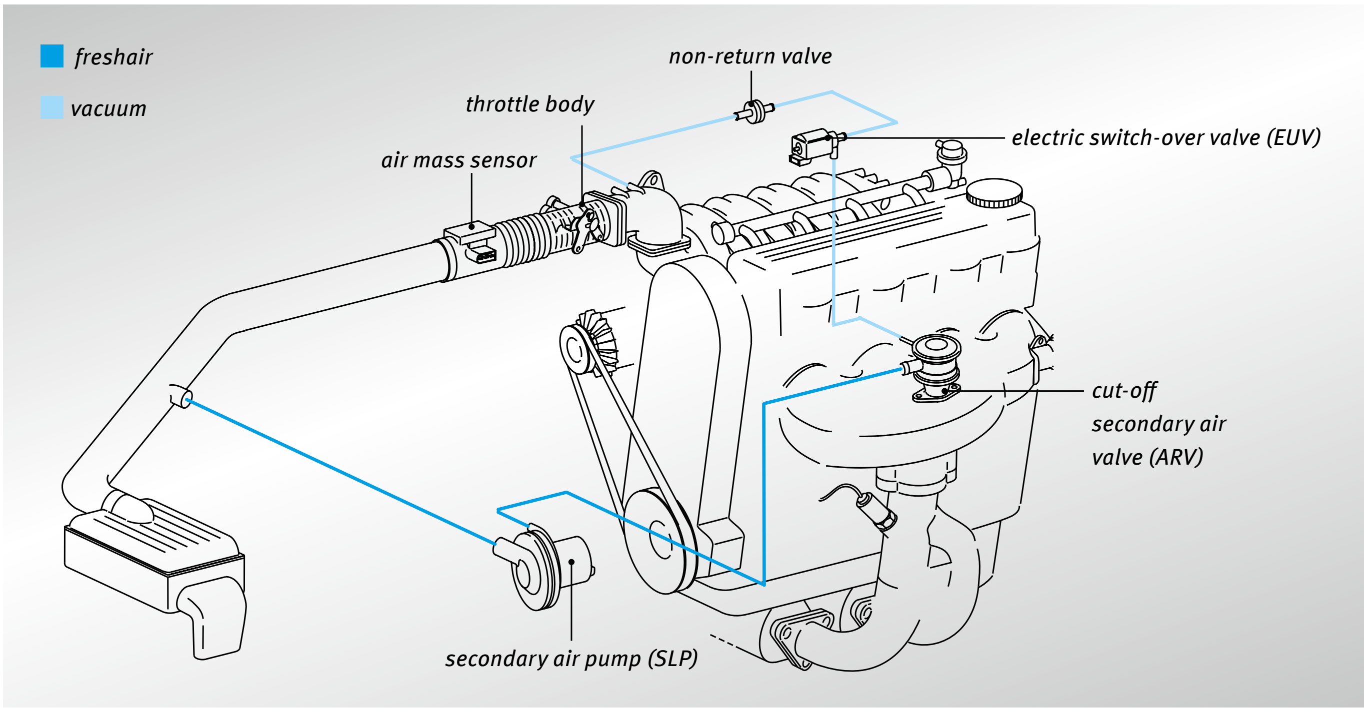

Fig. 20: secondary air system, schematic (newer version)

The additional air is provided by an electric secondary air pump (SLP) that blows the air into the exhaust manifold.
For this purpose appropriate tubing is required between the clean air side (downstream from the air filter) and the exhaust gas manifold.
The cut-off secondary air valve (ARV) is a pneumatically operated valve. An integrated non-return valve prevents exhaust gas or pressure peaks from reaching and damaging the secondary air system and the secondary air pump.
The ARV is controlled by an electric switch-over valve (EUV) based on the time after a cold start.

Important note:
Newer versions of cut-off secondary air valves are opened by the pressure of the secondary air. In this case the EUV is no longer applicable.

Cut-off secondary air valves are opened only while secondary air is being blown in immediately after cold start.

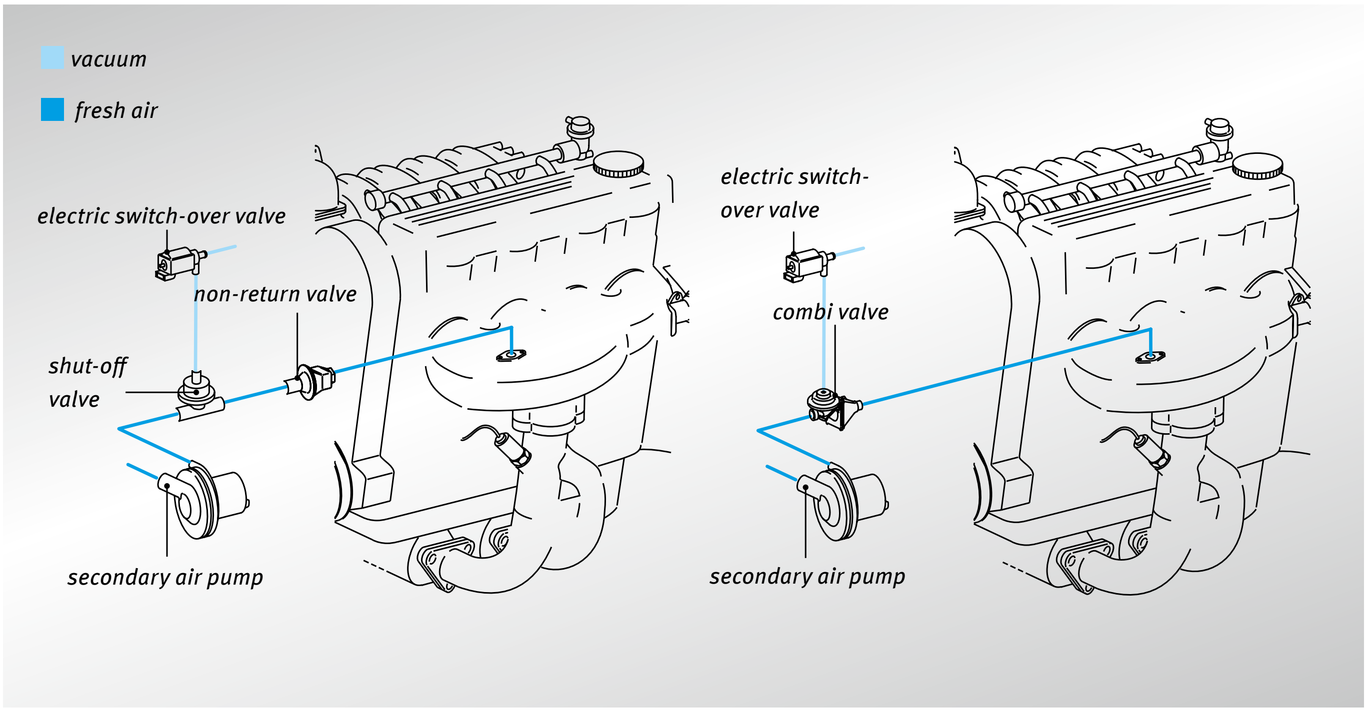

Fig. 22: secondary air system, schematic (older variants)

Fig. 23: combi valve

Fig. 24: shut-off valve, older version

Fig. 22 shows two older variants frequently used with

- separate shut-off and non-return valves
- adjacent shut-off and non-return valves together as a combi valve

Combi valves consist of a shut-off valve with a built-in non-return valve.

Shut-off valves are vacuum operated diaphragm valves. They are installed between the SLP and the non-return valve to the exhaust gas manifold. They seal off the secondary air system to the exhaust gas manifold. They are opened for secondary air mode only immediately after cold start. They are actuated by the electric switch valve.

4.4.1 Monitoring

The functioning and electric equipment of the secondary air system are monitored in OBD.

- The functioning is monitored with the help of the lambda probe by monitoring the flow rate of the secondary air at certain operating points. When certain limits are exceeded, an error will be detected.
- The electrical equipment is monitored for short circuit to earth, short circuit in the supply voltage and interruption.

In EOBD the secondary air system is chekked only with respect to the electric connections of the secondary air pump, but not with respect to its functioning.

Two different processes are used to check the functioning.

Immediately after a cold start
The secondary air pump will be switched on for approximately 90 seconds.
The secondary air blown in will not be regulated.
If the lambda probe is ready for operation, and if useful probe signals are emitted, they will be compared with the set-point values.

At operating temperature
This monitoring occurs during an idling phase when the engine is at an operating temperature.
To run the test, the SLP is switched on.
This causes the lamba probe to register a lean mixture. The probe signal is compared with the set-point values in the control unit.

Possible fault codes (with diagnostic instructions)

Errors in the secondary air system are indicated by fault codes P0410 – P0419.

Fault code	Possible causes/errors	Possible solutions/actions
P0410 Secondary air system-malfunction		
no detection of secondary air by lambda probe (no lean signal)	The secondary air pump is not working.	• If fault codes P0418/0419 are recorded, energise the secondary air pump externally to run the test. If the SLP is now working, check all relays, lines and plug-in connections. If the SLP is not working, it will have to be replaced. • If there is a secondary air pump failure due to condensates (detectable by soiling in the pump output), check the cut-off secondary air valve on the secondary air side for leaks and the electric switch-over valve for functioning. • If there is soiling on the secondary air side input of the cut-off secondary air valve, the valve must be replaced. • Check whether the secondary air pump has malfunctioned due to water (detectable by water residue in the pump). Check the suction pipe for leaks.

Fault code	Possible causes/errors	Possible solutions/actions
Secondary air system – insufficient quantity		
set-points not reached	The secondary air rate detected is too low (insufficient lean signal). The secondary air pump is running, but the air does not reach the exhaust gas manifold.	• Check cut-off secondary air valve for functioning with vacuum hand pump. If the ARV does not open when there is a vacuum, replace it. • If the ARV does open when there is a vacuum, check the electric switch-over valve and the vacuum line. • Check the power supply to the EUV. If the EUV does not switch when current is being supplied, replace it. • Check the EUV for free flow and replace if necessary. Check the non-return valve and the secondary air lines for free flow. To do this, disconnect the line from the exhaust manifold, let the secondary air pump run, and check the air output ortake out the non-return valve and check the free flow by blowing the air through; here no essential air resistance should be detectable.
P0412 Secondary Air Injection System Switching Valve "A" Circuit (EUV-SL)		
P0415 Secondary Air Injection System Switching Valve "B" Circuit (EUV-SL)		
activation not OK	The electric switch-over valve (EUV) does not activate. • power is not being supplied to the EUV • electrical error	• lines, plug-in connections and EUV check
P0413 Secondary Air Injection System Switching Valve "A" Circuit (EUV-SL) Open		
P0416 Secondary Air Injection System Switching Valve "B' Circuit (EUV-SL) Open		
the electric switch-over valve (EUV) do not activate	• power is not being supplied to the EUV • activation not OK • electrical error	• lines, plug-in connections and EUV check
P0414 Secondary Air Injection System Switching Valve "A" Circuit (EUV-SL) Shorted		
P0417 Secondary Air Injection System Switching Valve "B" Circuit (EUV-SL) Shorted		
the electric switch-over valve (EUV) does not activate	The electric switch-over valve (EUV) does not activate. • power is not being supplied to the EUV • activation not OK • electrical error • ahort circuit	• lines, plug-in connections and EUV check
P0418 Secondary Air Injection System Relay "A" Circuit Malfunction		
P0419 Secondary Air Injection System Relay "B" Circuit Malfunction		
secondary air pump is not working	Secondary air pump relay A or B does not activate. • activation not OK • electrical error • short circuit	• check relays, lines, plug-in connections and secondary air pump

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Further fault codes that are of significance in connection with the secondary air system

P0100	mass or volume air flow circuit	malfunction
P0101	mass or volume air flow circuit	range/performance problem
P0102	mass or volume air flow circuit	low input
P0103	mass or volume air flow circuit	high input
P0104	mass or volume air flow circuit	intermittent
P0105	manifold absolute pressure/ barometric pressure circuit	malfunction
P0106	manifold absolute pressure/ barometric pressure circuit	range/performance problem
P0107	manifold absolute pressure/ barometric pressure circuit	low input
P0108	manifold absolute pressure/ barometric pressure circuit	high input
P0109	manifold absolute pressure/ barometric pressure circuit	intermittent
P0110	intake air temperature circuit	malfunction
P0111	intake air temperature circuit	range/performance problem
P0112	intake air temperature circuit	low input
P0113	intake air temperature circuit	high input
P0114	intake air temperature circuit	intermittent

Non-return valves are installed between the shut-off valve and the exhaust gas manifold to prevent pressure peaks from causing damage to the secondary air system. They are opened by the pressure of the secondary air flow.

Secondary air pumps are high-speed one or two-stage fans.
If the air is not extracted from the inlet port but directly from the engine compartment, an air filter is integrated.

Electric switch-over valves (EUV) are 2/3 way valves. They are used for vacuum control valves, EGR valves, secondary air valves and for many other purposes.
You will find further information on EUVs in the Service Information SI 0050, SI 0051 and SI 052.

