

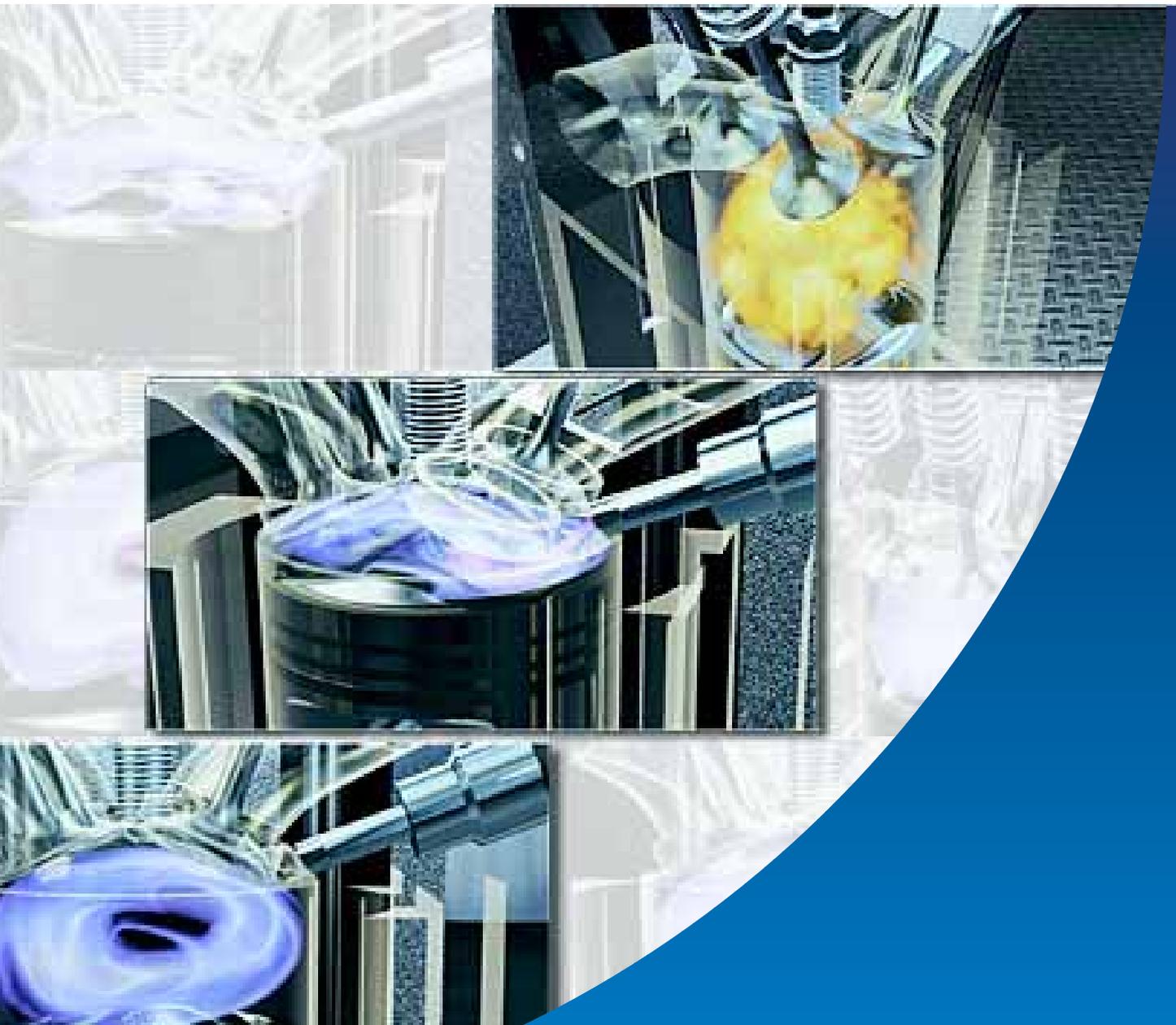
Service.



## Self-Study Programme 253

# Direct Petrol Injection System with Bosch Motronic MED 7

Design and Function



The primary objective of engine development is to minimise fuel consumption and exhaust emissions.

A closed-loop catalyst reduces emission of hydrocarbons, nitrogen oxides and carbon monoxide by up to 99%.

However, the emission of carbon dioxide (CO<sub>2</sub>), a greenhouse gas produced by combustion, can only be reduced by lowering fuel consumption.

But this is hardly feasible in systems with external mixture formation (intake manifold injection systems).

This is why engines equipped with the Bosch Motronic MED 7 direct petrol injection system will be used for the first time in the Lupo FSI and Golf FSI.

They have the potential to reduce fuel consumption by up to 15% compared to a similar engine with intake manifold injection.



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In this Self-Study Programme we will show you the component parts of the direct petrol injection system together with the Bosch Motronic MED 7 used in the Lupo FSI and Golf FSI.

**This Self-Study Programme explains the design and function of new developments.**

**The contents will not be updated.**

**NEW**



**Important Note**

Please refer to the relevant Service

Literature for up-to-date inspection, adjustment and repair instructions.

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# Introduction

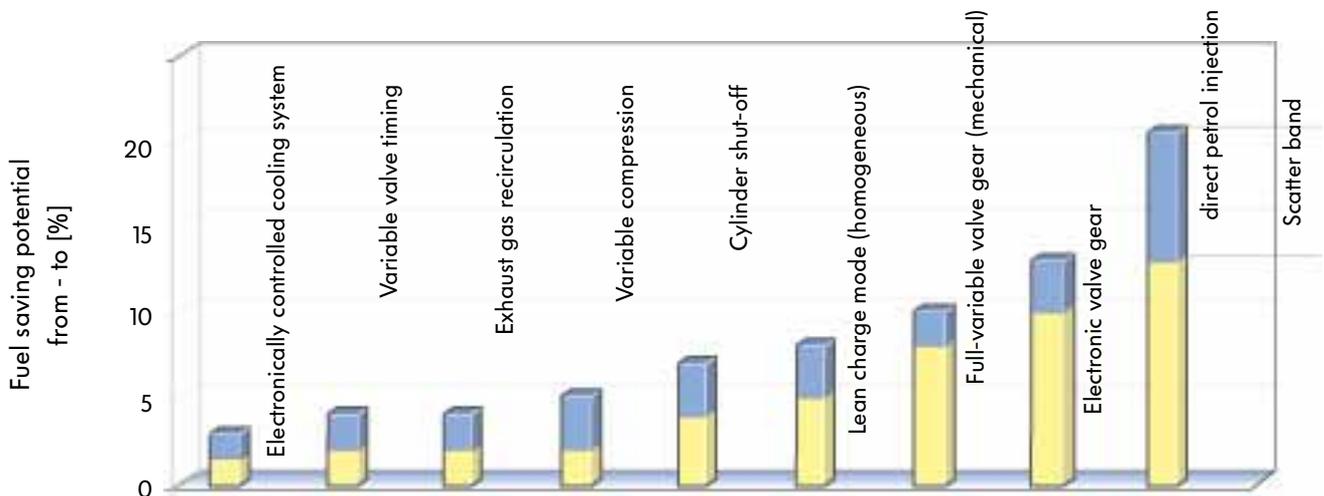
## Why the direct petrol injection system?

The primary objective of engine development is to minimise fuel consumption and exhaust emissions.

This has the following advantages:

- vehicle operating costs are reduced, firstly through lower fuel consumption and, secondly through tax incentives provided to low emission vehicles
- environmental pollution is reduced as fewer pollutants are emitted into the atmosphere, and
- natural resources are conserved

The diagram shows measures to improve fuel economy.



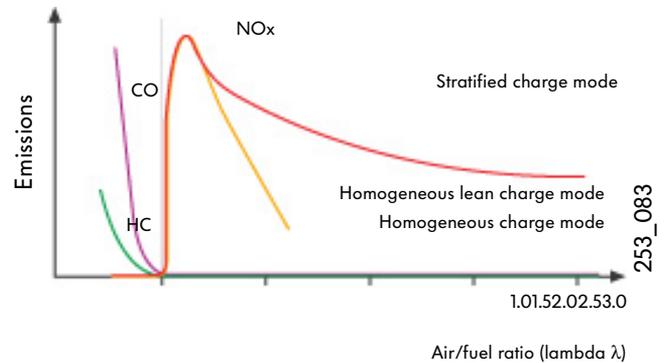
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- Electronically controlled cooling systems, variable valve timing and exhaust gas recirculation are already used in many engines.
- For reasons of smooth engine running, a cylinder shut-off function would only make sense in connection with multi-cylinder engines.
- Variable compression and variable port timing call for high-performance mechatronic components with suitably rated actuators and control circuits.
- Lean-burn engine concepts were abandoned in favour of engines with direct petrol injection.
- The direct petrol injection system is favoured by Volkswagen as it offers the greatest potential improvement in fuel economy (up to 20%).

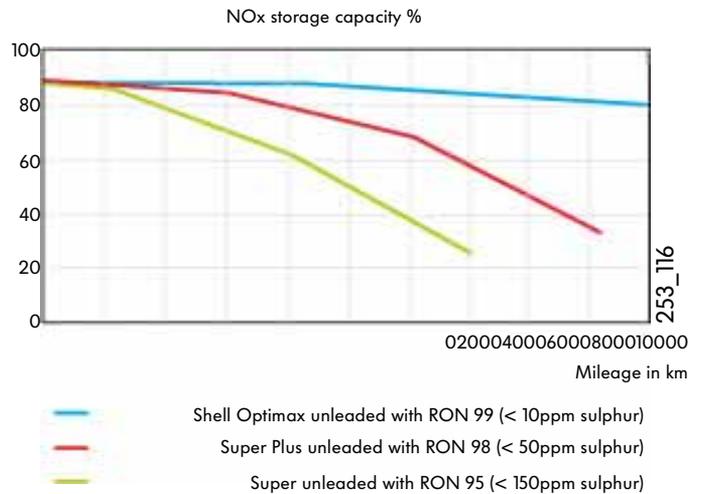
Balancing shafts would have to be used to improve smooth running in four-cylinder engines.

## Why has Volkswagen waited until now to introduce the direct petrol injection system?

One of the major problems with direct petrol injection is that of exhaust gas aftertreatment. In stratified charge mode and in homogeneous lean charge mode, a conventional closed-loop catalyst cannot convert the nitrogen oxides produced by combustion into nitrogen fast enough. Through the development of the NO<sub>x</sub> storage catalyst, however, it is now possible to meet EU4 exhaust emission standard in these modes. In this system, nitrogen oxides are stored temporarily and systematically converted to nitrogen.



Another reason is the problem of sulphur in fuel. Due to its chemical similarity to nitrogen oxides, sulphur is also stored in the NO<sub>x</sub> storage catalyst and occupies the spaces intended for nitrogen oxides. The higher the sulphur content in the fuel, the more often the storage catalyst has to be regenerated and the higher the fuel consumption.



The adjacent diagram shows the effect of sulphur content on the storage capacity of the NO<sub>x</sub> storage catalyst.

## What are Volkswagen's future plans regarding the direct petrol injection system?

- In the year 2000, the 1.4l 77kW FSI engine will be introduced in the Lupo FSI
- In the year 2002, the 1.6l 81kW FSI engine will be introduced in the Golf FSI
- In the year 200, the 1.4l 63kW FSI engine will be introduced in the Polo FSI
- In the year 2003, the 2.0l 105kW FSI engine will be introduced in the Passat FSI

Volkswagen's goal is to convert all its petrol engines to direct petrol injection by the year 2005.



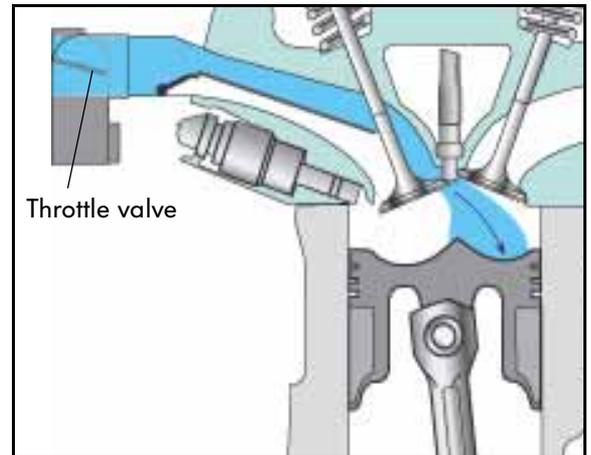
# Introduction

## Advantages of the direct petrol injection system

This system offers fuel savings of up to 15% in Volkswagen vehicles. The individual factors contributing to these savings are presented on the next two pages.

### De-throttling in stratified charge mode and homogeneous lean charge mode

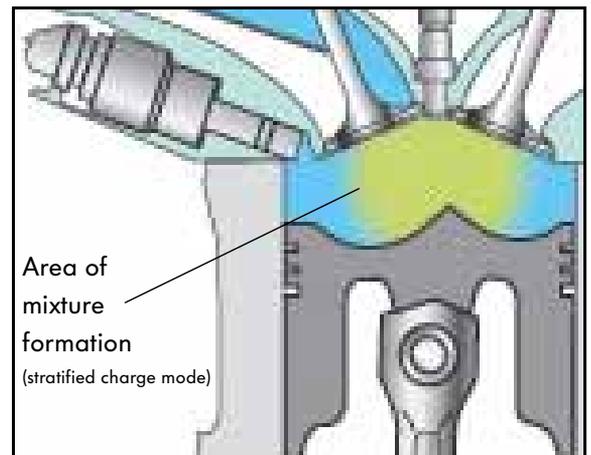
In these operating modes, the vehicle operates at a lambda between 1.55 and 3. This allows the throttle valve to open further, thus reducing the resistance against which the air is induced.



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### Lean mode

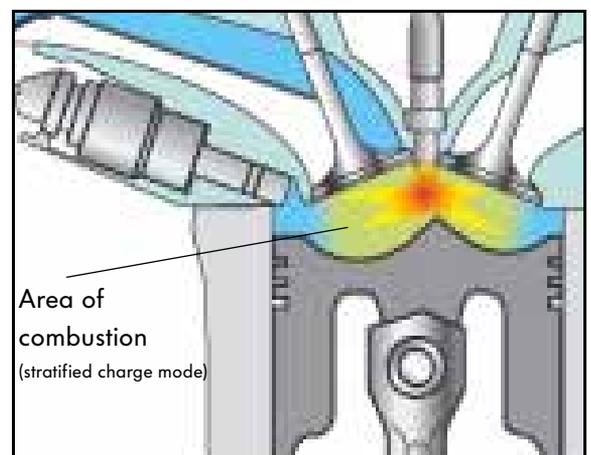
The engine operates at a lambda between 1.6 to 3 in stratified charge mode and approximately 1.55 in homogeneous lean charge mode.



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### Lower heat loss through cylinder wall

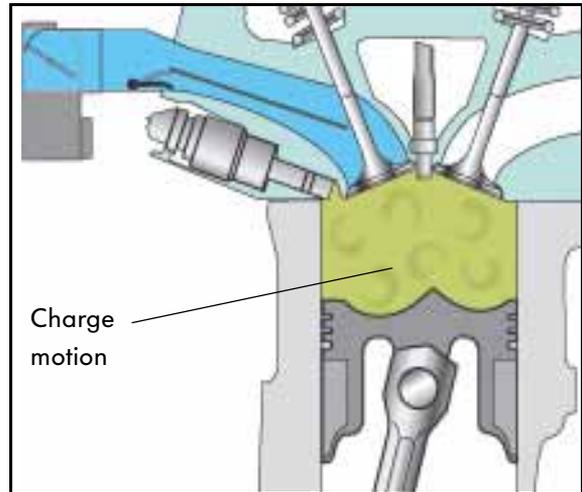
In stratified charge mode, combustion takes place only in the region around the spark plugs, which means less heat loss at the cylinder wall and higher thermal efficiency.



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### Homogeneous operation at high exhaust gas circulation rates

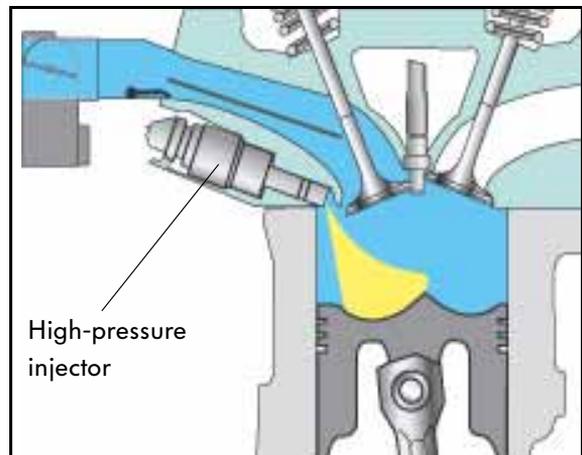
Due to the intensive charging motion, the engine has a high exhaust gas recirculation compatibility of up to 25% when operated in homogeneous charge mode. In order to achieve the same fresh air intake as at low exhaust gas circulation rates, the throttle valve is opened wider. This allows air intake against a low resistance, thereby decreasing throttle losses.



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### Compression ratio

By injecting fuel directly into the cylinder, heat is extracted from the intake air and the air is thus cooled. This reduces the engine's tendency to knock and allows the compression ratio to be increased. A higher compression ratio results in higher terminal compression and increases thermal efficiency.

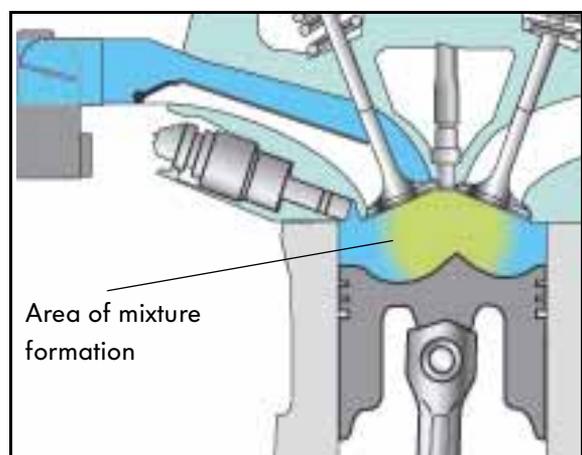


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### Extended deceleration fuel cut-off

The cut-in speed can be reduced because no fuel is deposited on the combustion chamber walls at cut-in.

The bulk of the injected fuel can be converted immediately into useful energy. As a result, the engine runs smoothly even at lower cut-in speeds.



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## Operating modes

In addition to "stratified charge mode" and "homogeneous charge mode", the 1.6l - 81kW FSI engine has a third operating mode: homogeneous lean charge mode. This operating mode offers a further reduction in fuel consumption compared to  $\lambda=1$  mode with exhaust gas recirculation. The engine control unit selects the operating mode depending on torque, power, exhaust gas and safety requirements.

### Stratified charge mode

The engine runs in stratified charge mode up to the medium engine load and speed range.

Through mixture stratification in the combustion chamber, the engine can be operated at a total  $\lambda$  of approx. 1.6 to 3.

- A highly ignitable mixture forms around the spark plugs at the centre of the combustion chamber.
- This mixture is enveloped by an outer layer which ideally comprises fresh air and recirculated exhaust gas.

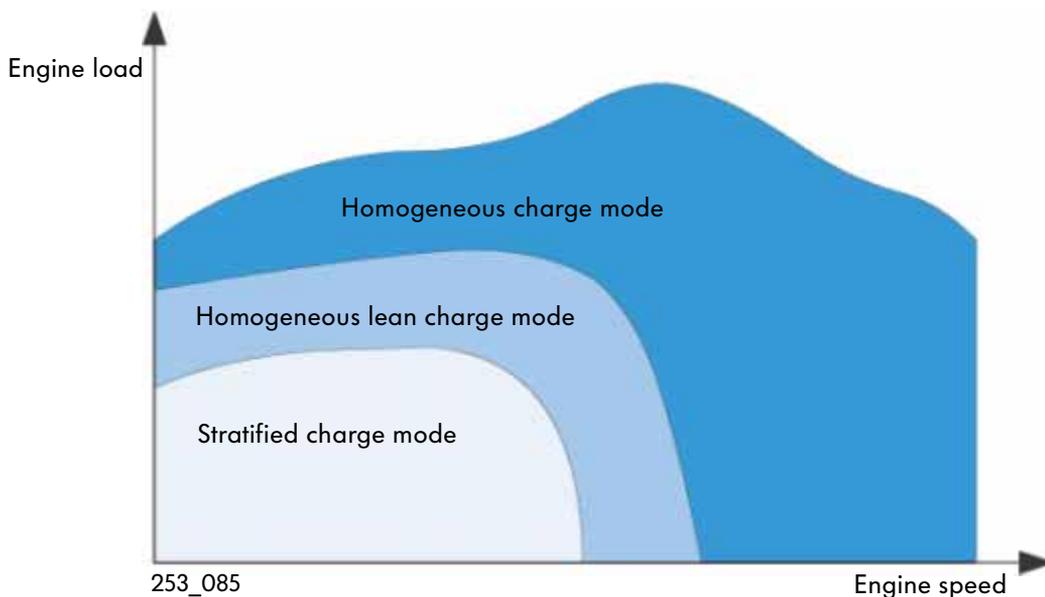
### Homogeneous lean charge mode

In the transition zone between stratified charge mode and homogeneous charge mode, the engine runs in homogeneous lean charge mode.

The lean mixture is distributed homogeneously (evenly) throughout the combustion chamber. The air/fuel ratio is approximately  $\lambda$  1.55.

### Homogeneous charge mode

At higher engines loads and speeds, the engine runs in homogeneous charge mode. The air-fuel ratio in this operating mode is  $\lambda=1$ .



## Combustion process

The term "combustion process" describes the way in which the air/fuel mixture forms and energy is converted inside the combustion chamber.

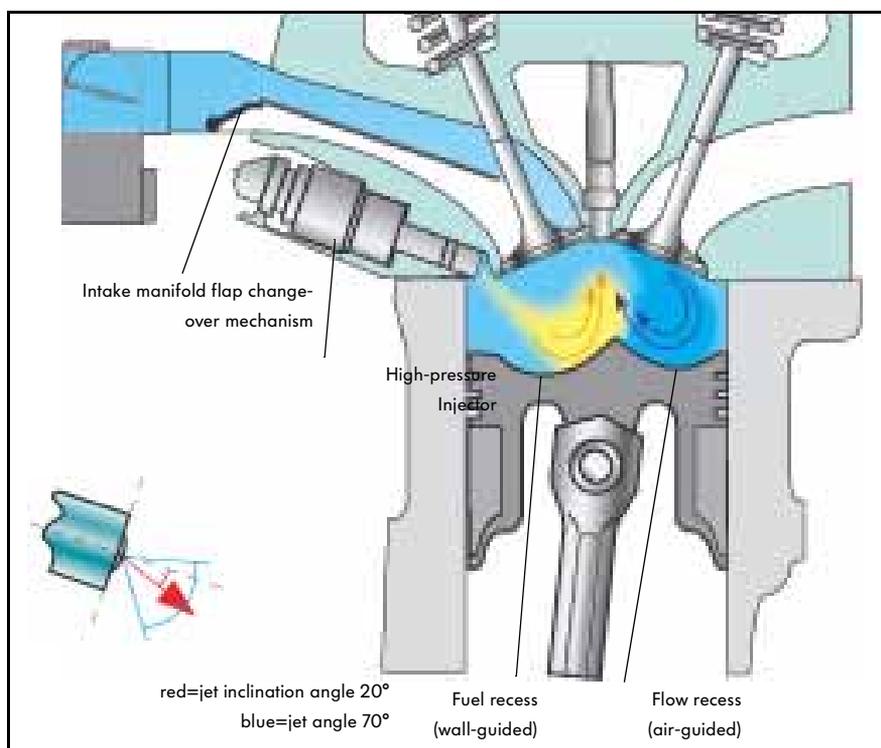
### In homogeneous charge mode and homogeneous lean charge mode,

the fuel is injected into the cylinder during the intake stroke and mixes homogeneously with the intake air.

