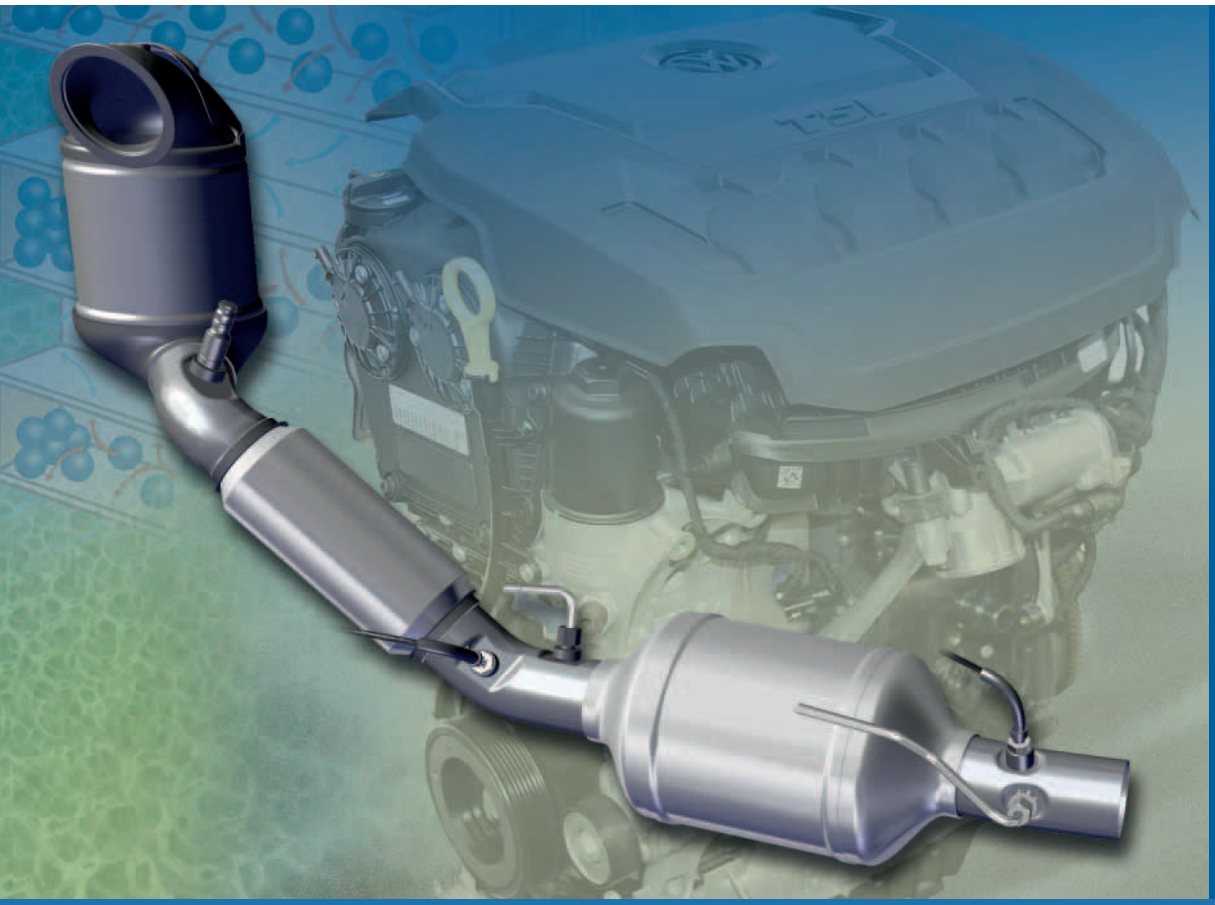
Service Training

Volkswagen

Self-Study Programme 590

Underbody Petrol Particulate Filter

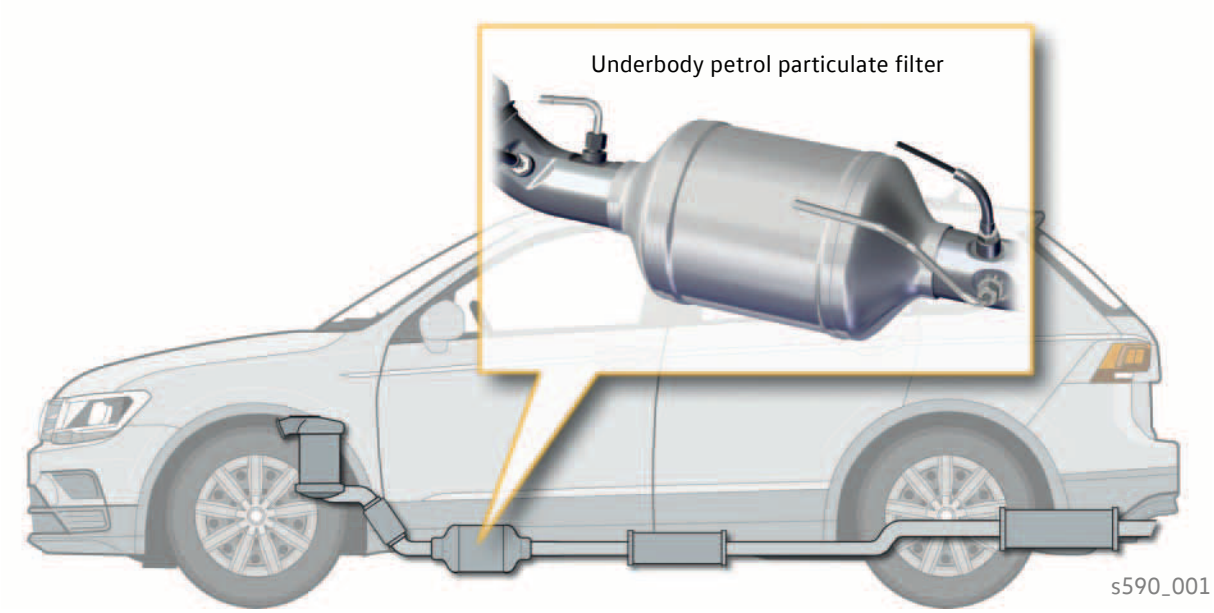
Design and function



Volkswagen launched its first petrol engine featuring a particulate filter in 2017. It was a so-called "close-coupled petrol particulate filter" that was mounted directly to the turbocharger. That particulate filter actually has an ideal fitting location because it quickly reaches the temperature of approx. 600°C required for regeneration.