Fig. 25: non-return valve (older version)

Fig. 26: secondary air pump

Fig. 27: electric switch-over valve (EUV)

Diagnostic instructions

A malfunction of a component in the secondary air system will often cause damage to several components.
A frequently occurring error is a malfunctioning secondary air pump. Almost always damage is caused by exhaust gas condensates in the pump.
During the repair the actual cause of the damage is often not detected and the secondary air pump is just replaced. The cause of the damage remains in the vehicle and can cause the secondary air pump to malfunction again.
For this reason, when there is damage, all associated components must be checked. For example, stuck non-return valves are classified by OBD as malfunctions of the secondary air pump even if they are working properly.
Moreover, damage to the secondary air system can cause errors that are attributed to other components by the error detection.

Fig. 28: condensate in the secondary air pump

Fig. 29: secondary air pump – corroded electric connections

Fig. 30: cut-off secondary air valve – damage to the diaphragm and valve plate due to condensates

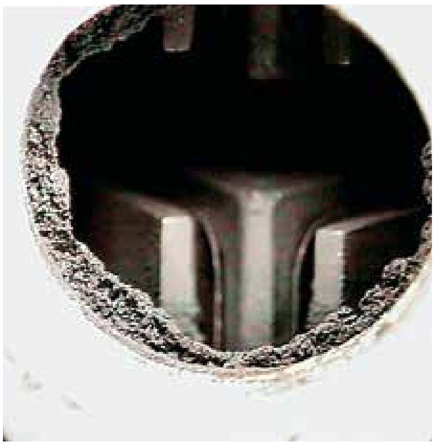

Fig. 31: deposits in the non-return valve

Malfunction	Possible causes/errors	Possible solutions/actions
loud whistle (“howling”) after cold start. SLP generates noises. SLP fails repeatedly.	• Bearing corroded with condensates. • Lines and insulation destroyed by condensates. • EUV incorrectly connected (to wrong cables).	If the SLP causes noises, replace it and determine the cause of the damage as described under fault codes P0410 and P0411. Check the ARV and the EUV. If there are several EUVs in the vehicle, ensure that the connections are not mixed up.
exhaust pipe noises or smell of exhaust gas in the engine compartment.	Leaks in the exhaust gas tract or in the secondary air system, between the exhaust gas manifold and the cut-off secondary air valve or non-return valve.	Let the secondary air pump run still installed (externally powered). Determine the leaky places (e.g. using leak detection spray). Replace faulty line or gasket. Attention: When the line between the SLP and the exhaust manifold is scorched, proceed as for fault codes P0410 and P0411.

Frequent causes of damage:

Bad location for the electric switch-over valve (EUV)
EUVs are often located in areas exposed to splashing water. When the EUV is switched off, water can penetrate it through the aeration system and cause corrosion. The valve no longer switches and the ARV remains open. Exhaust gas gets into the secondary air system, condenses there and causes consequential damage. In many cases water also gets into the vacuum side of the ARV and causes damage there. Damage of this type is not detected as error by the monitoring of electric components in EOBD.

Bad location for the SLP in areas exposed to splashing water
Especially secondary air pumps in which the air is extracted from of the inlet port but directly from the engine compartment are at risk. Here water can be drawn in from the SLP.

No activation of the ARV
The vacuum line between the EUV and the ARV is disconnected, pinched or broken off.

Defective, non-activated or leaky ARV
A leak causes exhaust gas to get into the secondary air system and to condense there. In both cases the secondary air pump and the cut-off secondary air valve are damaged by the aggressive, extremely acidic condensates.

“Garage cars”
Vehicles with frequent long periods of inactivity are especially affected by corrosion. In this case water and condensates can cause damage after a brief time. In vehicles that are continuously being used, secondary air is regularly blown out of the system. Here damage occurs later.

Leaky suction pipe to the secondary air pump
Splashing water can also get in between the air filter and the SLP causing corrosion and later the failure of the secondary air pump. Therefore attention must be given to the lines to ensure that they are correctly inserted and not broken off. Check older lines for cracks. Check gaskets. Splashed water does not lead to damage as quickly as condensates.

Mechanical damage
To secondary air pumps, lines and cables due to accident or also during repairs.

Electrical disturbances
Due to short circuit or interruption.

Stuck non-return valves
(in older systems with separate non-return valves).
If oil vapours (blow-by gases) get into the non-return valve from the inlet port here, the valve can become so stuck that it will also remain closed when the secondary air pump is running.

Important note:
Further information on error diagnosis and function descriptions can be found in the Service Information SI 0012, SI 0024, SI 0049, SI 0050, and SI 0059.

Fig. 32: simple check of the check valve

Non-return valves can be checked for leaks
very simply:

- Release the connection hose on the non-return valve that leads to the secondary air pump.
- If there are deposits on this side of the valve (for the finger test, see illustration), the non-return valve is leaking and must be replaced. In this case the secondary air pump may already be damaged. Check the secondary air pump and replace as well if necessary.

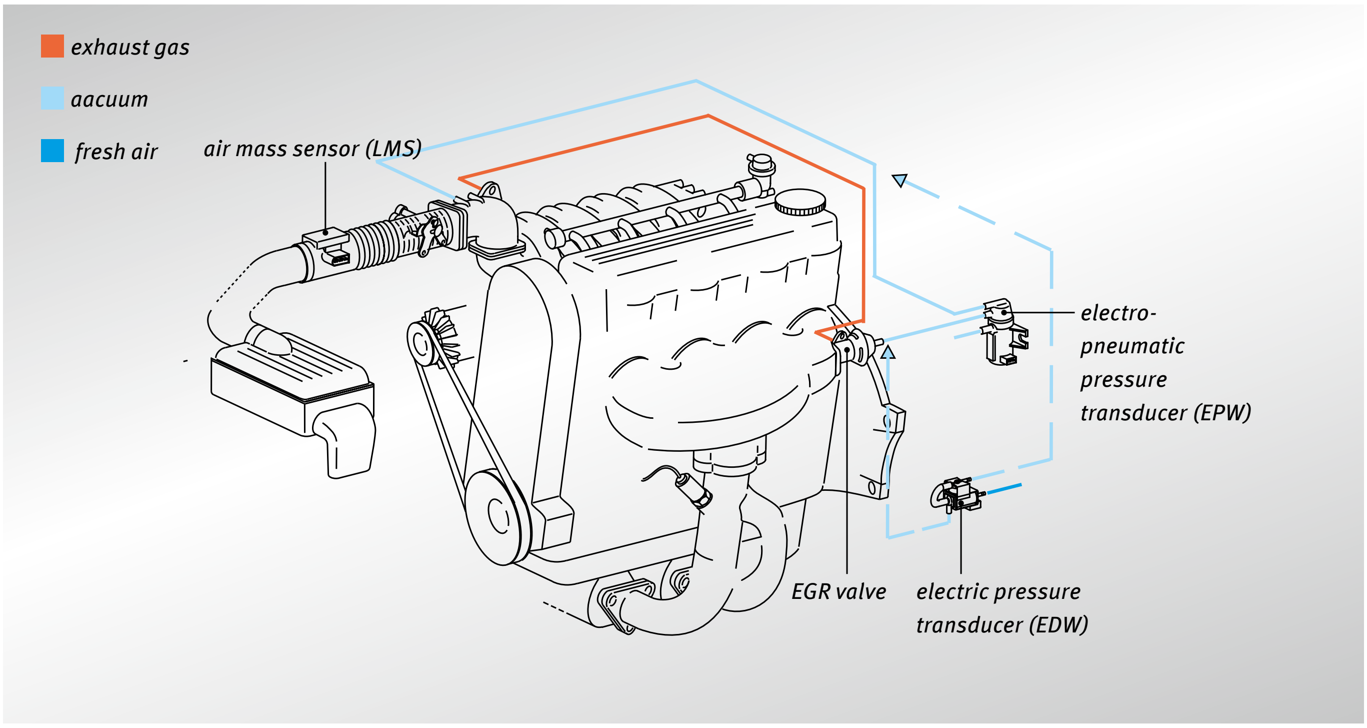

Fig. 33: exhaust gas recirculation in a petrol engine (with pneumatic EGR valve), schematic

4.5
Exhaust gas recirculation (EGR)

Mixing the exhaust gas with the intake air reduces the oxygen content of the fuel/air mixture. This reduces the combustion temperature in the cylinders. Depending on the operating point, this produces a reduction in nitrogen oxide (NOx) in the exhaust gas by up to 50%.
In addition, in diesel engines the particle formation is lowered by approx. 10%, and the noise emissions are reduced.
In petrol engines the lower fuel consumption can be detected. Thus a regulated addition of exhaust gas can influence the exhaust gas behaviour of the vehicle according to the load conditions. Thus exhaust gas recirculation (EGR) is an effective process for reducing nitrogen oxide emissions.
Therefore it is monitored for functioning in the OBD II standard.

Until about 1998 predominantly pneumatic valves were used. In newer applications electric EGR valves (EEGR) are used almost exclusively.

Advantages of pneumatic valves:
- less weight
- good pushing force
- simple construction

Advantages of electric valves:
- no additional components
- quick functioning because they are actuated directly
- good to monitor
- do not require a vacuum to be switched

Exhaust gas lines connect the exhaust manifold to the EGR valve and the valve to the inlet port/intake manifold. In many cases EGR valves are attached directly to the exhaust manifold or the inlet port.
Fig. 33 shows two variants of exhaust gas recirculation with a pneumatic EGR valve. It is actuated by an electropneumatic pressure transducer (EPW) or an electric pressure transducer (EDW).

The vacuum in the intake manifold is used to operate the EGR valve. The valve opens and a certain amount of exhaust gas is fed back into the exhaust manifold and thus into the combustion.
Some EGR valves are equipped with potentiometers for position feedback. Position feedback allows both opening correction as well as permanent monitoring. Other EGR valves are additionally equipped with integrated temperature sensors for monitoring. Because high temperatures arising when electric EGR valves are used can cause malfunctions, these valves are connected to the coolant circuit for certain applications. The air mass sensor (LMS) in the intake system continuously measures the air mass supplied to the engine. In diesel vehicles the LMS signal is used to control the exhaust gas recirculation.

The control unit activates the exhaust gas recirculation in the case of pneumatic as well as electric valves based on the temperature, the air mass (load) and the engine speed. The position of the EGR valve is detected by a sensor (generally a potentiometer).

- In simpler or older systems pneumatically operated EGR valves are operated by an electric switch-over valve (EUV) by means of a vacuum. In the case of this simple system structure the EGR valve has only an open/close function.
- In newer systems the actuation is handled by an electropneumatic transducer (EPW) that is able to adjust the EGR valve continuously. This allows quick and very accurate adjustments to the respective operating points. Before the introduction of EPWs, electric pressure transducers (EDWs) were used.
- Electric EGR valves are actuated directly by the control unit.

Exhaust gas recirculation is switched on only in certain operating points.

- For diesel engines up to 3000 RPM and at an average load.
- For petrol engines above idle up to the upper partial load.
- Exhaust gas recirculation does not occur at full load. This does not affect the ultimate performance.

EGR valves for diesel applications have large open cross sections because of their high return rates.
They are often integrated in housing with a throttle valve (“EGR emulsion housing”).

Fig. 34: EGR valves for diesel applications

In petrol engine applications the cross-sections are considerably smaller.

Fig. 35: EGR valves for petrol engines

4.5.1 Monitoring

In OBD II (USA) the EGR system is monitored for functioning and effect.
In EOBD an electric monitoring of the components and a monitoring of the functioning is sufficient.
A test of the effectiveness is not required by the EOBD. Various manufacturers do supply EU vehicles that comply with OBD II standards.

Fig. 36: electric pressure transducer (EDW)

Electric pressure transducers consist of an electric switch-over valve (EUV) with added pressure limiter. They are similar in their function to an electric pneumatic transducer (EPW).

You will find further information on EDWs in Service Information SI 0027.

Different processes can be used to monitor the exhaust gas recirculation:

Measuring the pressure in the intake manifold
During the deceleration phase the EGR valve is opened briefly and the intake manifold pressure sensor registers the pressure increase.
The EGR valve is monitored for leaks by closing it briefly and testing the associated pressure reduction in the partial load range.

Measuring the intake manifold temperature
During the deceleration phase the EGR valve is opened briefly. The temperature sensor for the intake air registers the temperature rise by measuring the temperature of the incoming warm exhaust gas.

Measuring the temperature on the cold side of the EGR valve
When a valve is open the exhaust gas will cause the temperature on the cold side of the valve to rise. The increase in temperature is registered by a sensor. In addition the signals of the potentiometer are also registered.

Registering the EGR potentiometer signals
Electric EGR valves (EEGR) and in part also mechanical EGR valves have a potentiometer that detects the position of the valve. There are applications with additional monitoring of the pressure or temperature in the intake manifold.

Plausibility check (especially for diesel engines)
In yet another type of monitoring, especially for diesel engines, the air mass is registered with and without exhaust gas in relationship to the engine speed.