### In stratified charge mode,

The air-fuel mixture is positioned in the area of the spark plugs by a wall/air guided tumble combustion process. The injector is positioned in such a way that the fuel is injected into the fuel recess (wall-guided configuration) and guided from here to the spark plugs.

The intake manifold flap change-over mechanism and the flow recess produce tumble air motion inside the cylinder. This airflow (air-guided configuration) assists in transporting the fuel to the spark plugs. Mixture formation takes place on the way to the spark plugs.



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## Stratified charge mode

Among other things, several important conditions must be met before the engine management system can change over to stratified charge mode:

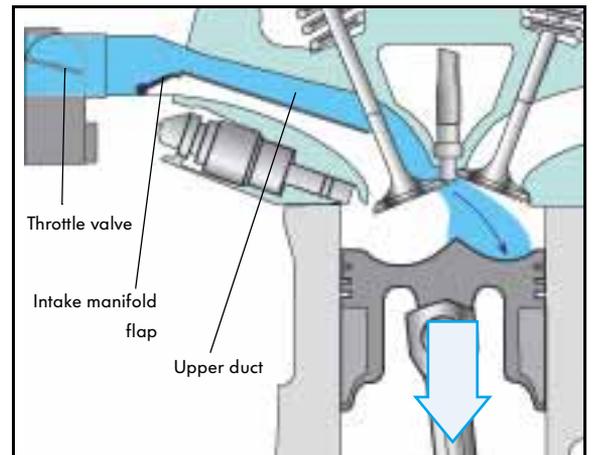
- the engine is in the corresponding engine load and speed ranges
- there are no exhaust emission faults in the system
- the coolant temperature is above 50°C
- the NO<sub>x</sub> sensor is ready, and
- the temperature of the NO<sub>x</sub> storage catalyst is between 250°C and 500°C

If the above conditions are met, the engine management system can change over to stratified charge mode.

### Intake process

In stratified charge mode, the throttle valve is opened as wide as possible in order to minimise throttle losses.

The intake manifold flap closes the lower duct in the cylinder head. The intake air flows at a faster rate and tumbles into the cylinders via the upper duct.



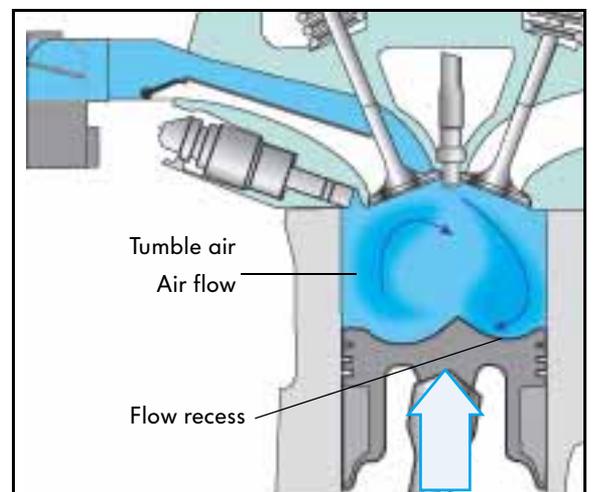
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The throttle valve cannot be opened completely as a certain vacuum must always be present due to the activated charcoal canister system and exhaust gas recirculation.

### Air flow

In the cylinder, the tumble motion of the air is increased by the special shape of the piston crown.

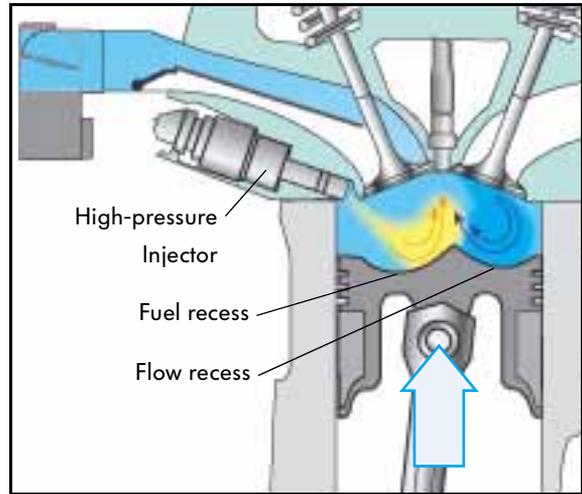


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## Injection cycle

Fuel is injected during the last third of the compression stroke. It begins approximately  $60^\circ$  before ignition TDC and ends approximately  $45^\circ$  before ignition TDC.

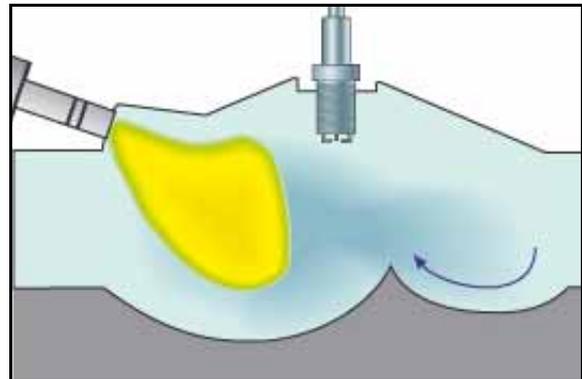
The injection point has a major role to play in the position of the atomised mixture in the area of the spark plugs.



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The fuel is injected in the direction of the fuel recess.

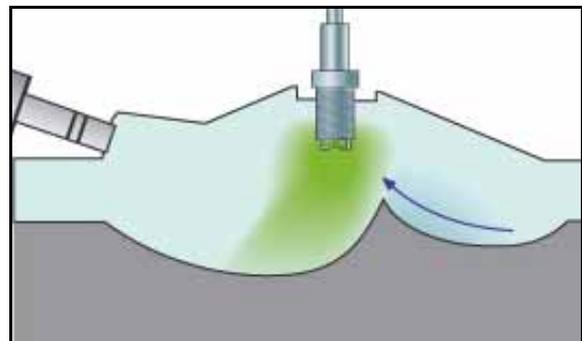
The injector geometry is such that the atomised mixture disperses as required.



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The fuel is transported towards the spark plugs by the fuel recess and the upward movement of the piston.

This process is aided by the tumble motion of the air flow, which also transports the fuel to the spark plugs. The fuel mixes with the intake air on the way to the spark plugs.



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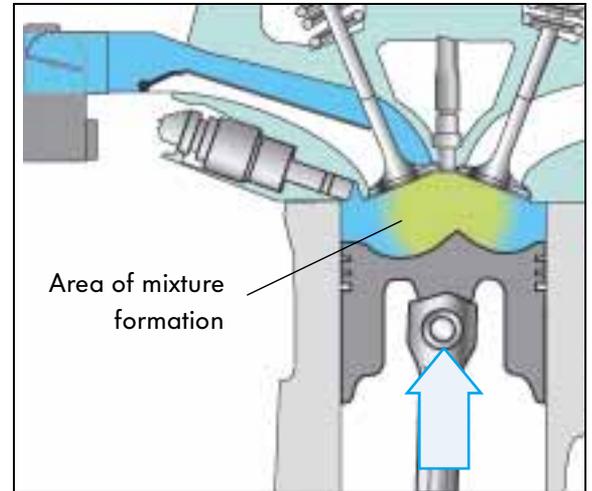
# Fundamentals

## Mixture formation process

In stratified charge mode, a crank angle of only  $40^\circ - 50^\circ$  is available for mixture formation. This is a decisive factor influencing the ignitability of the mixture. If the interval between injection and ignition is shorter, the mixture is not ignitable because it has not been sufficiently prepared. A longer interval would lead to further homogenisation throughout the combustion chamber.

This is why a highly ignitable atomised mixture forms around the spark plug at the centre of the combustion chamber. This is enveloped by an outer layer which is ideally composed of fresh air and recirculated exhaust gas.

The air-fuel ratio throughout the combustion chamber is between  $\lambda=1.6$  and 3.



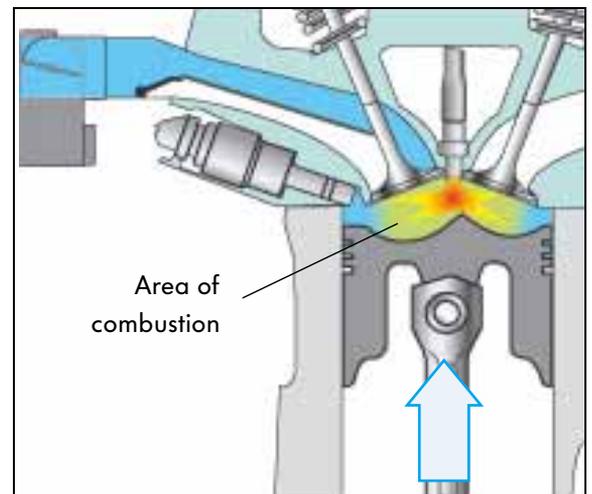
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## Combustion process

The ignition cycle commences when the air-fuel mixture is positioned exactly in the area of the spark plugs.

Only the atomised mixture is ignited, while the other gases act as an insulating envelope. Thus, heat losses through the cylinder wall are reduced and the engine's thermal efficiency is increased.

The ignition point lies within a narrow crankshaft window because of the retarded injection end point and the time available for mixture formation at the end of the compression stroke.



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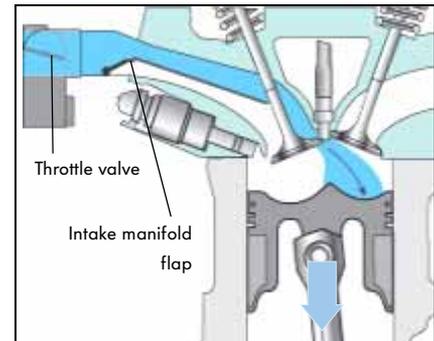
In this operating mode, torque developed by the engine is determined only by the injected fuel quantity. Intake air mass and ignition advance angle are minor factors here.

## Homogeneous lean charge mode

This is located in the mapped area between stratified charge mode and homogeneous charge mode. A homogeneous lean mixture is present throughout the combustion chamber. In this mode, the air-fuel ratio is approximately  $\lambda = 1.55$ . The same conditions apply here as to stratified charge mode.

### Intake process

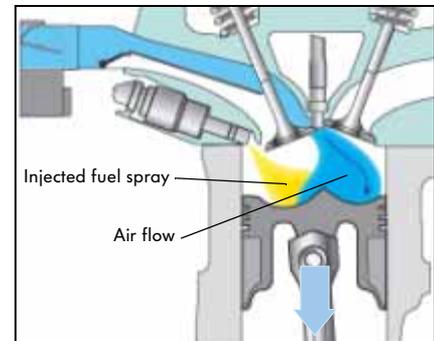
As in stratified charge mode, the throttle valve is opened as far as possible and the intake manifold flap is closed. This firstly reduces throttle losses and, secondly, produces an intensive air flow in the cylinder.



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### Injection cycle

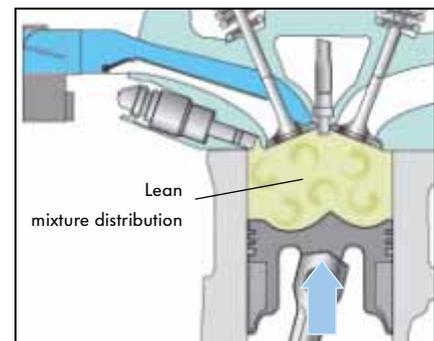
Fuel is injected directly into the cylinder approximately  $300^\circ$  before ignition TDC during the intake stroke. The injection quantity is regulated by the engine control unit in such a way that the air-fuel ratio is approximately  $\lambda = 1.55$ .



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### Mixture formation process

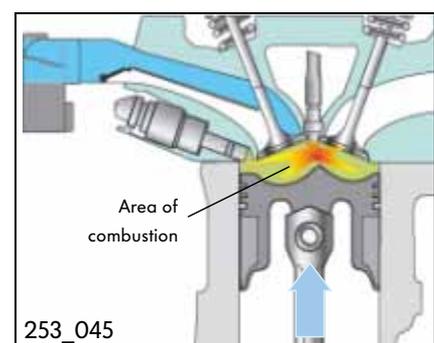
Due to the advanced injection point, more time is available for pre-ignition mixture formation, resulting in a homogeneous mixture distribution in the combustion chamber.



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### Combustion process

As in homogeneous charge mode, the ignition point can be selected freely due to the homogeneous air/fuel mixture distribution. The combustion process takes place throughout the combustion chamber.



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# Fundamentals

## Homogeneous charge mode

An engine running in homogeneous charge mode operates in much the same way as an engine with intake manifold injection.

The essential difference is that the fuel in the direct petrol injection engine is injected directly into the cylinder.

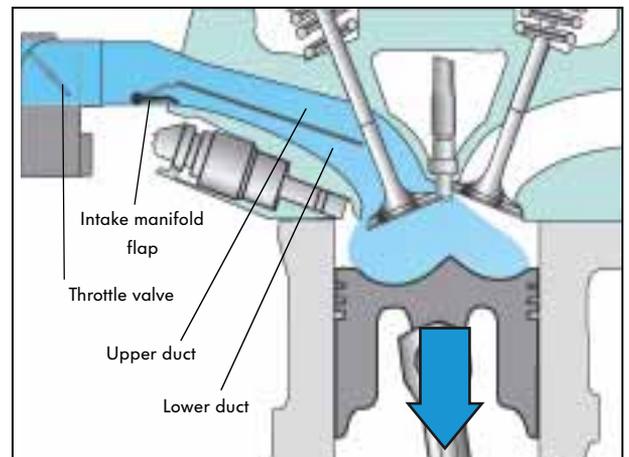
Engine torque is determined by the ignition point (short term) and by the intake air mass (long term). The quantity of fuel injected is adapted to the air mass so that  $\lambda = 1$ .

### Intake process

The throttle valve is opened depending on the accelerator pedal position.

The intake manifold flap is opened or closed depending on the operating point.

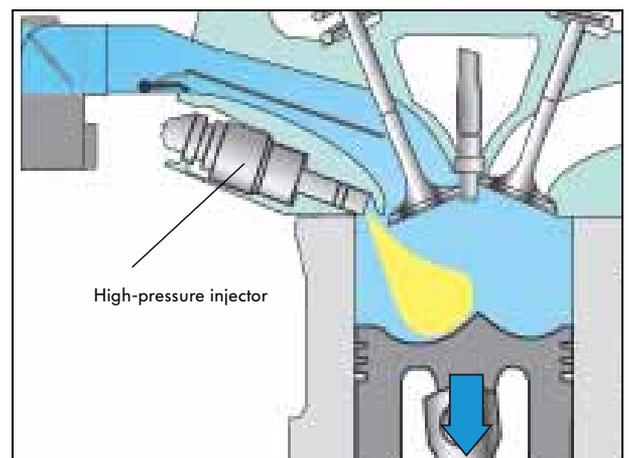
- In the medium engine load and speed ranges, the intake manifold flap is closed. As a result, the intake air tumbles into the cylinder, thus improving mixture formation.
- As engine load and speed increases, the air mass that can only be induced via the upper duct would no longer be sufficient. The lower duct of the intake manifold flap then opens in addition.



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### Injection cycle

Fuel is injected directly into the cylinder approximately  $300^\circ$  before ignition TDC during the intake stroke.



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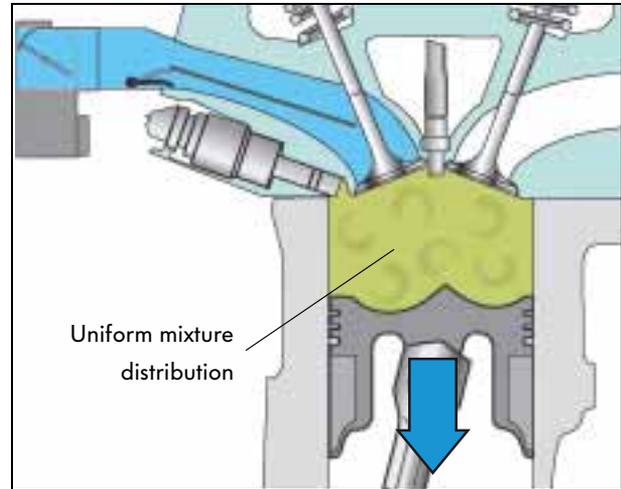


The energy required for evaporation of the fuel is extracted from the air trapped inside the combustion chamber, thus cooling the air down. As a result, the compression ratio can be raised above that of an engine with intake manifold injection.

## Mixture formation process

By injecting the fuel during the intake stroke, a relatively large amount of time is available for mixture formation. As a result, a homogeneous (uniformly distributed) mixture of injected fuel and induced air forms inside the cylinder.

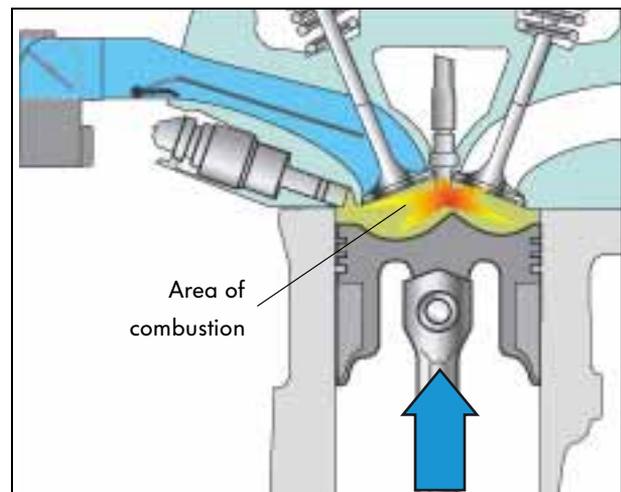
The air-fuel ratio in the combustion chamber amounts to  $\lambda = 1$ .



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## Combustion process

In homogeneous charge mode, the ignition point is a major factor influencing engine torque, fuel consumption and emission behaviour.



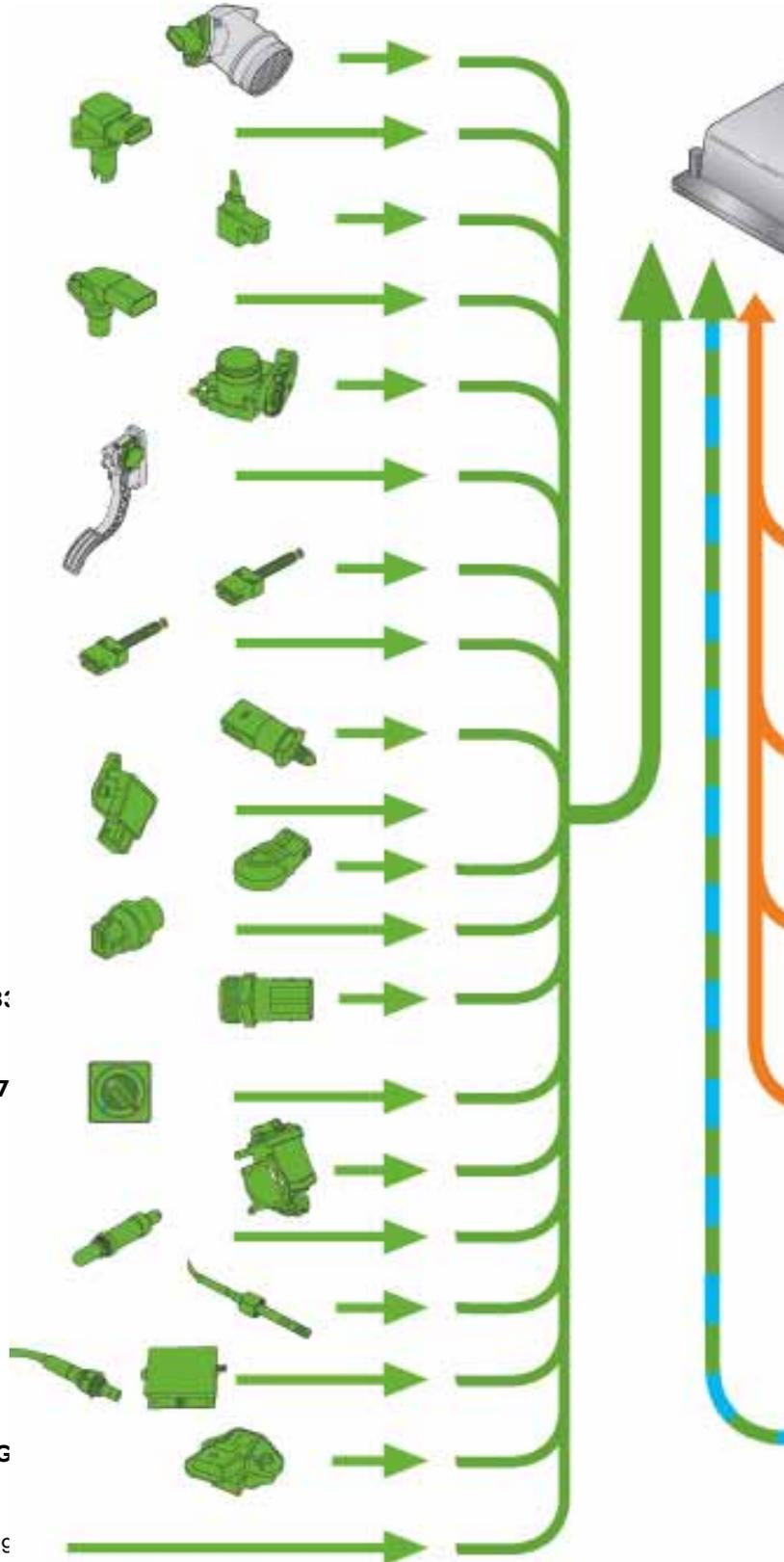
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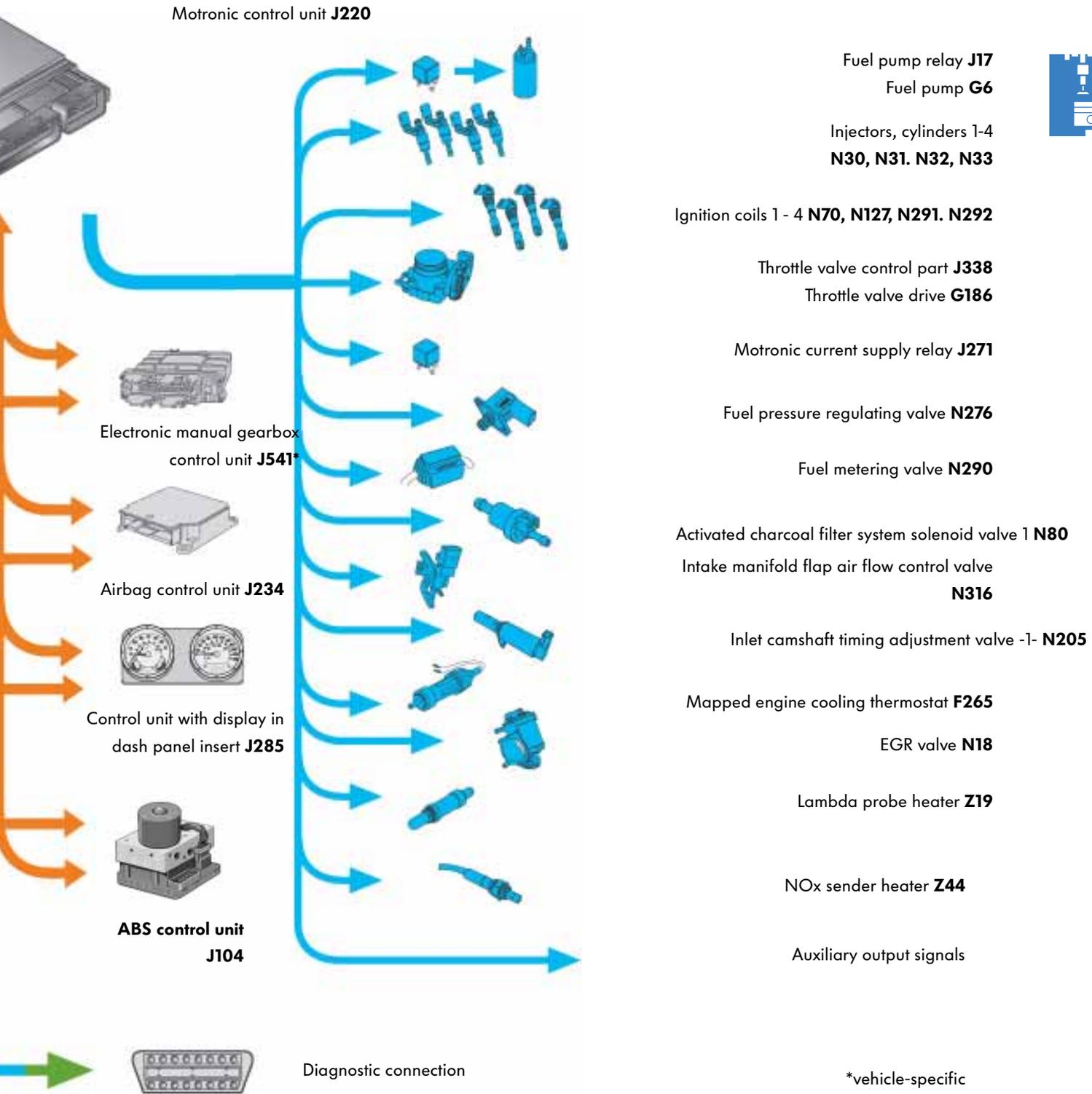
# Engine management

## System overview

- Air-mass flow meter **G70**,  
intake air temperature sender **G42**
- Intake manifold pressure sender **G71**
- Engine speed sender **G28**
- Hall sender **G40** (camshaft position)
- Throttle valve control part **J338**  
Angle senders 1 + 2 **G187, G188**
- Accelerator pedal position sender **G79**,  
accelerator pedal position sender -2- **G185**
- Brake light switch **F**,  
brake pedal switch **F47**
- Clutch pedal switch **F36\***
- Fuel pressure sender **G247**
- Intake manifold flap potentiometer **G336**
- Knock sensor **G61**
- Coolant temperature sender **G62**
- Coolant temperature sender - radiator outlet **G83**
- Rotary knob temperature selection potentiometer **G267**
- Exhaust gas recirculation potentiometer **G212**
- Lambda probe **G39**
- Exhaust gas temperature sender **G235**
- NOx sender **G295**,  
NOx sensor control unit **J583**
- Brake servo pressure sensor **G**
- Additional input sig



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# Engine management

## Engine control unit

The engine control unit is fitted in the plenum chamber and has 121 pins.