However, due to the lack of space in the engine compartment when larger engines are installed, we need to install the petrol particulate filter further along the exhaust system. This is known as an underbody petrol particulate filter due to its installation position.
This installation position requires different regeneration strategies and monitoring processes particularly when the vehicle is used for short journeys and driven continuously at very slow speeds. This Self-study Programme describes the other components that are required for this system.

The underbody petrol particulate filter is installed mainly in vehicles with 2.0-l TSI engines from the EA888 series, e.g. the Polo, Passat, Golf and Tiguan as well as the Passat GTE (plug-in hybrid) with 1.4-l TSI engine.



Self-study Programme no. 558 describes the design and function of the "close-coupled petrol particulate filter". Furthermore, it provides basic information on soot and ash particles as well as on passive and active regeneration.

**The Self-study Programme shows the design and function of new developments.
The contents will not be updated.**

For current testing, adjustment and repair instructions, refer to the relevant service literature.

Important Note

Contents

Exhaust system with particulate filter

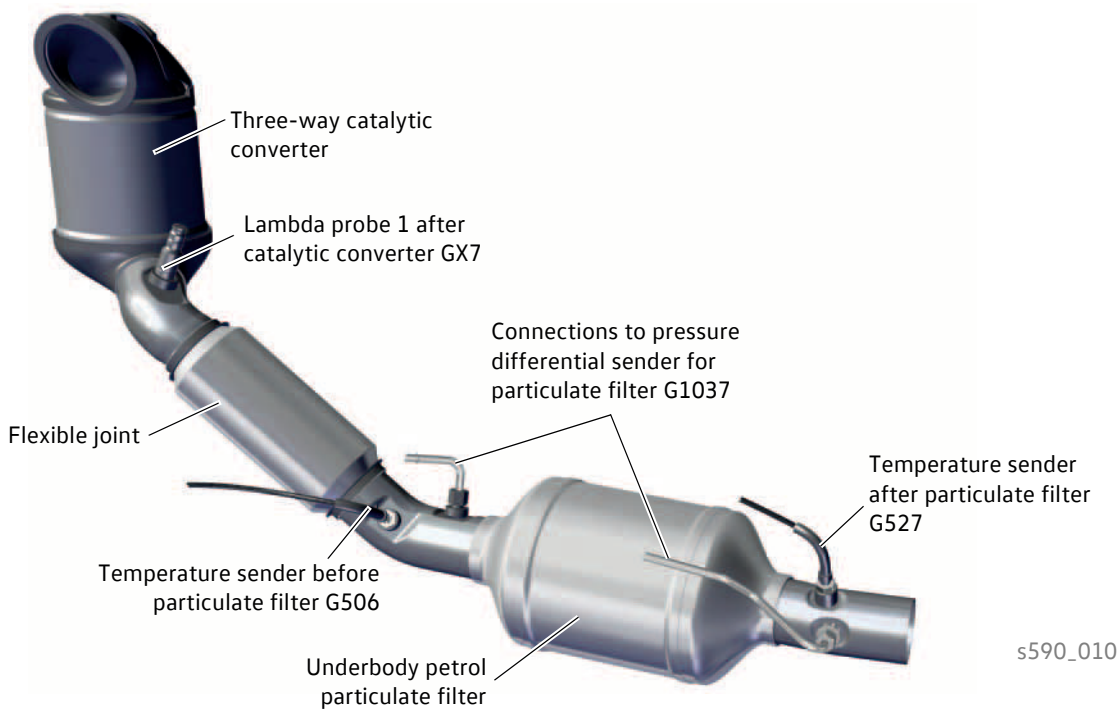
The following components belong to the particulate filter system:

- Petrol particulate filter
- Pressure differential sender for particulate filter G1037
- Two temperature senders (temperature sender before particulate filter G506 and temperature sender after particulate filter G527)

A three-way catalytic converter is bolted directly to the turbocharger. This has the advantage that it reaches its catalytic effect very quickly. Due to the small amount of space available, it is not possible to combine this three-way catalytic converter with the petrol particulate filter. Therefore the petrol particulate filter has been positioned on the underbody.

Front-wheel drive

On vehicles with front-wheel drive, a petrol particulate filter is installed in the exhaust system on the underbody.



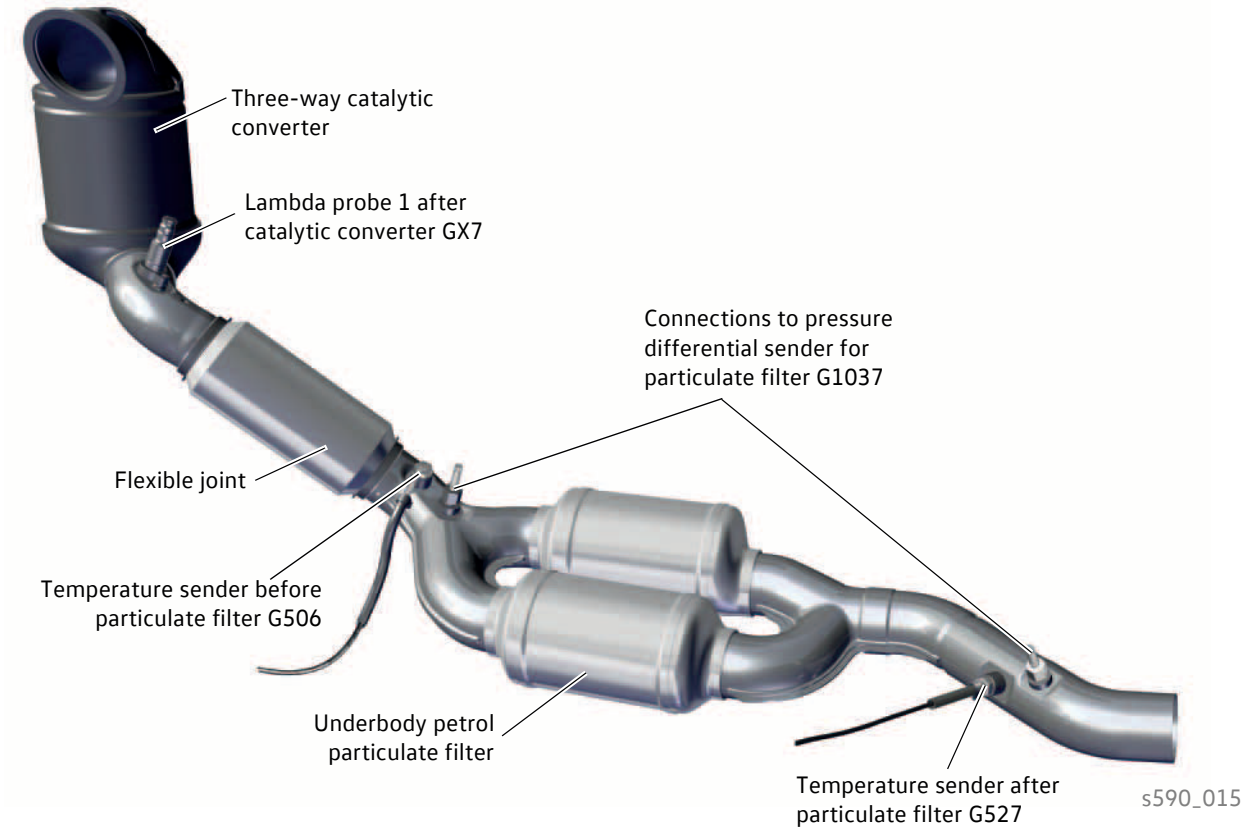
When the underbody petrol particulate filter is installed in the Passat GTE, it has an additional catalytic coating. An additional lambda probe is not fitted after the particulate filter with an integrated catalytic converter because:

- The close-coupled three-way catalytic converter performs the main conversion task.
- The particulate filter with integrated catalytic converter is installed further away from the engine. It does not "age" as quickly as the close-coupled catalytic converter. As a result, the catalytic function of the particulate filter does not need to be monitored.

All-wheel drive

On vehicles with all-wheel drive, the propshaft in particular influences the routing of the exhaust system. For reasons of space, two smaller underbody petrol particulate filters are therefore installed in a parallel arrangement in the exhaust system.

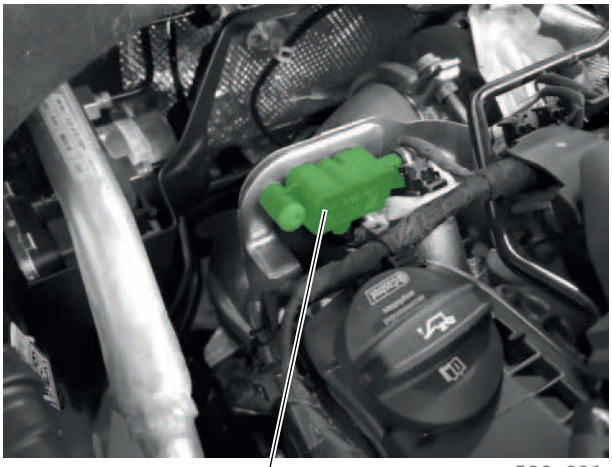
The parallel arrangement of the two petrol particulate filters does not have an influence on the number of sensors or their tasks compared with the single-filter variant for front-wheel drive models.



Pressure differential sender for particulate filter G1037

Fitting location

The pressure differential sender for particulate filter is located at the rear right of the engine compartment.



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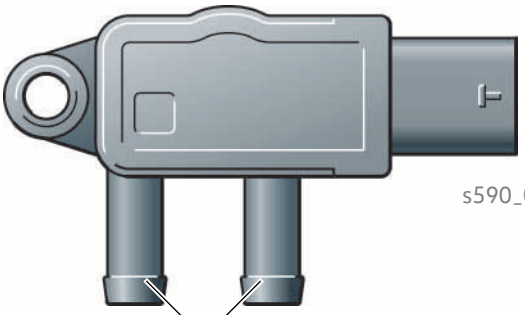
Pressure differential sender for particulate filter G1037

Task

The sender has the task of measuring the difference in exhaust gas pressure before and after the particulate filter.

Pneumatic connection

The pressure differential sender for the particulate filter has two pneumatic connections. It is connected via these connections by pipes and hoses to the connections on the particulate filter.



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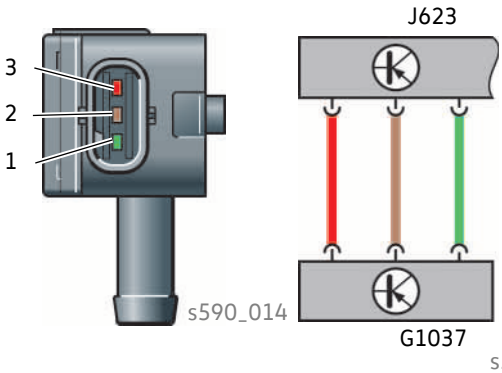
Pneumatic connections

Electrical connection

The sender G1037 is connected via a three-pole wire to the engine/motor control unit J623.

The three-pole electrical connection on the sender has the following pin assignment:

- Pin 1: SENT signal
- Pin 2: earth
- Pin 3: +5 volts



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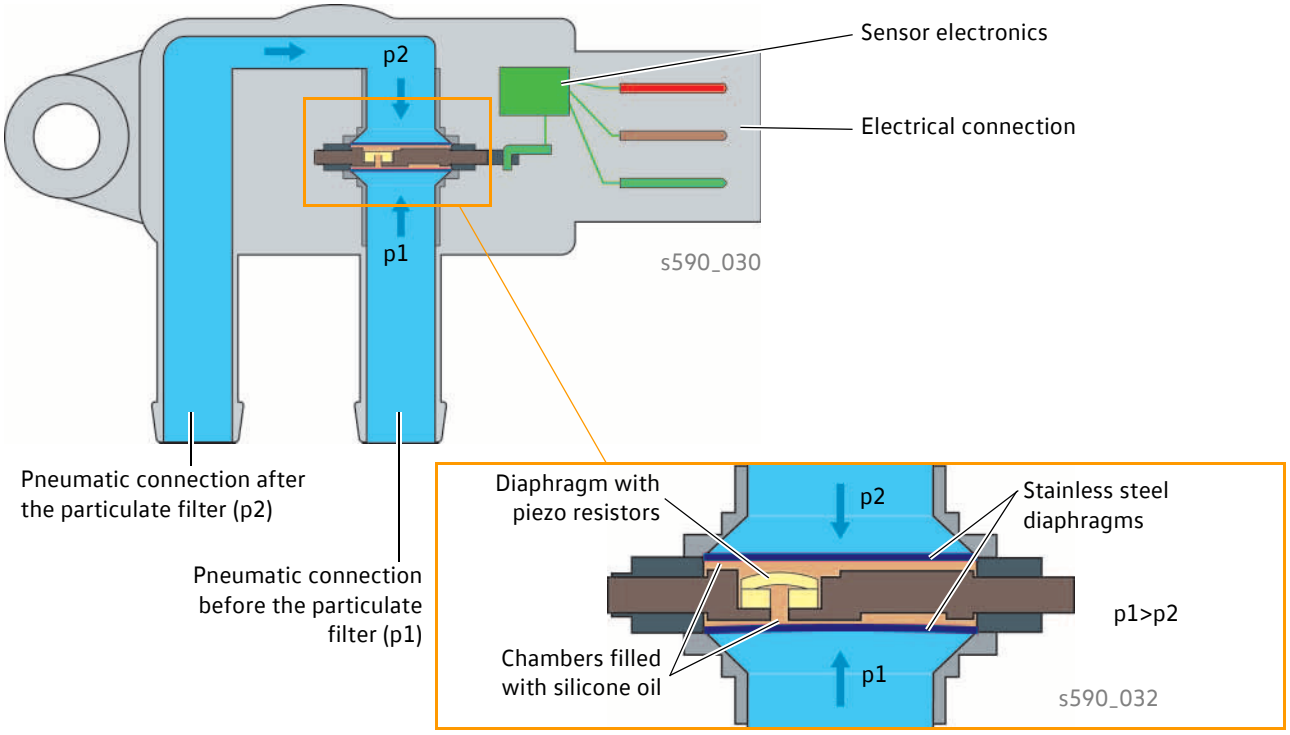
Positive supply: +5 volts
Earth
Signal voltage

Design

There are two pressure connections on the pressure differential sender for the particulate filter G1037. Pressure lines connect one to the exhaust gas stream before the particulate filter (p1) and the other to the exhaust gas stream after the particulate filter (p2).

Two stainless steel diaphragms, on which the respective exhaust gas pressures act, form the separating diaphragms between the exhaust gas streams and the chambers filled with silicone oil. There is a pressure-sensitive diaphragm with piezo resistors between the chambers.



How it works

In a particulate filter with very low particulate accumulation, the pressures before and after the filter are almost equal. The diaphragm with the piezo elements is in the rest position.

If soot has accumulated in the particulate filter, the exhaust pressure before the filter will increase. This pressure acts on the diaphragm with piezo resistors.

The diaphragm with the piezo resistors is deformed as a result. The voltage at the resistors is processed by the sensor electronics and transmitted to the engine/motor control unit in the form of a SENT signal.

The system works in a different way in the Passat GTE and also in other vehicles in future. The atmospheric pressure is also measured as well in that variant.

Sensors

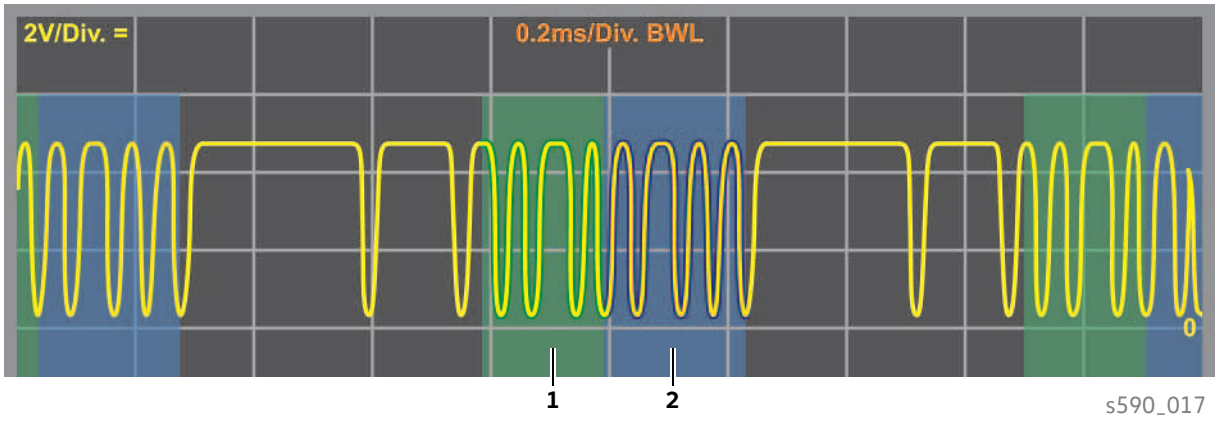
Signal use

The pressure differential sender measures the exhaust gas pressure before and after the particulate filter. The differential pressure is measured in this way and is transmitted to the engine/motor control unit using a SENT signal. The engine/motor control unit uses this signal to determine the accumulation level in the particulate filter and initiates the necessary regeneration procedure.

Furthermore, the signals are checked for plausibility in the engine/motor control unit and the particulate filter is thus monitored to see whether it is producing exhaust gas back pressure.

SENT signal

SENT (**S**ingle **E**dge **N**ibble **T**ransmission) is a standard for communication between sensors and control units that describes a data protocol. The SENT protocol consists of different sections. The sensor message is transferred via the signal 1 sequence or signal 2 sequence.



Key

1 Signal 1 sequence – for the pressure differential before and after the particulate filter

2 Signal 2 sequence – counter

You will find further information on the SENT signal in Self-study Programme no. 547.

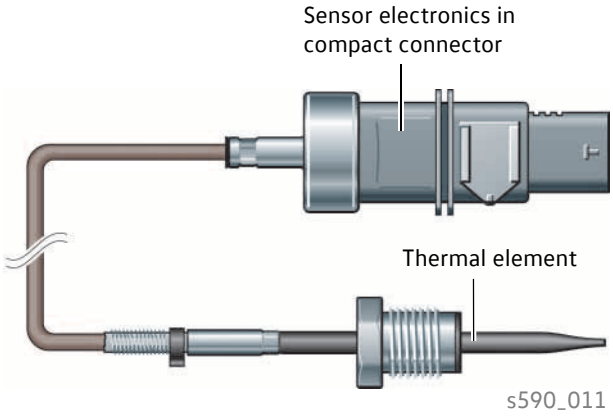
Effects upon failure

If the sensor fails or there is an implausible signal, a corresponding event memory entry is created. In addition, the exhaust emissions warning lamp K83 (MIL) and the particulate filter warning lamp K331 are switched on after the third engine start. Active regeneration is initiated.