Monitoring the air mass (especially for diesel engines)
In exhaust gas recirculation the intake air mass is reduced by the amount of recirculated exhaust gas. The air mass sensor registers this reduction in the air mass. In addition, the potentiometer signals are also monitored.

Fig. 37: electropneumatic transducer (EPW)

Monitoring the uneven running
During idling, the EGR valve is opened a small amount. Exhaust gas gets into the idle mixture and the idling becomes uneven. This uneven running is detected and used for the diagnosis.

Possible fault codes (with diagnostic instructions)

Errors in the exhaust gas recirculation system are indicated by fault codes P0400 – P0409.

Fault code	Possible causes/errors	Possible solutions/actions
P0400 EGR system - flow malfunction		
• there is no exhaust gas recirculation, or it is not detected • expected performance not reached • engine goes into limp home mode • driving behaviour is deficient • uneven idling	• the EGR valve does not open	• Check pneumatic EGR valve for functioning with vacuum hand pump. It doesn't open. If there is a vacuum, check the EGR valve for sticking or carbonisation; if the vacuum is not maintained, replace the EGR valve. If a pneumatic valve is not actuated, check the vacuum lines for continuity. • If there is sticking, replace the EGR valve and check the injection system and the oil vapour separator (blow-by separator) • Examine the EGR valve for visible damage or discolorations. In this case the exhaust gas back pressure could be too high or the actuation could be incorrect. Check the exhaust gas system for free flowing, and the boost pressure control valve and electric actuators for functioning. • Check the power supply to the EGR valve (connections, cables, plug-in connections and electric actuators) and check the electropneumatic transducer, electric pressure transducer, or electric switch valve. Replace the defective parts.
P0401 EGR system - flow insufficient detected		
too little exhaust gas is being recirculated	• the EGR valve does not open wide enough • width restricted by impurities (carbonisation) • EGR valve opening time too little • air mass sensor defective or soiled	• Check electric supply. • Check pneumatic supply (vacuum). • Take valve out and check its condition. • If there is sticking, replace the EGR valve and check the injection system and the oil vapour separator (blow-by separator). • Especially for electric EGR valves, check the supply and the sensors. • Check air mass sensors and replace if necessary.
P0402 EGR system - flow insufficient detected		
excessive exhaust gas recirculation	• the EGR valve opens to an extent that deviates from the set-point values • the valve does not close completely • air mass sensor defective or soiled	• Check sensors and supply. • Take valve out and check its condition. • If there is sticking, replace the EGR valve and check the injection system and the oil vapour separator (blow-by separator). • Check air mass sensors and replace if necessary.

Fault code	Possible causes/errors	Possible solutions/actions
P0403 EGR system – circuit malfunction		
• EGR signals wrong or implausible	• wear/soiling of the potentiometer in the EGR valve • temperature sensor defective	• Check signals and compare with set-point values.
P0404 EGR system – circuit measurement/power problem		
• exhaust gas recirculation outside set-point range • EGR signals wrong or implausible	wear/soiling in • potentiometer EGR valve • pressure sensor • temperature sensor • air mass sensor • electric plug-in connections and lines	• Check signals and compare with set-point values. • Check electric connections and lines.
P0405 EGR system – sensor A circuit low		
P0406 EGR system – sensor A circuit high		
P0407 EGR system – sensor B circuit low		
P0408 EGR system – sensor B circuit high		
• EGR signals wrong or implausible	wear/soiling in • potentiometer EGR valve • pressure sensor • temperature sensor • air mass sensor • electric plug-in connections and lines	• Check signals and compare with set-point values. • Check electric connections and lines.

Important note:
When there are malfunctions in the EGR system or damage to its components, the periphery must always be checked as well. Deposits can be caused by errors in the injection system or an oil content that is too high. In OBD, errors of this kind are detected only partially and are sometimes classified incorrectly.

Further information on EGR valves and ways to check can be found in our Service Informations, contain comprehensive troubleshooting tables.

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Further fault codes that are of significance in connection with the EGR

P0100	mass or volume air flow circuit	malfuction
P0101	mass or volume air flow circuit	range/performance problem
P0102	mass or volume air flow circuit	low input
P0103	mass or volume air flow circuit	high input
P0104	mass or volume air flow circuit	intermittent
P0105	manifold absolute pressure/ barometric pressure circuit	malfunction
P0106	manifold absolute pressure/ barometric pressure circuit	range/performance problem
P0107	manifold absolute pressure/ barometric pressure circuit	low input
P0108	manifold absolute pressure/ barometric pressure circuit	high input
P0109	manifold absolute pressure/ barometric pressure circuit	intermittent
P0110	intake air temperature circuit	malfunction
P0111	intake air temperature circuit	range/performance problem
P0112	intake air temperature circuit	low input
P0113	intake air temperature circuit	high input
P0114	intake air temperature circuit	intermittent

Errors in the sensors affect the functioning of the exhaust gas recirculation. They can result in a “lack of power” or an “engine limp home”.

Diagnostic instructions

EGR valve

The most frequent causes of malfunctions are deposits in the valve plate or seat.

The consequences are:

- The valve is stuck and doesn't open.
- Deposits have caused the opening width to be reduced.
- The valve does not close completely.

Unusually heavy deposits can be caused by errors in the injections or by intake or charge air with a high oil content.

In diesel engines, deposits are also caused by soot.

Important note:

Examples of causes of very oily intake or charge air can be:

- Malfunctions in the crankcase ventilation (e.g. oil separator, engine exhaust valve).
- Increased blow-by gas emission due to increased wear on the pistons and cylinders.
- Malfunctions in the turbocharger (e.g. worn bearing, plugged oil return line).
- Exceeding of the maintenance intervals (failure to change oil and oil filter).
- Use of engine oil quality not suited for the application.
- Frequent short trips (especially during colder months, formation of oil/water emulsion that gets into the engine exhaust).
- Engine oil level too high.
- Worn valve stem seals or guides causing increased oil transfer into the inlet port.

Fig. 38: EGR valve (diesel) with heavy deposits and new

Solenoid valves (EUV, EDW, EPW)

The most frequent causes of malfunctions are water or dirt or leaky connecting hoses.

These faults are not always detected by the component diagnosis.

High ambient temperatures can cause sporadic malfunctions.

Malfunctions are seldom caused by incorrectly attached connecting hoses.

Air mass sensors (LMS)

See Section 4.6.3.

Further malfunctions in EGR valves:

- Potentiometers can send out faulty signals or fail when greater distances.
- When the exhaust gas back pressure is too great (exhaust pipe partially plugged) in diesel vehicles the EGR valve can be pushed open under higher loads. This "burns" the diaphragm and destroys the valve. This can be detected by the blue colouring of the valve chamber.

Important note:

A vacuum hand pump can be used to check the functioning of the pneumatic EGR valve.

Further details can be found in our Service Informations.

4.6
Air supply

Fresh air is required for mixture formation and combustion. It is fed into the engine through the inlet port.
The components involved are the air mass sensor, throttle body, intake manifold and inlet port shut-off (“tumbles flaps”).

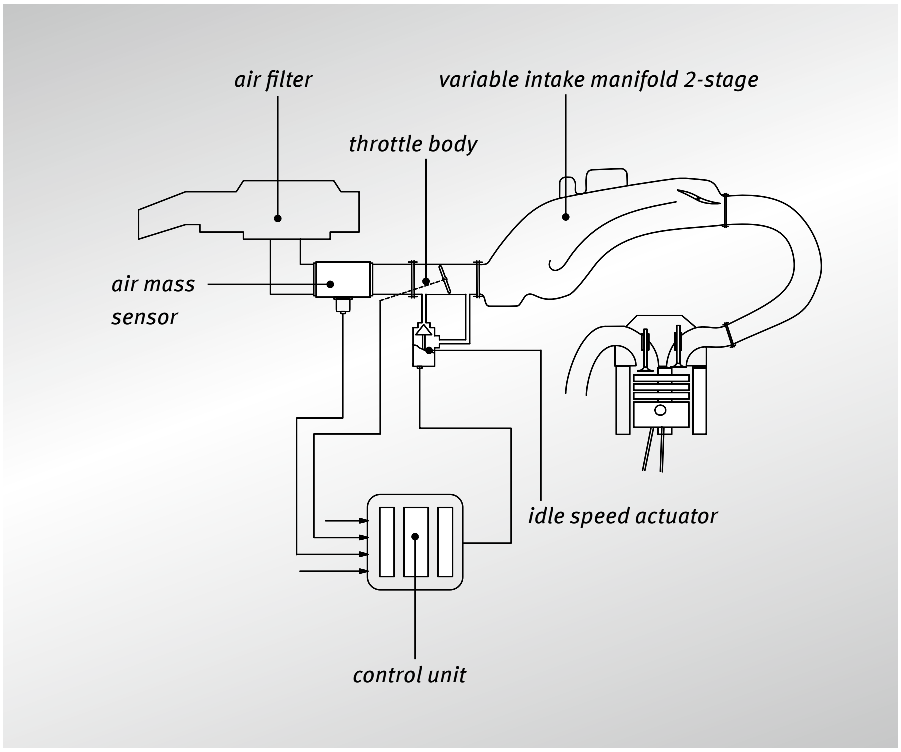

Fig. 39: air supply (schematic)

Air mass sensors (LMS)
Air mass sensors (LMS) continuously measure the air mass supplied to the engine. The LMS signal is used to calculate the injection quantity, and for diesel engines, to control the exhaust gas recirculation as well.

> ! **Further details can be found in our Service Informations.**

Fig. 40: different air mass sensors

Throttle bodies

The air flow drawn in by the engine is controlled by throttle valves. The cylinder is filled based on the throttling of the intake air. In the past throttle bodies were used mainly for petrol engines. Now they are being used more and more in diesel engines as well in connection with emissions control.

In the newer diesel engines the pressure difference between the exhaust gas side and the intake side alone is not sufficient to obtain greater exhaust gas recirculation rates (up to 60%). For this reason “regulating throttles”[5] are used in the intake manifold to increase the vacuum in order to enhance the exact regulation of the exhaust gas recirculation rates. This regulating throttle is mostly integrated in the EGR emulsion housing.

Whereas until about 1995 the idle speed was controlled by separate actuators (in the intake manifold, for example), more recent mechanical throttle bodies have an integrated idle speed actuator (LLFR) as an attachment[6].

Depending on the operating state, the LLFR regulates the air quantity that is necessary for warm-up and to maintain the idle speed through an air duct as a bypass to the throttle valve. The actuation is handled directly by the control unit.

In more recent applications idle control and start-up enrichment are achieved by adjusting the throttle valve. Here the throttle valve is adjusted by an electric motor. This process is faster, it allows small air flows for idling and an adjustment of the throttle valve without a mechanical link to the accelerator pedal (e-gas, electronic accelerator pedal; “drive by wire”).

In order for the fuel/air mixture to burn as quickly as possible, the air is given a swirl by two separate inlet ports for each piston. Each of these inlet ports is also equipped with an adjustable “tumble flap” that is operated by the EAM-i (electric drive module with integrated “intelligence”) by means of a leverage system.

Fig. 41: intake manifold with tumble flaps and EAM-i

Fig. 42: different throttle bodies

Fig. 43: inlet manifolds, different versions

[5] In practice, different names are used for throttle valves in diesel engines, such as regulating throttles, diesel valves, diesel front valves.

[6] Please refer also to Service Information SI 0060 and SI 0061. In practice, different names are used such as idle controller, idle setting valve, valve for idle stabilisation, idling actuator etc.

Variable intake manifolds
In petrol engines, intake manifolds are generally used complete with throttle bodies.
Instead of intake manifolds with a fixed length, "variable intake manifolds" are also being used in petrol engines more and more.
With variable intake manifolds the actual length of the air intake channels can be changed. This produces clear improvements in the torque and in fuel consumption.
To change ("to vary") the length, pneumatic actuators (vacuum units) or electromotive actuators ("electric drive modules – EAMs") are used.
The pneumatic actuators are operated by pneumatic valves (e.g. EUV). The electric drive modules (EAMs) are actuated by the engine control unit directly.
Furthermore, direct injection engines are often equipped with additional valves between the actual intake manifold and the inlet ports in the cylinder head ("intake manifold and inlet port shut-off", "tumble flaps"). The valves can be adjusted to change the air supply (flow speed, direction).

Electropneumatic pressure transducer (EPW) for actuating a turbocharger (VTG)
The engine torque that can be achieved in a vehicle is based on the fresh gas content of the cylinder filling. Exhaust gas turbochargers use the energy of the exhaust gas in a turbine to raise the cylinder filling via a connected compressor. VTG turbochargers vary the required boost pressure by adjusting the blades in the turbine. This adjustment has to be very precise.
The EPW is actuated by the engine control unit via the corresponding map. Depending on the duty cycle of the signal the control pressure by which the turbine blades are adjusted via a vacuum unit is set.

4.6.1 Monitoring

The electric components are monitored for continuity, short circuit and short circuit to earth. The position of actuators (final position open/closed) is registered. The position is registered by potentiometers or non-contact measured-value readings. In part the adjustment time is also monitored (e.g. tumble flaps).