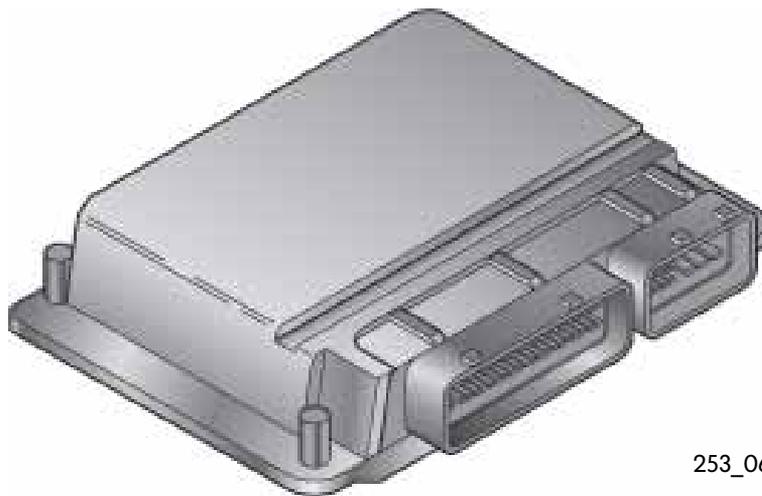
- The Bosch Motronic MED 7.5.10 is used as an engine management system in the 1.4l 77kW engine, while the
- Bosch Motronic MED 7.5.11 is used in the 1.6l 81kW engine.

The key difference between these two systems is that the Bosch Motronic MED 7.5.11 has a faster processor.

Direct petrol injection is an additional function common to both engine management systems.

The onboard diagnostics have been expanded by adding the following components:

- NOx sender (G295)
- Exhaust gas temperature sender (G235)
- Exhaust gas recirculation potentiometer (G212)
- Intake manifold flap potentiometer (G336)
- Fuel pressure sender (G247)
- Inlet camshaft timing adjustment valve (N205)
- Diagnostics during lean operation



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**The designation MED 7.5.10/11 stands for:**

**M** = Motronic

**E** = electronic throttle

**D** = direct injection

**7.** = version

**5.10/11** = development level

## Torque-based engine management system

As with the Bosch Motronic ME 7.5.10, the Bosch Motronic MED 7.5.10/11 has a torque-based engine management system which gathers, evaluates, co-ordinates and implements all torque requirements.

Internal torque requirements are:

- engine start-up
- catalyst warm-up
- idle speed control
- power limitation
- Speed governor
- Lambda control

External requirements are:

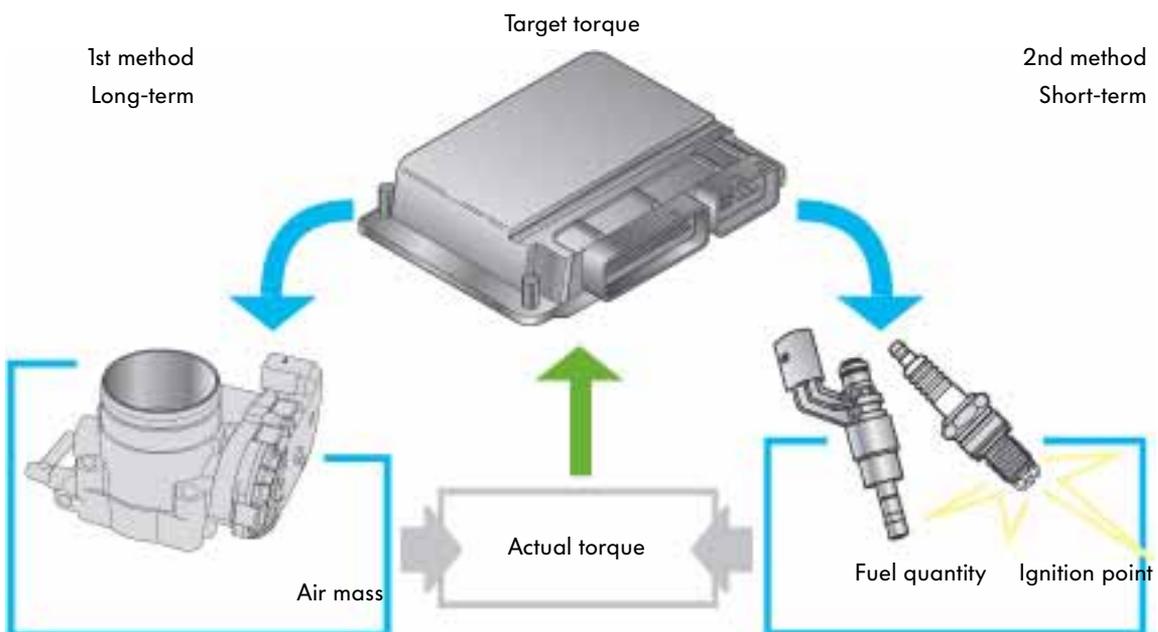
- driver inputs
- automatic gearbox (shift point)
- brake system (traction control system, engine braking control)
- air conditioning system (air conditioner compressor on/off)
- cruise control system

After the target engine torque is computed, the torque requirement is implemented by two methods:

The first method involves controlling the cylinder charge. It serves to meet long-term torque requirements.

The cylinder charge is of little importance in stratified charge mode because the throttle valve is opened very wide in order to reduce throttle losses.

The second method involves short-term control of engine torque regardless of the cylinder charge. In stratified charge mode, torque is solely determined by the fuel quantity. In homogeneous lean charge mode and homogeneous charge mode, torque is solely determined by the ignition point.



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# Engine management

## Engine torque implementation in the direct petrol injection system

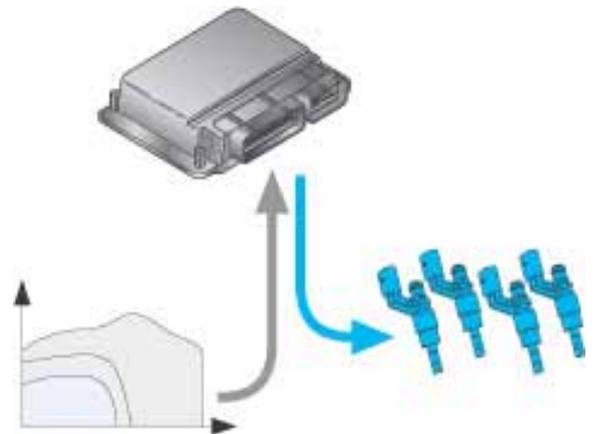
The engine control unit uses the internal and external torque requirements to compute the target torque and how it is to be implemented.

### Implementation in stratified charge mode

In stratified charge mode, the target torque is implemented via the injection quantity.

The air mass is of secondary importance because the throttle valve is wide open in order to reduce throttle losses.

The ignition point is of little importance because of the retarded injection point.

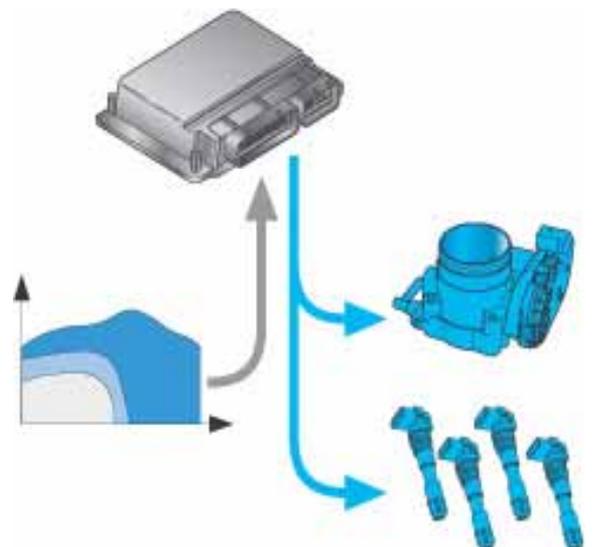


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### Implementation in homogeneous lean charge mode and in homogeneous charge mode

In both operating modes, the torque requirements are implemented in the short term via the ignition point and in the long term via the air mass.

As the air-fuel mixture in both operating modes has a fixed lambda of 1.55 and 1 respectively, the injection quantity is predefined by the air mass and, therefore, is not used for torque control.



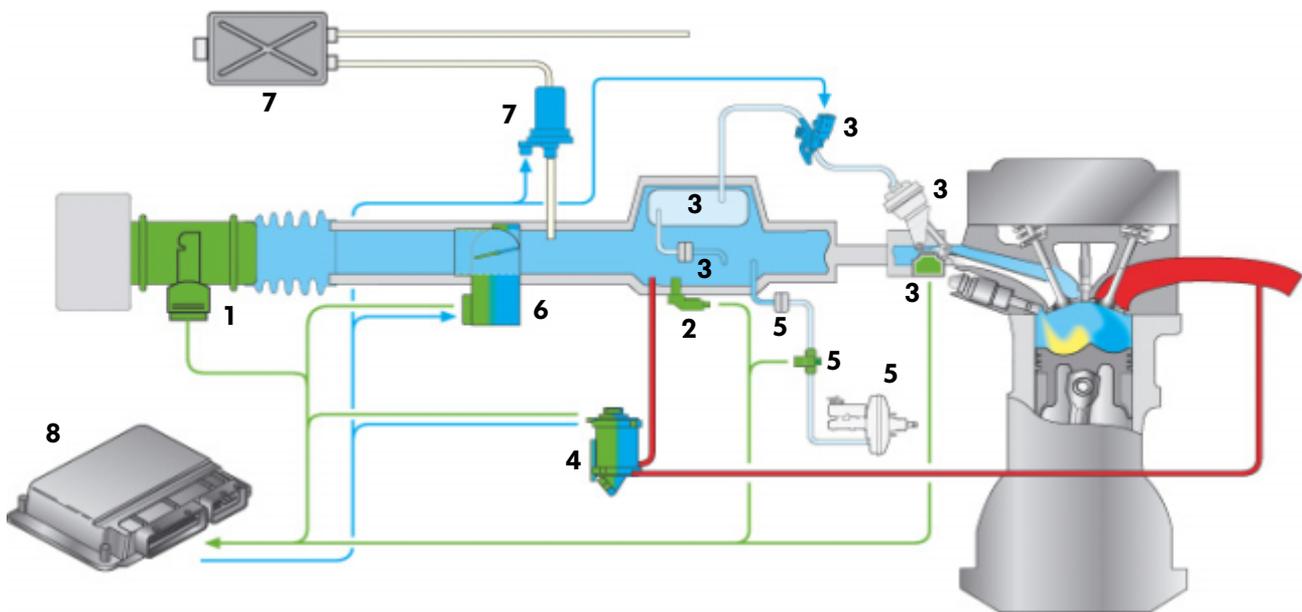
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## Intake system

In comparison with the Bosch Motronic ME 7.5.10, the intake system has been adapted to meet the requirements of a direct petrol injection engine. The special thing about this system is that in-cylinder air flow is controlled depending on the operating mode.

### The modifications include:

- 1 a hot-film air mass meter (G70) with intake air temperature sender (G42) for more precise load sensing
- 2 an intake manifold pressure sender (G71) for calculating the exhaust gas recirculation rate
- 3 an intake manifold flap change-over mechanism (N316, G336) for selective air flow control in cylinder
- 4 an electric EGR valve (G212, N18) with a large cross-section for high exhaust gas recirculation rates
- 5 a brake servo pressure sensor (G294) for brake vacuum control



- 6 Throttle valve control unit (J338)
- 7 Activated charcoal canister system (N80)
- 8 Motronic control unit (J220)

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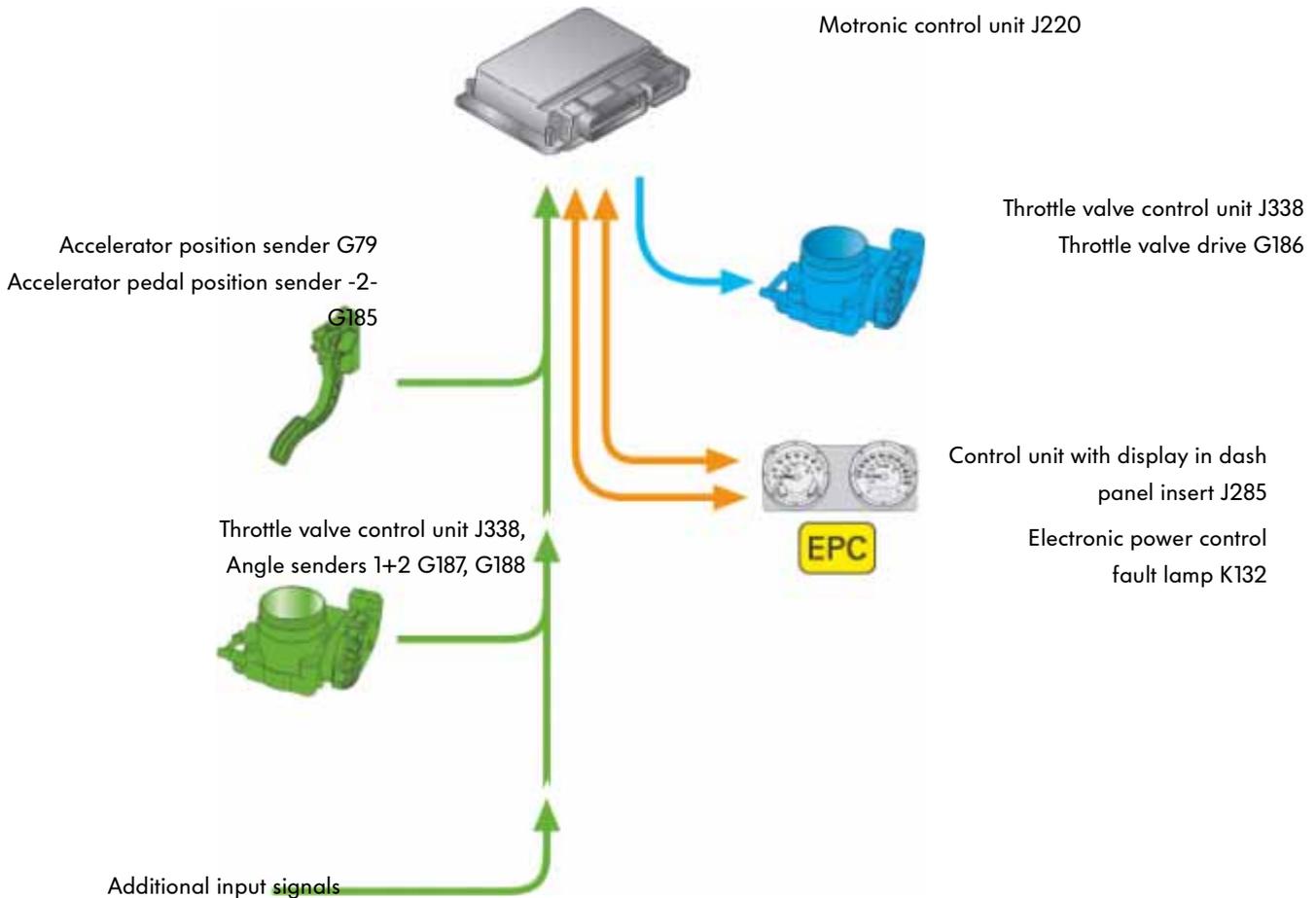


# Engine management

## Electronic accelerator

The electronic accelerator is a basic requirement for direct petrol injection. It helps to adjust the throttle valve regardless of accelerator pedal position. It is opened wider in stratified charge mode and homogeneous lean charge mode.

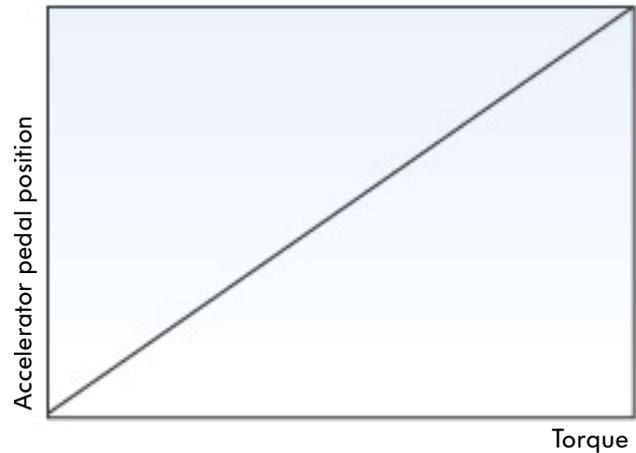
This has the advantage of almost throttle-free engine operation. The engine is able to draw in air against less resistance, reducing fuel consumption.



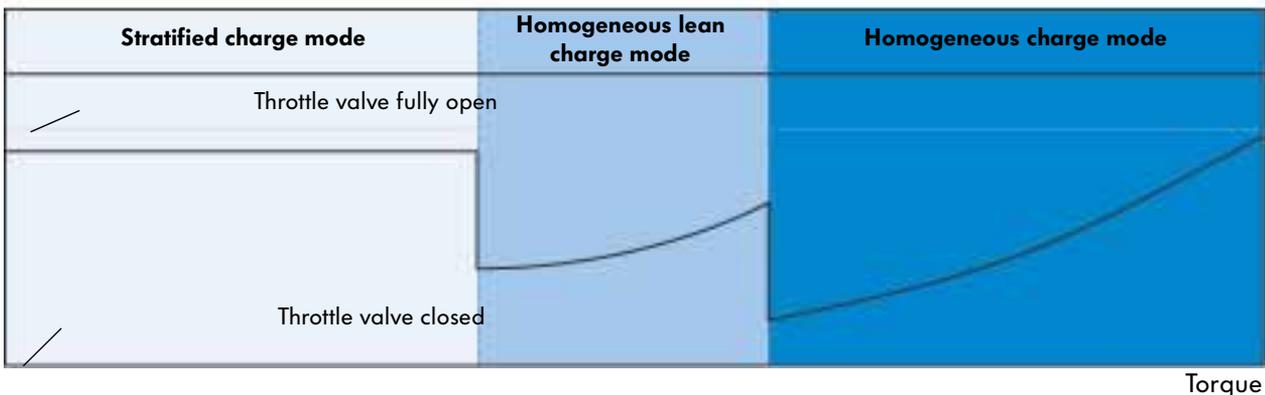
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## This is how it works

The driver input is identified by the accelerator position sender (G79, G185) and sent to the engine control unit. The engine control unit uses this signal and other additional signals to calculate how much engine torque is required and uses the actuators to generate this torque.



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**In stratified charge mode**, engine torque is determined by the fuel quantity.

The throttle valve is opened almost fully, apart from the necessary flow restrictions for the activated charcoal canister system, exhaust gas recirculation and possibly the brake vacuum control system.

**In homogeneous lean charge mode and homogeneous charge mode**, engine torque is determined by the ignition advance angle and by the intake air mass.

