



## 1,9 ltr-TDI-Industrial Engine



**Technical Status: 4/1999**

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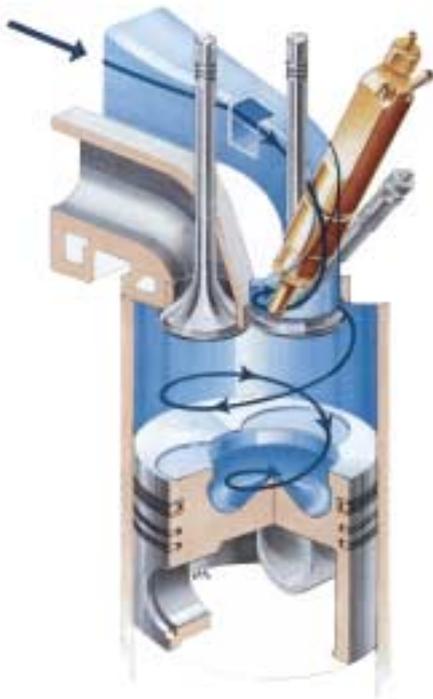
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Detailed instructions regarding testing, adjustment and repair can be found in the Workshop Manual "Volkswagen Industrial Engine".

# Combustion process

In the direct injection engine, diesel fuel is injected directly into the main combustion chamber. This results in more efficient combustion and lower consumption.

The intake port, pistons and injectors have been designed specifically to optimise the combustion process with respect to noise emission and running characteristics.



## Inlet swirl port

The intake port is shaped in such a way that it induces a swirling movement of the intake air and, as a result, produces greater turbulence in the combustion chamber and piston recess.

## Piston recess

The shape of the piston recess has been optimised specially for this engine.



## 5-hole injector

The fuel is injected into the piston recess in two stages and is ignited by the hot air. The two-stage injection process avoids a sharp pressure rise.

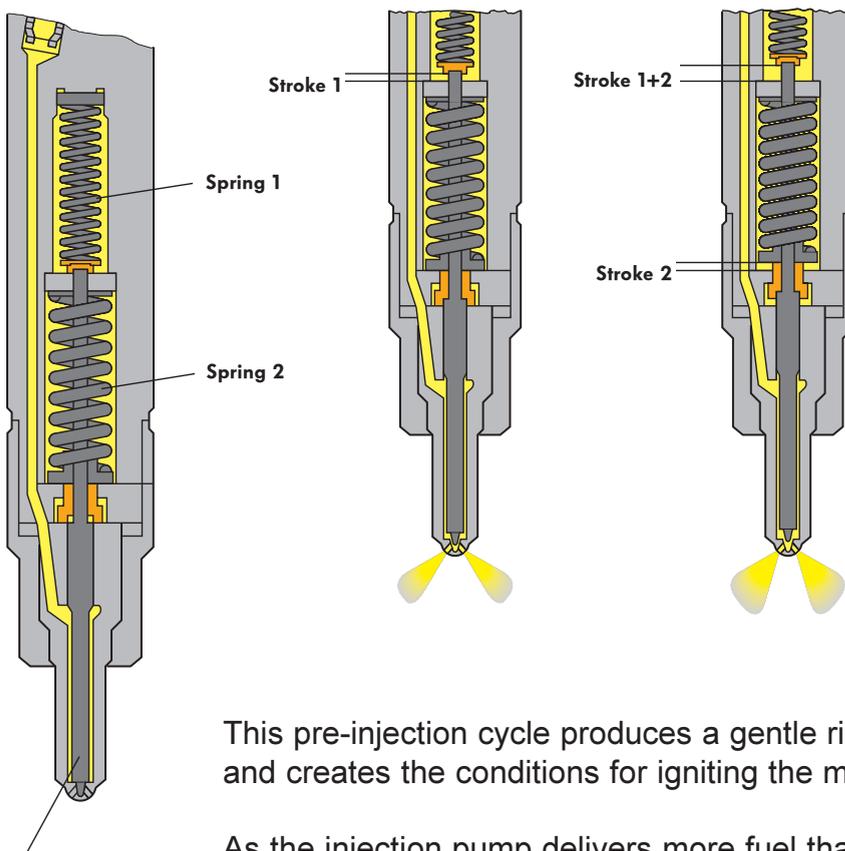
# Injector needle

## Two-spring injector holder

To minimise the combustion noise level in the diesel engine and keep mechanical load low, it is necessary for the pressure to rise gently in the combustion chamber. In the case of chamber-type diesel engines, this gentle rise in pressure is achieved, first, by injecting fuel into the pre-chamber or the swirl chamber and, secondly, by using pintle-type injectors. Also, the fuel should be injected gradually, not all at once.

A two-spring injector holder has been developed for the 1.9-ltr. direct injection engine. This injector holder, a key factor contributing to the engine's "soft" combustion characteristic, allows fuel to be injected in two stages.

The injector is designed as a five-hole nozzle.



### Function

Two springs with different thicknesses are integrated in the injector holder. The springs have been adapted in such a way that the injector needle is only lifted against the force of the first spring when injection starts. A small quantity of fuel is pre-injected through the small gap which appears at low pressure.

This pre-injection cycle produces a gentle rise in the combustion pressure and creates the conditions for igniting the main fuel quantity.

As the injection pump delivers more fuel than can actually flow through the small gap, the pressure in the injector rises. The force of the second spring is overcome, and the injector needle is lifted further. The main injection cycle now follows at a higher injection pressure.

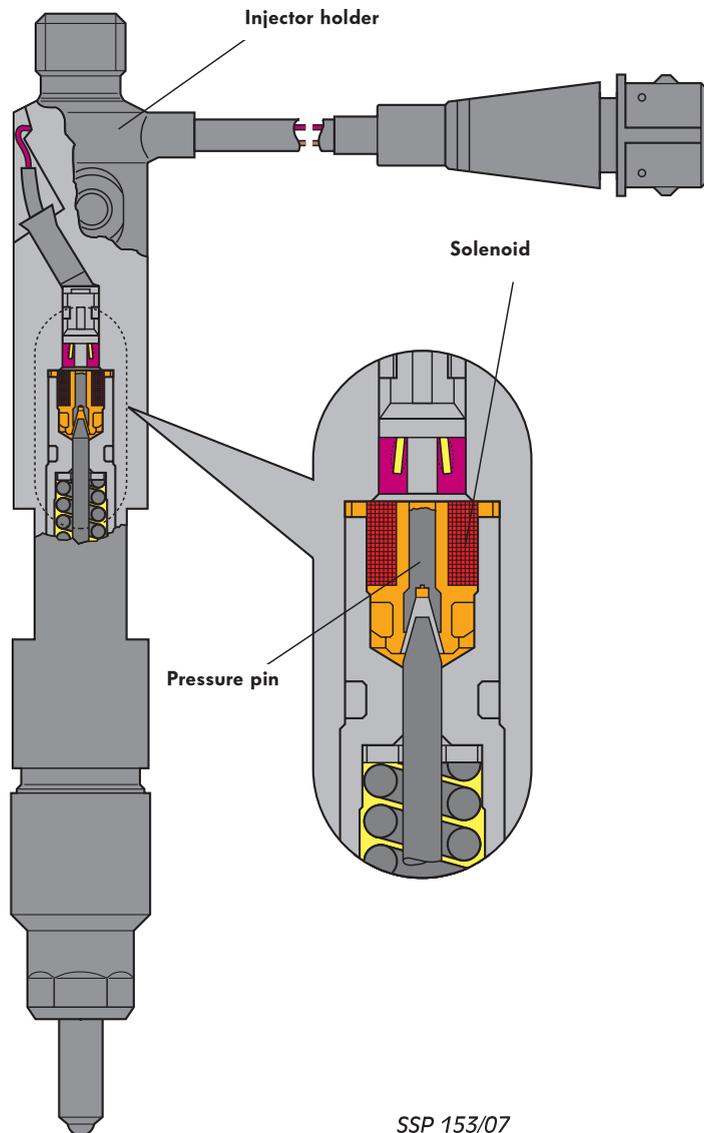
Injector needle

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# Needle Lift Sender

The injector of the 3rd cylinder is equipped with a needle lift sender (G80) for registering the point of commencement of injection.