Possible fault codes

Errors in air supply components are indicated by the following fault codes..

Air mass sensor

P0100	mass or volume air flow circuit	malfunction
P0101	mass or volume air flow circuit	range/performance problem
P0102	mass or volume air flow circuit	low input
P0103	mass or volume air flow circuit	high input
P0104	mass or volume air flow circuit	intermittent
P0110	intake air temperature circuit	malfunction
P0111	intake air temperature circuit	range/performance problem
P0112	intake air temperature circuit	low input
P0113	intake air temperature circuit	high input
P0114	intake air temperature circuit	intermittent

Intake manifold

P0105	manifold absolute pressure/barometric pressure circuit	malfunction
P0106	manifold absolute pressure/barometric pressure circuit	range/performance problem
P0107	manifold absolute pressure/barometric pressure circuit	low input
P0108	manifold absolute pressure/barometric pressure circuit	high input
P0109	manifold absolute pressure/barometric pressure circuit	intermittent

Throttle bodies

P0120	throttle/pedal position sensor/switch a circuit	malfunction
P0121	throttle/pedal position sensor/switch a circuit	range/performance problem
P0122	throttle/pedal position sensor/switch a circuit	low input
P0123	throttle/pedal position sensor/switch a circuit	high input
P0124	throttle/pedal position sensor/switch a circuit	intermittent
P0220	throttle/pedal position sensor/switch b circuit	malfunction
⋮		
P0229	throttle/pedal position sensor/switch c circuit	intermittent
P0510	closed throttle position switch	closed
P0638	throttle actuator control range/performance (bank 1)	performance problem
P0639	throttle actuator control range/performance (bank 2)	performance problem

Idle speed actuator:

P0505	idle control system	malfunction
P0506	idle control system	RPM lower than expected
P0507	idle control system	RPM higher than expected
P0508	idle control system	circuit low
P0509	idle control system	circuit high

Electropneumatic transducer:

P0033	turbo charger bypass valve control circuit	malfunction in electrical circuit
P0034	turbo charger bypass valve control circuit	signal too low
P0035	turbo charger bypass valve control circuit	signal too high
P0234	turbo/super charger overboost condition	limit value exceeded
P0235	turbo/super charger boost sensor a circuit	limit value not reached
P0243	turbo/super charger wastegate solenoid A	malfunction in electrical circuit
P0244	turbo/super charger wastegate solenoid A	range/performance
P0245	turbo/super charger wastegate solenoid A	signal too low
P0246	turbo/super charger wastegate solenoid A	signal too high
P0247	turbo/super charger wastegate solenoid B	malfunction in electrical circuit
⋮		
P0250	turbo/super charger wastegate solenoid B	signal too high

4.6.3 Diagnostic instructions

If malfunctions are produced, they are almost always caused by deposits and, sticking.
Wear can usually be detected only when large distances are driven.

Air mass sensors (LMS)
he most frequent causes of malfunctions in air mass sensors is soiling. This applies especially to the newer LMSs with back-flow detection. This way oily intake air can leave a film on the sensor. The result will be faulty signals. The result can be “ping-ing” and lack of power.

- When there are leaks in the inlet port, dirt particles can enter with the intake air, hitting the air mass sensor at a high speed and destroying it.
- Also errors made during servicing such as uncleanness when the filter is being changed, or the use of wrong filters can be the cause of soiling and damage to the air mass sensor.

Especially in the case of turbochargers the pressure on the air mass sensor is great because both the air flow and the air speed are very high.

Further details can be found in our Service Informations.

Throttle bodies
Frequent malfunctions in throttle bodies:

- Dirt deposits in the throttle valve can build up so heavily that idle control is no longer possible.
- Soiling in the idle speed actuator can produce sticking or decrease the cross-section to the extent that the engine “dies”.

Important note:
These errors are often caused by very oily intake or charge air.
Examples of causes of very oily intake or charge air can be:

- Malfunctions in the crankcase ventilation (e.g. oil separator, engine exhaust valve).
- Increased blow-by gas emission due to increased wear on the pistons and cylinders.
- Malfunctions in the turbocharger (e.g. worn bearing, plugged oil return line).
- Exceeding of the maintenance intervals (failure to change oil and oil filter).
- Use of engine oil quality not suited for the application.
- Frequent short trips (especially during colder months, formation of oil/water emulsion that gets into the engine exhaust).
- Engine oil level too high.
- Worn valve stem seals or guides causing increased oil transfer into the inlet port.

Further causes of malfunction, especially in the case of greater distances driven, are:

- Wear of or deposits on the potentiometer (sporadic malfunctions).
- Wear on the throttle valve.
- Failure of the throttle valve actuator motors (engine "saws" during idling).
- Defective micro switch in the throttle body (attachments).

Further details can be found in our Service Informations.

Important note:

If there are wear and damage on the potentiometer or micro switches, the throttle bodies should be replaced.
Due to the inability to make adjustments, it is impossible to include a repair in the service.
After a new throttle body has been installed, it may be necessary to "teach" the control unit.

Modern engine control units have adaptive "storage modules", i.e. some of the map data required for operation must be "learned".
The map data will first be recorded during driving and stored in the memory. This may take a few minutes!
For this reason a test drive should be taken and only then should the function be checked again.

Intake manifolds

Errors in intake manifolds are:

- Intake manifold is broken or cracked.
  Damage to intake manifolds is mostly due to severe damage resulting from improper work on the engine or heavy impact (misfires).
- Actuator does not work or is giving an incorrect signal.
  For pneumatic actuators:
  Check whether there is a vacuum, whether the electric switch-over valve is being actuated electrically and is functional.
  For electric actuators:
  Check electric supply and potentiometer signals.
  In both cases also check whether the intake manifold is stuck due to deposits.
- Intake manifold makes noises.
  In this case the intake manifold will have to be dismounted for a more exact diagnosis.
  Possible causes can be foreign objects such as loose parts in the intake manifold, slipped gaskets (under certain circumstances not detected) and missing or damaged connecting hoses.

Attention:

Be careful when dismounting the intake manifold so that loose parts do not get into the engine and cause damage, for example!
Modern (bonded) intake manifolds can no longer be taken apart.

Tumble flaps

n the case of tumble flaps/inlet port shut-off, sticking due to deposits is the most common cause of failure, especially in diesel applications.
The adjustment time is monitored in the diagnosis. If the valves are stuck, they will not be adjusted, or the set time will be exceeded. In the diagnosis, the actuator, usually an EAM-i, can be detected as faulty. This error cannot be corrected by replacing the actuator.

Further details on tumble flaps and EAM-i can be found in our Service Informations.

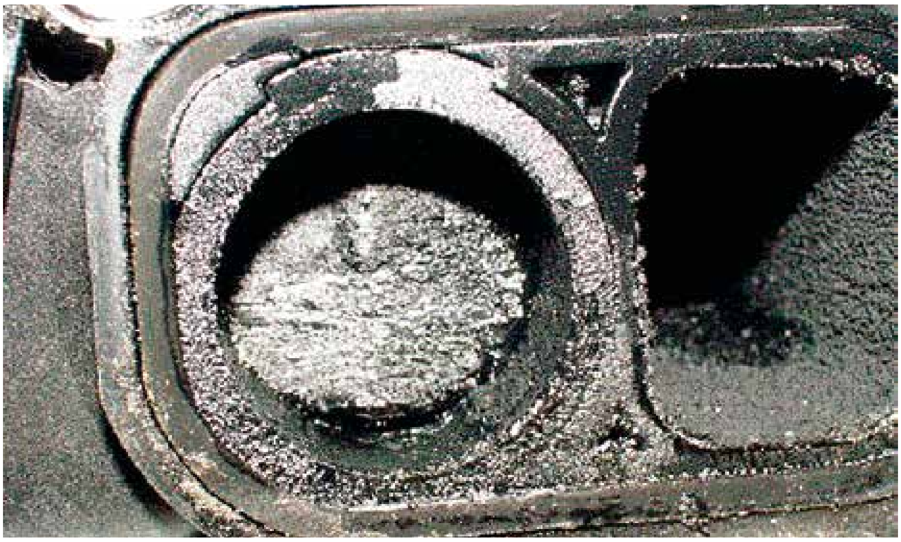

Fig. 44: thumble flaps, malfunction due to heavy deposits

Electropneumatic pressure transducer (EPW)

The most frequent causes of malfunctions are:

- water or soiling or
- leaky hose connections.

These errors are not always detected by the component diagnosis.
High ambient temperatures can cause sporadic malfunctions.
Malfunctions are seldom caused by incorrectly attached connecting hoses.

Further details can be found in our Service Informations.

5.1
Catalytic converter

Catalytic converters are chemical substances that affect a chemical reaction without changing themselves.
The catalytic converter is used in automobiles to clean exhaust gases:

- Nitrogen oxides (NOx) are reduced to carbon dioxides (CO_2) and nitrogen (N_2).
- Carbon monoxide (CO) is oxidised to carbon dioxide (CO_2).
- Hydrocarbons (HC) are oxidised to carbon dioxide (CO_2) and water (H_2O).

It is therefore one of the most important components of emissions control.
The state of current technology for petrol engines is the "regulated" catalytic converter.
Here a controlled fuel/air mixture, whose mix ratio fluctuates by lambda (λ) = 1, is supplied to the engine.
The volume control is handled by the engine control unit.
A lambda probe upstream from the converter measures the residual oxygen in the exhaust gas.
A corresponding voltage signal serves as a control value for the engine control unit.
The converter will reach its full functionality at temperatures between 350 and 750° C.
Leaded fuel and temperatures above 1000° C can destroy a converter.
Because the catalytic converter has a great influence on emissions control, it is monitored in OBD.

5.1.1
Monitoring

The catalytic converter is monitored for efficiency and ageing. To monitor the state of the converter, the residual oxygen in the exhaust gas is measured by a second lambda probe downstream from the converter. This probe is also referred to as the "secondary, monitor, or post-cat probe".
Here the voltage signal of the lambda probe upstream from the catalytic converter ("control probe") is compared with the signal from the post-cat.
The control probe signal fluctuates extremely (large controller transient oscillations). These fluctuations are caused by the different residual oxygen content in the exhaust gas as a result of the lambda control (rich/lean).
A functioning catalytic converter accumulates large quantities of oxygen.
This causes the measurable oxygen content downstream from the converter to fluctuate only slightly.
As a result, the voltage signal is relatively constant. The controller transient oscillations of the post-cat probe are low.

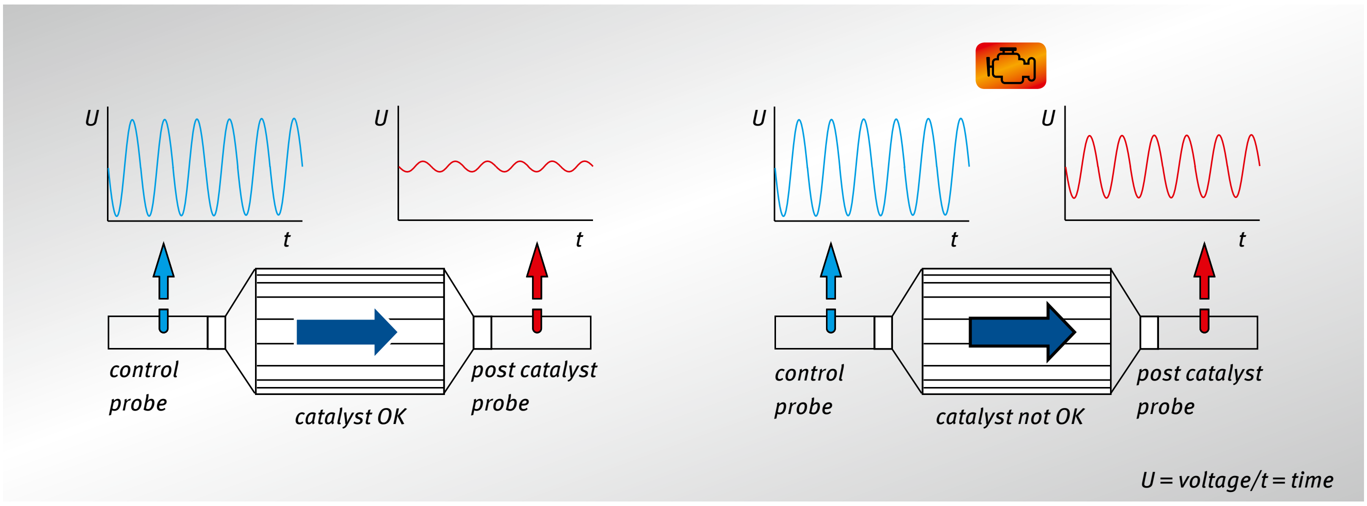

Fig. 45: monitoring the efficiency of the catalytic converter

Evaluation:
small controller transient oscillations of the post-cat probe = catalytic converter effective
large controller transient oscillations of the post-cat probe = catalytic converter ineffective
When a catalytic converter is defective, both probe signals will be almost identical.