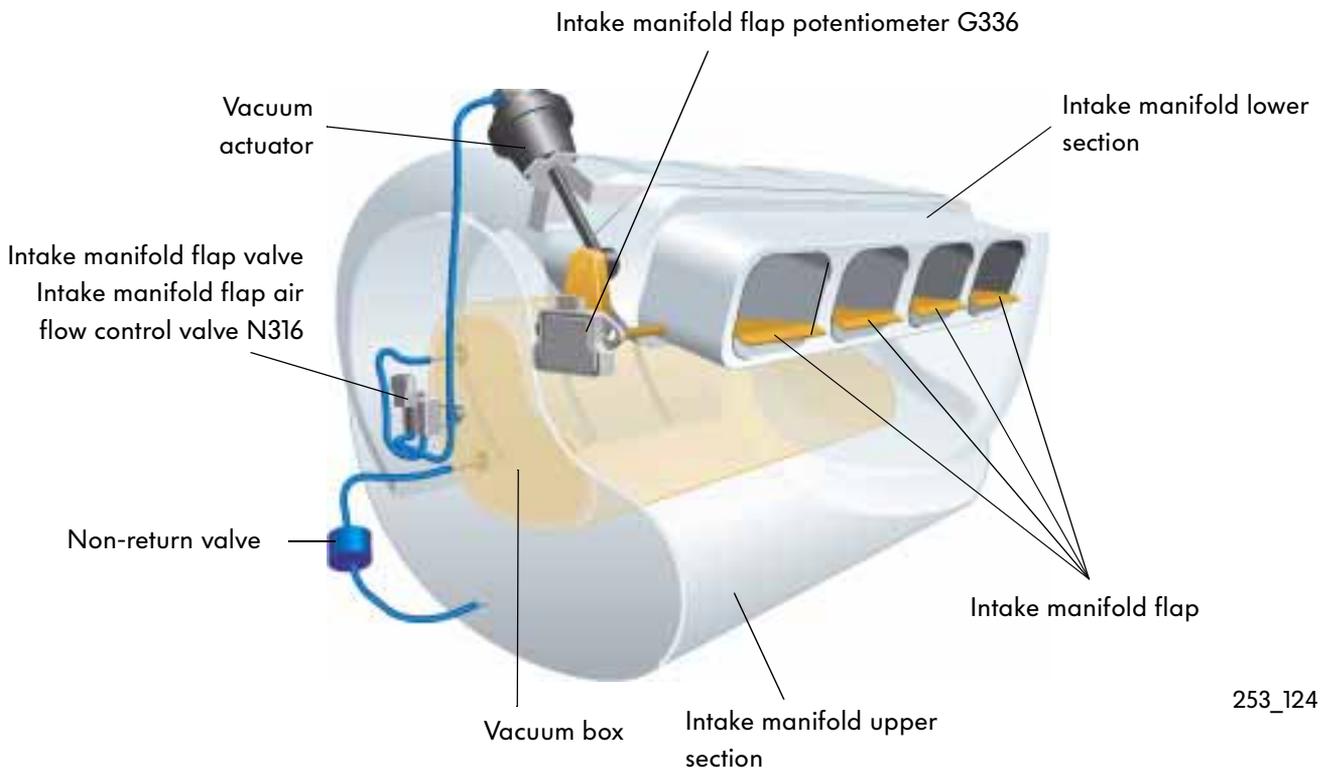
The throttle valve is opened as far as is necessary to produce the required amount of engine torque.



# Engine management

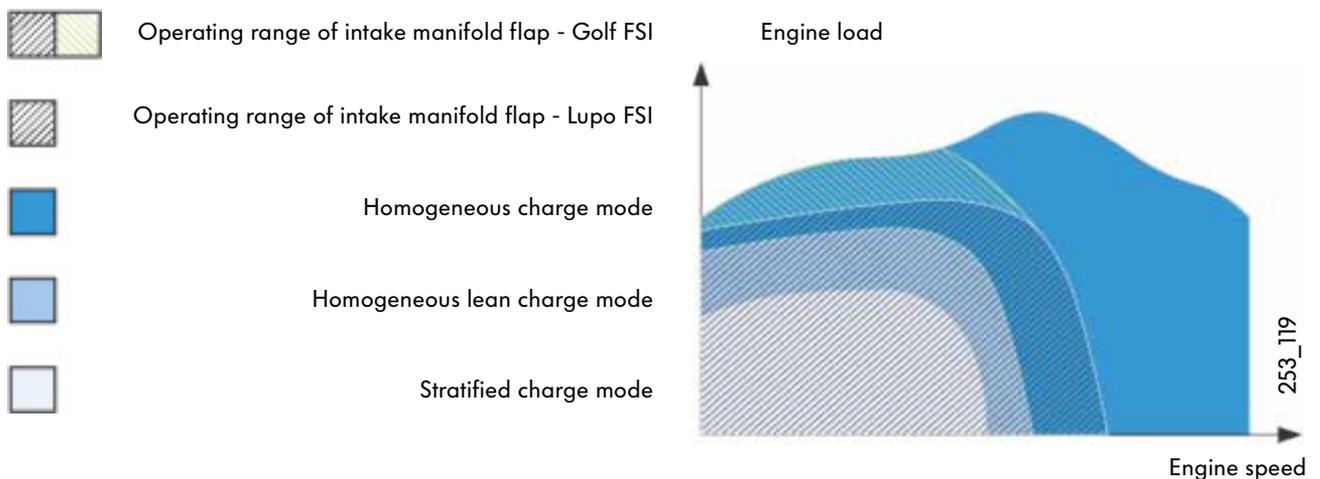
## Intake manifold flap changeover mechanism

is located in intake manifold upper and lower sections. It is used to control air flow in the cylinder depending on operating mode.



253\_124

The diagram shows the operating range of the intake manifold flap.

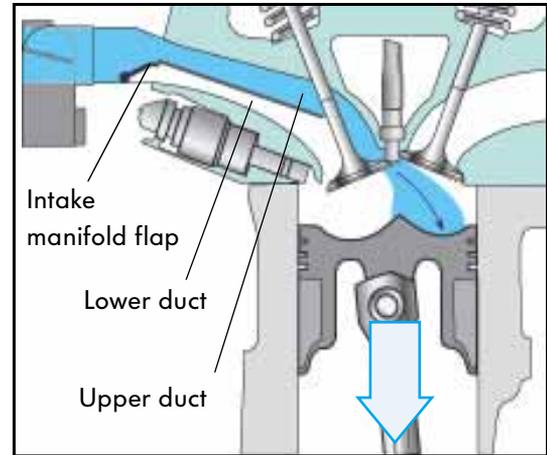


253\_119

### Intake manifold flap actuated

In stratified charge mode, homogeneous lean charge mode and under certain homogeneous charge operating conditions, the intake manifold flap is actuated and the lower duct in the cylinder head is closed.

As a result, the intake air only flows via the upper duct to the cylinder. This duct is designed in such a way that the intake air tumbles into the cylinder. The narrow upper duct causes the flow rate to increase, promoting mixture formation.



253\_037

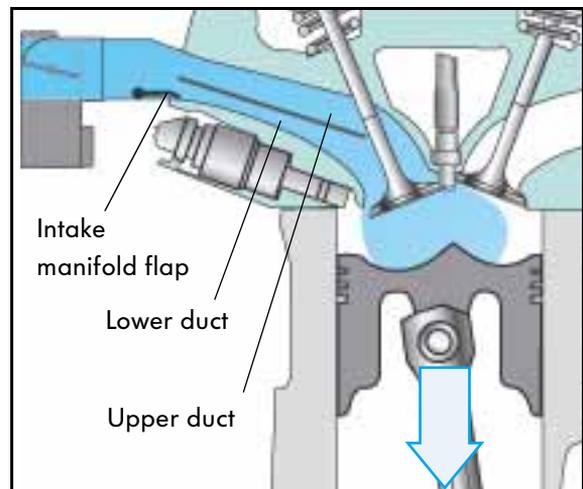
### This has two advantages:

- In stratified charge mode, the tumble motion of the air flow transports the fuel to the spark plugs. Mixture formation takes place on the way to the spark plugs.

- In homogeneous lean charge mode and under certain homogeneous charge operating conditions, the tumble air flow assists mixture formation. This results in highignitability and stable combustion of the air/fuel mixture, and also allows lean operation.

### Intake manifold flap not actuated

In homogeneous charge mode at higher engine loads and speeds, the intake manifold flap is not actuated and both ducts are open. The larger cross-section of the intake duct allows the engine to draw in the air mass required to generate high engine torque and high power outputs.



253\_127



# Engine management

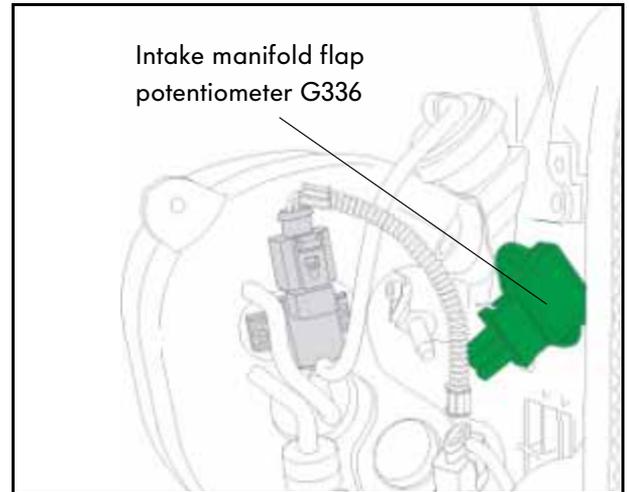
## Intake manifold flap potentiometer G336

### Fitting location

It is attached to the intake manifold lower section and connected to the shaft for the intake manifold flaps.

### Task

The intake manifold flap potentiometer recognises the position of the intake manifold flap and sends this information to the engine control unit. This is necessary because the intake manifold flap changeover mechanism affects ignition, residual gas concentration and pulsation in the intake manifold. The position of the intake manifold flaps is therefore relevant to exhaust emissions and must be checked by the self-diagnosis.



253\_154

### Signal failure strategies

If the signal from the potentiometer fails, the engine will only be allowed to operate in homogeneous charge mode.

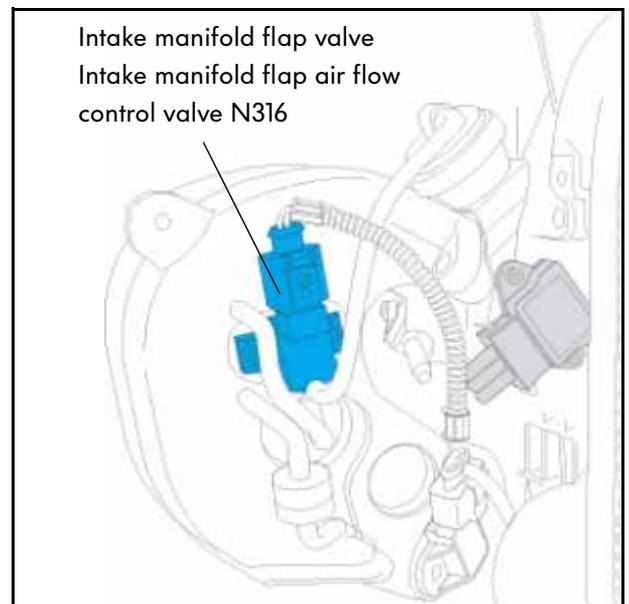
## Intake manifold flap air flow control valve N316

### Fitting location

This valve is attached to the intake manifold upper section.

### Task

This valve is activated by the engine control unit and opens the path from the vacuum reservoir to the vacuum actuator. The intake manifold flaps are then actuated by the vacuum actuator.



253\_153

### Failure strategies

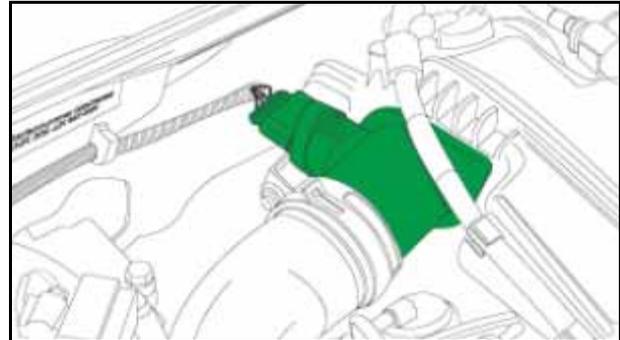
If the valve fails, the engine will only be allowed to operate in homogeneous charge mode.

## Air-mass flow meter G70 and intake air temperature sender G42

Both sensors are integrated in a single housing and are located in the intake path upstream of the throttle valve control part.

A hot-film air mass meter with reverse flow recognition is used to generate as accurate an engine load signal as possible. It measures not only the air intake but also recognises how much air flows back when the valves are opened and closed.

The intake air temperature serves as a correction value.



253\_060

### Signal utilisation

The signals are used to calculate all load-dependent functions. These include injection time, ignition point and the activated charcoal canister system.

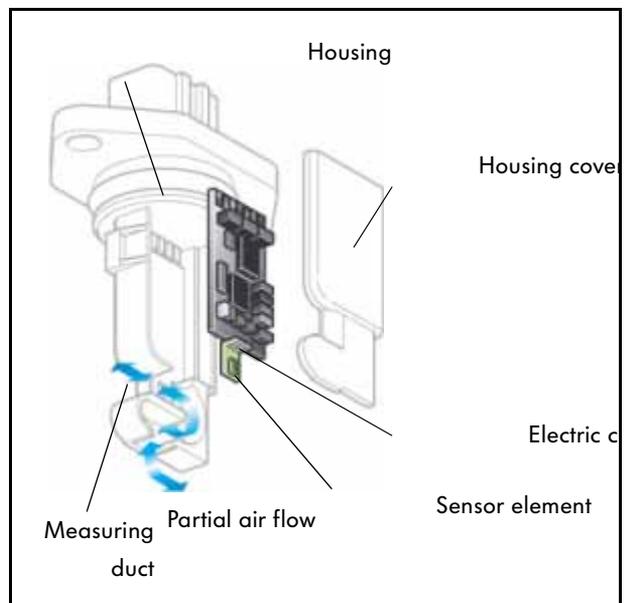
### Signal failure strategies

If the air-mass flow meter fails, the signal from the intake manifold pressure sender G71 is used as a load signal.

### Design

The hot-film air mass meter comprises a plastic housing with a measuring duct and an electric circuit with a sensor element. The measuring duct is shaped in such a way that a portion of the intake air, as well as the returning air, is guided past the sensor element.

This produces a signal at the sensor element which is processed by the electric circuit and sent to the engine control unit.



253\_076



For detailed information about the function, please refer to Self-Study Programme No. 195 "2.3l V5 Engine".



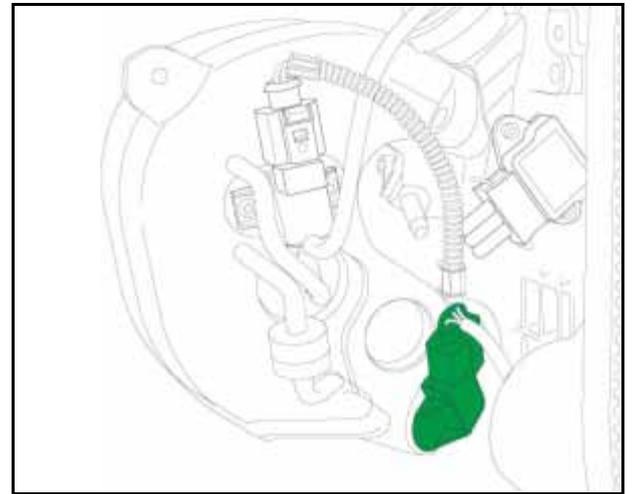
# Engine management

## Intake manifold pressure sender G71,

This sender is attached to the intake manifold upper section. It measures the pressure inside the intake manifold and sends a corresponding signal to the engine control unit.

### Signal utilisation

The engine control unit utilises this signal, as well as the signals from the air-mass flow meter and the intake air temperature sender, to compute the exact exhaust gas recirculation rate. The intake manifold pressure sender is also used for load sensing during engine start-up since the signals from the air mass meter are too inaccurate due to intake pulsation.



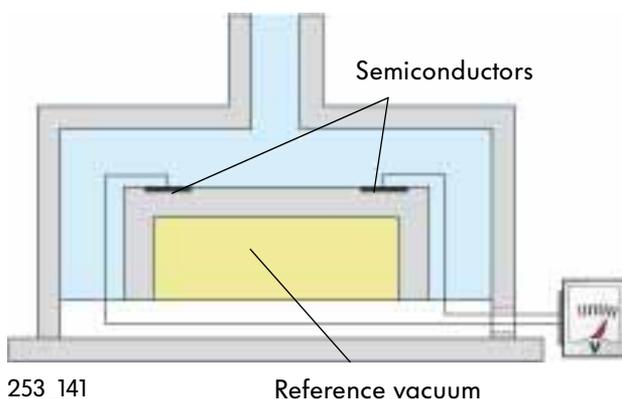
253\_061

### This is how it works

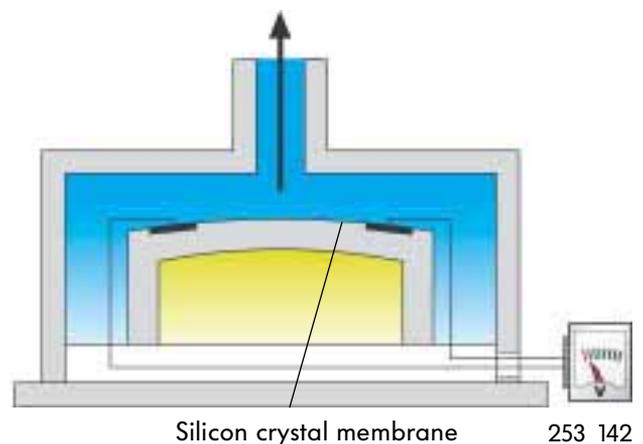
Intake manifold pressure is measured via a silicon crystal membrane. Located on this membrane are strain gauges whose resistance is altered when the membrane is deformed. The reference vacuum is used for pressure comparison purposes.

Depending on intake manifold pressure, the membrane undergoes deformation, causing a change of resistance which results in different signal voltages. The engine control unit uses this signal voltage to determine the pressure inside the intake manifold.

Low vacuum = high output voltage



High vacuum = low output voltage



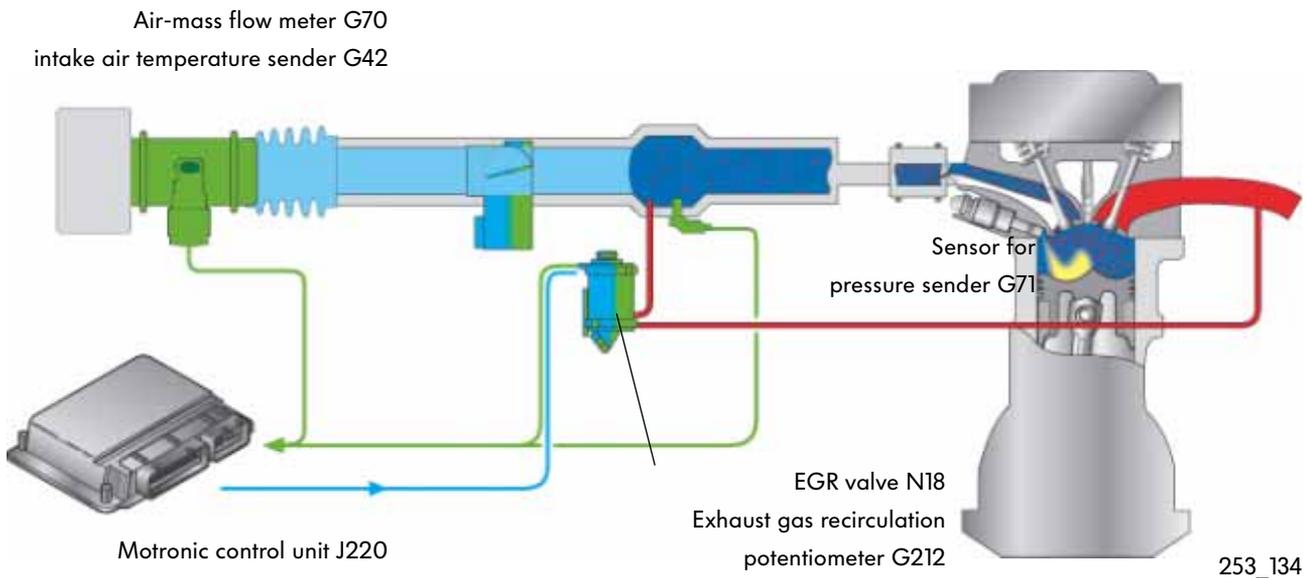
## This is how the exhaust gas recirculation rate is determined

Using the air-mass flow meter, the engine control unit measures the intake fresh air mass and calculates from this the corresponding intake manifold pressure. If exhaust gas is fed in via the exhaust gas recirculation system, then the fresh air mass is increased by the exhaust gas intake and the intake manifold pressure rises. The intake manifold pressure sender measures this pressure and sends a corresponding voltage signal to the engine control unit.

The total quantity (fresh air+exhaust gas) is determined from this signal.

The engine control unit subtracts the fresh air mass from this total quantity and thus obtains the exhaust gas quantity.

The advantage is that the exhaust gas recirculation rate can be raised closer to the operating limit.



## Signal failure strategies

If the intake manifold pressure sender fails, then the exhaust gas quantity is calculated by the engine control unit and the exhaust gas recirculation rate is reduced in relation to the map.



253\_134

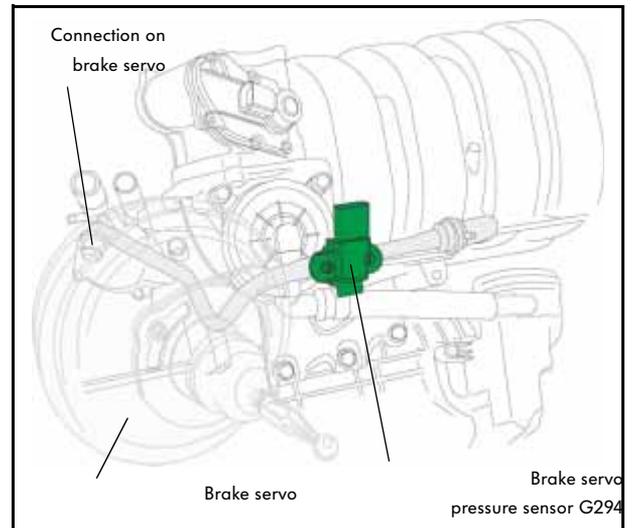
# Engine management

## Brake servo pressure sensor G294

This sender is located in the line between the intake manifold and the brake servo. It measures the pressure in the line or in the brake servo.

## Signal utilisation

From the pressure sensor voltage signal, the engine control unit can determine whether the vacuum is sufficient to operate the brake servo.



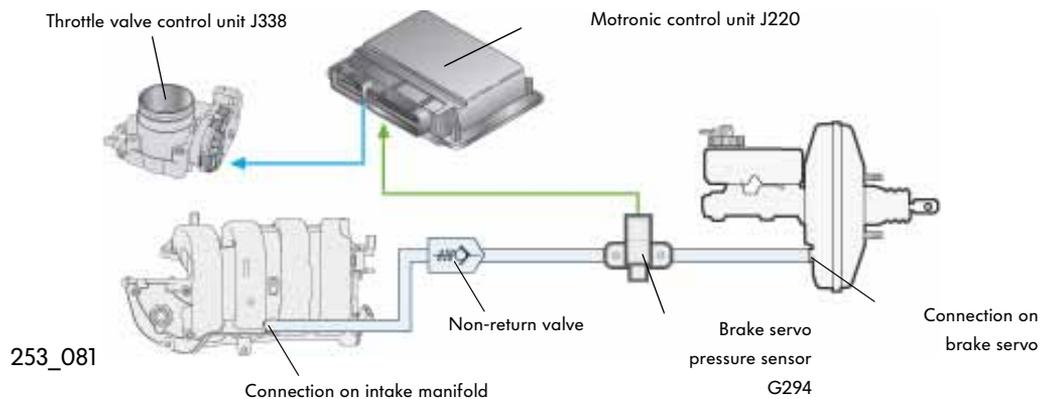
253\_059

## This is how it works

The brake servo requires a certain vacuum in order to reach full brake pressure as quickly as possible.

In stratified charge mode and in homogeneous lean charge mode, the throttle valve is opened wider and consequently there is very little vacuum inside the intake manifold. If the brake is now operated several times in succession, the

vacuum accumulated in the brake servo will no longer be sufficient. To prevent this, the throttle valve is closed slightly further to increase the vacuum. If the vacuum in the brake servo is still insufficient, the throttle valve is closed still further and, if need be, the homogeneous charge mode is activated.



## Signal failure strategies

If the signal from the pressure sensor fails, the engine will only be allowed to operate in

homogeneous charge mode.