The sender signals the actual opening time of the injector to the control unit. This signal provides the control unit with feedback on whether the point of commencement of fuel injection conforms to the map.



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## Function

Needle lift sender G80 is a solenoid and is supplied with a constant current by the control unit. This produces a magnetic field.

A pressure pin inside the solenoid forms an extension to the end of the injector needle. The movement of the injector needle alters the magnetic field and causes distortion of the DC voltage applied to the solenoid.

The control unit calculates the actual point of commencement of fuel injection from the time difference between the needle lift pulse and the TDC signal supplied by the engine speed sender. At the same time, the system compares the actual point of commencement of injection with the setpoint stored in the control unit and corrects any deviations from the setpoint.

## Substitute function

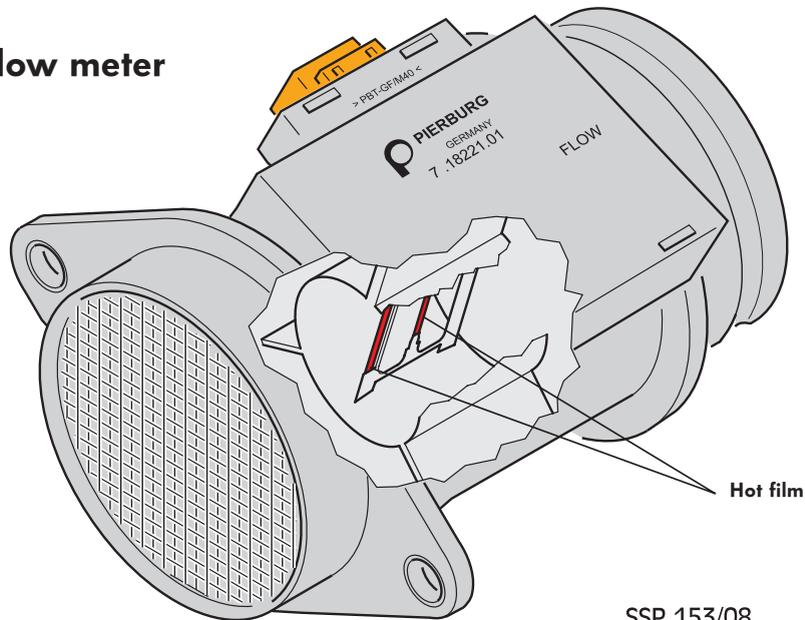
If the needle lift sender fails, an emergency running program is started. In this program, the commencement of fuel injection is controlled according to fixed setpoints as defined in a map. The injection quantity reduced in addition.

# Air-mass flow meter

The task of the air-mass flow meter is to measure the fresh air mass supplied to the engine.

This fresh air mass is used to calculate the exhaust gas recirculation rate and the permissible injection quantity.

## Air-mass flow meter



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## Function

A heated surface, the hot film, is regulated to a constant temperature.

The intake air cools the hot film as it flows past.

The current serves as a measure of the intake air mass necessary to keep the temperature of the hot film constant.

## Substitute function

If the air-mass flow meter fails, the control unit defaults a fixed air mass value.

This fixed value is calculated such that a reduction in engine performance can only occur in the part-throttle range.

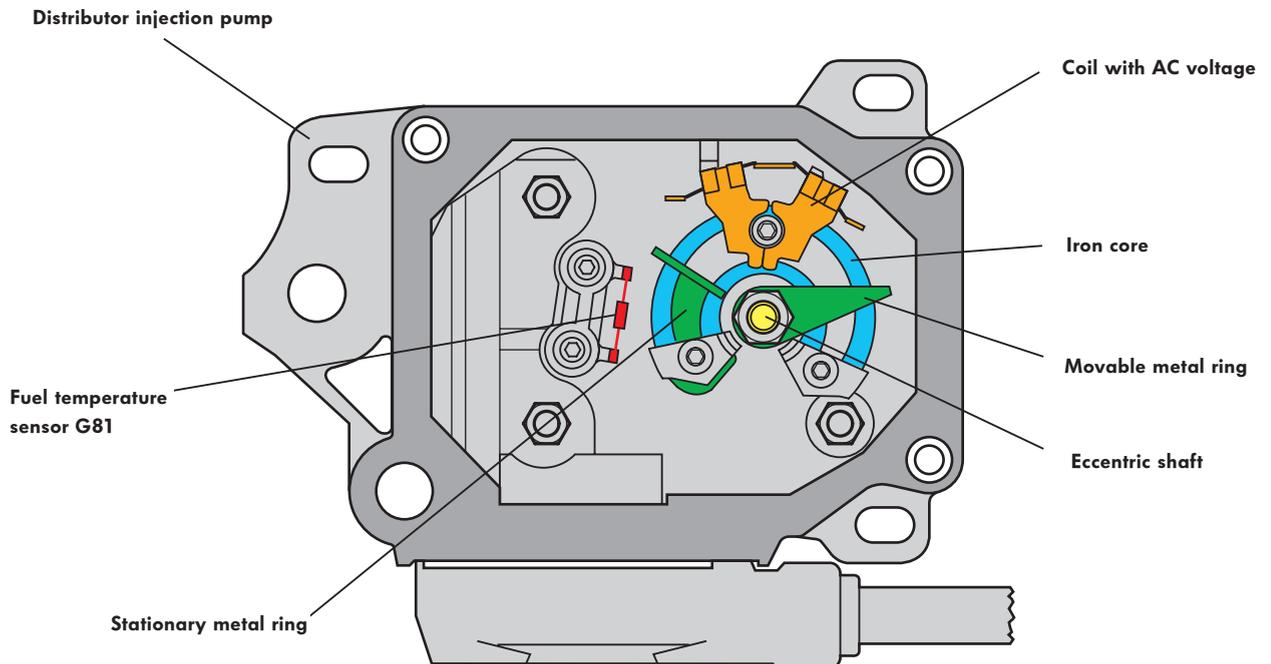
## Advantages of hot-film air mass metering

- Air-mass data can be acquired without additional air pressure and temperature sensors
- Reduced flow resistance compared to sensor flap air-flow metering
- It is no longer necessary to burn off the hot wire as in the hot wire air-mass flow meter.

# Modulating Piston Movement Sender

Modulating piston movement sender G149 supplies the control unit with information on the momentary position of the quantity adjuster in the injection pump. The injected fuel quantity is calculated from this information.

Sender G149 is a non-contact sensor for measuring the angle of rotation. It is attached to the eccentric shaft of the quantity adjuster.



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## Function

An alternating magnetic field is produced in a specially shaped iron core by AC voltage. A metal ring attached to the eccentric shaft moves along the iron core and influences this magnetic field. The change in the magnetic field is evaluated electronically in the control unit and indicates the position of the quantity adjuster.