Temperature sender before particulate filter G506 and temperature sender after particulate filter G527

Fitting location and task

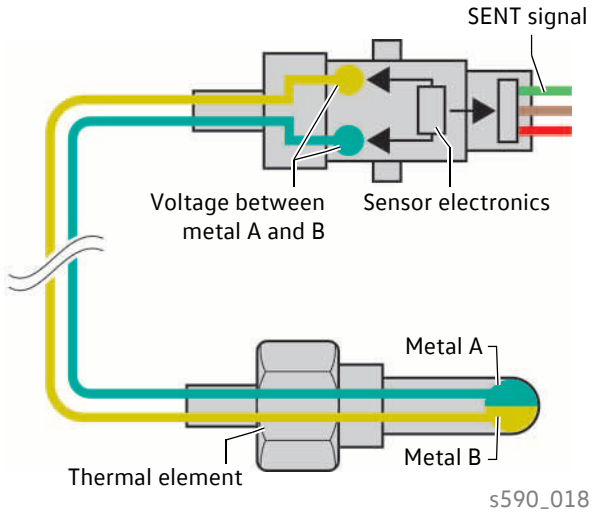
The temperature sender G506 is located in the exhaust system before the particulate filter and the temperature sender G527 is located after the particulate filter. Both measure the temperature of the exhaust gas at those points.



Design and function

The design and function of the two temperature senders is identical. They both consist of a thermal element and sensor electronics. The sensor electronics and the thermal element are arranged separately from each other so that the sensor electronics are not exposed to the high exhaust gas temperatures.

The temperature sender works according to the Seebeck effect – named after German physicist August Seebeck.



Seebeck effect

To make use of this effect, two metal strips made from different nickel alloys are fitted in the thermal element so that their ends touch each other. At very high temperatures, this generates a low voltage in the microvolt to millivolt range. The higher the temperature is, the higher the voltage. Since this voltage is so low, it is hard transfer the signal to the engine/motor control unit. For this reason, sensor electronics are built into the compact connector. The electronics are supplied with 5 volts and transmit a SENT signal as a signal.

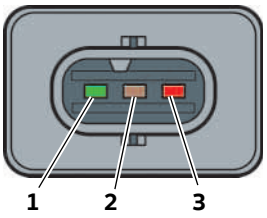
Sensors

Electrical connection

Both temperature senders G506/G527 have one compact connector each with sensor electronics. This connector is connected via a three-pole wire to the engine/motor control unit J623.

The three-pole electrical connection on the sender has the following pin assignment:

- Pin 1: SENT signal
- Pin 2: earth
- Pin 3: +5 volts



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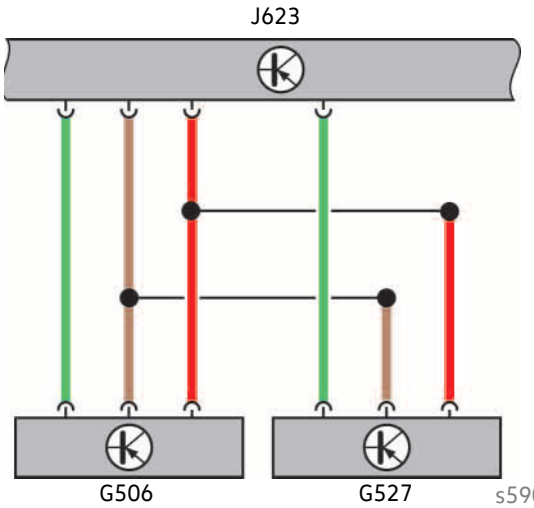

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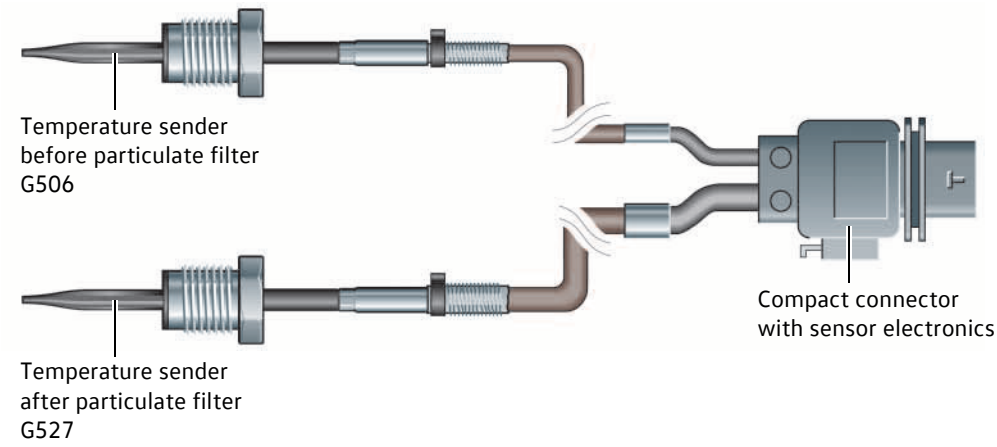
In another variant, both temperature sensors have a common compact connector with sensor electronics. This connector is also connected via a three-pole wire to the engine/motor control unit J623.