Monitoring conditions

- The vehicle is operating at speeds between 5 and 80 km/h.
- The engine has reached operating temperature.
- The catalytic converter has reached temperatures between 350 and 650° C.
- The engine speed and the accelerator pedal position are basically constant.

The catalytic converter will be detected as faulty if 150% of the pollution limit is exceeded.

Possible fault codes

P0420	catalyst system (bank 1)	efficiency below threshold
P0421	warm up catalyst (bank 1)	efficiency below threshold
P0422	main catalyst (bank 1)	efficiency below threshold
P0423	heated catalyst (bank 1)	efficiency below threshold
P0424	heated catalyst (bank 1)	temperature below threshold
P0425	catalyst temperature sensor (bank 1)	malfunction
P0426	catalyst temperature sensor (bank 1)	range/performance
P0427	catalyst temperature sensor (bank 1)	low input
P0428	catalyst temperature sensor (bank 1)	high input
P0429	catalyst heater control circuit (bank 1)	malfunction
P0430	catalyst system (bank 2)	efficiency below threshold
⋮		
P0439	catalyst heater control circuit (bank 2)	malfunction

Diagnostic instructions

Error	Causes
insufficient effect caused by deposits on the catalytic effective surface	• leaded fuel has "contaminated" the converter, i.e., the active surface is plugged • oil deposit in the active surface • premature ageing due to high temperatures • In these cases the catalytic effect is reduced.
lack of power (caused by increased exhaust gas back pressure) uneven running is detected (caused by increased exhaust gas back pressure)	• the monolith is broken due to excessive mechanical pressure (there will be noises if the converter is moved/shaken) • the monolith had melted down or is partially melted due to very high temperatures • the monolith has been destroyed by a "water hammer" In these cases the catalytic converter may be so damaged that the free area is no longer sufficient. The exhaust gas back pressure increases, power decreases noticeably. For the error diagnosis: check whether the back pressure in the exhaust gas system has increased. For the test, remove the pre-cat probe and measure the pressure there with a precision manometer. The exhaust gas back pressure is usually about 0.2 bar.

5.2 Lambda probes

Lambda probes measure the oxygen content in the exhaust mixture. They are part of a control loop that continuously ensures that the composition of the fuel/air mix is correct.

The mix ratio of air to fuel in which the maximum conversion of pollutants is reached in the catalyst is (λ) =1 (stoichiometric mix ratio = 14.7 kg air to 1 kg fuel, expressed in volume: 1 litre fuel to approx. 9500 litres air).

Changes in the exhaust gas composition are taken into account by the engine management as it controls numerous functions, and is often the first hint that there may be errors.

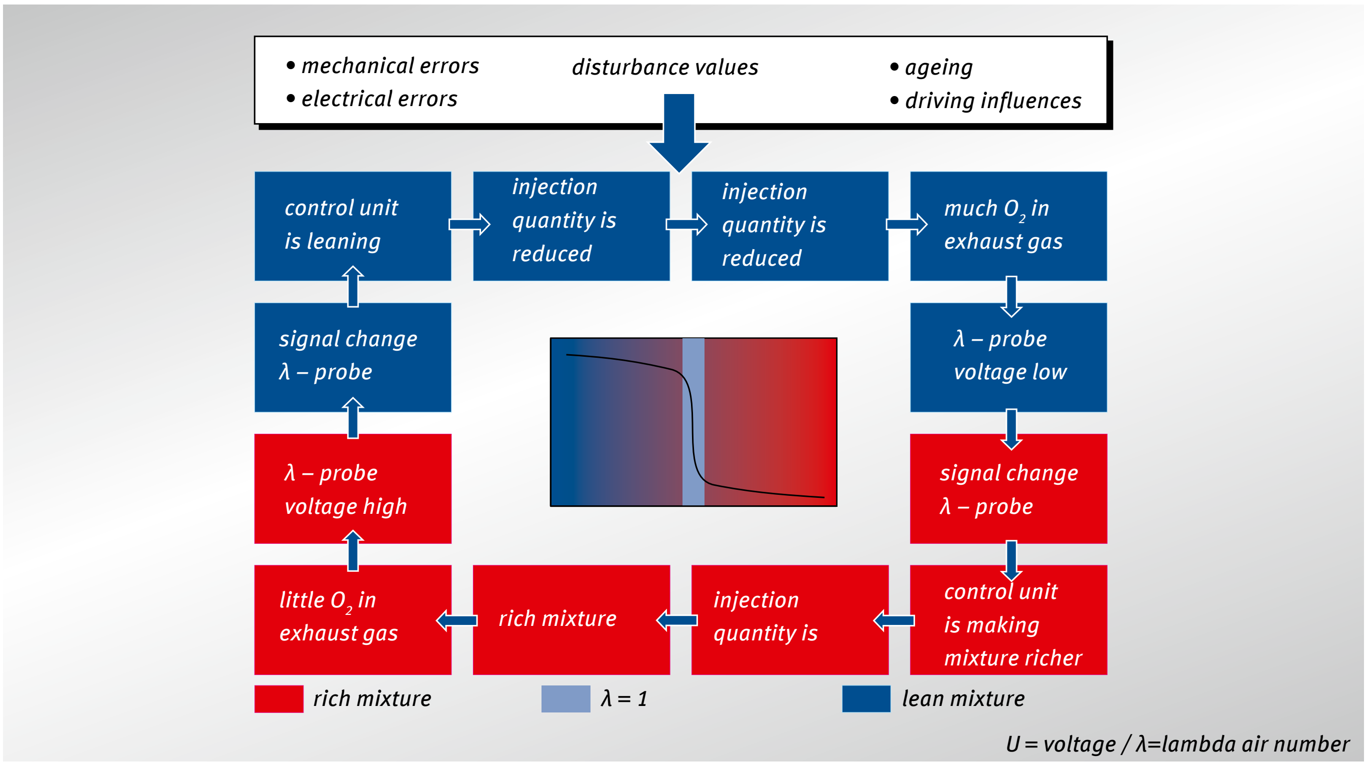

Fig. 46: control loop with lambda jump sensor

The engine control unit uses this signal to control the injection times. For control purposes, only one probe upstream from the catalyst ("pre-cat" or "control" probe) is needed. In OBD II an additional lambda probe that is downstream from the catalyst ("post-cat", "correction" or "monitor" probe) has been integrated into the system.
It is used to check the catalytic converter and can be constructed the same way as the pre-cat probe.

Accidental mixing up of the plug-in connections of the two probes is usually prevented by different types of plugs and colours.

Lambda probes work starting at a temperature of 350° C. The operating point is at about 600° C. A temperature of 850° C should not be exceeded because damage occurs after 930° C.

A distinction is made between broadband and jump probes.

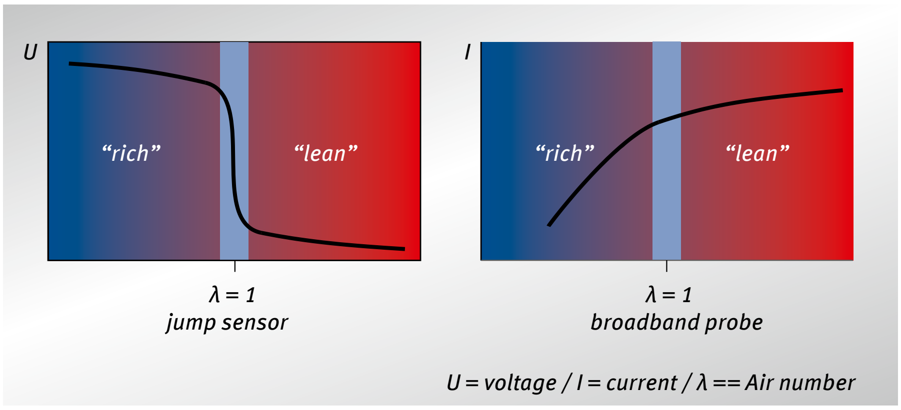

Fig. 47: behaviour of jump and broadband probe control

Jump probes
The output signal of the lambda probe ("probe voltage") is based on the fuel/air ratio.
In the case of a jump probe, the voltage changes abruptly at $\lambda = 1$. For this reason the signal can be used only in a range of $\lambda = 1 \pm 0.03$. In engines in a lean range of $\lambda > 1.03$, the signal cannot be processed. Therefore with this probe only a two-point control is possible. Pre and post-cat probes have the same construction.

- A rich mixture ($\lambda < 1$) creates a probe voltage of approx. 800 mV. For control purposes the injection times are shortened.
- A lean mixture ($\lambda > 1$) creates a probe voltage of approx. 20 mV. For control purposes the injection times are extended.
- There are different versions of jump probes.
- The titanium probe (titanium dioxide probe) responds to changes in the mixture composition by a change in the electric resistance. It works with a higher probe voltage of up to 5 volts. With this probe critical exhaust gas temperatures can be detected.
- The potential-free lambda probe has a separate earth cable from the control unit. The voltage of the control range is increased by 700 mV. This produces a control voltage between 700 and 1700 mV (measured against the vehicle weight). This technical change was necessary for self diagnosis and EOBD.

Important note:
A distinguishing characteristic of the potential-free lambda probe is the 4-pin probe line.
But: Not all 4-pin lambda probes are potential-free!

Broadband probes
Contrary to the jump probes, the broadband probe measures across a wide lambda range from rich to lean continuously. There are no abrupt changes at $\lambda = 1$. This way lambda control is possible in the case of "rich" as well as "lean" air/fuel mixtures from about lambda = 0.7 to 3.0. It can also be used for direct injection and future "lean concepts".

This process is carried out by a pump cell (miniature pump) that supplies the electrodes on the exhaust gas side with sufficient oxygen that the voltage between both electrodes is constantly 450 mV. The power consumption of the pump is converted to a lambda value by the control unit.

Important note:
Conventional lambda probes are designed as "finger probes".
Newer jump and broadband probes are increasingly being made in planar constructions ("planar probes"). Planar probes are further developed lambda probes that are heated. Heating causes these probes to be functional shortly after a cold start. This way the volume control can start sooner.

5.2.1
Monitoring

Conditions for monitoring lambda probes.
- Lambda control is working in the control range.
- The vehicle is operating at speeds between 5 and 80 km/h.
- The engine has reached operating temperature.
- The catalytic converter has temperatures between 350 and 650° C.
- The engine speed and the accelerator pedal position are basically constant.
- Monitoring occurs whenever there is a constant operation that lasts more than 20 seconds.

Control probe (jump probe)
Ageing or contamination can affect the response of a lambda probe. Deterioration can manifest itself in an increase in the response time (period duration) or a shifting of the measuring range (probe shift). Either will cause the λ window to be smaller, which will produce a deterioration of the exhaust gas conversion by the catalyst.
The post-cat signal is evaluated for monitoring.

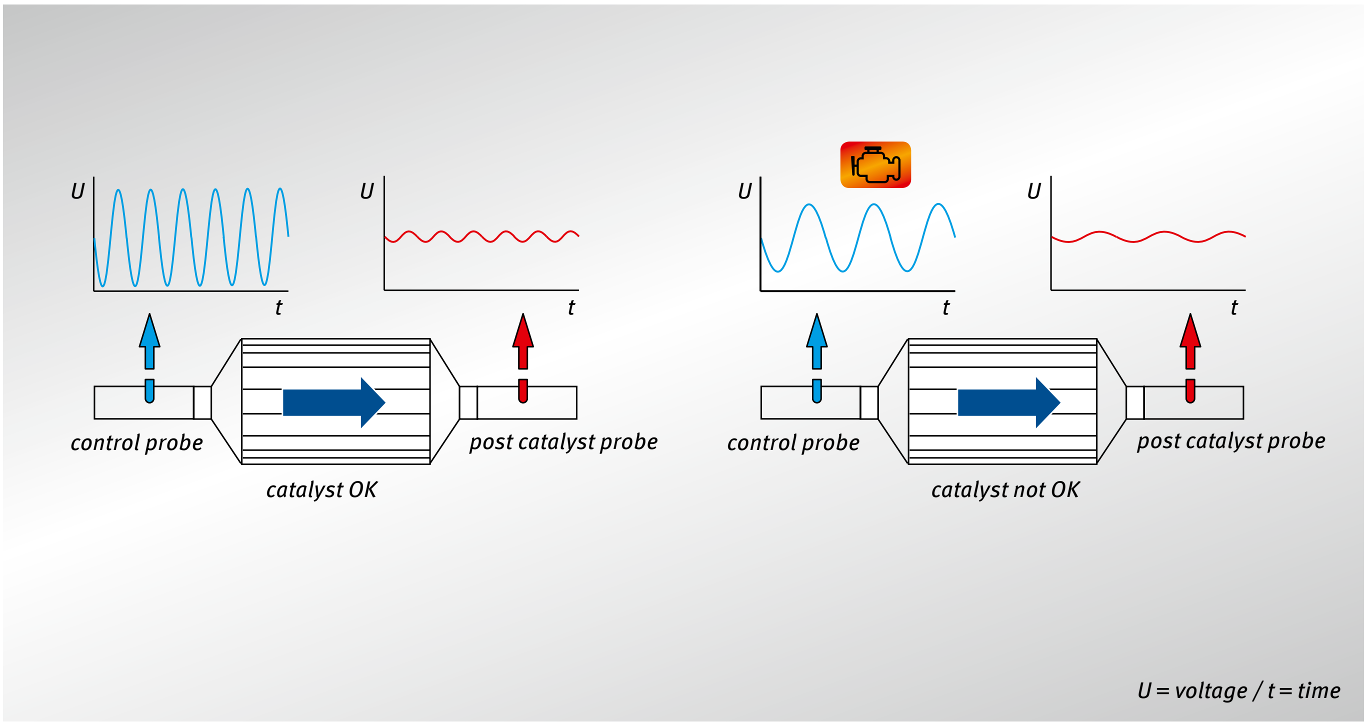

Fig. 48: check of the control frequency (s s of the control probe – jump probe)

Control probe (broadband probe)
Because a broadband probe does not respond with a noticeable jump at λ = 1, the fuel/air mixture has to be "modulated".
A slight switch between lean and rich mixture is created artificially.
The response time of the broadband to these fluctuations created is monitored.
The current actual values are compared with the specified set-point values.