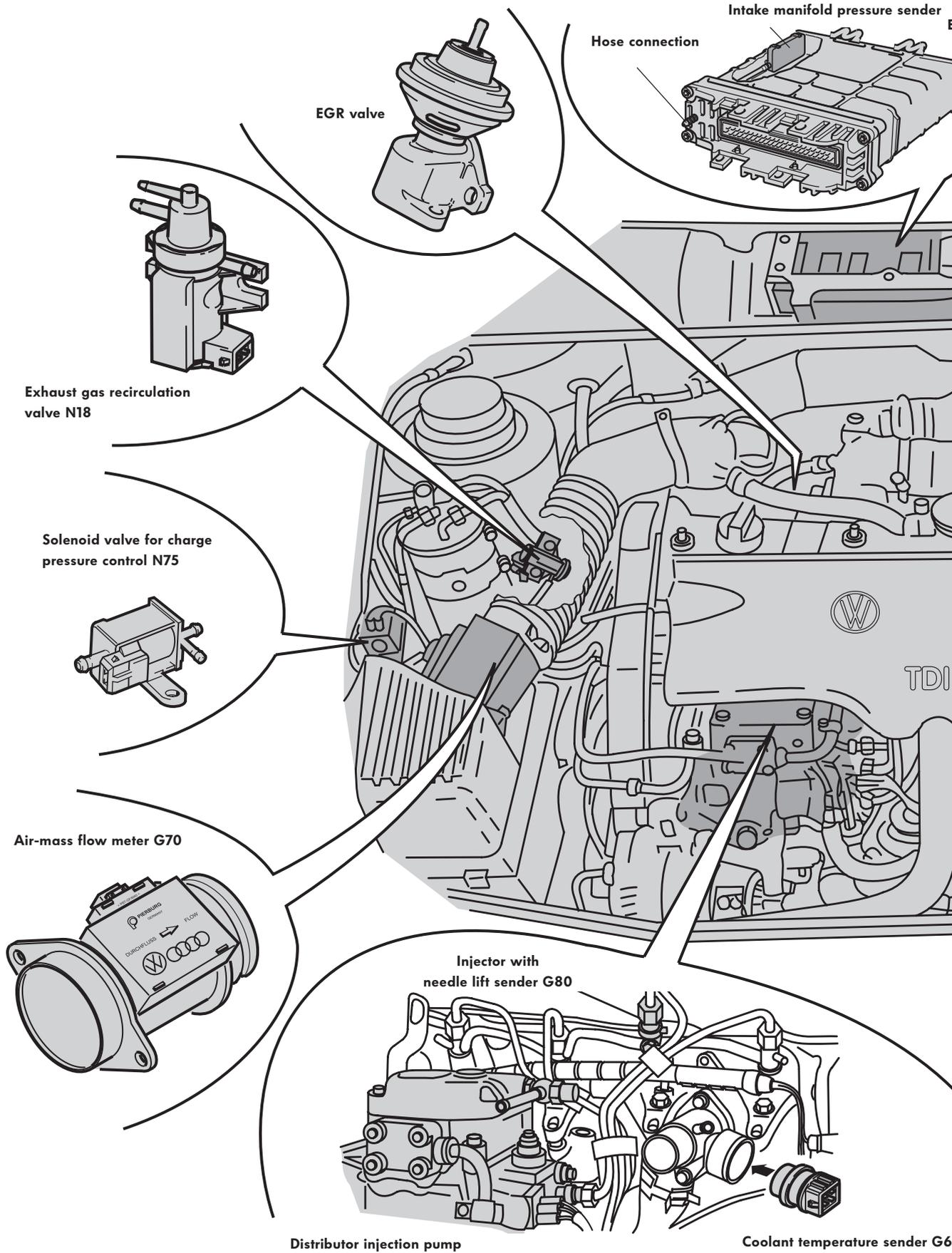
## Substitute function

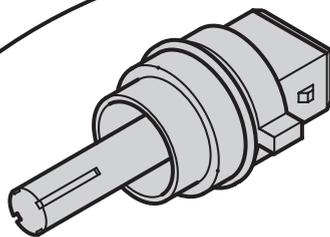
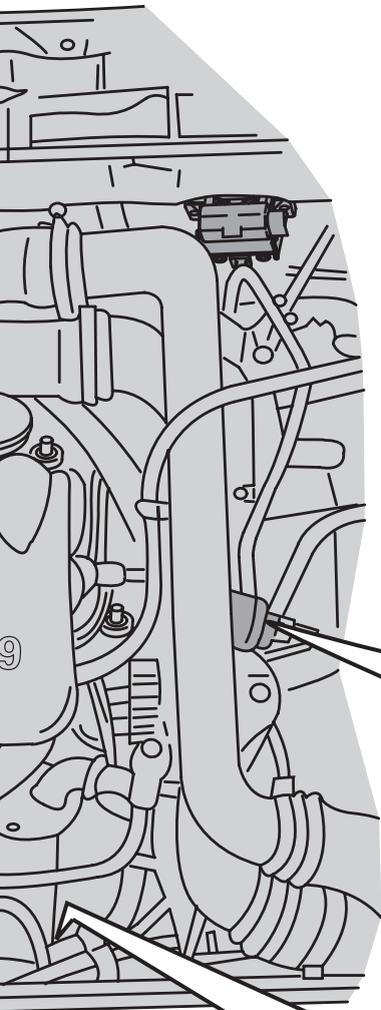
If the control unit does not receive a signal from the sender for modulating piston movement, the engine is turned off for safety reasons.

The new non-contact sender offers the following advantages:

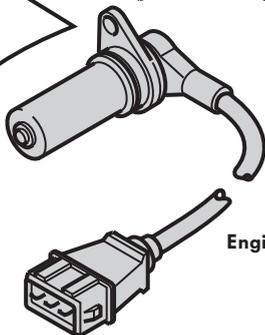
- High wear resistance
- High interference immunity
- Low susceptibility to temperature fluctuation