## Fuel system

The fuel system is divided into a low-pressure fuel system and a high-pressure fuel system. In addition, fuel is fed in via the activated charcoal canister system of the combustion system.

### In the low pressure fuel system,

the fuel is transported to the high-pressure fuel pump by the electric fuel pump in the fuel tank. The fuel pressure during normal operation is 3 bar and max. 5.8 bar under hot start conditions.

It comprises:

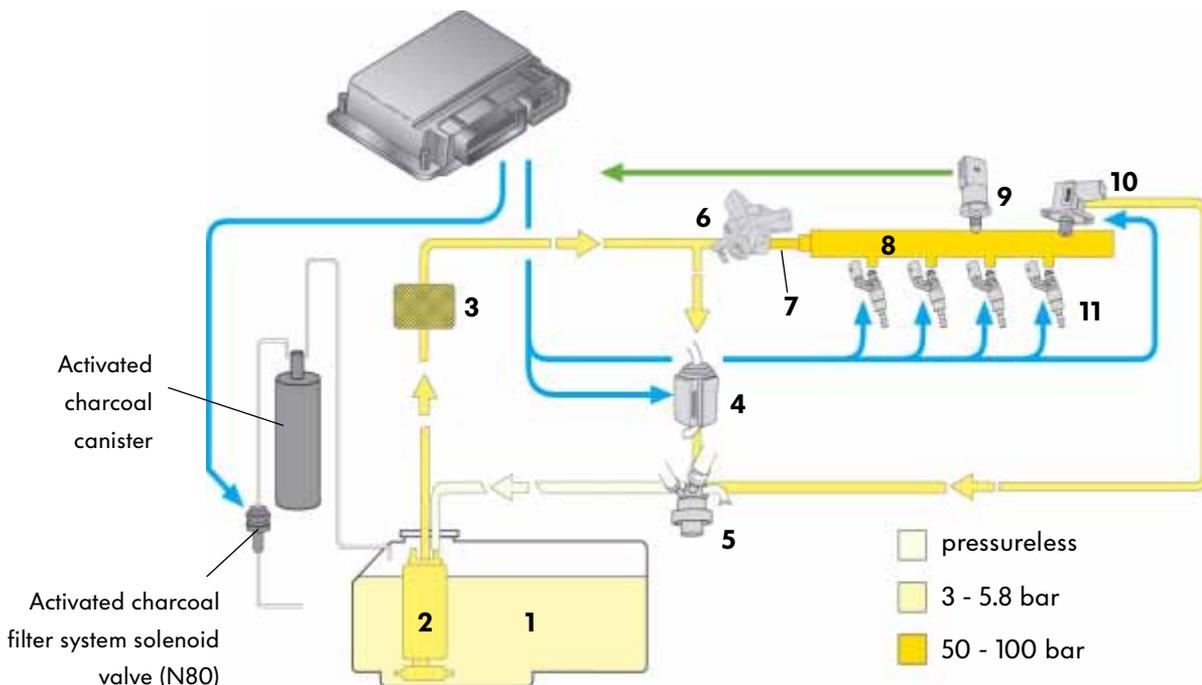
- 1 the fuel tank
- 2 the electric fuel pump (G6)
- 3 the fuel filter
- 4 the fuel metering valve (N290)
- 5 the fuel pressure regulator

### In the high-pressure fuel system,

the fuel is pumped into the fuel rail by the high-pressure fuel pump. In the fuel rail, the pressure is measured by the fuel pressure sender and adjusted to between 50 and 100 bar by the fuel pressure regulating valve. Fuel is injected by the high-pressure injectors.

It comprises:

- 6 the high-pressure fuel pump
- 7 a high-pressure fuel line
- 8 the fuel rail
- 9 the fuel pressure sender (G247)
- 10 the fuel pressure regulating valve (N276)
- 11 the high-pressure injectors (N30-N33)



253\_092

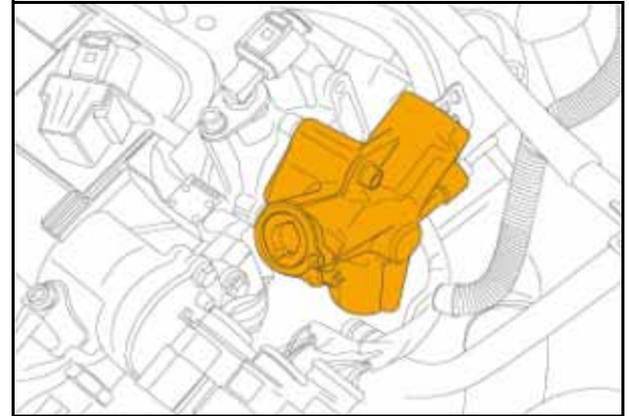
# Engine management

## High-pressure fuel pump

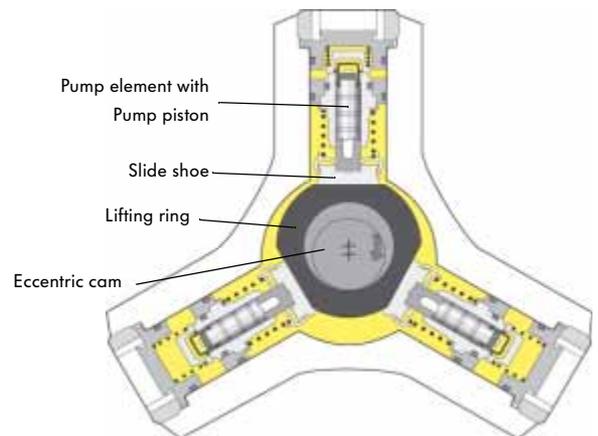
is screwed to the camshaft housing.

This three-cylinder radial piston pump is driven by the inlet camshaft. Pressure fluctuation in the fuel rail is kept to a minimum by the three pump elements which are arranged at 120° apart.

The task of the high-pressure fuel pump is to develop fuel pressure up to 100 bar in the high-pressure fuel system.



253\_058



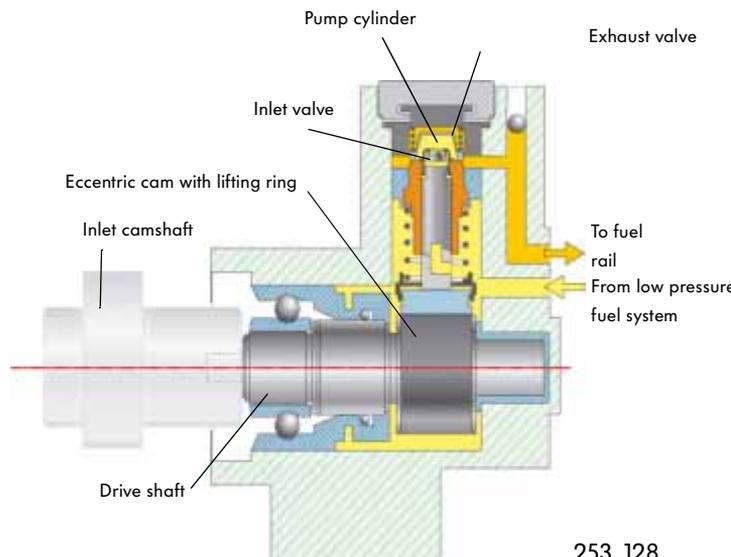
253\_030

## Drive

The input shaft of the high-pressure fuel pump is driven by the inlet camshaft.

An eccentric cam on which a lifting ring is mounted is located on the input shaft. When the input shaft rotates, the eccentric cam, in conjunction with the lifting ring, provides for upward and downward motion of the pump piston.

- Fuel is drawn out of the low pressure fuel system during the downward movement of the pump piston.
- Fuel is pumped into the fuel rail during the upward movement of the pump piston.



253\_128

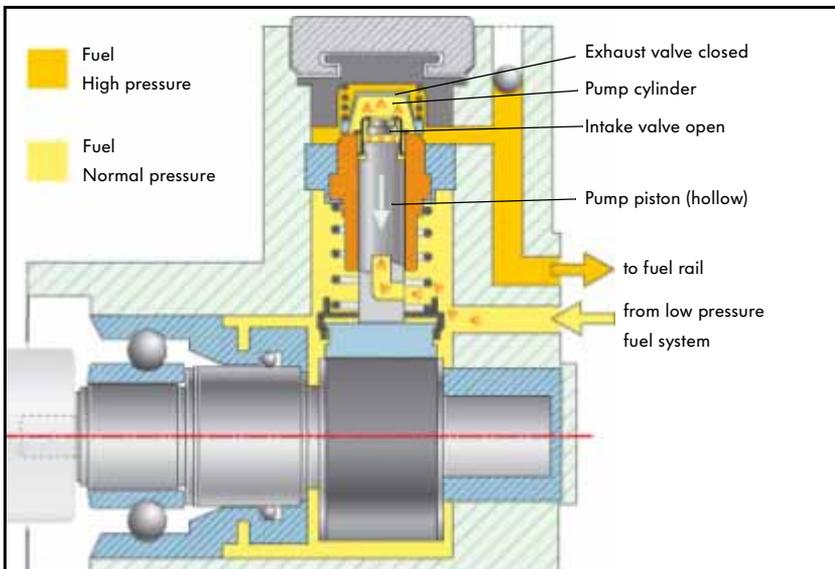
## This is how it works

The fuel flows from the low pressure fuel system into the high-pressure fuel pump where it flows through the hollow pump piston to the intake valve.

### Suction lift

The downward motion of the pump piston produces an increase in volume inside the pump cylinder, causing the pressure to drop. As soon as the pressure in the

hollow pump piston is greater than the pressure in the pump cylinder, the intake valve opens and additional fuel flows into the cylinder.

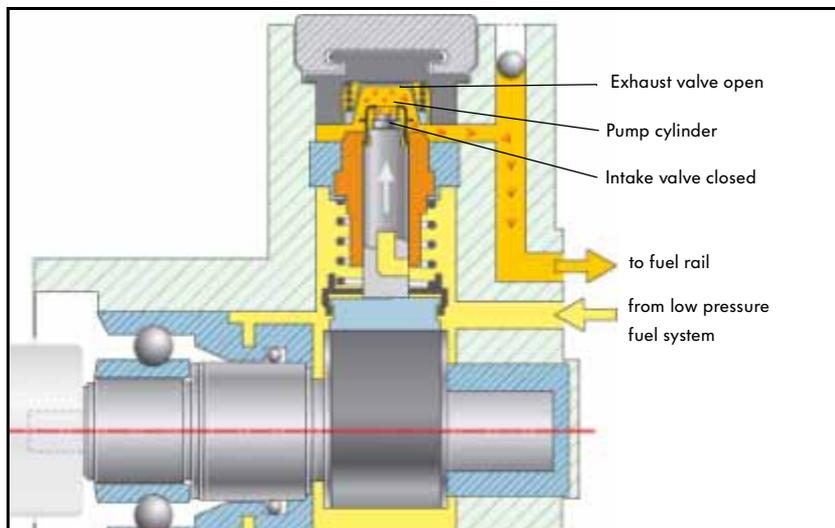


253\_096

### Delivery head

At the start of the upward movement of the pump piston, the pressure in the pump cylinder rises and the intake valve closes. If the pressure in the pump cylinder

is greater than the pressure in the fuel rail, the exhaust valve opens and fuel is pumped to the fuel rail.



253\_026



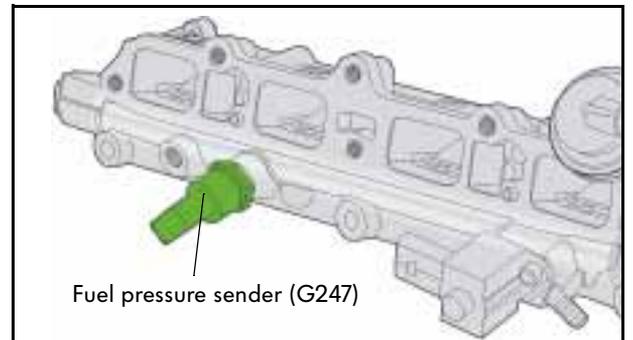
# Engine management

## Fuel pressure sender (G247)

is located on the intake manifold lower section and is screwed into the fuel rail. it measures the fuel pressure in the fuel rail.

### Signal utilisation

The engine control unit utilises the signal from the fuel pressure sender for map-dependent regulation of the fuel pressure in the high-pressure fuel system.



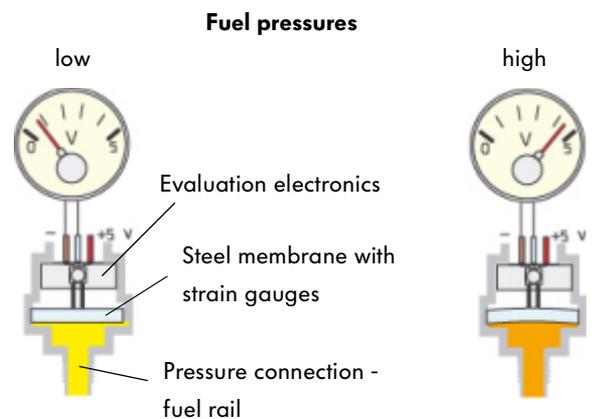
253\_046

### This is how it works

Fuel flows out from the fuel rail into the fuel pressure sender.

- The steel membrane is only slightly deformed at low fuel pressure, with the result that the resistance in the strain gauges is high and the signal voltage is low.
- The steel membrane is heavily deformed at high fuel pressure, with the result that the resistance in the strain gauges is low and the signal voltage is high.

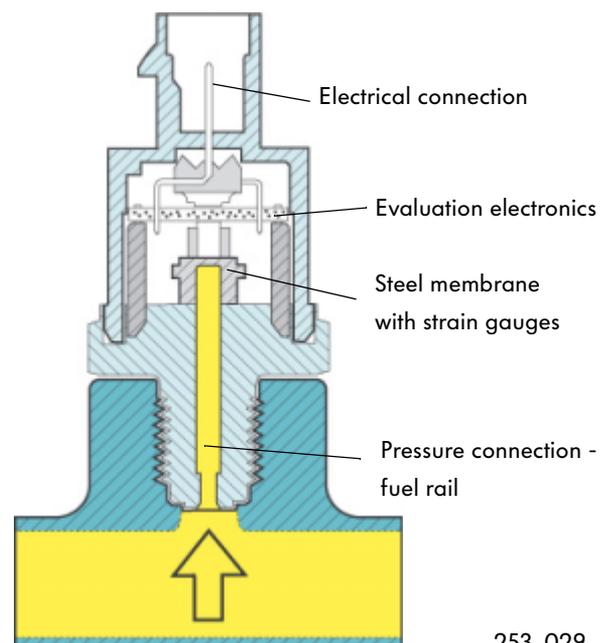
The signal voltage is amplified by the electronics and sent to the engine control unit. The fuel pressure is regulated by the fuel pressure regulating valve.



253\_091

### Signal failure strategies

If the signal from the intake manifold pressure sender fails, the fuel pressure regulating valve is activated by the engine control unit at a fixed value.



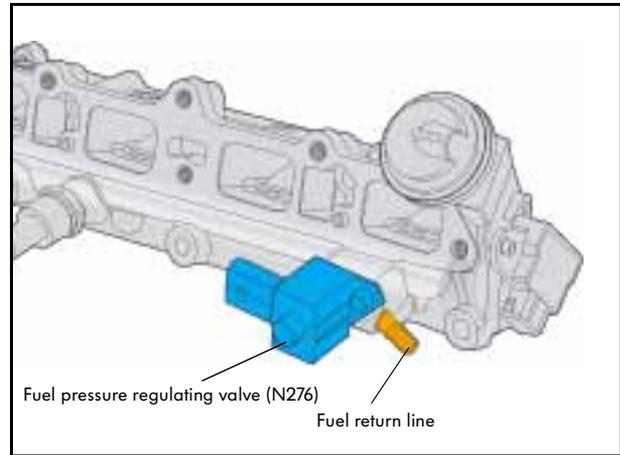
253\_029

## The fuel pressure regulating valve (N276)

is located on the lower section of the intake manifold and is screwed in place between the fuel rail and the return line leading to the fuel tank.

### Task

The task of the fuel pressure regulating valve is to adjust the fuel pressure in the fuel rail irrespective of the injection quantity and pump delivery rate.



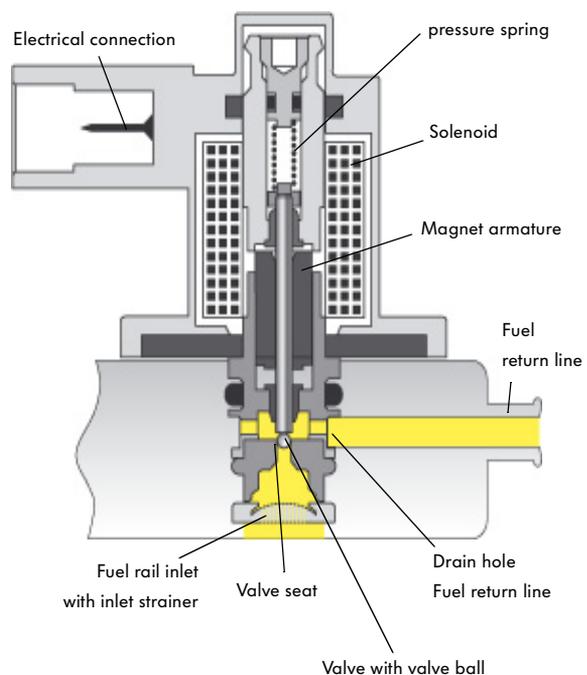
253\_129

### This is how it works

If deviations from the setpoint pressure are detected, the fuel pressure regulating valve is activated by a pulse-width modulated signal from the engine control unit. As a result of this, a magnetic field is induced in the magnetic coil and the valve with the valve ball lifts off the valve seat. In this way, the flow cross-section to the return line is changed depending on signal size, thus altering the discharge rate and regulating the fuel pressure.

### Failure strategies

The regulating valve is closed in de-energized state. This ensures that sufficient fuel pressure is always present. To protect the components against excessively high pressures, a spring-operated mechanical pressure limiting device is built into the fuel pressure regulating valve. It opens at a fuel pressure of 120 bar.



253\_033



# Engine management

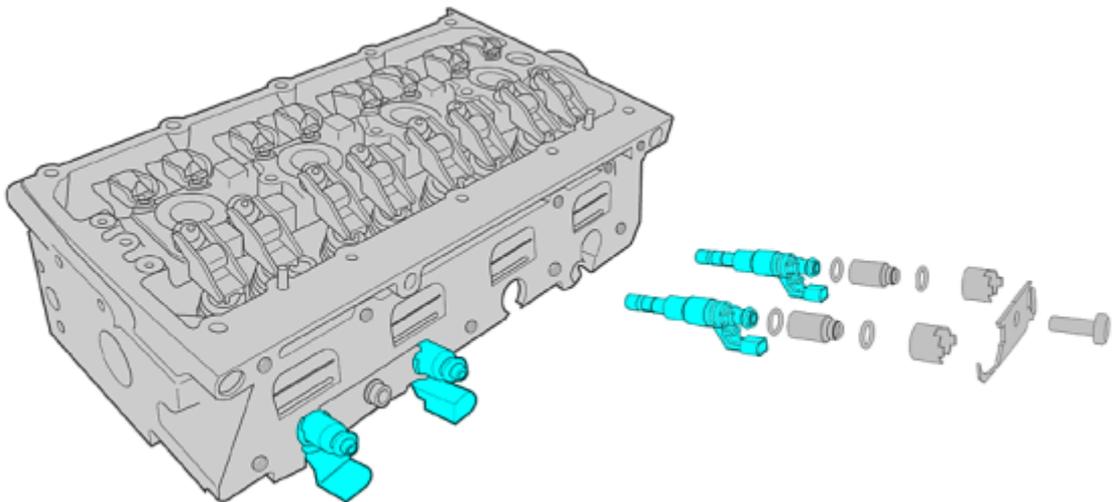
## High-pressure injectors (N30-N33)

They are attached to the cylinder head and inject the fuel directly into the cylinder at high pressure.

### Task

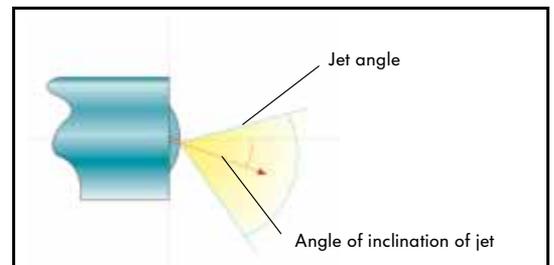
The task of the injectors is to thoroughly atomise the fuel as fast as possible under controlled conditions and depending on the operating mode.

Thus, the fuel is concentrated around the spark plugs in stratified charge mode, and evenly atomised throughout the combustion chamber in homogeneous lean charge mode and in homogeneous mode.



253\_149

The jet angle of  $70^\circ$  and the angle of inclination of the jet of  $20^\circ$  allow the fuel to be positioned precisely, particularly in stratified charge mode.

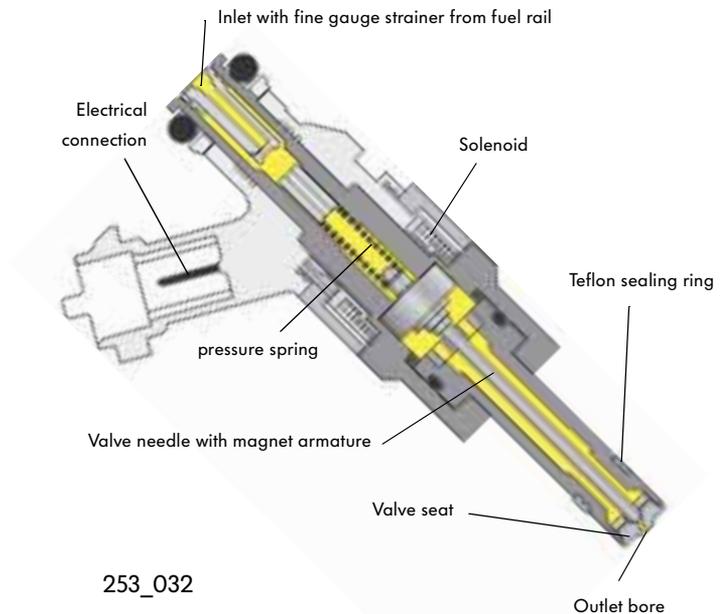


253\_056

## This is how it works

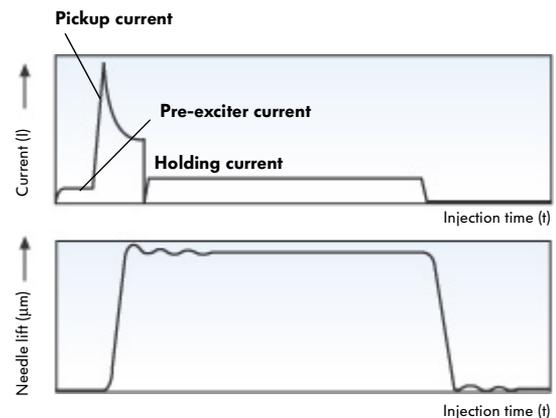
During the injection cycle, the magnetic coils in the injector are activated and a magnetic field is induced. The magnet armature and the valve needle pick up, the valve opens and fuel is injected.

If the coil is no longer activated, the magnetic field collapses and the valve needle is pushed into the valve seat by the pressure spring. The fuel flow is blocked.