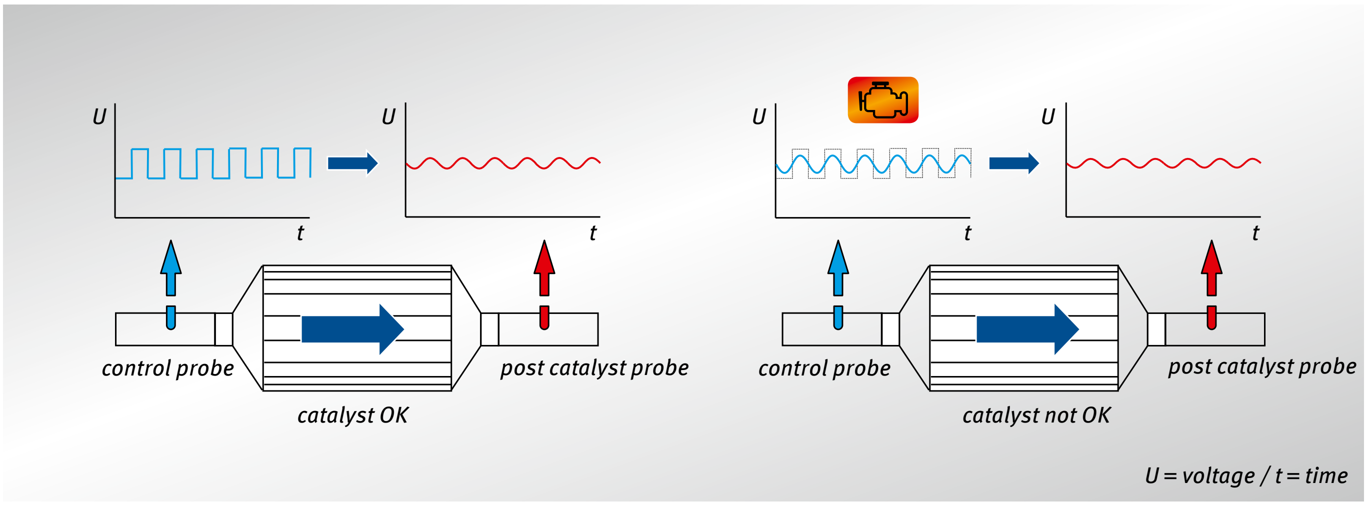

Fig. 49: response time of the control probe (broadband probe)

Post catalyst probe
The lambda control value is monitored for compliance with the specified control limits.
For example, if the air/fuel ratio changes in the "lean" direction during operation, the post catalyst probe will report an increase in the oxygen content of the exhaust gas to the control unit by lowering the voltage. The mixture will be made richer again by the lambda control. The post catalyst probe voltage will rise and the control unit will be able to lower the lambda control value again.
If the probe voltage remains low in spite of the fact that the mixture was made richer, it will continue to be made richer until the control limit is exceeded. This will be detected as an error.
This control will extend over a longer drive.

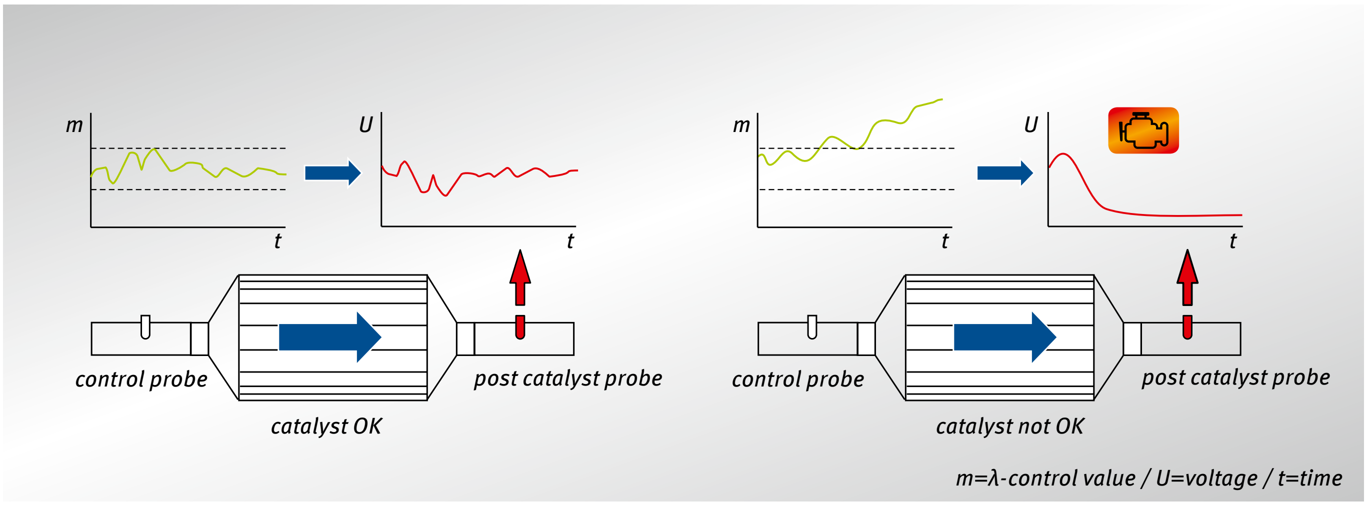

Fig. 50: diagnosis of the post catalyst probe control limit

A further possibility for monitoring is a diagnosis of the control behaviour during acceleration or deceleration. Here as well the effects of the "richer" mixture during acceleration and "leaner" mixture during deceleration are used to evaluate the probe.

Possible fault codes

P0036	HO_2S heater control circuit (bank 1 sensor 2)	malfunction
P0037	HO_2S heater control circuit (bank 1 sensor 2)	low
P0038	HO_2S heater control circuit (bank 1 sensor 2)	high
P0042	HO_2S heater control circuit (bank 1 sensor 3)	malfunction
P0043	HO_2S heater control circuit (bank 1 sensor 3)	low
P0044	HO_2S heater control circuit (bank 1 sensor 3)	high
⋮		
P0064	HO_2S heater control circuit (bank 2 sensor 3)	high
P0130	O_2 sensor circuit (bank 1 sensor 1)	malfunction
P0131	O_2 sensor circuit (bank 1 sensor 1)	low voltage
P0132	O_2 sensor circuit (bank 1 sensor 1)	high voltage
P0133	O_2 sensor circuit (bank 1 sensor 1)	slow response
P0134	O_2 sensor circuit (bank 1 sensor 1)	no activity detected
P0135	O_2 sensor heater circuit (bank 1 sensor 1)	fault in heater circuit
⋮		
P0167	O_2 sensor heater circuit (bank 2 sensor 3)	fault in heater circuit

Diagnostic instructions

Error	Causes
• increased fuel consumption • jerking during deceleration • engine “saws” during idling	• The lambda probe is soiled or has deposits due to bad combustion or leaded fuel. • The lambda probe responds too sluggishly, i.e., the lambda control tends to be too “rich”. • The lambda probe is damaged by exhaust gas temperatures that are too high as a result of a faulty mixture formation or ignition misfires. • The electric earth connection is not OK.

Important note:
Please observe the general instructions in Section 3.
For the error diagnosis, check the
- voltage signal
- earth connection
- heater (if present).

Then read the fault code memory and compare the actual values with the set-point values. If the set-point values are not available, it could be of assistance to read the values from a vehicle of a similar model that doesn’t have any errors.

5.3
Ignition misfires (uneven running detection)

"Jerking" or a reduced performance is the noticeable result of malfunctions in the engine running. These malfunctions are caused by errors in the ignition system and in the mixture preparation, but also by mechanical damage in the engine.
The results of combustion malfunctions and ignition misfires are:

- the engine loses power
- the quality of the exhaust gas deteriorates
- unburned fuel gets into the exhaust gas system and overheats, damaging the catalyst
- the unburned fuel can cause flooding of the cylinder. This will weaken the oil film or wash it away completely.
  This will produce mixed friction, increased wear, and thus damage to the pistons, piston rings and cylinders.

For this reason, the engine running is monitored permanently for misfires and uneven running.

Monitoring
To detect misfires, the uneven running of the engine is monitored by registering the rotational speed of the crankshaft.

Using a toothed wheel on the crankshaft ("increment wheel" or "crankshaft sensor wheel") and the position of the camshaft, it is possible to attribute ignition misfires to an individual cylinder ("cylinder-selective"). This toothed wheel is divided into sectors. The breakdown corresponds to the working cycles per crankshaft rotation.
In a 4-cylinder engine there are two sectors, in a 6-cylinder engine there are three, and in an 8-cylinder engine there are four. The cycle time for each sector is recorded based on the engine speed and the time of the ignition.

- If there are no misfires, the times are the same for all sectors.
- If misfires occur in a cylinder, the rotational speed in the allocated sector will decrease and the cycle time for this sector will increase.

To compensate for small errors/tolerances in the toothed wheel, a sensor adaptation takes place during driving in the deceleration phase. Errors that are detected and confirmed are recorded and indicated by the malfunction indicator lamp (MIL).

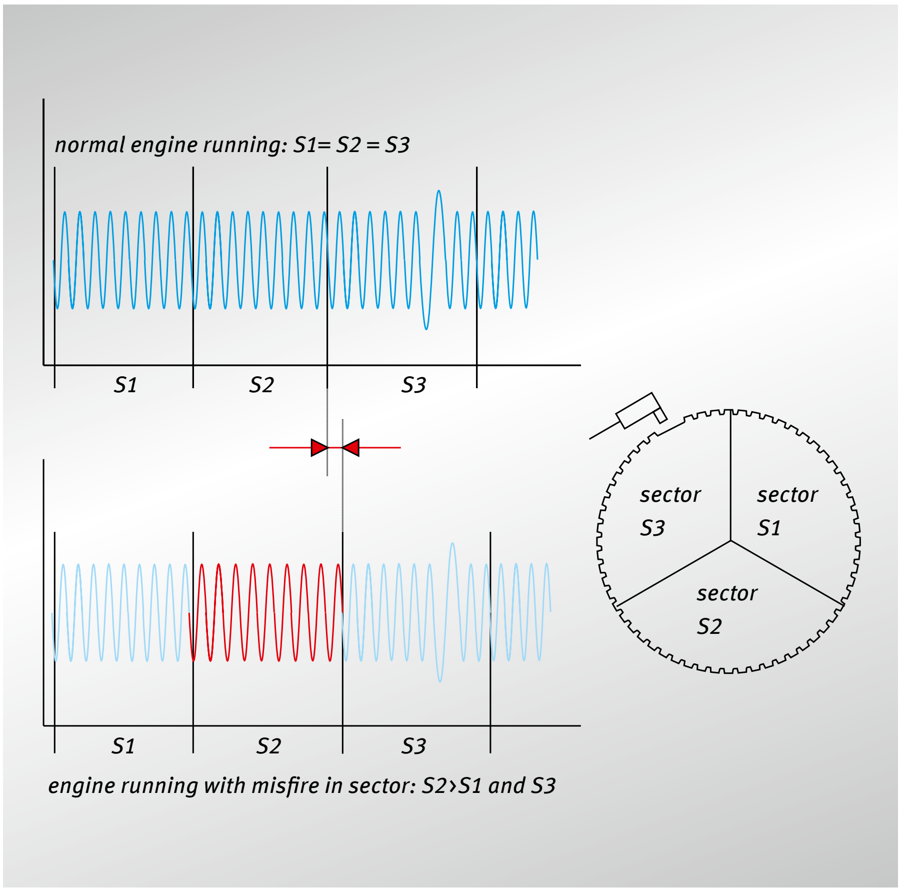

Fig. 51: misfire detection in the S2 sector (6-cylinder engine)

Not every misfire will cause the MIL to light up directly. For this reason the consecutive misfires are counted and evaluated according to their ability to cause damage.

For this purpose, all misfires that occur within 200 rotations are evaluated.
The MIL is blinking. The vehicle can only be driven as far as the closest workshop, and with limited power.