# Air-mass flow meter





Intake manifold temperature sensor G72

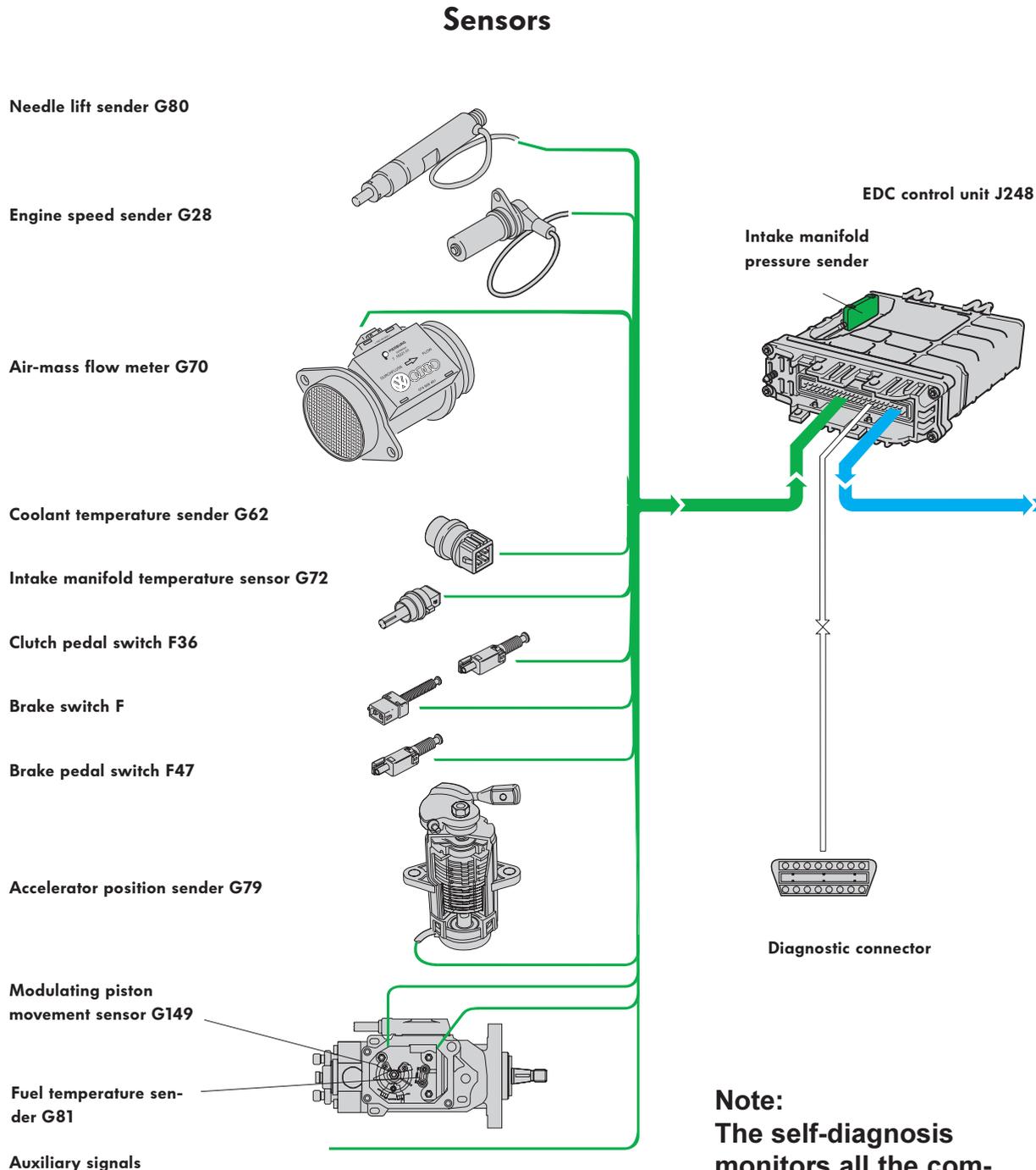


Engine speed sender G28

# System overview

To optimise engine performance with respect to torque delivery, consumption and emission in every operating situation, the EDC control unit refers to 25 maps and characteristic curves.

Sensors supply the control unit with information regarding the vehicle's momentary operating state.



**Note:**  
The self-diagnosis monitors all the components above.

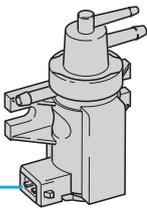
After the information supplied by the sensors has been evaluated, the control unit sends signals to the final control elements (actuators). Injection quantity, commencement of injection, charge pressure and exhaust gas recirculation are monitored and regulated in this way.

The EDC control unit also assumes the tasks of controlling the glow plug system, the auxiliary heater and the cruise control system.

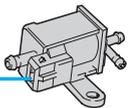
## Actuators



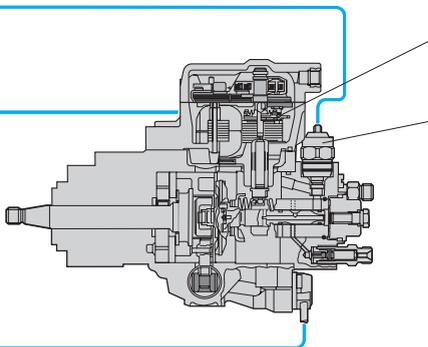
Glow plug warning lamp  
Fault warning lamp K29



Exhaust gas recirculation valve N18



Solenoid valve for charge pressure control N75



quantity adjuster N146

Fuel cut off valve N109

Commencement of injection valve N108

Auxiliary signals

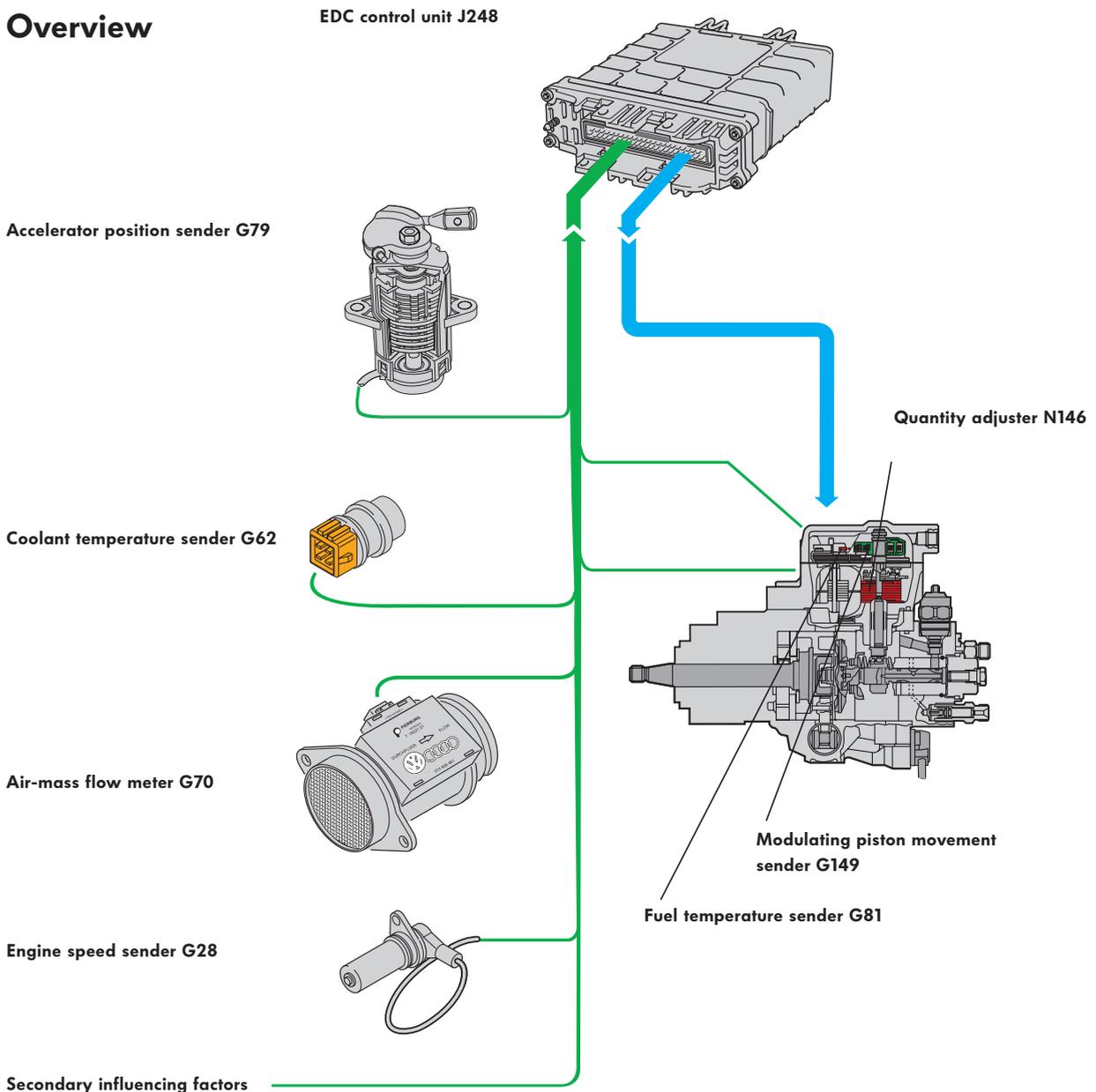
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# Fuel regulation

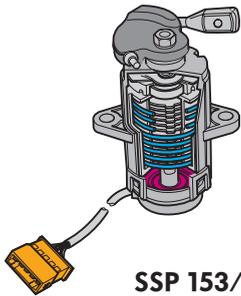
The 1.9-ltr. TDI engine meters the fuel quantity electronically. The correct quantity is determined in the EDC control unit using the sensor information as detailed below, and a signal is sent to the quantity adjuster N146 in the injection pump. There is no mechanical link between the accelerator pedal and the injection pump.