## Activating high-pressure injectors

High-pressure injectors are activated by an electronic circuit in the engine control unit. In order to ensure that the injector opens as quickly as possible, a voltage of approximately 90V is applied to the valve after it is briefly premagnetised. The result is a current intensity of up to 10A. If the valve is fully open, a voltage of 30V and a current intensity of 3-4A are sufficient to hold the valve in the fully open position.



## Failure strategies

A defective injector is recognised by the misfire detector and no longer activated.



After renewing an injector, the learnt values must be cleared and re-adapted to the engine control unit. Please refer to the relevant Workshop Manual.



# Engine management

## Fuel metering valve (N290)

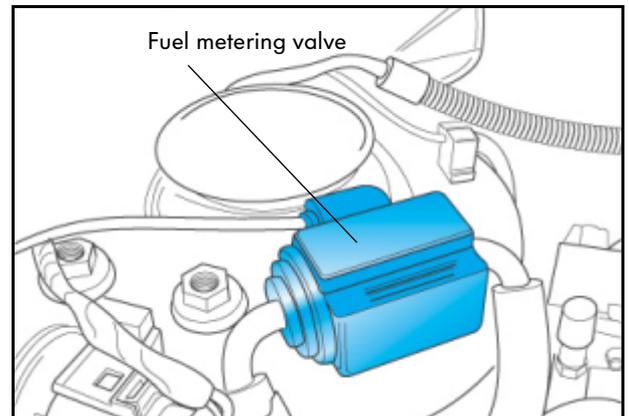
It is located in the supply line leading to the high-pressure fuel pump and the fuel pressure regulator. It is attached to the suspension strut tower.

### Task

During normal operation, the valve is open and releases the path to the fuel pressure regulator.

A hot start occurs when the coolant temperature is higher than 110°C and the intake air temperature is higher than 50°C at engine start-up.

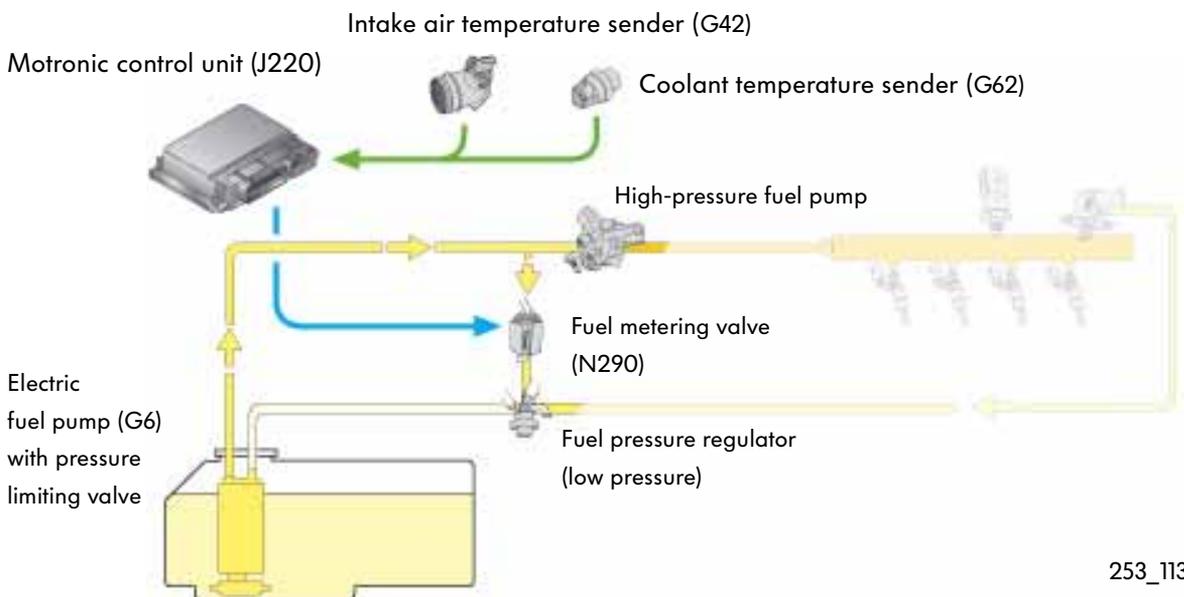
In this case, the valve is activated by the engine control unit for approx. 50 seconds and closes off the path to the fuel pressure regulator.



253\_049

As a result, the pressure in the low pressure fuel system rises to the maximum feed pressure of the electric fuel pump, which is limited to 5.8 bar by an internal pressure limiting valve.

This pressure increase prevents vapour bubbles from forming on the suction side of the high-pressure fuel pump and allows a high pressure to build up safely.



253\_113

## Failure strategies

If the fuel metering valve fails, it is kept closed by a pressure spring. As a result, the pressure in the

low pressure fuel system rises to 5.8 bar to prevent a vehicle breakdown during the hot start.

## Activated charcoal canister system

This is necessary in order to meet the statutory requirements relating to hydrocarbon emissions (HC). It prevents fuel vapour from escaping the fuel tank to the surrounding atmosphere. Fuel

vapour is stored in the activated charcoal canister and burned off at periodic intervals.

### In homogeneous lean charge mode and in homogeneous charge mode,

the ignitable mixture is evenly distributed inside the combustion chamber. So the combustion process takes place in the whole of the combustion chamber. The fuel discharged from the activated charcoal canister system is also burned.

### In stratified charge mode,

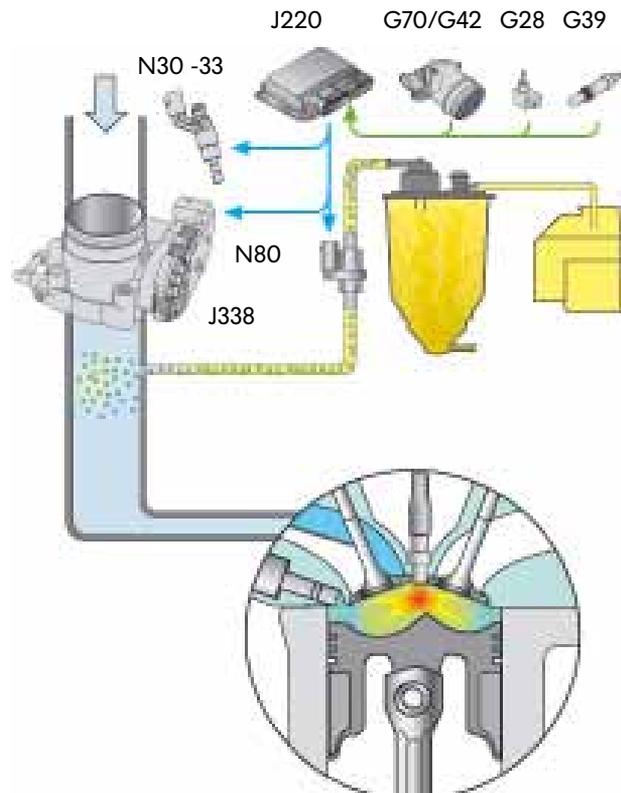
the ignitable mixture is present only in the area of the spark plugs. However, a portion of the fuel from the activated charcoal canister system is located in the non-ignitable outer region. This can lead to incomplete combustion and an increase in HC emissions in the exhaust gas. For this reason, stratified charge mode is only allowed if a low activated charcoal canister load is calculated.

The engine control unit calculates how much fuel may be fed from the activated charcoal canister system.

Then the solenoid valve is activated, the injection quantity is adapted and the throttle valve is adjusted.

As a result, the engine control unit requires the following information:

- the engine load from the hot-film air mass meter (G70)
- the engine speed from the engine speed sender (G28)
- the intake air temperature from the intake air temperature sender (G42), and
- the load state of the activated charcoal canister from the lambda probe (G39)



253\_077



# Engine management

## Ignition system

It has the task of igniting the air/fuel mixture at the correct moment in time. To achieve this, the engine control unit has to determine the ignition point, the ignition energy and the ignition spark duration at all operating points. The ignition point influences the engine's torque, emission behaviour and fuel consumption.

### In stratified charge mode,

the ignition point must lie within a narrow crank angle window due to the special mixture formation process. The mixture will only ignite safely in this way.

### In homogeneous lean charge mode and in homogeneous charge mode,

the engine's mode of operation is no different to that of an engine with intake manifold injection. Due to the similarities in mixture distribution, both injection systems use comparable ignition points.

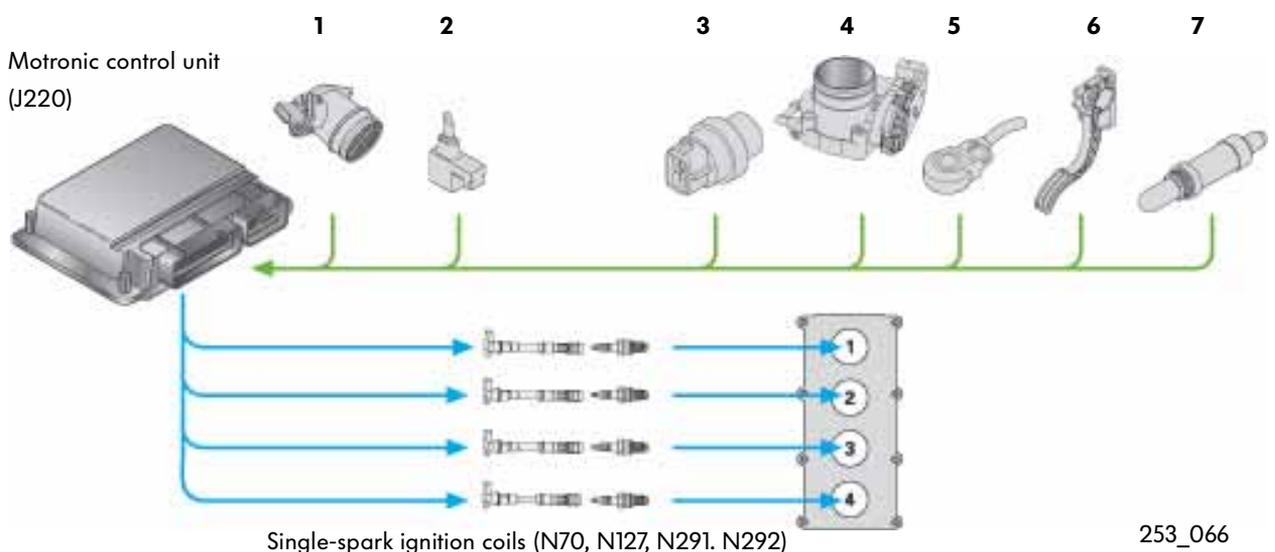
The optimum ignition point is calculated from the

#### Key information:

- 1 Engine load from air-mass flow meter (G70) and from intake air temperature sender (G42)
- 2 Engine speed from engine speed sender (G28)

#### Corrective information:

- 3 Coolant temperature sender (G62)
- 4 Throttle valve control unit (J338)
- 5 Knock sensor (G61)
- 6 Accelerator position sender (G79, G185)
- 7 Lambda probe (G39)

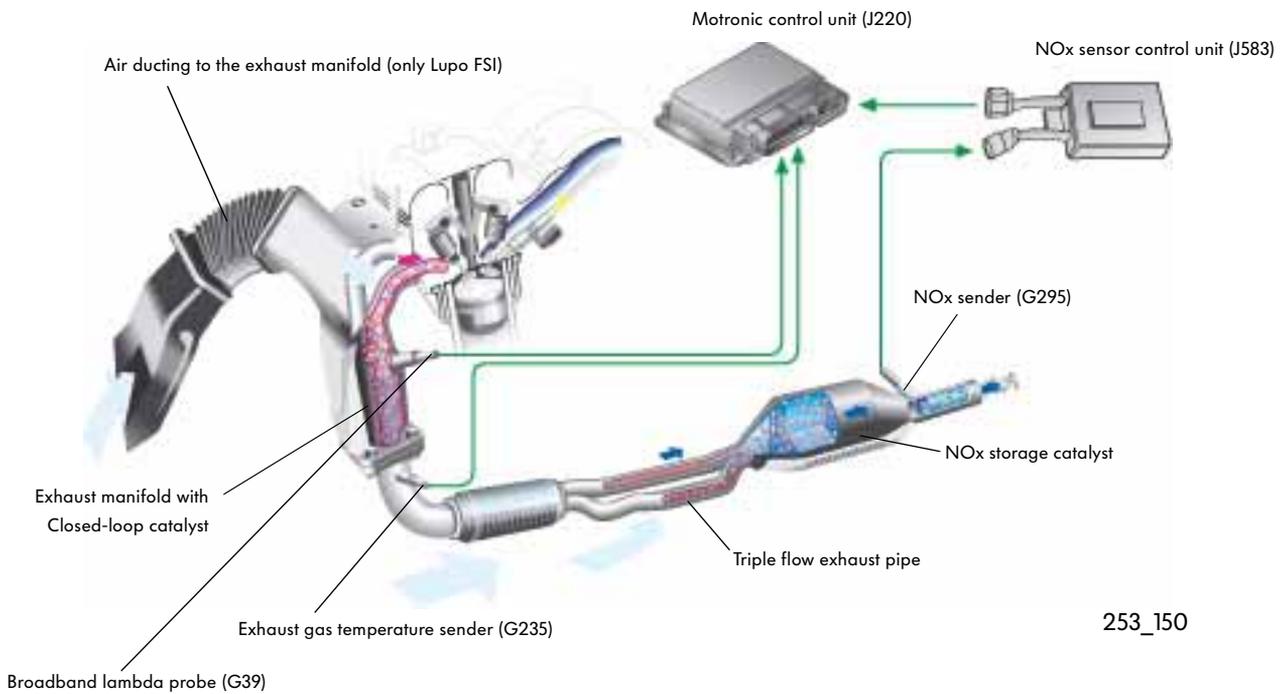


253\_066

## Exhaust system

This was adapted to the requirements of a direct petrol injection engine. Exhaust gas aftertreatment was previously a major problem in connection with direct petrol injection engines. This is because the statutory nitrogen oxide limits cannot be achieved in lean stratified charge mode or in homogeneous lean charge mode by

using a conventional closed-loop catalyst. A NO<sub>x</sub> storage catalyst which accumulates nitrogen oxides (NO<sub>x</sub>) in these operating modes is therefore fitted to these engines. When the reservoir is full, the system goes a regeneration mode, releasing the nitrogen oxides from the storage catalyst and converting them to nitrogen.



The advantage of exhaust gas recirculation and variable valve timing is that nitrogen oxide emissions are reduced during the combustion process.



# Engine management

## Exhaust gas cooling system

The objective is to cool the exhaust gas to such an extent that the temperature in the NO<sub>x</sub> storage catalyst lies within the range between 250°C and 500°C as often and for as long as possible. This is firstly because the NO<sub>x</sub> storage catalyst can only store nitrogen oxides within this temperature range and, secondly, because the capacity of the NO<sub>x</sub> storage catalyst is permanently impaired if it is heated to temperatures above 850°C.

## Exhaust manifold cooling system (only Lupo FSI)

At the front end of the vehicle, fresh air is directed to the exhaust manifold, to reduce the exhaust gas temperature.



253\_131

## Triple flow exhaust pipe

This is located upstream of the NO<sub>x</sub> storage catalyst. It also serves to reduce the temperature of the exhaust gases and NO<sub>x</sub> storage catalyst. It has a larger surface area which effectively increases heat dissipation to the surrounding atmosphere and decreases the exhaust gas temperature.

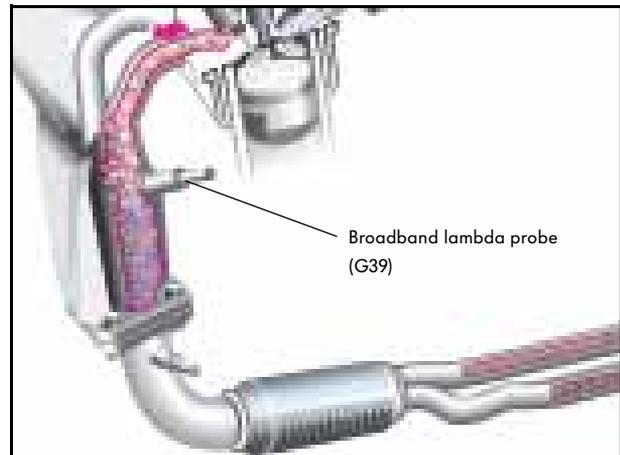


253\_131

Both measures collectively result in an exhaust gas temperature reduction of between 30°C and 100°C depending on vehicle road speed.

## Broadband lambda probe (G39)

The broadband lambda probe is screwed into the exhaust manifold upstream of the catalyst and is used to determine the residual oxygen fraction in the exhaust gas.



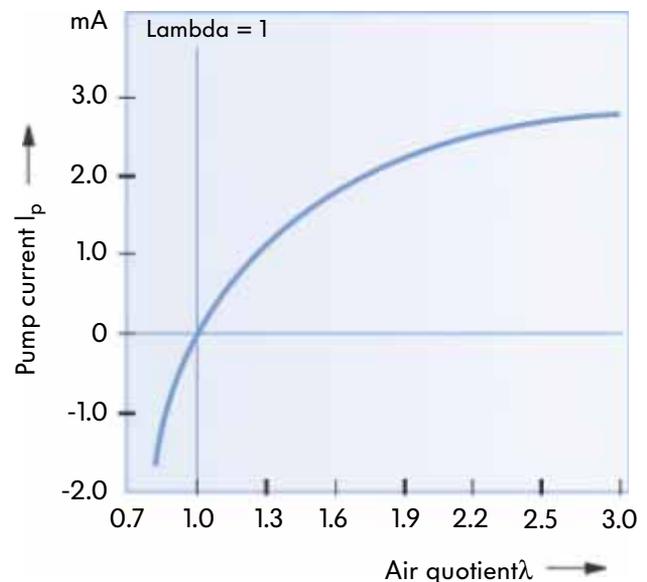
253\_131

## Signal utilisation

The broadband lambda probe can be used to define the air/fuel ratio accurately, and even ratios deviating from  $\lambda = 1$ .

As a result, a lean lambda of 1.55 can be set in homogeneous lean charge mode. In stratified charge mode, the lambda is calculated because broadband lambda probes are too inaccurate in this range.

Taking this signal as a basis, the engine control unit calculates the actual lambda value and commences lambda control when deviations from the target lambda value are detected. The lambda is controlled via the injection quantity.



253\_088

## Signal failure strategies

If the signal from the lambda probe fails, the system adopts an injection quantity precontrol strategy rather than a lambda control strategy. In addition, lambda adaption is disabled and the activated charcoal canister system goes into emergency running mode.



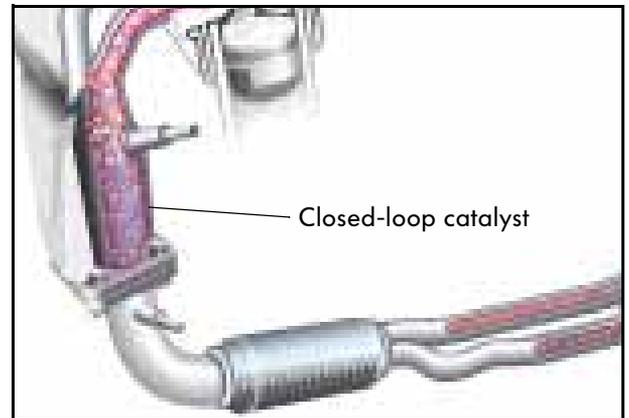
# Engine management

## Closed-loop starter catalyst

This is located in the exhaust manifold. Due to its position close to the engine, it quickly reaches its operating temperature and commences exhaust gas treatment. As a result, the strict exhaust emission limits can be met.

### Task

The closed-loop starter catalyst catalytically converts the pollutants produced by combustion into non-toxic substances.

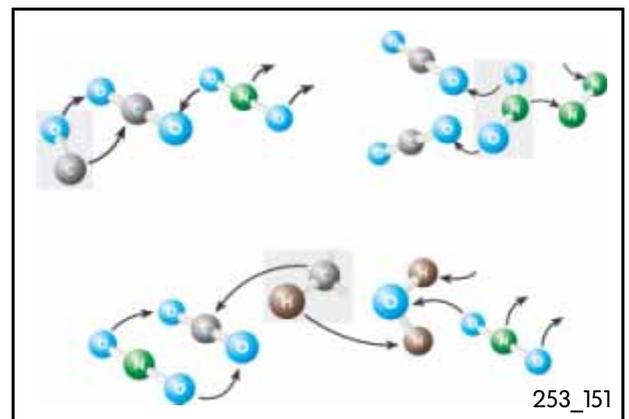


253\_131

### This is how it works

#### Homogeneous charge operation at $\lambda = 1$

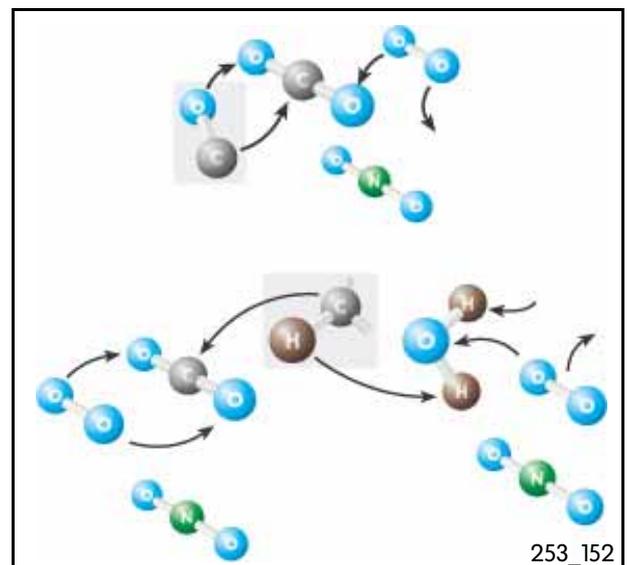
The hydrocarbons (HC) and the carbon monoxides (CO) react with oxygen (O) to oxidise the nitrogen oxides (NO<sub>x</sub>) to form water (H<sub>2</sub>O) and carbon dioxide (CO<sub>2</sub>). The nitrogen oxides are simultaneously reduced to nitrogen (N<sub>2</sub>) by this reaction.



253\_151

#### In stratified charge mode and in homogeneous lean charge mode at $\lambda > 1$

The hydrocarbons and the carbon dioxides preferably oxidise with the oxygen which is present in abundance in the exhaust gas, and not with the oxygen present in the nitrogen oxides. For this reason, the nitrogen oxides are not converted to nitrogen by a closed-loop catalyst during lean charge operation. They flow through the closed-loop catalyst to the NO<sub>x</sub> storage catalyst.

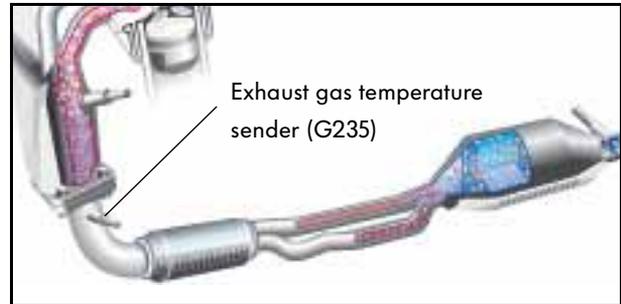


253\_152

## Exhaust gas temperature sender (G235)

The exhaust gas temperature sender is screwed into the exhaust pipe downstream of the starter catalyst.

It measures the exhaust gas temperature and sends this information to the engine control unit.