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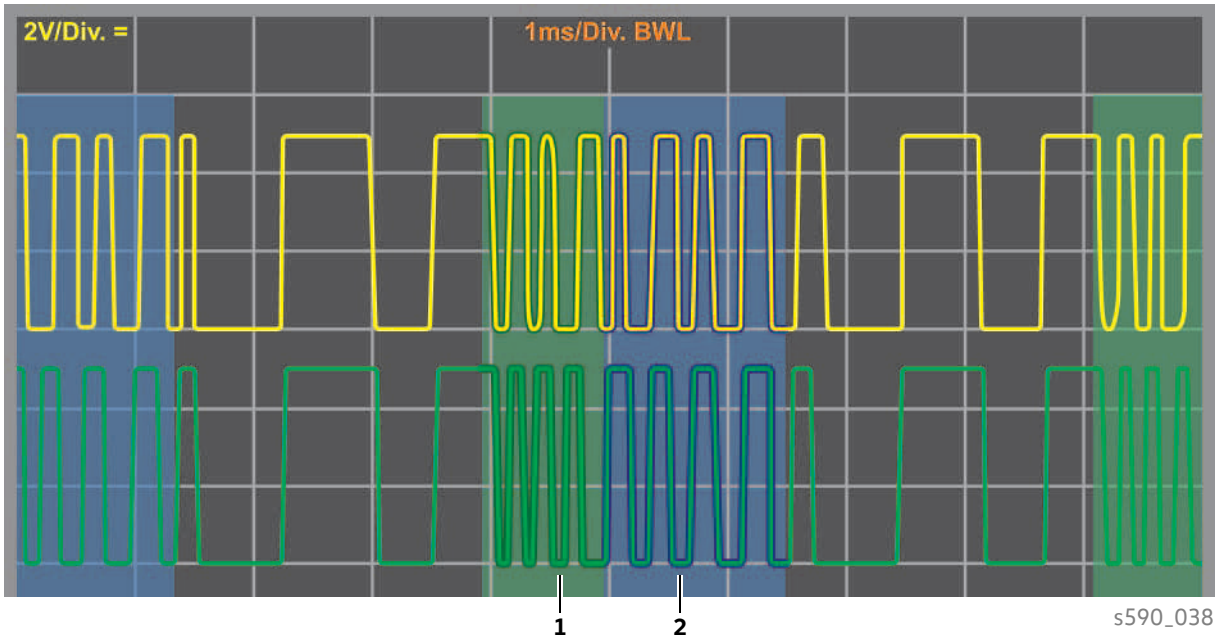
SENT signal

As shown in the diagram below, both temperature senders transmit a SENT signal to the engine/motor control unit.



Key

1	Signal 1 sequence – for the respective exhaust gas temperature before and after the particulate filter	Signal from temperature sender before particulate filter G506
2	Signal 2 sequence – counter	Signal from temperature sender after particulate filter G527

The temperature sender message is also transferred via the signal 1 sequence or signal 2 sequence in this case. The respective exhaust gas temperature is transferred via the signal 1 sequence. The signal 2 sequence is a counter and is not evaluated by the engine/motor control unit.

If the variant where both temperature sensors have a common compact sensor with sensor electronics is fitted, the exhaust gas temperature of the temperature sender before particulate filter G506 is transmitted via the signal 1 sequence to the engine/motor control unit. The exhaust gas temperature of the temperature sender after particulate filter G527 is transmitted via the signal 2 sequence.

When configuring the oscilloscope for reading the temperature signals, a different time setting needs to be used since the signal from the temperature sender is slower compared with the signal from the pressure differential sender.

Sensors

G506 signal use

The temperature sender G506 measures the temperature before the particulate filter and transmits this information to the engine/motor control unit in the form of a SENT signal. The engine/motor control unit requires this information to calculate the accumulation of soot in the particulate filter.

The engine/motor control unit requires further information for this calculation such as:

- Engine load
- Engine speed
- Coolant temperature
- Lambda value

The engine/motor control unit uses this information to calculate how much soot has accumulated in the particulate filter. We call this the soot accumulation model.
The particulate filter is only regenerated from approx. 600 °C. Using the information from the temperature sender, the engine/motor control unit detects whether and for how long the particulate filter has been regenerated. We call this the soot discharge model.
Overall, the engine/motor control unit can calculate how much soot has entered the particulate filter and how much soot has been discharged again.

In addition, the signal is used for component protection in order to protect the particulate filter from excessively high exhaust gas temperatures.

G527 signal use

The temperature sender G527 measures the temperature after the particulate filter and transmits this information to the engine/motor control unit in the form of a SENT signal. Since the underbody particulate filter is located further away from the engine, it is exposed to environmental influences more than a close-coupled particulate filter. This makes calculating the temperature of the particulate filter too inaccurate. For this reason, the temperature after the particulate filter also needs to be measured for the soot discharge model.

The signal from the temperature sender after particulate filter is also used for component protection in order to protect the particulate filter against excessively high exhaust gas temperatures.

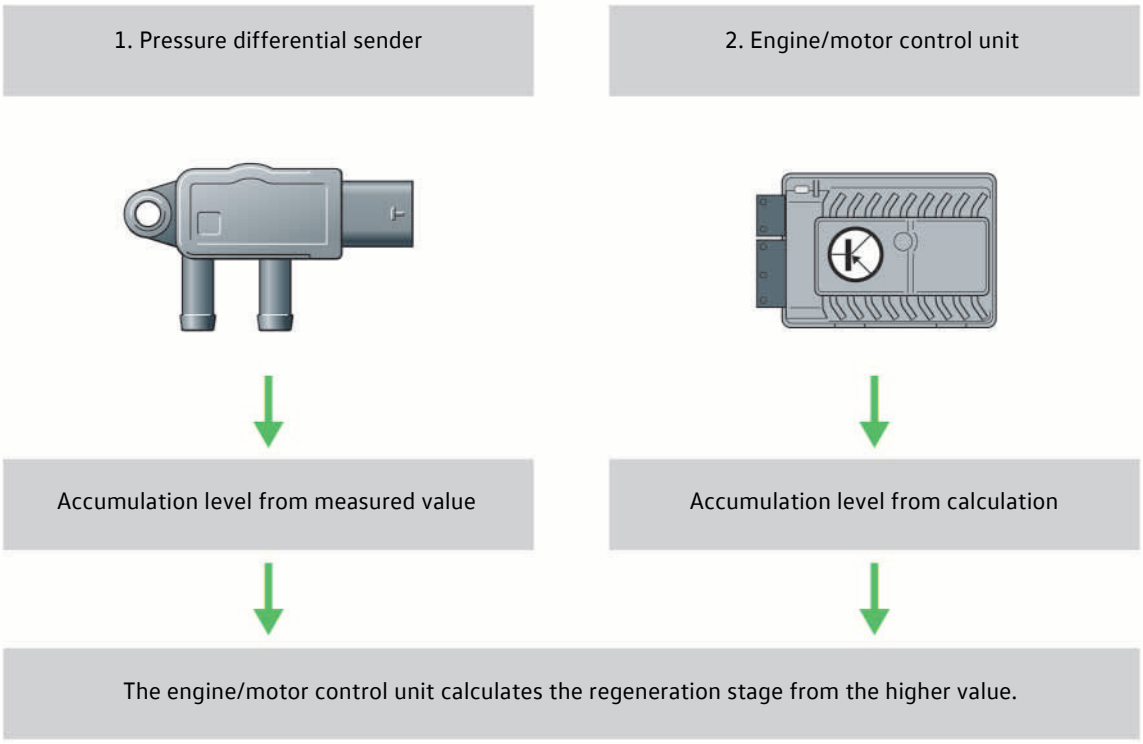
Effects upon failure

If a temperature sender fails or there is an implausible signal, a corresponding event memory entry is created. In addition, the exhaust emissions warning lamp K83 (MIL) and the particulate filter warning lamp K331 are switched on after the third engine start. Active regeneration is initiated.