To avoid black exhaust, the injection quantity is limited via a smoke characteristic curve in order to avoid black smoke.

## Overview



## Main influencing factors

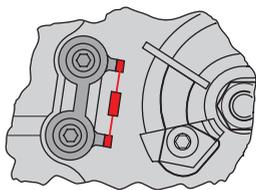


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### Pedal position determined by G79

A decisive factor for the injection quantity is the accelerator pedal position, i.e. the driver input.

The accelerator position sender is a sliding contact potentiometer and includes an idling switch and a kick-down switch (refer to Function Diagram). From these signals, the control unit calculates the necessary fuel quantity using additional parameters.

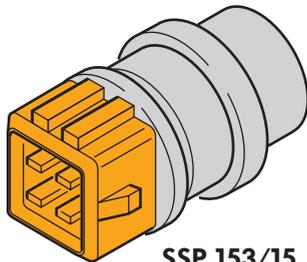


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### Substitute function

If a fault occurs, the engine runs at a higher idling speed so that the customer can reach the next workshop.

The accelerator position sender is then deactivated.



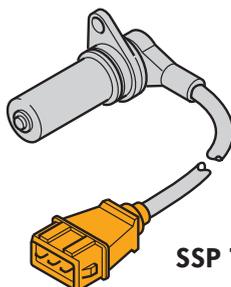
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### Fuel temperature as determined by G81 and coolant temperature determined by G62

The control unit calculates the quantity of fuel to be injected. To make a precise calculation, allowance must be made for the coolant temperature and the density of the diesel fuel. The temperature of the fuel is therefore determined.

Substitute function for G81 and G62

If one of these signals is missing, or both, the coolant and fuel temperatures are calculated with stored substitute values.



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### Engine speed as determined by G28

The engine speed is one of the main factors which the control unit processes in order to calculate the injection quantity.

### Substitute function

If the engine speed sender is faulty, an emergency running program is activated. The needle lift sender G80 supplies a substitute engine speed signal for this purpose.

The injection quantity is reduced, the commencement of fuel injection is controlled and the charge pressure control is switched off during emergency operation.

If the substitute engine speed signal of G80 fails as well, the engine is turned off.

# Fuel regulation

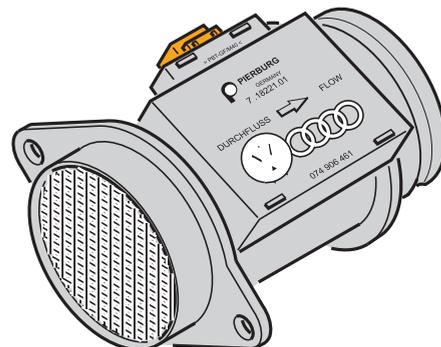
## Main influencing factors

Air mass determined by G70

The air-mass flow meter determines the intake air mass. A smoke map stored in the control unit limits the injection quantity if the induced air mass is too low for smoke-free combustion.

## Substitute function

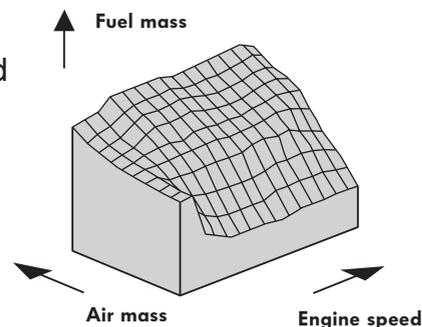
If this signal fails, an emergency program is activated (refer to page 10).



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## Smoke map

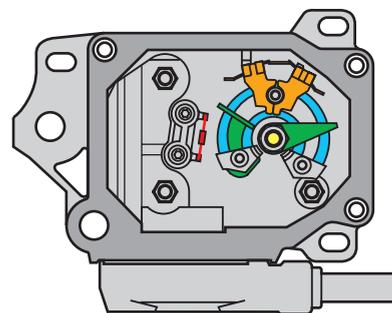
The permissible injection quantity is determined using the smoke map stored in the control unit. If the air mass is too low, the injection quantity is limited to the extent that no black smoke occurs.



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## Modulating piston movement determined by G149

To check the quantity adjuster and to calculate the fuel quantity, the control unit requires feedback on the actual quantity of fuel injected. Sender G149 is permanently linked to the eccentric shaft of the quantity adjuster. It signals the position of the shaft to the control unit, and thus the exact position of the modulating piston.



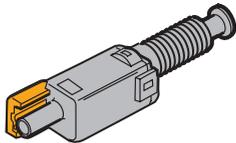
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## Substitute function

If the sender fails, the engine is turned off for safety reasons.

## Secondary influencing factors ( as required)

### Clutch pedal position determined by F36

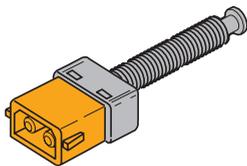


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Engine shudder suppression is a convenience function of the quantity control. To suppress engine shudder, the control unit needs to know whether the clutch is engaged or disengaged.

When the clutch is engaged, the injection quantity is briefly reduced.

### Brake pedal position determined by F and F47



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The switch supplies the "brake actuated" signal (redundant system) for safety reasons.

This is monitored by the control unit. In addition, the two switches use these signals to check the accelerator position sender (plausibility).

This prevents the brake being applied at full throttle for example.

#### Substitute function

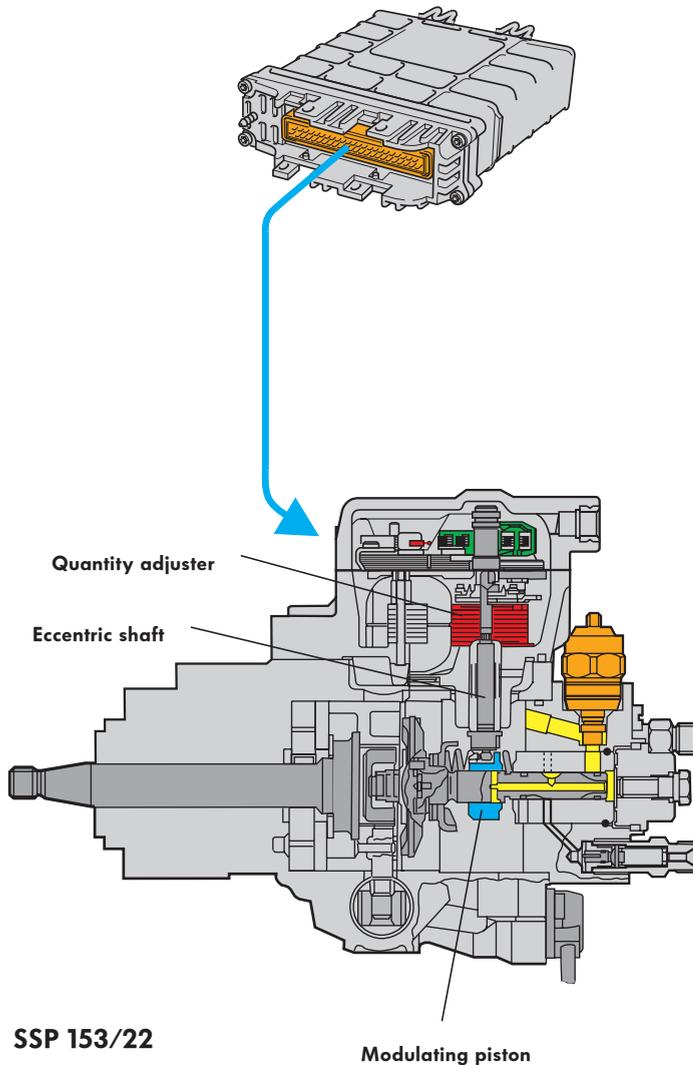
If one of the two switches fails or if the switches are not set identically, the system activates an emergency running program which intervenes in fuel regulation.