Misfires that damage the catalytic converter
This is the case after a misfire rate of 2%. For this purpose, all misfires that occur within 1000 rotations are evaluated.
The MIL will go on (continuously lit) only if the error is detected again in the subsequent driving cycle. This will confirm ("debounce") the error.

Misfires that cause the exhaust gas limits to increase more than 150%
This is the case after a misfire rate of 2%. For this purpose, all misfires that occur within 1000 rotations are evaluated.
The MIL will go on (continuously lit) only if the error is detected again in the subsequent driving cycle. This will confirm ("debounce") the error.

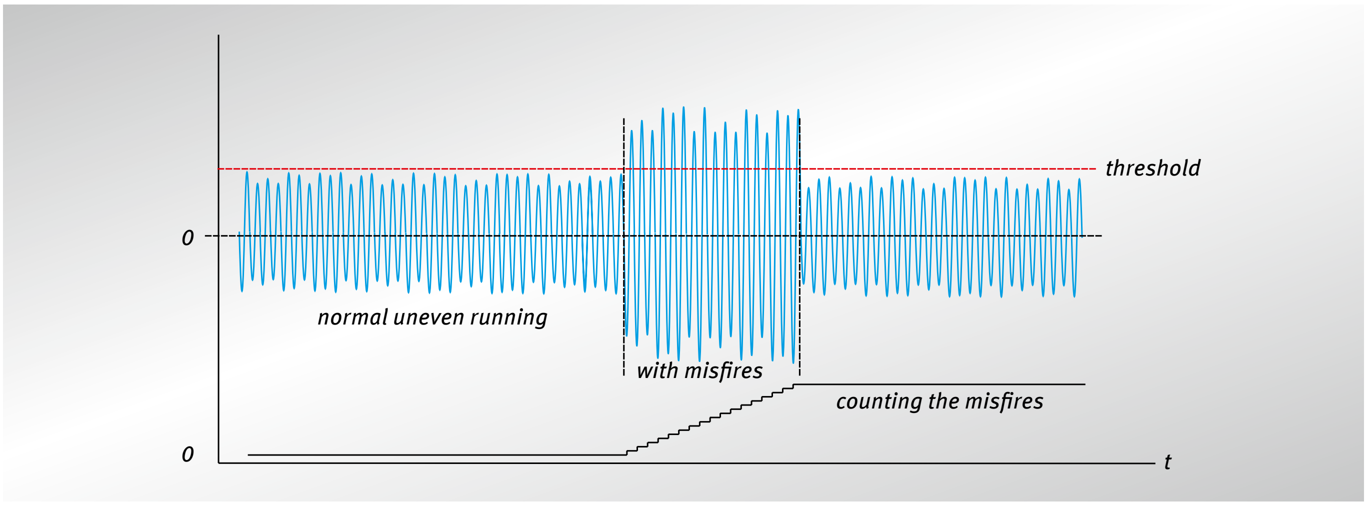

Fig. 52: counting the misfires for the evaluation

Important note:
In one variant of the monitoring the current rotational speed curves are compared with the recorded characteristic curves of the engine. A sudden change in these curves and an exceeding of the exhaust gas limits are detected and indicated as a misfire.

5.3.1 Monitoring

Monitoring occurs permanently. Outside influences can be misinterpreted as combustion misfires. To prevent this, the vehicle speed and body acceleration are also taken into account. This way changes in the rotational speed of the crankshaft, that come through the drive train, are detected and not registered as errors.

For this reason the detection of combustion misfires can be suppressed by the engine management when certain conditions occur:

- falling below/exceeding a certain speed threshold (cut•off, speed limitation, deceleration)
- high jumps in speed (gear shifts)
- the time after engine start (up to 5 seconds)
- the time after the air conditioning is switched on (up to 5 seconds)
- below a load threshold (road resistance)
- detection of a bad road surface (potholes, wheelspins)
- external cylinder - selective ignition interventions (knock control)

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Possible fault codes

P0300	random/multiple cylinder	misfire detected
P0301	cylinder 1	misfire detected
⋮		
P0312	cylinder 12	misfire detected
P0313	ignition misfire detected	when fuel is too low
P0314	single cylinder (cylinder not specified)	misfire
P0320	ignition/distributor engine speed input circuit	malfunction
P0321	ignition/distributor engine speed input circuit	range/performance
P0322	ignition/distributor engine speed input circuit	no signal
P0323	ignition/distributor engine speed input circuit	intermittent
P0324	knock control system error	
P0325	knock sensor 1 circuit (bank 1 or single sensor)	malfunction
P0326	knock sensor 1 circuit (bank 1 or single sensor)	range/performance
P0327	knock sensor 1 circuit (bank 1 or single sensor)	low input
P0328	knock sensor 1 circuit (bank 1 or single sensor)	high input
P0329	knock sensor 1 circuit (bank 1 or single sensor)	input intermittent
⋮		
P0334	knock sensor 2 circuit (bank 2)	input intermittent
P0335	crankshaft position sensor a circuit	malfunction
P0336	crankshaft position sensor a circuit	range/performance
P0337	crankshaft position sensor a circuit	low input
P0338	crankshaft position sensor a circuit	high input
P0339	crankshaft position sensor a circuit	intermittent
P0340	camshaft position sensor a circuit (bank 1 or single sensor)	malfunction
P0341	camshaft position sensor a circuit (bank 1 or single sensor)	range/performance
P0342	camshaft position sensor a circuit (bank 1 or single sensor)	low input
P0343	camshaft position sensor a circuit (bank 1 or single sensor)	high input
P0344	camshaft position sensor a circuit (bank 1 or single sensor)	intermittent
⋮		
P0349	camshaft position sensor a circuit (bank 2)	intermittent
P0350	ignition coil primary/secondary circuit	malfunction
P0351	ignition coil a primary/secondary circuit	malfunction
⋮		
P0362	ignition coil l primary/secondary circuit	malfunction
P0365	camshaft position sensor b circuit (bank 1)	malfunction
P0369	camshaft position sensor b circuit (bank 1)	intermittent
P0370	timing reference high resolution signal a	malfunction
P0371	timing reference high resolution signal a	too many pulses
P0372	timing reference high resolution signal a	too few pulses
P0373	timing reference high resolution signal a	intermittent/ erratic pulses
P0374	timing reference high resolution signal a	no pulse
⋮		
P0379	timing reference high resolution signal b	no pulses
P0385	crankshaft position sensor b circuit	malfunction
⋮		
P0394	camshaft position sensor b circuit (bank 2)	intermittent

Diagnostic instructions

Misfires can have multiples causes. Therefore, in troubleshooting, the first thing is to read out the fault code memory.

Component	Possible causes/errors	Possible solutions/actions
Fuel system/mixture formation		
fuel	• defective fuel quality, fuel deficiency • soiling, blending with external substances such as diesel in the petrol fuel	• visual inspection, odour check • cleaning of the fuel systems • replacement of the fuel • replace the fuel filter and possibly the injection valves
fuel pumps	• fuel pump delivery rate (prefeeder and main pump) too low • fuel pressure too low	• measure pressure and delivery rate if present as well in the prefeeder pump • replace faulty pump
pressure regulator	• pressure regulator defective, pressure too high/too low - thus injection quantity deviating	• check pressure and regulation function • replace faulty pressure regulator • check fuel system
fuel filter	• clogged fuel filters; flow too	• measure delivery rate behind the filter • replace filter
fuel lines	low fuel lines broken off • in the flow - fuel supply insufficient • in the return - fuel pressure too high	• when delivery rate is insufficient and pressure deviates, visual inspection • align lines and replace if necessary
injection valves	• function errors • incorrect injection times • incorrect injection direction • leaky injection valves	• when the engine is off use a suitable instrument to check the HC value in the intake manifold • check injection times, injection signal and impermeability • clean valves or replace if necessary
Secondary air system		
secondary air system	• damage to the secondary air pump, the lines or in the shut-off valve, and thus leak air in the exhaust manifold	• please refer to Sections 4.4.2 and 4.4.3.
Engine control		
sensors for • rotational speed • camshaft position	• signals insufficient or distances wrong, sensor loose or soiled	• test with scan tool • clean sensors and readjust if necessary • if sensors are faulty, replace them
increment wheel	• loose or damaged	• secure, if faulty, replace • check position of increment wheel and crankshaft/camshaft sensor, and control times. Determine the OT of cylinder 1
catalytic converter	• clogged/plugged • pressure in manifold too high (exhaust gas accumulation)	• test with scan tool (measure voltage curve) • measure exhaust gas back pressure • if faulty, replace
lambda probe	• ageing, short circuit; faulty signal	• test with scan tool • correct line/earthing error • if probe is faulty, replace it

Continued on the next page

Component	Possible causes/errors	Possible solutions/actions
Engine control		
temperature sensors	• sporadically faulty signal	• test with scan tool • check lines and contacts • if faulty, replace sensor
engine control unit	• internal error	• control unit diagnosis, test with scan tool • check status of data, reload if necessary at a contract workshop
Engine		
engine	• damaged, worn	• compression test • pressure loss test • replace defective parts
inlet/outlet valves	• damaged, don't close • wrong setting • faulty control	• compression test • pressure loss test • check basic setting of valves • check control times • correct faulty settings • replace defective parts
Ignition system		
spark plugs	Ignition faulty due to • wrong spark plugs • electrode distance incorrect • burnout • spark plugs oily, carbonised • crack in insulator • oxidation in plug	• check primary and secondary circuits with scan tool, ignition tester, oscilloscope • visual inspection and resistance measurements • correct errors • replace defective parts
components in secondary circuit	Ignition faulty • due to moisture • corrosion • contact and insulation errors	• check primary and secondary circuits with scan tool, ignition tester, oscilloscope • visual inspection and resistance measurements • correct errors • replace defective parts
ignition coils, plugs and wire harness	• voltage supply faulty • short circuit to "plus" (+)/to "earth" • contact error • insulation damage • abrasions and breaks in the • wire harness	• check primary and secondary circuits with scan tool, ignition tester, oscilloscope • visual inspection and resistance measurements • correct errors • replace defective parts

Important note:
After the engine has been worked on, for example, after taking the flywheel out and putting it back, it may be necessary to "teach" the control unit. Modern engine control units have "adaptive storage modules", i.e. some of the map data required for operation must be "learned".

The map data will first be recorded during driving and stored in the memory. This may take a few minutes.
For this reason a test drive should be taken and only then should the function be checked again. If this does not happen, an uneven running error will be detected although all the functions are OK.

6.1 Formation of exhaust gas

Exhaust gases are caused by engine combustion. Part of these exhaust gases contain pollutants.