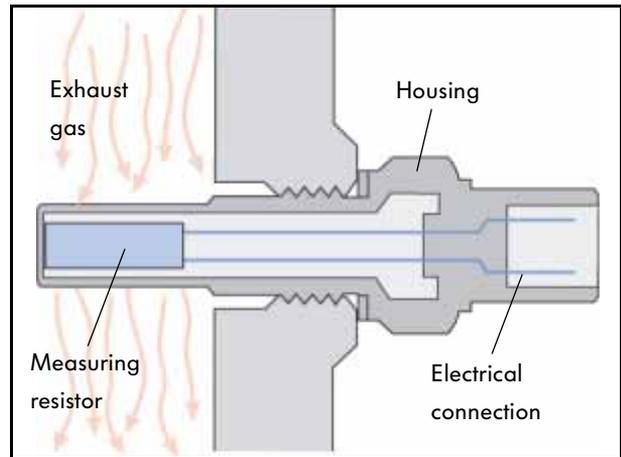
253\_131

## Signal utilisation

Taking the signal from the exhaust gas temperature sender as a basis, the engine control unit calculates, among other things, the temperature in the NOx storage catalyst.

This is necessary because:

- the NOx storage catalyst can only store nitrogen oxides at operating temperatures between 250°C and 500°C. Therefore, it is only possible to switch to stratified charge mode or homogeneous lean charge mode within this temperature range.
- the sulphur is also stored temporarily in the NOx storage catalyst. In order to release the sulphur from the storage pockets, the temperature inside the storage catalyst must be at least 650°C.



253\_089

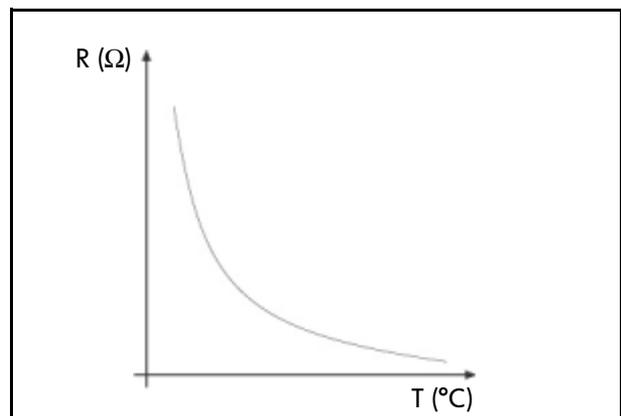
## Signal failure strategies

If the signal fails, the system goes into emergency running mode and the exhaust gas temperature is calculated by the engine control unit. As this calculation is not as accurate, the system switches to homogeneous charge mode earlier.

## This is how it works

A measuring resistor with a negative temperature coefficient (NTC) is built into the sender. This means that the resistance decreases and signal voltage increases as the temperature rises. This signal voltage is assigned to a temperature in the engine control unit.

## NTC resistance curve



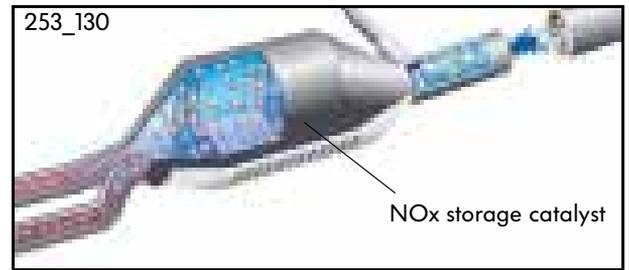
253\_114



# Engine management

## NOx storage catalyst

This catalyst is installed in the same position as a conventional closed-loop main catalyst. It also functions as a closed-loop catalyst and can store nitrogen oxides.



## Task

In homogeneous operation at  $\lambda = 1$ , the NOx storage catalyst operates in much the same way as a conventional closed-loop catalyst.

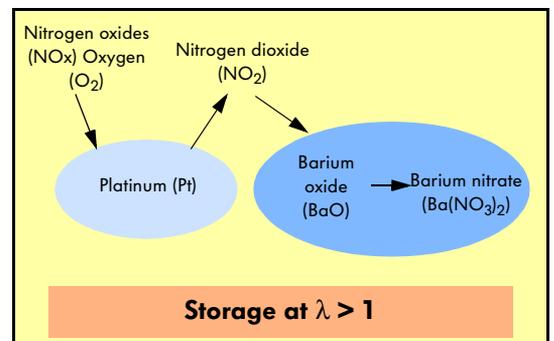
In stratified charge mode and in homogeneous lean charge mode at  $\lambda > 1$ , it is no longer able to convert the nitrogen oxides. This is why they are stored in the NOx storage catalyst. A regeneration cycle is initiated when the storage capacity of the catalyst is exhausted (see p 50/51). The sulphur is also stored due to its chemical similarity to nitrogen oxides.

## This is how it works

In addition to having platinum, rhodium and palladium coatings, the NOx storage catalyst has a fourth coating in the form of barium oxide. This enables it to store nitrogen oxides when operating in lean charge mode.

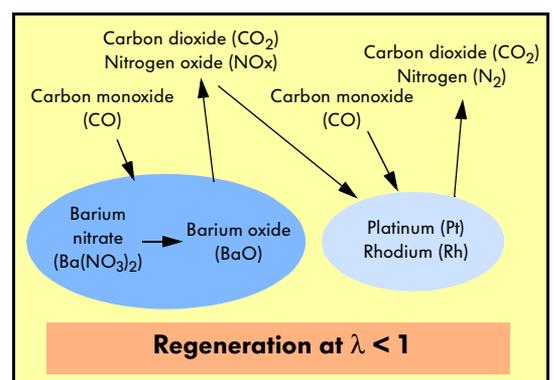
## Storage process

The nitrogen oxides are oxidised by the platinum coating to form nitrogen dioxide, and then react with the barium oxide to form barium nitrate.



## Regeneration process

In this example, nitrogen oxides are released from the catalyst by the CO, which are molecules abundantly present in the rich exhaust gas. First of all, the barium nitrate is reduced again to barium oxide by carbon monoxide. Carbon dioxide and nitrogen monoxide are released by this reaction. Rhodium and platinum reduce nitrogen oxides to nitrogen and oxidise carbon monoxide to form carbon dioxide.

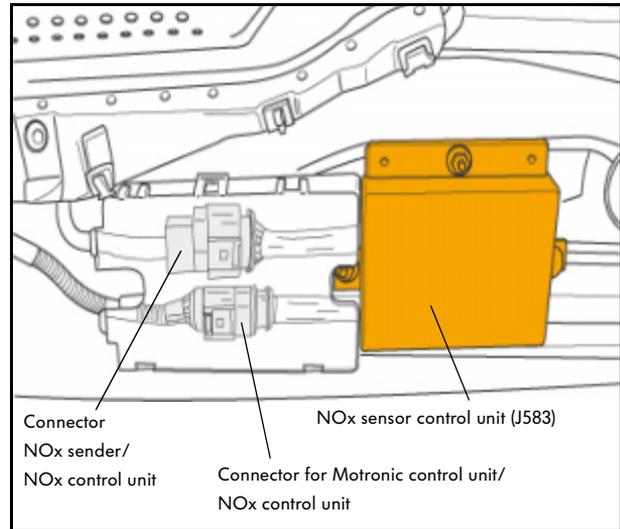


## NOx sensor control unit (J583)

This is located on the underbody close to the NOx sensor. This near-sensor layout prevents external interference from falsifying the signals generated by the NOx sensor.

### Task

In the NOx sensor control unit, the signals from the NOx sender are processed and sent to the engine control unit.



253\_103

## Electric circuit

From NOx sensor to the NOx sensor control unit:

### 1-6 Compensation resistors

(the signals from the NOx sender are adapted and sensor manufacturing tolerances are compensated via the compensation resistors.)

### 7-8 Unassigned

### 9 Sensor signal ground

### 10 NOx pump current ( $\mu\text{A}$ ), chamber 2

### 11 Lambda pump current (mA), chamber 1

### 12 Heater (negative)

### 13 Reference cell voltage

### 14 Heater (positive)

From NOx sensor control unit to Motronic control unit:

### 1 NOx signal, chamber 2

### 2 Oxygen fraction lambda, chamber 1

### 3 NOx temperature sender

### 4 Probe voltage

### 5 Reference cell voltage

### 6 Unassigned

### 7 Supply voltage

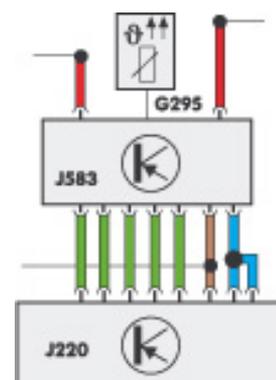
### 8 Heater (negative)

### 9 Ground

### 10 Heater (positive)

## Failure strategies

If the NOx sensor control unit fails, the system switches from closed-loop control to open-loop control. Due to the higher nitrogen oxide emissions involved, neither stratified charge mode nor homogeneous lean charge mode is allowed.



253\_115



# Engine management

## NOx sender (G295)

This sender is screwed into the exhaust pipe directly behind the NOx storage catalyst. It determines the nitrogen oxide (NOx) fraction and the oxygen fraction in the exhaust gas and sends this information to the NOx sensor control unit (J583).

## Signal utilisation

The signals are used to identify and check the following:

- whether the catalyst function is OK.
- whether the lambda = 1 regulation point of the broadband lambda probe upstream of the catalyst is OK or needs correction. This is made possible by an internal circuit in the control unit for NOx.

It can be used to pick up a probe like signal at the electrodes of the NOx sender.

Such a signal is very accurate in the region of lambda = 1.

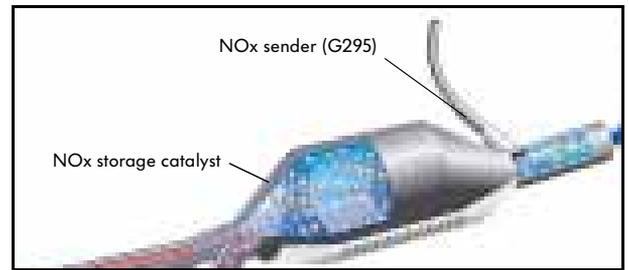
- when the storage capacity of the NOx storage catalyst is exhausted and a NOx or sulphur regeneration cycle is initiated.

The signals are sent from the NOx sender to the NOx sensor control unit.

## Design

It comprises two chambers, two pump cells, several electrodes and a heater. The sensor element is made of zirconium dioxide.

A typical characteristic of this substance is that negative oxygen ions migrate from the negative electrode to the positive electrode when a voltage is applied.



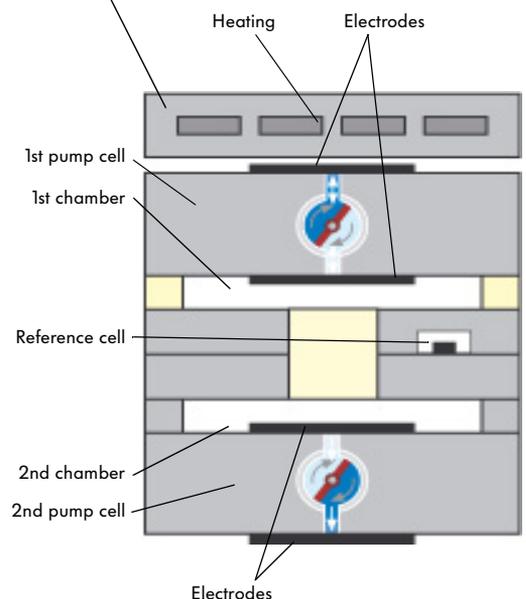
253\_130

## Signal failure strategies

If the signal from the NOx sender fails, the engine will only be allowed to operate in homogeneous charge mode.



253\_098



253\_099

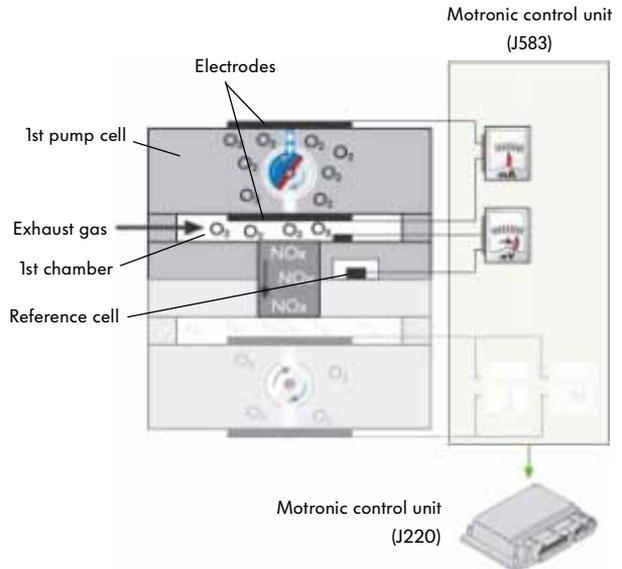
## Function of the NOx sender

The function of the NOx sender is based on oxygen measurement and can be derived from a broadband lambda probe.

### Determination of lambda in the first chamber

A portion of the exhaust gases flows into the first chamber. Due to the different oxygen fractions in the exhaust gas and the reference cell, an electrical voltage can be measured at the electrodes. The NOx sensor control unit sets this voltage to a constant 425mV. This corresponds to an air/fuel ratio of  $\lambda = 1$ .

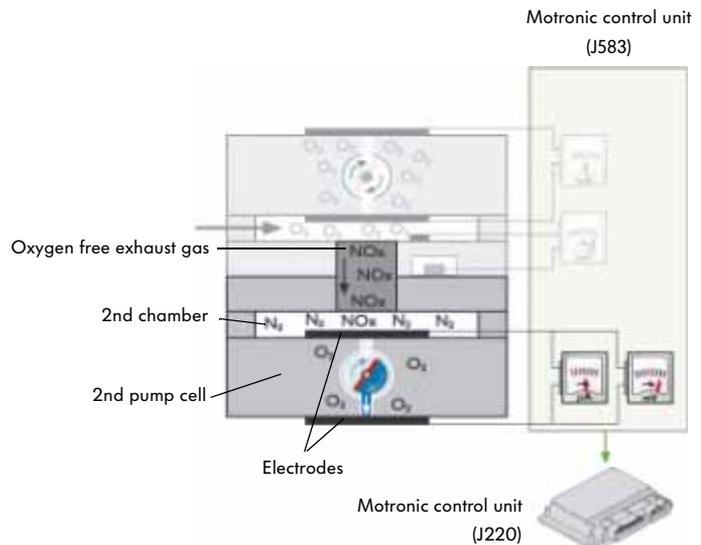
If deviations occur, oxygen is pumped out or in. The required pump current is an indication of the lambda value.



253\_101

### Determination of the NOx fraction in the second chamber

The oxygen free exhaust gas flows from the 1st chamber into the 2nd chamber. NOx molecules in the exhaust gas are split into  $N_2$  and  $O_2$  by a special electrode. Since the voltage at the inner and outer electrodes is adjusted to a constant value of 450mV, oxygen ions migrate from the inner electrode to the outer electrode. The oxygen pump current which flows during this process is an indication of the oxygen fraction in the 2nd chamber. As the oxygen pump current is directly proportional to the nitrogen oxide fraction in the exhaust gas, the amount of nitrogen oxide can be determined.



253\_102

If a certain nitrogen oxide threshold is exceeded, the storage capacity of the NOx storage catalyst is exhausted and a NOx regeneration cycle is initiated.

If the threshold is exceeded at ever-decreasing time intervals, then the storage catalyst is saturated with sulphur and a sulphur regeneration cycle is initiated.



# Engine management

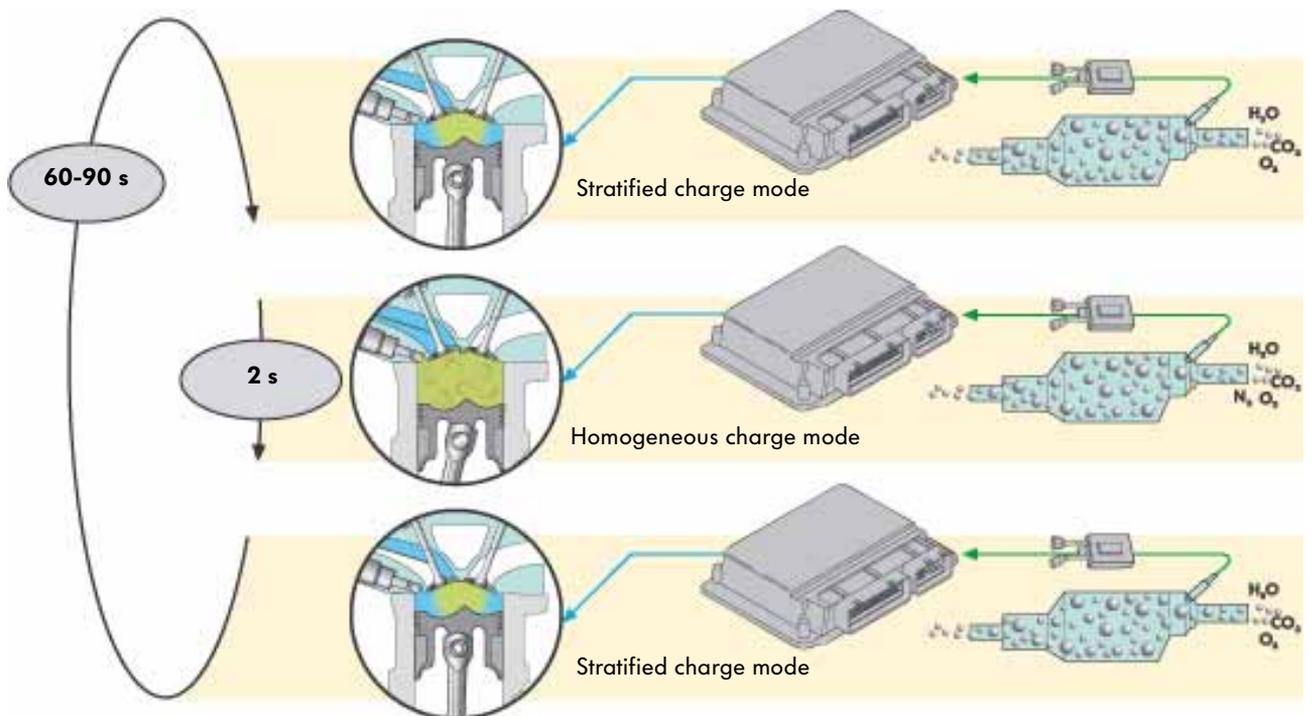
## Regeneration mode

In this mode, stored nitrogen oxides and sulphur are released from the NO<sub>x</sub> storage catalyst and converted to non-toxic nitrogen or sulphur dioxide.

### Regeneration of nitrogen oxides

takes place when the nitrogen oxide concentration downstream of the storage catalyst exceeds a fixed value. This indicates to the engine control unit that the catalyst can no longer store any more nitrogen oxides and that its storage capacity is exhausted. Regeneration mode is activated.

The engine control unit switches from lean stratified charge mode to a slightly rich homogeneous charge mode, so increasing the hydrocarbon and carbon monoxide fractions in the exhaust gas. In the storage catalyst, the hydrocarbons and the carbon monoxide combine with the oxygen of the nitrogen oxides to produce nitrogen from the nitrogen oxides.



252\_054

In stratified charge mode, the NO<sub>x</sub> storage catalyst can store nitrogen oxides for up to 90 seconds. This is followed by regeneration which lasts approximately 2 seconds.

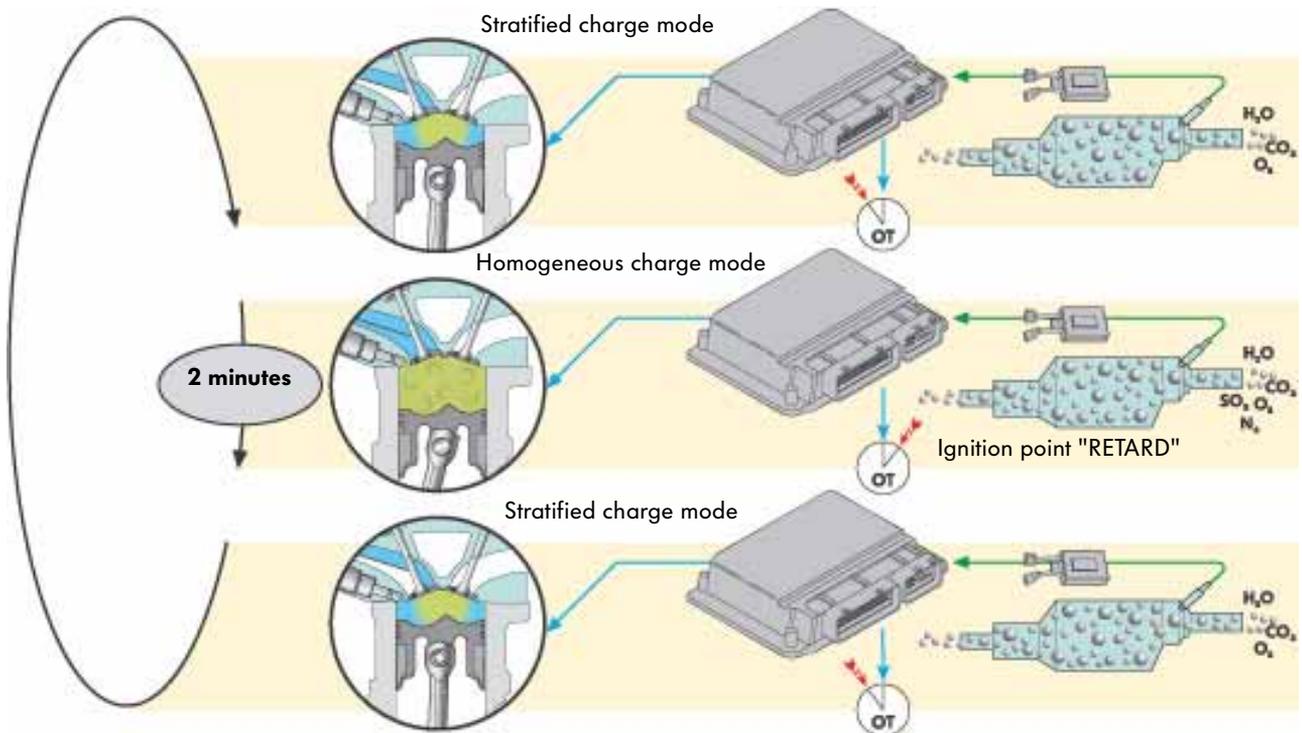
## Sulphur regeneration

is a technically more complex process because sulphur has greater heat resistance and remains in the catalyst after nitrogen oxide regeneration. The fuel is desulphurised when the storage capacity of the NO<sub>x</sub> storage catalyst is exhausted at ever-decreasing time intervals. This indicates to the engine control unit that the storage pockets are saturated with sulphur and that nitrogen oxides can no longer be stored.

Above a vehicle-specific minimum speed and for approx. 2 minutes, the engine control unit:

- switches to homogeneous charge mode, and
- increases the temperature of the storage catalyst to over 650°C by adjusting the ignition timing towards "retard".

Now the stored sulphur reacts to form sulphur dioxide (SO<sub>2</sub>).



252\_055

Desulphurisation takes place automatically when driving under high engine load and speed, because the vehicle is running in homogeneous charge mode and the required desulphurisation temperature in the NO<sub>x</sub> storage catalyst is reached.



A sulphur-free fuel (e.g. Shell Optimax) should be used in order to minimise fuel consumption due to sulphur regeneration.



# Engine management

## Exhaust gas recirculation system

This justifies the use of a NO<sub>x</sub> storage catalyst. This is because the incoming exhaust gases reduce combustion temperature and nitrogen oxide formation.

As a result, the catalyst can store nitrogen oxides over a longer period of time and is operable for longer in the fuel-saving stratified charge and homogeneous lean charge modes.