**Note:** The two switches must be set in such a way that their shift points are identical.

A precise adjustment according to the Workshop Manual is therefore necessary.

# Fuel quantity control

## Function



## EDC control unit

The EDC control unit processes the incoming information. From this, it calculates the necessary injection quantity and sends control signals to the quantity adjuster.

## Quantity adjuster N146

The quantity adjuster is integrated in the distributor injection pump. The task of the quantity adjuster is to generate the correct injection quantity from the control signals.

The quantity adjuster is a solenoid, a type of electric motor which adjusts the position of the modulating piston via an eccentric shaft and thus regulates the fuel quantity continuously from zero to max. delivery rate.

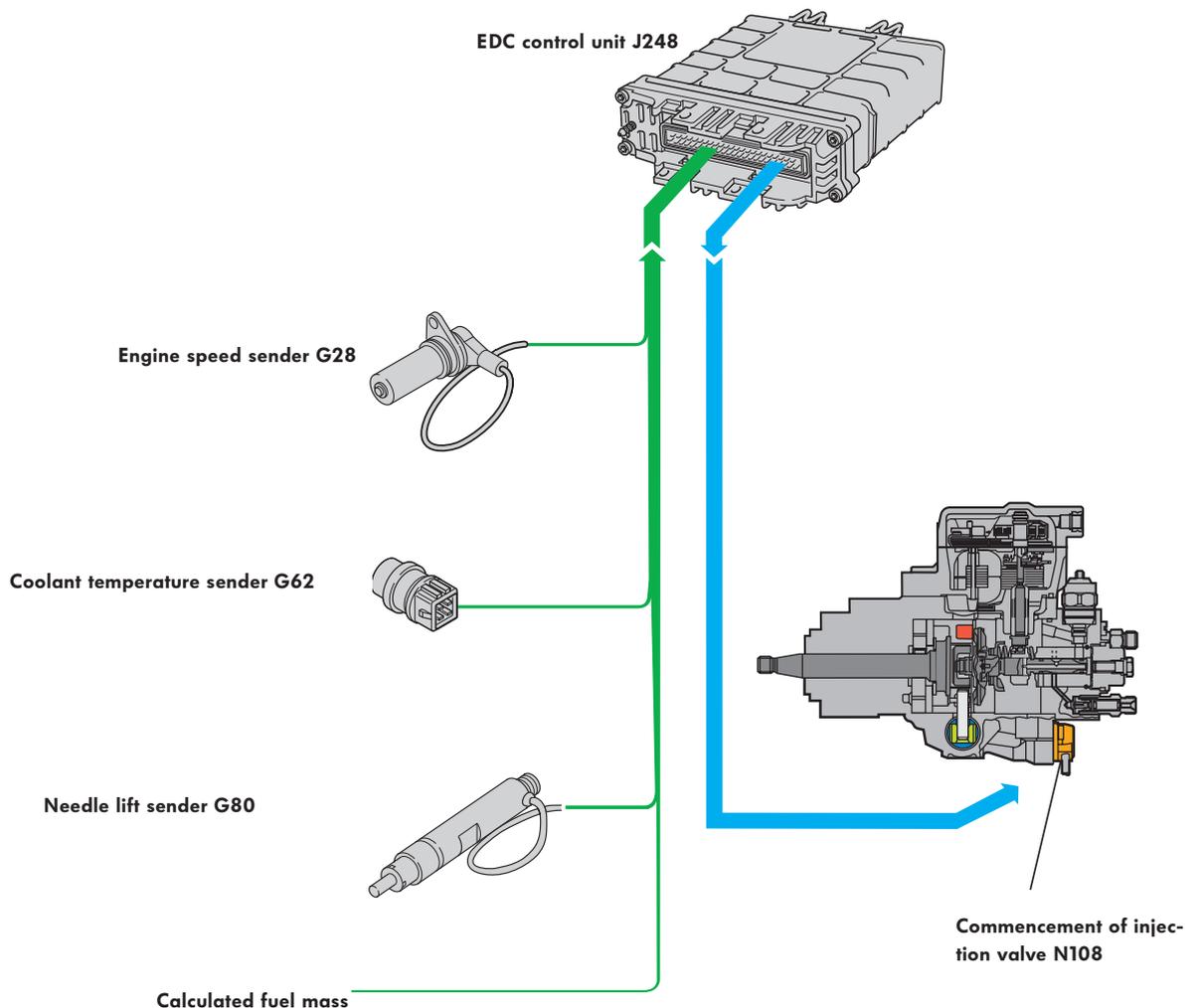
# Injection commencement control

The point of commencement of fuel injection influences various engine characteristics, such as starting response, fuel consumption and finally, exhaust emissions.

The task of the injection commencement control is to determine the correct point in time for fuel delivery.

The EDC control unit calculates the commencement of injection depending on the influencing factors as detailed below, and issues the corresponding output command to the commencement of injection valve N108 in the injection pump.

## Overview



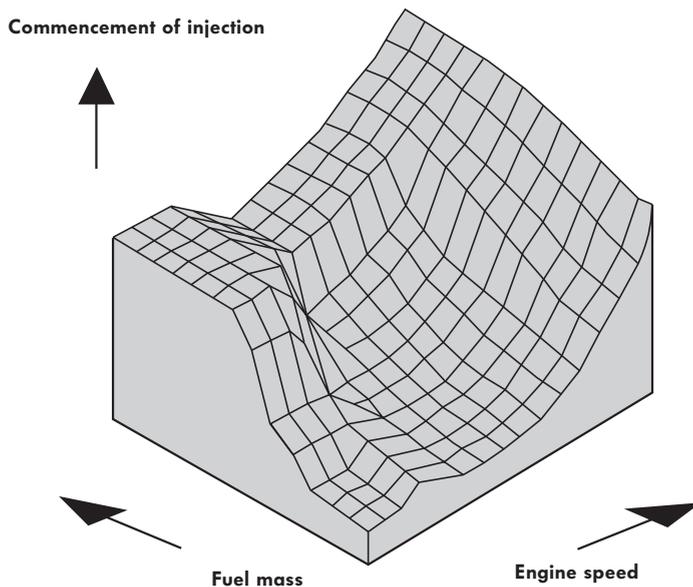
# Injection commencement control

## Influencing factors

### Commencement of injection map

A commencement of injection map is stored in the control unit. It essentially makes allowance for the engine speed and the fuel quantity to be injected. As a correcting parameter, the coolant temperature also has a bearing on the commencement of injection.

The map was determined empirically and represents an optimal compromise between good running characteristics and emission behaviour.



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### Calculated fuel mass

The point of commencement of injection must be brought forward with increasing injection quantity and engine speed because the injection cycle takes longer. The fuel mass to be injected was calculated by the control unit (refer to chapter "Fuel regulation").

This theoretical value is used in the commencement of injection map.