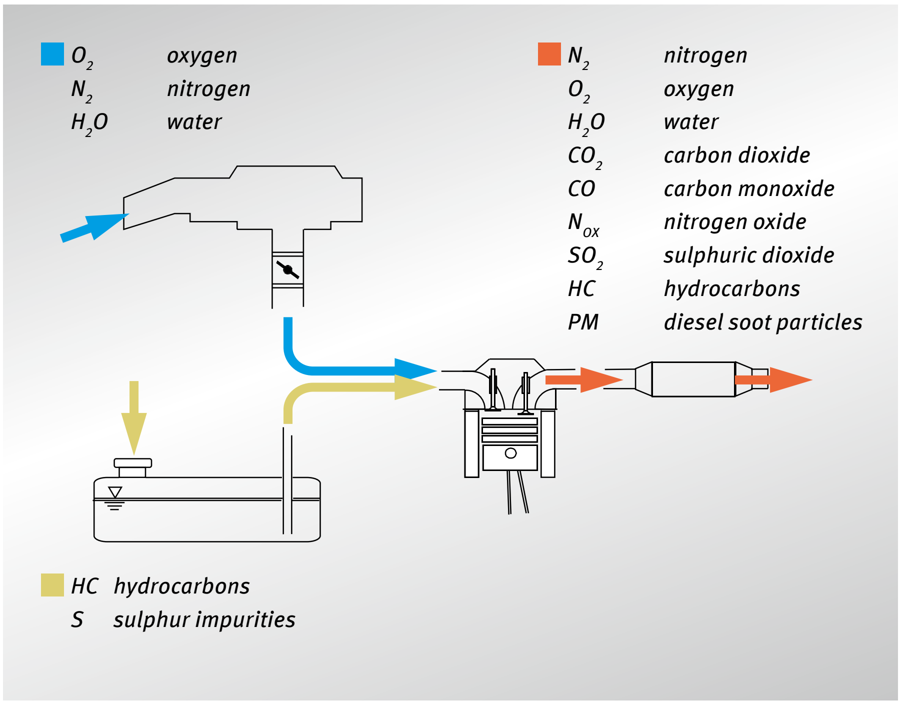

Fig. 53: formation of exhaust gas

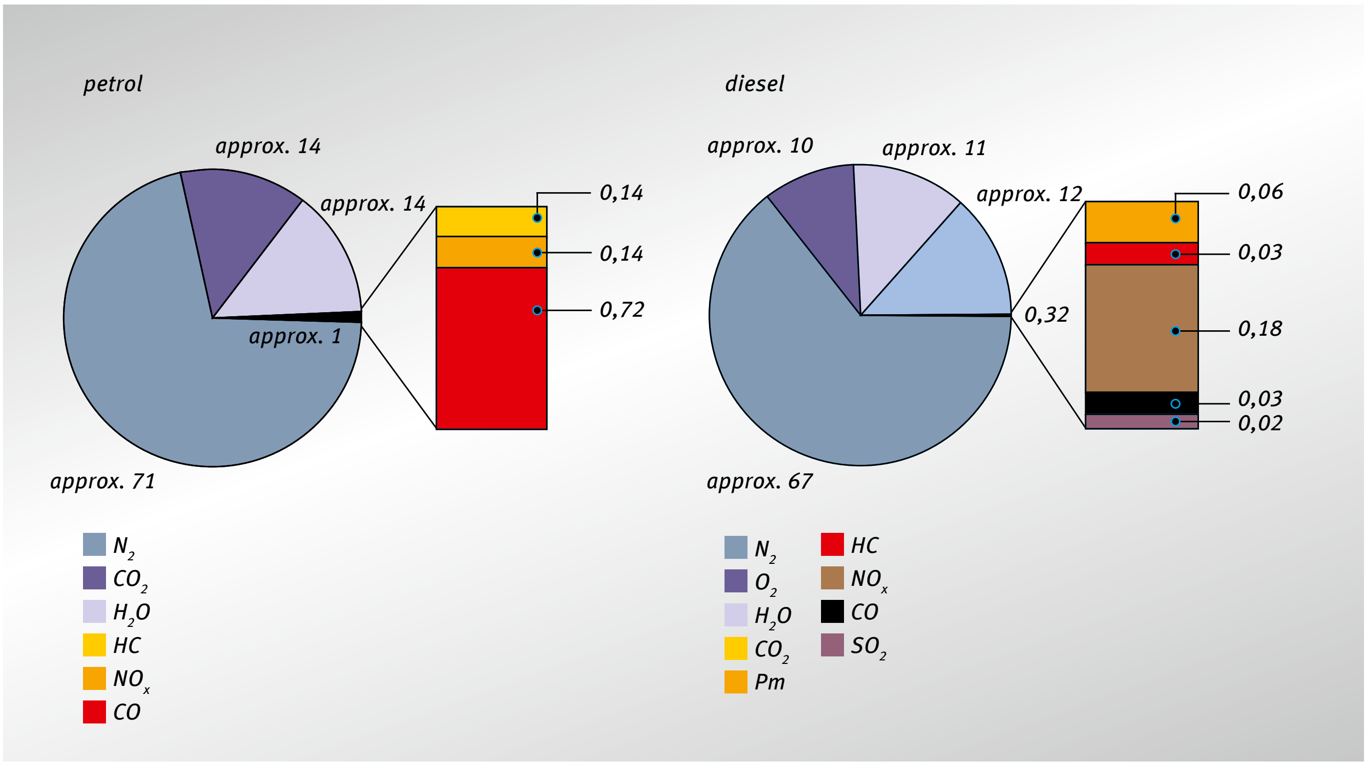

Fig. 54: composition of exhaust gas in petrol and diesel engines
The composition of the exhaust gases in petrol and diesel engines is different.

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6.1.1 Essential pollutants in the exhaust gas

Carbon monoxide (CO)
Carbon monoxide occurs when fuels containing carbon are not burned completely, especial after start-up and during idling. It is a colourless and odourless, but extremely toxic gas, and can be deadly even in the smallest quantities because, as a respiratory toxic, it prevents the distribution of oxygen in the blood.
Combined with oxygen it oxidises to CO_2 in a short time.

Sulphur dioxide (SO_2)
Sulphur dioxide is a chemical compound of sulphur and oxygen. It is a colourless, pungent smelling gas that contributes to respiratory sickness. Sulphur dioxide is the main cause of “acid rain” because it decomposes to sulphuric acid in the humidity, which erodes natural stone structures.
Only small amounts are contained in the exhaust gas, which can be lowered more by reducing the sulphur content of the fuel.

Nitrogen oxides (NO_x)
Nitrogen oxides are compounds of nitrogen N_2 and oxygen O_2. They occur in different forms such as NO, NO_2, or N_2O under high pressure, at high temperatures, and when there is excessive oxygen during engine combustion.
Measures to reduce fuel consumption, which produce more effective combustion, often cause an increase in the nitrogen oxides.
Nitrogen oxides are severe respiratory toxins. They irritate the eyes and mucous membranes and cause lung diseases.
Nitrogen oxides are responsible for the “acid rain” and the “forest dieback” (death of the forests) associated with it.
Furthermore they contribute to the formation of ozone, a respiratory toxic, in the atmosphere.

Hydrocarbons (HC)
Hydrocarbons are unburned fuel components, such as benzene, that are contained in the exhaust gas after incomplete combustion.
They occur in different forms and have different effects on the organism. They are partially carcinogenic.

Soot particles (PM)
Soot particles (PM – “particulate matter”) are produced from microscopic carbon beads on which the hydrocarbons originating in the fuel and grease accumulate.
They are carcinogenic.
Soot particles occur mostly in diesel vehicles.
Soot also occurs in petrol-based vehicles. But the amount is 20 to 200 times less than for diesel vehicles.

Carbon dioxide (CO_2)
Carbon dioxide is a colourless, noncombustible gas that is produced by bonding carbon from the fuel with oxygen from the combustion air.
It is undesirable because it reduces the earth’s protective shield against UV rays and contributes to climate changes (“greenhouse effect”).
When dissolved in water it produces carbonation, as in mineral water. Carbon dioxide is not directly toxic. Its toxic effect is based on the fact that it displaces oxygen for breathing, especially in closed rooms.

6.1.3
Emission limits

Since 1970 limits were established for the pollutant emissions of passenger vehicles. After January 1, 1971, these limits had to be met for all newly developed vehicles in the prototype testing.
The exhaust gas values were tested according to the newly introduced European driving cycle, nicknamed the “Europe test”. In the Europe test, driving in purely city traffic was simulated in 4 cycles. For the USA and other countries considerably more demanding tests were sometimes required. As this matter developed and as number of vehicles continued to rise, the limits continued to be lowered and the test criteria intensified.

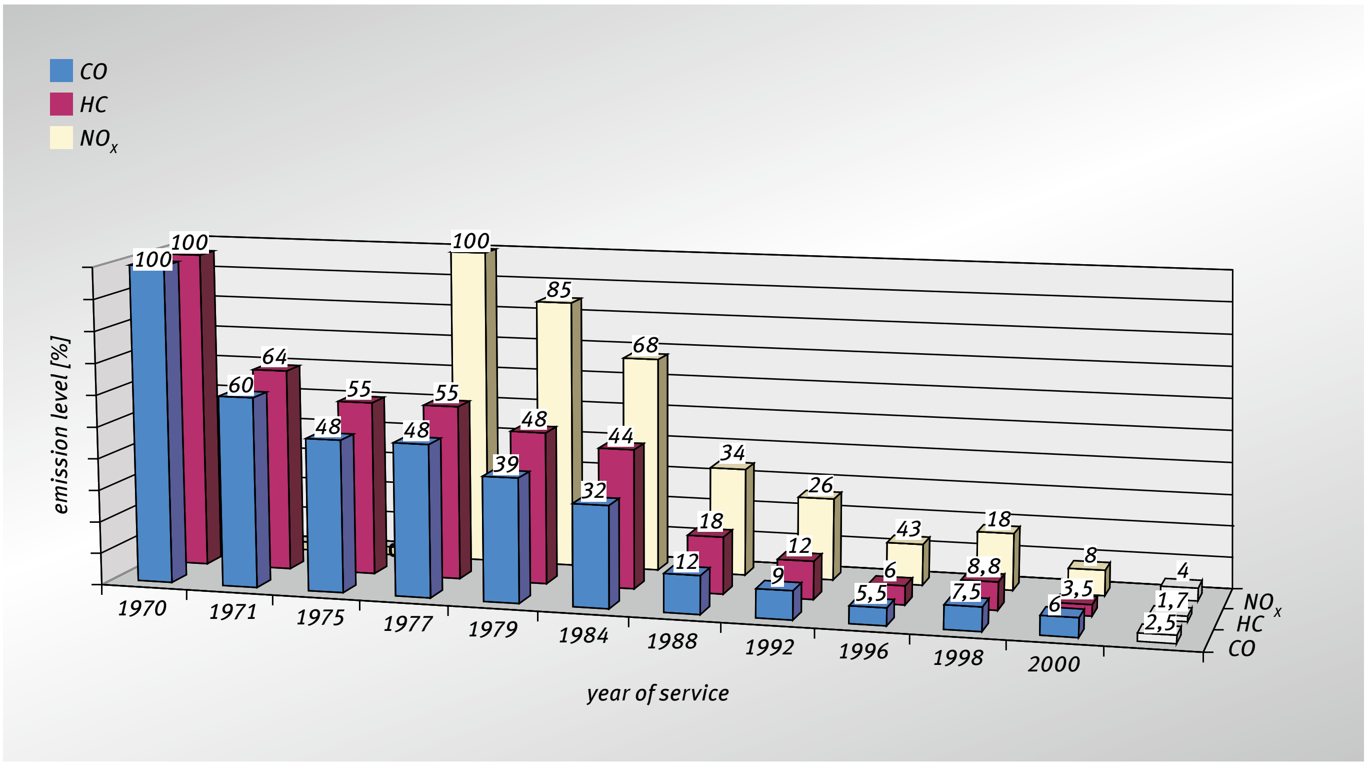

Fig. 55: development of emission limits (since 1970)

Frequently used abbreviations

AKF	activated carbon filter
ARV	cut-off secondary air valve
CARB	California Air Resources Board (California government agency for the maintenance of clean air)
CO	carbon monoxide
CO_2	carbon dioxide
DLC	data (or diagnostic) link connector (diagnostic connection)
DTC	diagnostic trouble code
EAM-i	electric drive module with integrated “intelligence”
EAV	electric cut-off valve
EDW	electric pressure transducer
EGR	exhaust gas recirculation
EOBD	european On-Board-Diagnosis
EPW	electropneumatic pressure transducer
EU	European Union
EUV	electric switch-over valve
H_2O	water
HC	hydrocarbon
LMS	air mass sensor
LS	lambda probe
MAF	mass air flow
MIL	malfunction indicator lamp
N_2	nitrogen
NEFZ	new european driving cycle
NN	sea level
NO_x	nitrogen oxide
O_2	oxygen
OBD	On-Board-Diagnosis
OBD II	On-Board-Diagnosis (USA)
PI	PIERBURG “Product Information”
ppm	parts per million
SI	PIERBURG “Service Information”
SL-	secondary air
SLP	secondary air pump
SLS	secondary air system
SLV	secondary air valve
ULEV	ultra low emission vehicles
FC	fault code
LNFZ	light utility vehicles
OT	top dead centre
UT	bottom dead centre

Glossary

Actors
Actuators, e.g. valve actuators.

Blow-By
Leakage gas flows past the piston rings into the crankcase during normal combustion. Here, the worse the piston sealing is in the cylinder, the greater the blow-by gas flow is. The crankcase ventilation returns these harmful gases back to the engine for combustion.

CAN
“Controller area network” stands for a standardised serial realtime bus system that connects control units in the vehicle.

CARB
California Air Resources Board is the California government agency that is responsible for the maintenance of clean air.

Debounced
Confirmed errors
If an error occurs again during the consecutive driving cycles under the same conditions or over a certain time period, it will be labelled as “debounced” (confirmed) and recorded as an OBD error.

Driving cycle
Operating conditions required to run the test of “cyclically monitored” components and systems.
Not identical with the “New European Driving Cycle (NEFZ)”

Freeze Frame
Operating data and ambient conditions that were present when an error occurred.

Lambda; λ
Air number: dimensionless coefficient that describes the air content of the fuel/air mixture.

$$\lambda = \frac{\text{air quantity supplied}}{\text{air requirement}}$$

Limp home
Limp home

Post-cat probe/secondary probe/correction probe/monitor probe
Different designations for the lambda probe downstream from the catalytic converter.

Pre-cat probe/control probe
Different designations for the lambda probe upstream from the catalytic converter.

NEFZ
New European Driving Cycle for determining the exhaust gas emission of vehicles. Compulsory for the prototype certification test of a vehicle.
Testing begins as soon as the engine is started. The omission of the previously common warm-up phase signifies an intensification of the test process because all exhaust gas components that occur during a cold start are included in the test results.
Not identical with the driving cycle.

Readinesscode
12-digit numerical code that indicates whether the OBD diagnosis of the vehicle system have been carried out.

SAE
The Society of Automobile Engineers publishes suggestions and guidelines on how to implement the legal requirements.

Scan Tool; Generic Scan Tool
Data readout instrument used to read the (E)OBD data.

Sensors
Measuring sensors such as air mass sensor, pressure sensor, speed sensor, temperature sensor, position potentiometer.

Stoichiometric
A stoichiometric fuel/air mixture identifies the ideal volume ratio of intake air and fuel in the vehicle construction for complete combustion.

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