The recirculated exhaust gas quantity amounts to no more than 35% of the overall gas volume.

Exhaust gas recirculation always takes place

- in stratified charge mode, in homogeneous lean charge mode and
- in homogeneous charge mode up to engine speeds of 4000rpm and at medium engine load, but not in idling mode.

### The exhaust gas recirculation valve (N18)

is attached to the intake manifold by bolts. It was redesigned to permit high exhaust gas recirculation rates.

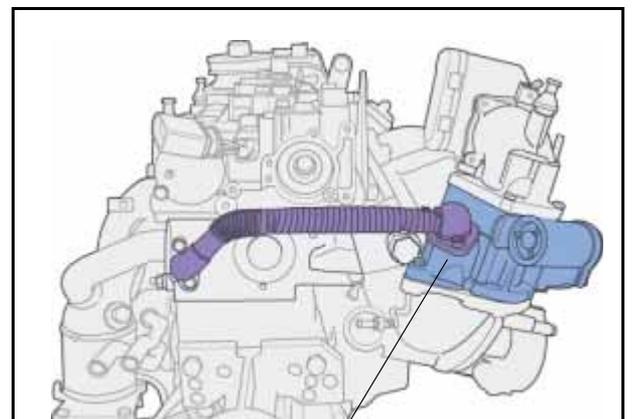
It comprises a housing with a throttle valve, an electric motor and an exhaust gas recirculation potentiometer (G212).

The exhaust gas is extracted via a connecting tube on the cylinder head of the fourth cylinder.

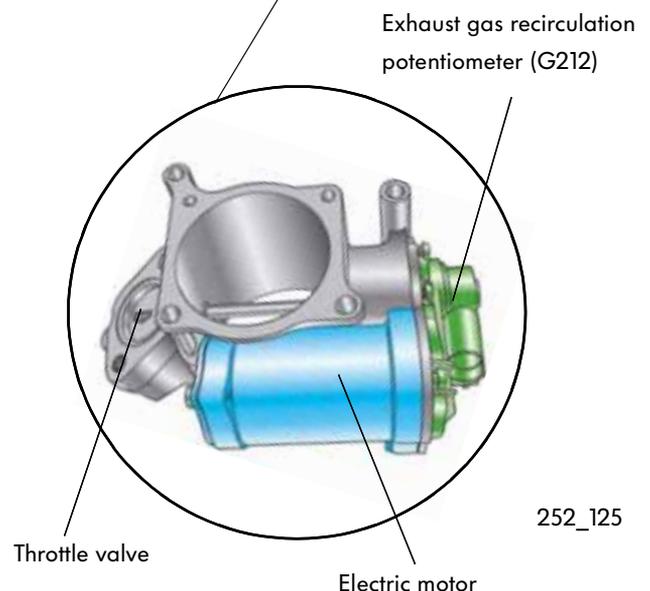
The engine control unit activates the electric motor depending on a characteristic map and actuates a throttle valve.

Depending on throttle valve position, a certain quantity of exhaust gas now flows into the intake manifold and mixes with the induced fresh air.

The exhaust gas recirculation potentiometer in the housing cover recognises the position of the throttle valve. This allows the exhaust gas recirculation valve to be diagnosed.



253\_052



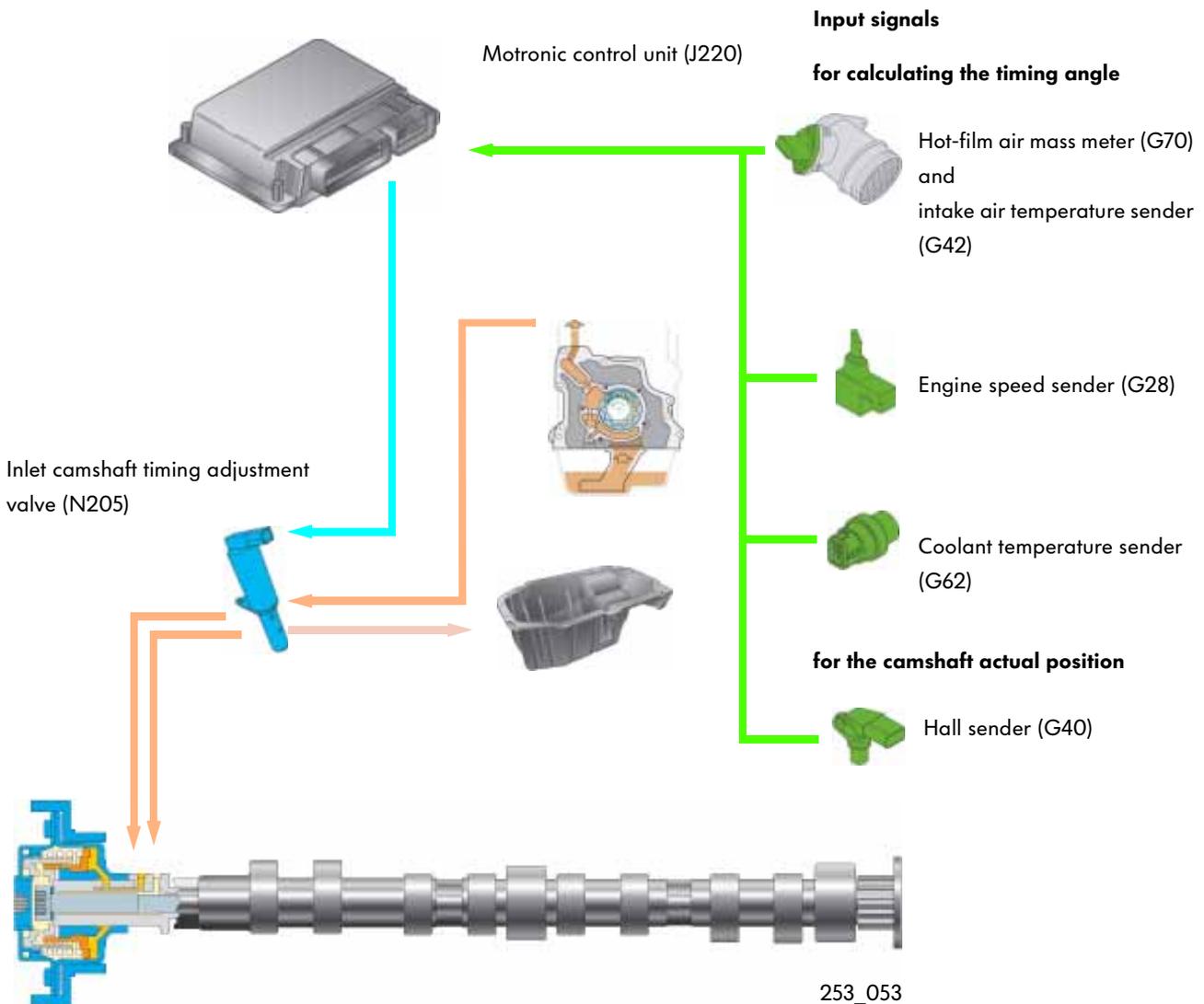
252\_125

## Variable valve timing

Inner exhaust gas recirculation takes place by intake port variable valve timing. Valve timing is adjusted by a max. crank angle of  $40^\circ$  from the basic setting in the "advance" direction depending on engine load and speed.

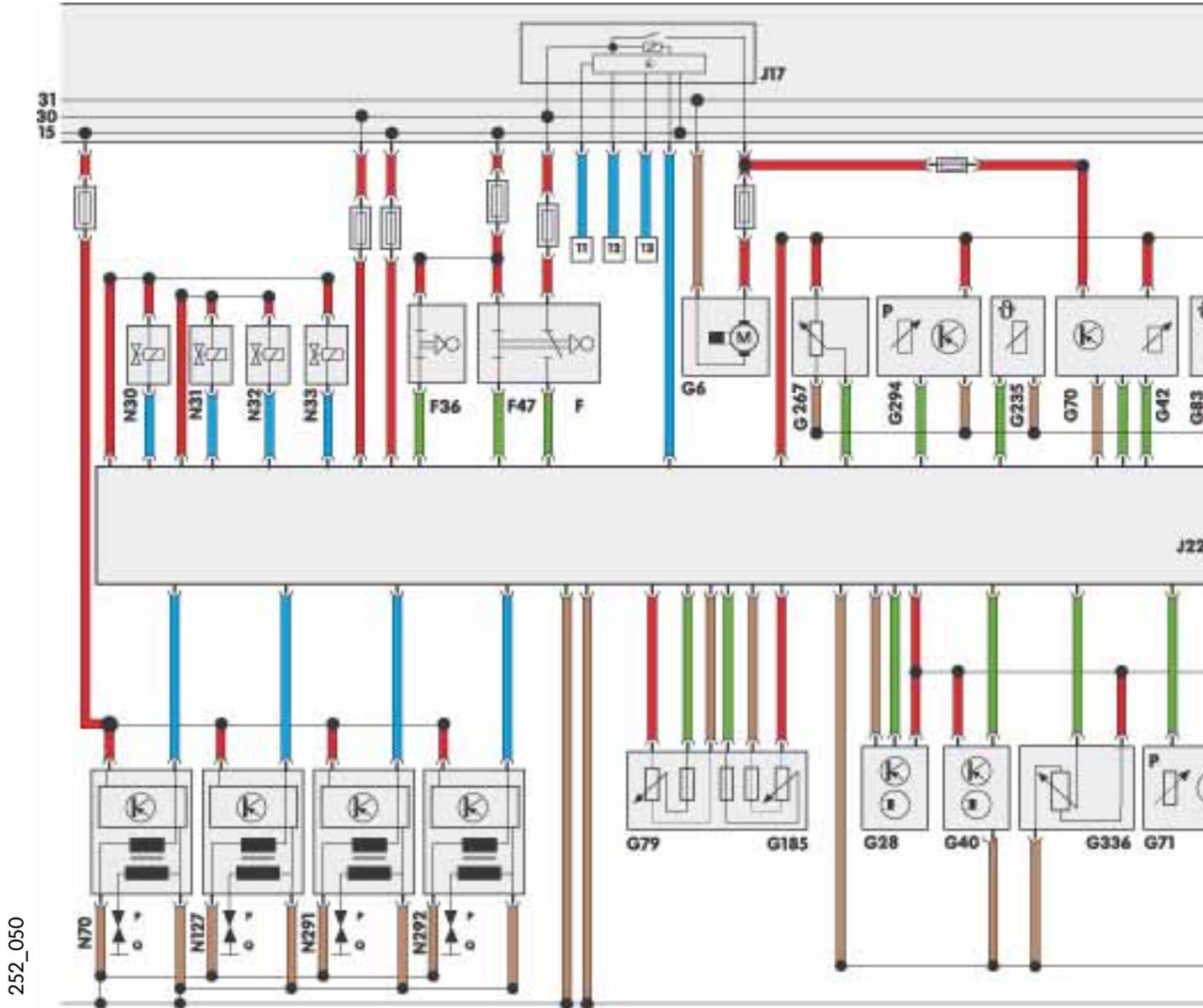
The advantages are:

- optimal interior exhaust gas recirculation and this produces a reduction in combustion temperature and nitrogen oxide emissions, as well as an improved torque curve.

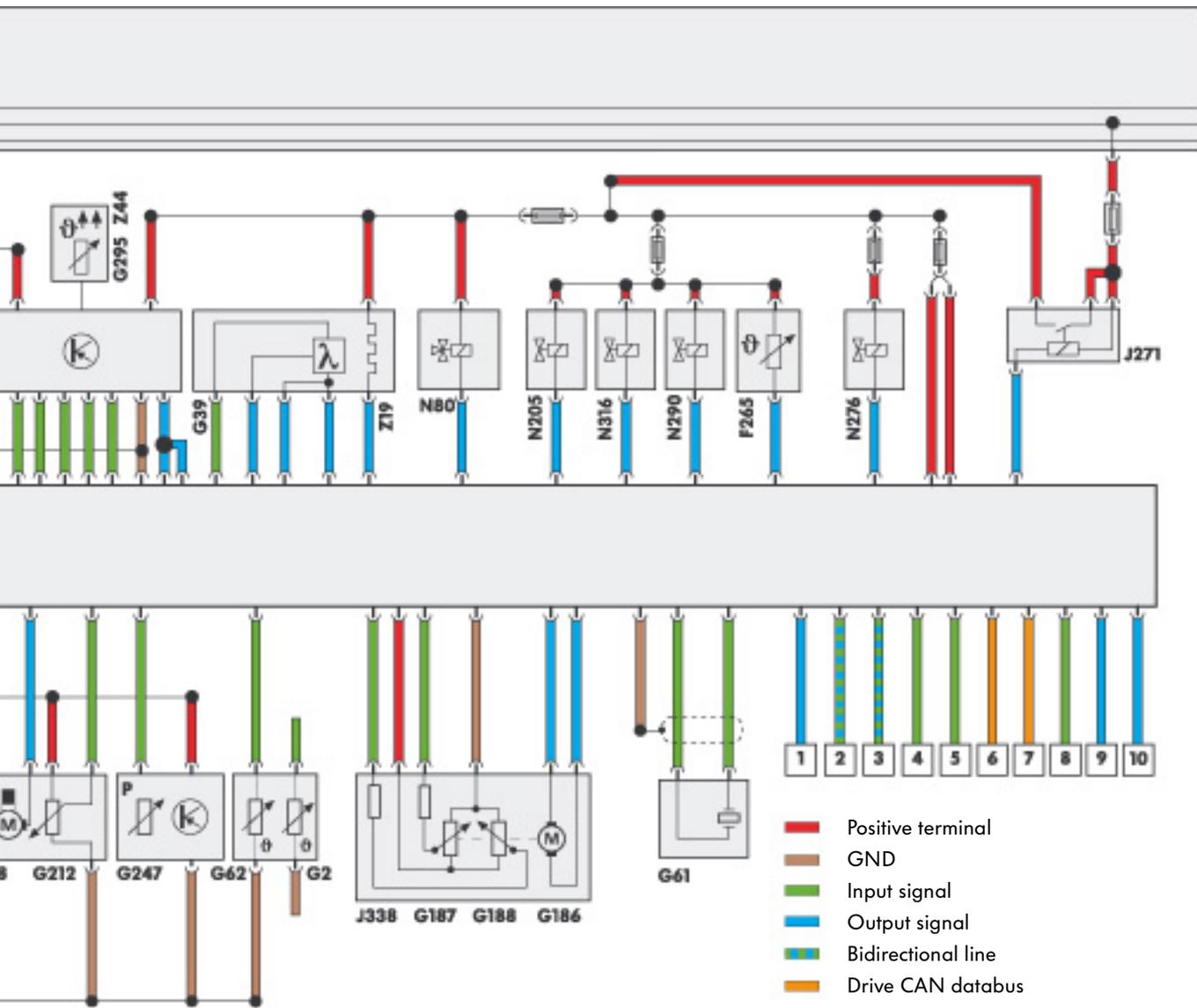


# Engine management

## Function diagram



- |             |  |             |   |
|-------------|--|-------------|---|
| <b>F</b>    | Brake light switch                           | <b>G185</b> | Accelerator pedal position sender -2-   |
| <b>F36</b>  | Clutch pedal switch                          | <b>G186</b> | Throttle-valve drive  |
| <b>F47</b>  | Cruise control system brake pedal switch     | <b>G187</b> | Throttle valve drive angle sender -1-   |
| <b>F265</b> | Mapped engine cooling thermostat             | <b>G188</b> | Throttle valve drive angle sender -2-   |
| <b>G2</b>   | Coolant temperature sender                   | <b>G212</b> | Exhaust gas recirculation potentiometer   |
| <b>G6</b>   | Fuel pump                                    | <b>G235</b> | Exhaust gas temperature sender -1-  |
| <b>G28</b>  | Engine speed sender                          | <b>G247</b> | Fuel pressure sender  |
| <b>G39</b>  | Lambda probe                                 | <b>G267</b> | Rotary knob temperature selection potentiometer<br>(not used in combination with Climatronic) |
| <b>G40</b>  | Hall sender                                  | <b>G294</b> | Brake servo pressure sensor   |
| <b>G42</b>  | Intake air temperature sender                | <b>G295</b> | NOx sender  |
| <b>G61</b>  | Knock sensor 1                               | <b>G336</b> | Intake manifold flap potentiometer  |
| <b>G62</b>  | Coolant temperature sender                   | <b>J17</b>  | Fuel pump relay   |
| <b>G70</b>  | Air-mass flow meter                          | <b>J220</b> | Motronic control unit   |
| <b>G71</b>  | Intake manifold pressure sender              | <b>J271</b> | Motronic current supply relay   |
| <b>G79</b>  | Accelerator position sender                  | <b>J338</b> | Throttle valve control unit   |
| <b>G83</b>  | Coolant temperature sender - radiator outlet |             |   |



- J583** NOx sensor control unit
- N70, N127,**
- N291, N292** Ignition coils 1 - 4 with output stages
- N18** EGR valve
- N30-N33** Injectors 1 - 4
- N80** Activated charcoal filter system solenoid valve I
- N205** Inlet camshaft timing adjustment valve -I-
- N276** Fuel pressure regulating valve
- N290** Fuel metering valve
- N316** Intake manifold flap air flow control valve
- P** Spark plug socket
- Q** Spark plugs
- Z19** Lambda probe heater
- Z44** NOx sender heater

- 1** TD signal
- 2** K/W line
- 3** Air conditioner compressor
- 4** A/C ready
- 5** Air conditioner PWM
- 6** Drive train CAN databus
- 7** Drive train CAN databus
- 8** Alternator terminal, 3-phase AC alternator DFM
- 9** Fan control 1
- 10** Fan control 2
- 11** Line to terminal 50
- 12** Line to door contact switch
- 13** Line to airbag

252\_051



# Engine management

## Self-diagnosis

The sensors and actuators are checked during the course of the self-diagnosis procedure. For diagnosis please use the current workshop literature and the VAS 5051 Vehicle Diagnostic, Testing and Information System or the VAS 5052 Vehicle Diagnosis and Service Information System.



253\_132

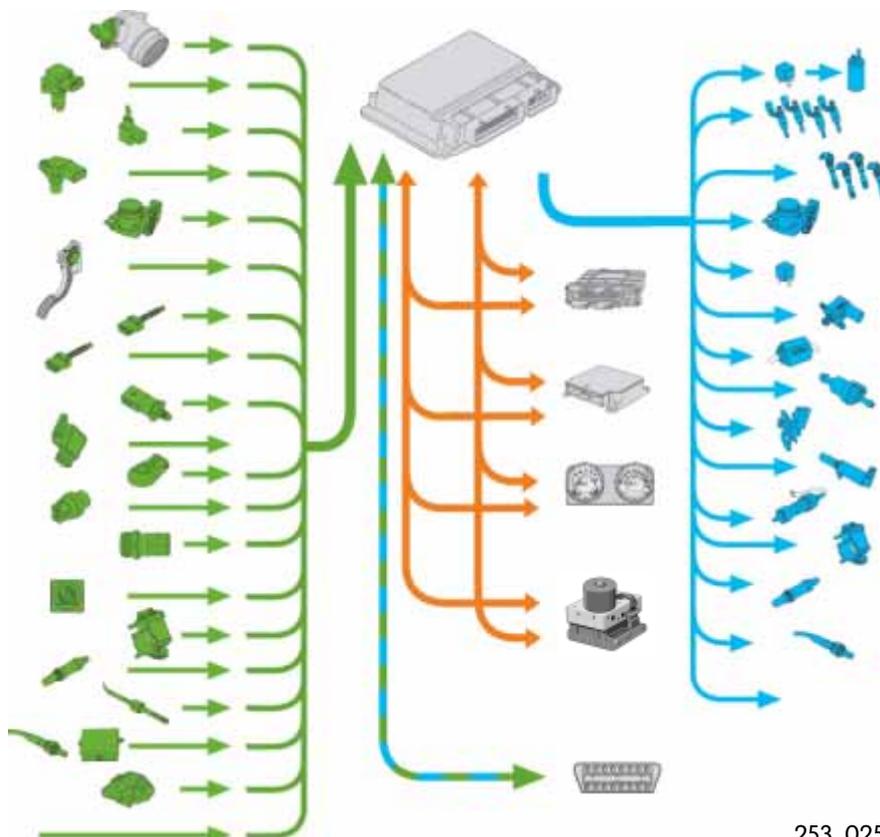


253\_036



Please note that repair group 01 is an integral part of "Guided Fault-Finding". It also includes the functions "Read data block" and "Final control diagnosis".

The sensors and actuators shown in colour are checked during the self-diagnosis and Guided Fault-Finding procedures.



253\_025

**Solutions to questions on pages 58-59**

1.) a,b,c

2.) c

3.) a,c

4.) b

5.) b, c

6.) a,b

7.) b,c

8.) c



# Test your knowledge

## 1. What are the advantages of the direct petrol injection system?

- In lean operating modes, the throttle valve is opened wider and air can be drawn in against less resistance.
- Heat is extracted from the intake air by directly injecting the fuel into the cylinders, so allowing the compression ratio to be increased.
- The direct petrol injection system allows the engine to be operated at an air/fuel ratio up to  $\lambda = 3$ .

## 2. When is fuel injected during stratified charge operation, in homogeneous lean operation and homogeneous operation?

- In all three operating modes, fuel is injected during the intake stroke.
- Fuel is injected during the intake stroke when the engine is operated in stratified charge mode and during the compression stroke when the engine is operated in homogeneous lean charge mode and homogeneous charge mode.
- Fuel is injected during the compression stroke when the engine is operated in stratified charge mode, and during the intake stroke when the engine is operated in homogeneous lean charge mode and homogeneous charge mode.

## 3. What do the terms stratified charge, homogeneous lean and homogeneous mean?

- "Stratified charge" means that the mixture is located in the region of the spark plugs and is enveloped by a layer of fresh air and recirculated exhaust gases.
- "Homogeneous" means that the mixture forms shortly before ignition.
- "Homogeneous lean" means that a lean mixture is evenly distributed throughout the combustion chamber.

## 4. Why is the throttle valve not opened fully when the engine is operated in stratified charge mode?

- Because the hydrocarbon and carbon monoxide emissions would otherwise be too high.
- Because a certain vacuum must always be present for the activated charcoal canister and exhaust gas recirculation systems.
- Because the engine torque is controlled via the quantity of fresh air and the engine does not require as much air at low loads and speeds.

**5. What is the signal from the intake manifold pressure sender G71 used for?**

- As a load signal for changing over between operating modes.
- For load sensing at engine start-up.
- In order to be able to determine the exhaust gas recirculation rate more accurately.

**6. How high are the pressures in the fuel system?**

- In the high-pressure fuel system, the pressures range between 50 and 100 bar depending on the characteristic map.
- Under normal operating conditions, the pressure in the low pressure fuel system is 3 bar.
- During normal operation, the maximum fuel pressure in the low pressure fuel system is 7.5 bar.

**7. Which of the following statements on the NO<sub>x</sub> storage catalyst are true?**

- It stores nitrogen oxides at  $\lambda = 1$  in order to be able to convert hydrocarbons and carbon dioxides more effectively during lean operation.
- It stores nitrogen oxides at  $\lambda > 1$  because a closed-loop catalyst is unable to convert nitrogen oxides to nitrogen during lean charge operation.
- It also functions as a closed-loop catalyst and can store nitrogen oxides.

**8. When are nitrogen oxides and sulphur regenerated?**

- At regular intervals.
- Special regeneration is not necessary, because this takes place automatically at higher engine loads.
- Whenever the NO<sub>x</sub> sender detects a certain defined fraction of nitrogen oxides in the exhaust gases.





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