## TDC signal and engine speed determined by G28

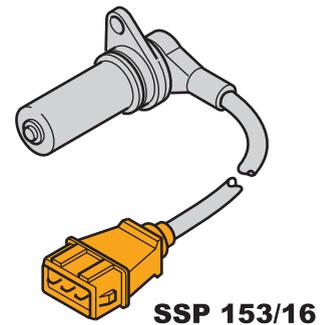
The engine speed sender, in co-operation with the sender wheel on the crankshaft, supplies a TDC signal to the control unit for each cylinder.

### Substitute function

If engine speed sender G28 is defective, the system activates an emergency running program for which needle lift sender G80 supplies a substitute engine speed signal.

In emergency running mode, commencement of fuel injection is controlled in an open loop only (as opposed to a closed control loop), injection quantity is reduced and the charge pressure control is switched off.

If the substitute engine speed signal also fails, the engine is turned off.



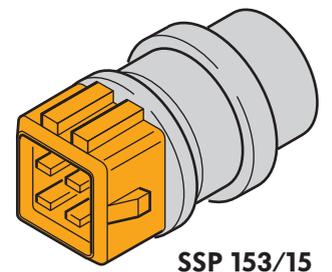
## Coolant temperature as determined by G62

To compensate for the longer firing delay when the engine is cold, the injection cycle must be advanced.

The temperature signal corrects the map accordingly.

### Substitute function

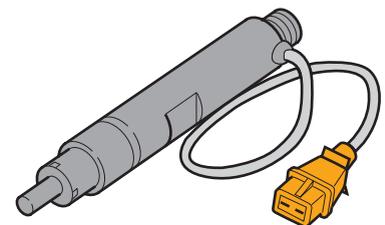
If the temperature sender fails, a fixed coolant temperature is defaulted.



## Point of commencement of injection determined by G80

From the signal supplied by the needle lift sender, the control unit recognises the actual point of commencement of fuel injection and compares this with the setpoint as defined in the commencement of injection map.

If deviations from the setpoint occur, the point of commencement of injection is corrected via valve N108.



### Substitute function

If the signal is missing, no feedback is provided regarding the commencement of injection. The system activates an emergency running program in which the commencement of injection is only just controlled. The injection quantity is limited at the same time.

# Injection commencement control

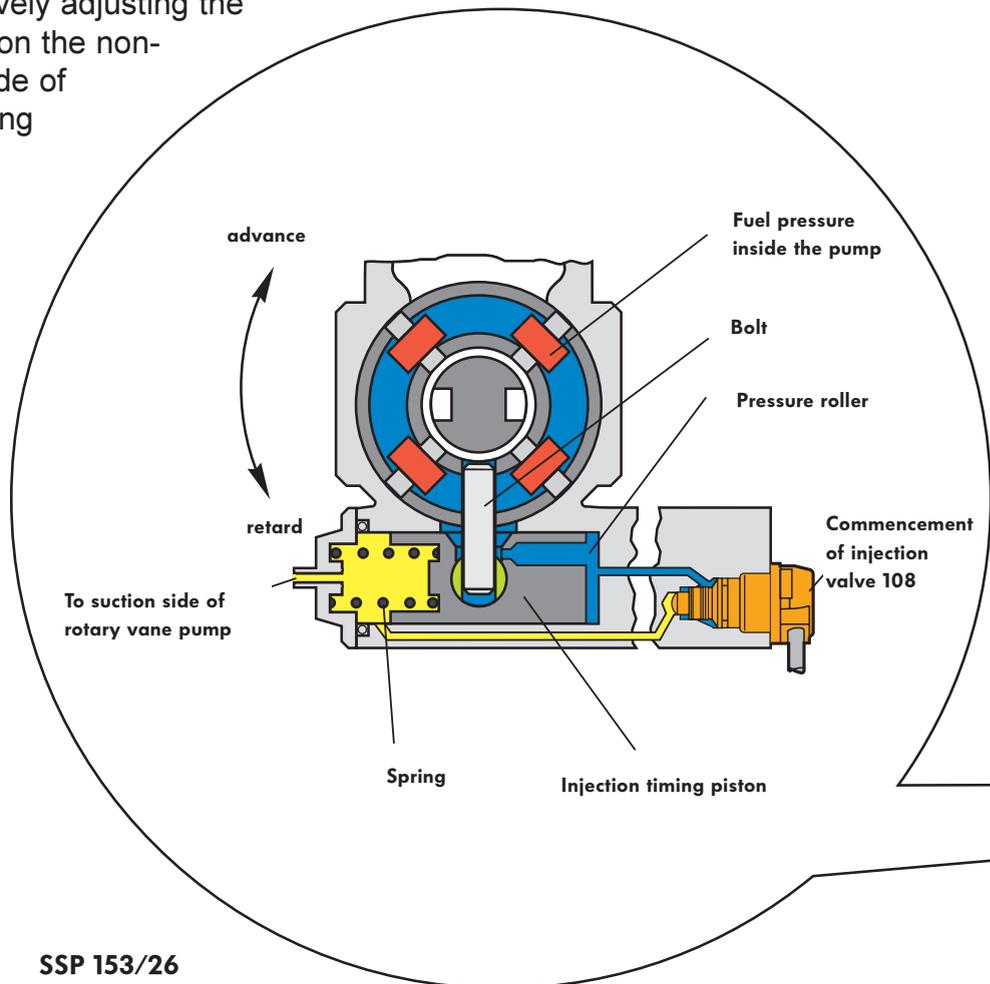
## Injection timing device (schematic diagram)

To provide a better overview, the commencement of injection valve N108 is shown here rotated through 90°. The diagram shows the point of commencement of fuel injection adjusted towards "advance".

The mechanical injection timing device in the distributor injection pump operates using the speed-dependent fuel pressure inside the pump.

The injection timing devices works by selectively adjusting the pressure acting on the non-spring-loaded side of the injection timing piston.

The pressure is adjusted by means of



defined pulse  
duty factors

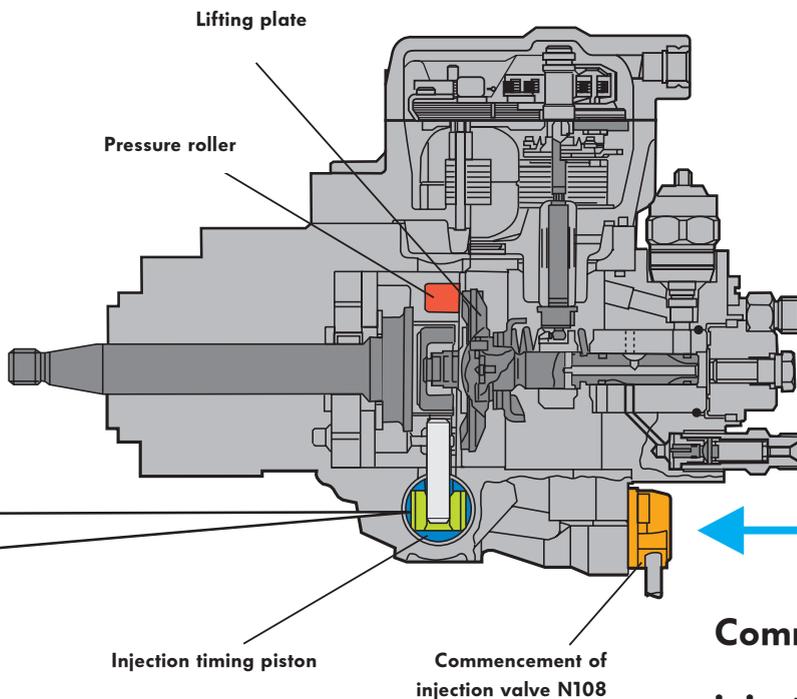
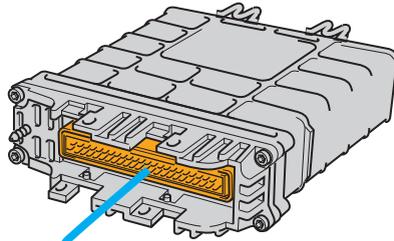
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which are used to control commencement of injection valve N108, i.e. an exact point of commencement of fuel injection is assigned to each pulse duty factor.