Detecting the accumulation level

The accumulation of soot in the underbody petrol particulate filter is detected simultaneously via two different sources of information:

1. The signal from the pressure differential sender is used to determine the accumulation level in the particulate filter.
2. An accumulation or calculation model stored in the engine/motor control unit is used to calculate the accumulation level. The engine/motor control unit uses maps for this purpose.



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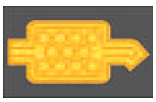
Particulate filter regeneration

Regeneration stages

Similar to the close-coupled petrol particulate filter, the underbody petrol particulate filter has various regeneration stages depending on the accumulation level. The corresponding maps for the regeneration stages differ according to vehicle model and engine variant. The soot burn-off process takes place as required on the basis of the measured or calculated soot quantity.

Accumulation*	**Measures**
Low accumulation	• No measures active • **Passive** regeneration takes place during “normal” engine running.
Medium accumulation	• Continued passive regeneration • In addition, **active** regeneration can be performed with the following measures: - Deactivating the coasting function (see Self-study Programme no. 555 for explanation of function) - Deactivating start/stop - Increased idling speed - Adapted shifting rpm - Increasing the exhaust gas temperature
Increased accumulation	• The particulate filter warning lamp K331 lights up. • Entry in the event memory that indicates the lit up warning lamp. • Regeneration drive by the driver required 
High accumulation	• Now the electronic power control fault lamp K132 and the exhaust emissions warning lamp K83 (MIL)** light up in addition to K331. • Entry in the event memory that indicates the excessively high accumulation in the particulate filter. • Workshop regeneration necessary • Measures to burn off the soot are deactivated from this stage.  **
Limit accumulation reached	• Entry in the event memory that indicates the excessively high accumulation in the particulate filter. • Workshop regeneration is no longer possible. The particulate filter must be renewed.  **

* The accumulation can be read via a measured value in the self-diagnosis.

** The exhaust emissions warning lamp K83 (MIL) does not light up for all variants.

Things to note

Workshop regeneration for engines above 169 kW

When an underbody petrol particulate filter is combined with a petrol engine from the EA 888 series delivering more than 169 kW, workshop regeneration is currently not possible. In this case, there is a danger that the turbocharger in particular will become too hot during workshop regeneration. The particulate filter must be renewed in this case.

Please always refer to the latest workshop manuals or the Guided Fault Finding about this.

Workshop regeneration for engines below 169 kW

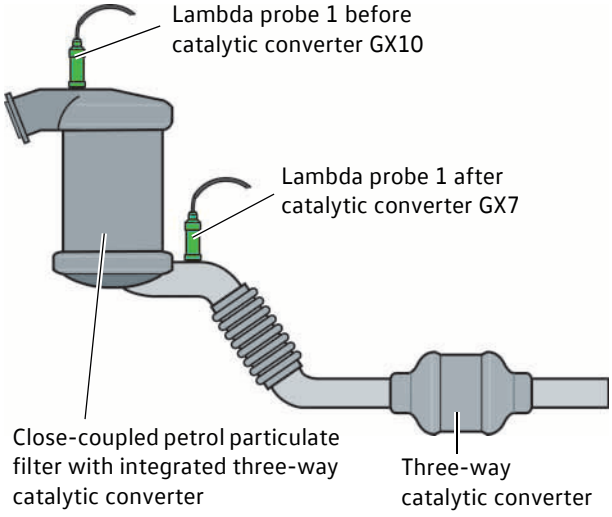
The workshop regeneration is performed with the aid of the Guided Fault Finding. In vehicles with petrol engines delivering less than 169 kW, there are the following changes in the Guided Fault Finding procedure:

- There are prior tests for some variants, for example, whether the bonnet is closed.
- The workshop regeneration is aborted if critical temperatures above 115°C are reached in the coolant.
- There is a cooling phase at the end.

Summary

Comparison of petrol particulate filters

Exhaust system with close-coupled petrol particulate filter



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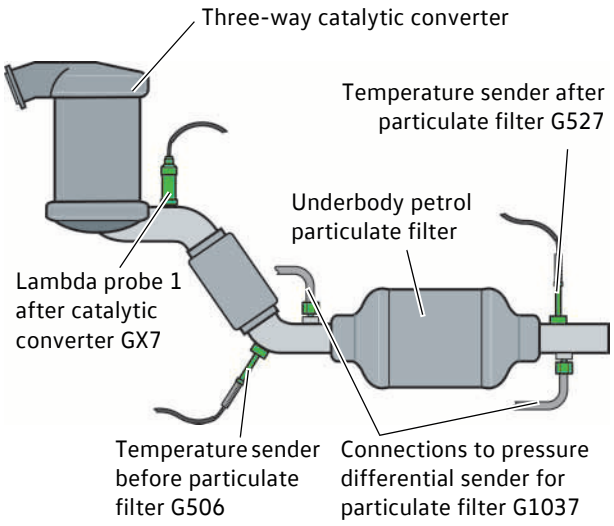
Exhaust system with underbody petrol particle filter



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Common features

- Both particulate filter systems have similar regeneration strategies.
- A particulate filter warning lamp K331 is installed in both systems. When it lights up, the system is recommending that the driver goes on a regeneration drive.
- Both systems are mainly required for cold starts and the subsequent first one to two minutes – particularly in conjunction with direct injection petrol engines.
- The channels in the particulate filter are sealed alternately by plugs in both systems.
  (see Self-study Programme no. 558)
- The exhaust gas pressure is measured via a sensor in both systems.

Differences

- The fitting location of the particulate filter is different. The close-coupled petrol particulate filter is bolted directly to the turbocharger. The underbody petrol particulate filter is installed on the underbody.

- On the underbody petrol particulate filter, the accumulation is detected using the SENT signal from the pressure differential sender G1037 and is calculated simultaneously by the engine/motor control unit. The accumulation is only calculated for the close-coupled petrol particulate filter. The analogue signal from the exhaust gas pressure sensor 1 G450 is used to detect blockages.

- The underbody petrol particulate filter uses two temperature senders to measure the exhaust gas temperature before and after the particulate filter. The exhaust gas temperature is calculated for the close-coupled petrol particulate filter.

- The close-coupled petrol particulate filter with integrated three-way catalytic converter is monitored indirectly using two Lambda probes. The underbody petrol particulate filter is monitored by the pressure differential sender and the two temperature senders.

- There are several versions of the underbody petrol particulate filter for which workshop regeneration is currently not possible.

Test your knowledge

Which answers are correct?

One or several of the given answers may be correct.

1. Which sensors are installed in addition for the underbody petrol particulate filter system?

❒ a) Temperature sender before particulate filter G506

❒ b) Temperature sender after particulate filter G527

❒ c) Pressure differential sender for particulate filter G1037

❒ d) Air mass meter G70

2. Why does the underbody petrol particulate filter use this additional concept in contrast to the close-coupled petrol particulate filter?

❒ a) It allows the particulate filter to be regenerated better due to the installation position on the underbody.

❒ b) When larger engines are installed, there is not enough space in the engine compartment.

❒ c) The installation position on the underbody allows temperature senders that measure the exhaust gas temperature to be omitted.

3. What kind of signal do the two temperature senders G506/G527 and the pressure differential sender G1037 transmit to the engine/motor control unit?

❒ a) Analogue voltage signals

❒ b) Pulse-width modulated signals (PWM)

❒ c) Frequency modulated signals

❒ d) A LIN data protocol (Local Interconnect Network)

❒ e) A SENT signal (Single Edge Nibble Transmission)

4. Where are the sensor electronics installed in both temperature senders G506/G527?

❒ a) In the thermal element

❒ b) In the compact connector

❒ c) In the engine/motor control unit

❒ d) In the onboard supply control unit

5. How do we determine whether active regeneration of the underbody petrol particulate filter needs to be initiated?

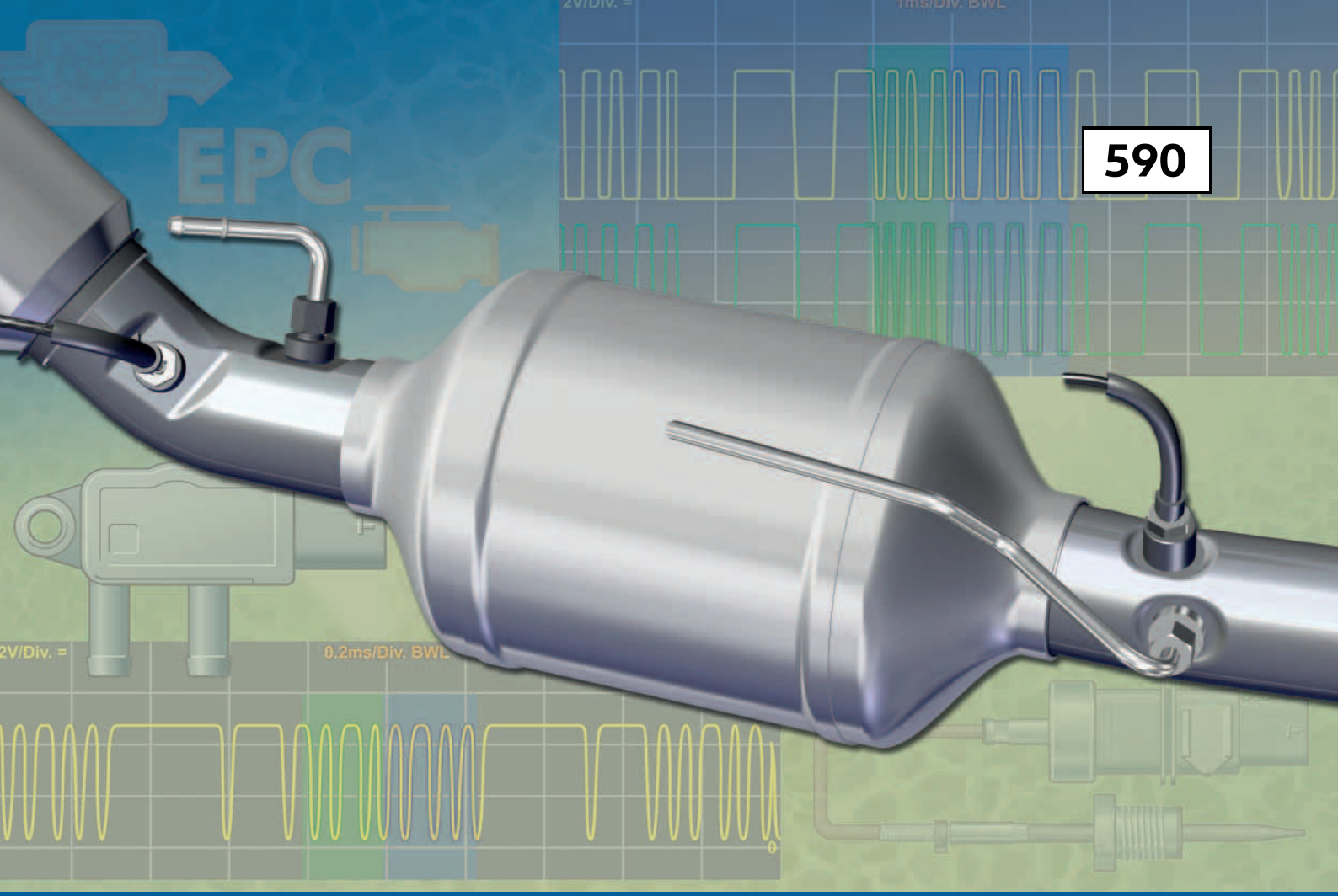
❒ a) The accumulation level is detected by a pressure differential sender G1037 and calculated simultaneously by the engine/motor control unit J623. The two values are compared. The engine/motor control unit calculates the regeneration stage from the higher value.

❒ b) The engine/motor control unit determines the regeneration stage from the difference between the signals transmitted by the two temperature senders G506 and G527.

❒ c) If the analogue signal from the pressure differential sender for particulate filter G1037 exceeds certain voltage values, the corresponding regeneration stage is initiated.

❒ d) The accumulation level is determined exclusively by means of a calculation model in the engine/motor control unit.

Answers:
1. a), b), c); 2. b); 3. e); 4. b); 5.a)



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