In this way it is possible to continuously regulate the point of commencement of fuel injection between max. advance and max. retard.

## EDC control unit

From the incoming values, the EDC control unit calculates the setpoint for injection commencement and sends a corresponding pulse duty factor to commencement of injection valve N108.



## Commencement of

## injection valve N108

The valve converts the pulse duty factor into a change in control pressure which acts on the non-spring-loaded side of the injection timing piston.

## Substitute function for N108

If the valve fails, the point of commencement of injection is no longer regulated. Instead it is permanently defaulted.

# Exhaust gas recirculation

The exhaust gas recirculation (EGR) system is designed to reduce pollutant emissions in the exhaust gas.

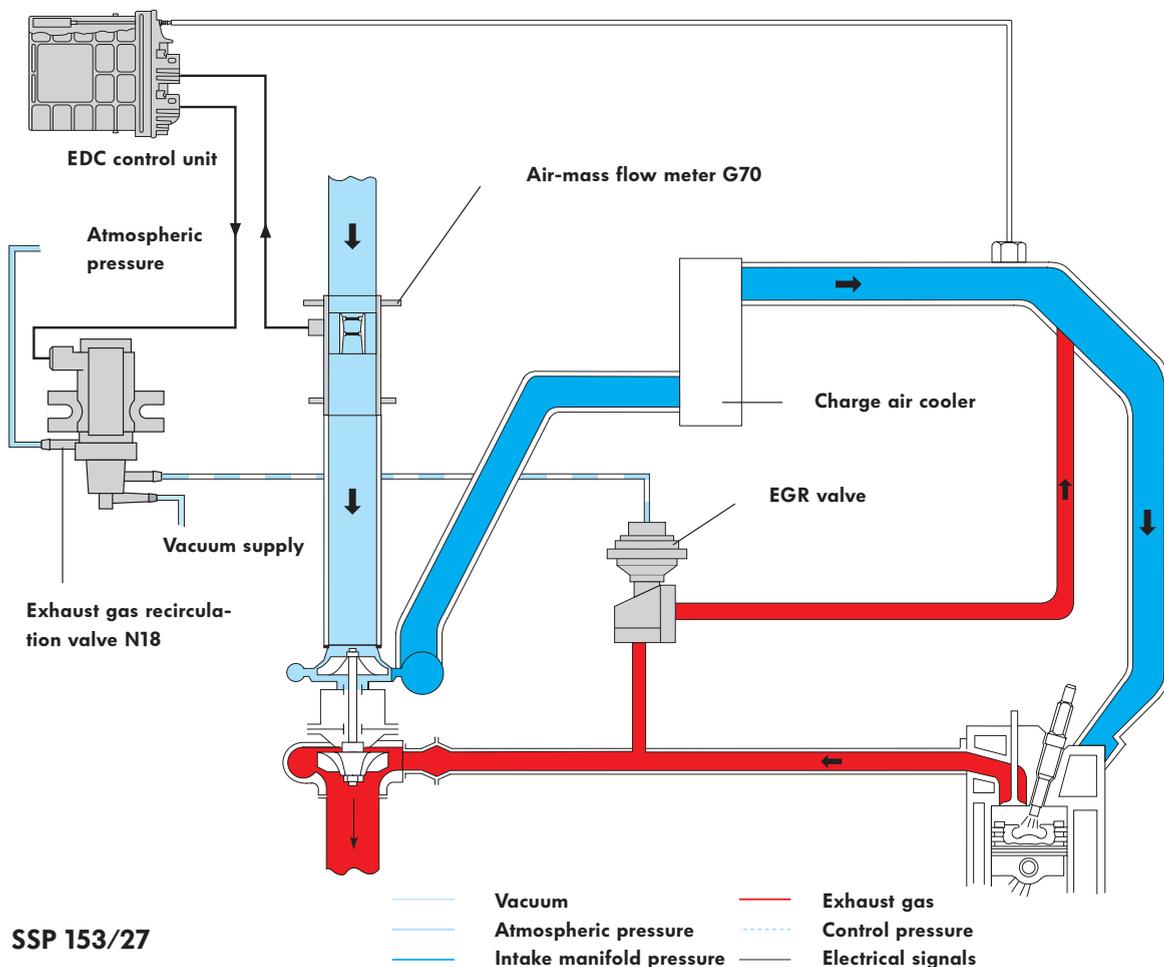
The direct injection process uses higher combustion temperatures than the chamber process. The formation of nitrogen oxides (NO<sub>x</sub>) increases with higher temperatures, provided that sufficient excess air is available.

The EGR valve adds a fraction of the exhaust gases to the fresh air supplied to the engine.

This reduces the oxygen content in the combustion chamber and slows down NO<sub>x</sub> formation.

The exhaust gas recirculation rates are, however, limited by a rise in hydrocarbon (HC), carbon dioxide (CO) and particle emissions.

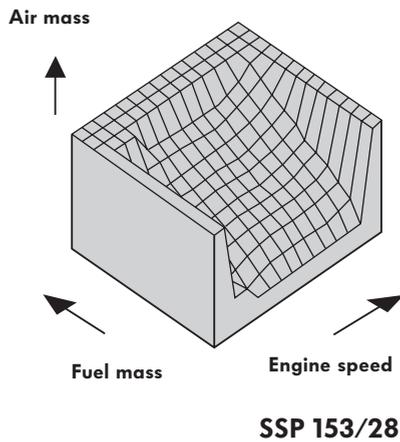
## Regulation of exhaust gas recirculation (schematic diagram)



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# Fuel regulation

## Function



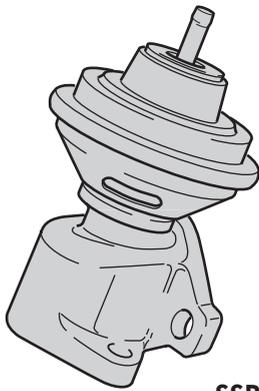
## EGR map

An EGR map is stored in the control unit. It contains the necessary air mass for every operating point of the engine; this is dependent on engine speed, injection quantity and engine temperature.

The control unit recognises from the air-mass flow meter signal whether the intake air mass is too high for the vehicle in its momentary operating state.

To compensate for any deviation, more exhaust gas is supplied as required.

If the supplied exhaust gas quantity is too high, the intake air mass decreases. The control unit then reduces the proportion of the exhaust gases.

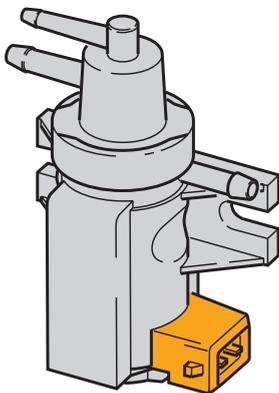


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## EGR valve

The EGR valve is mounted in a connecting duct between the exhaust gas and the intake pipe.

When the valve is subjected to a vacuum, it opens and allows exhaust gas to enter the fresh air flow.



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## Exhaust gas recirculation valve N18

Valve N18 converts the signals supplied by the control units into a control vacuum for the EGR valve.

It is supplied by the engine's vacuum pump and is opened by signals from the control unit. The pulse duty factor of these signals defines the vacuum which is admitted to the EGR valve.

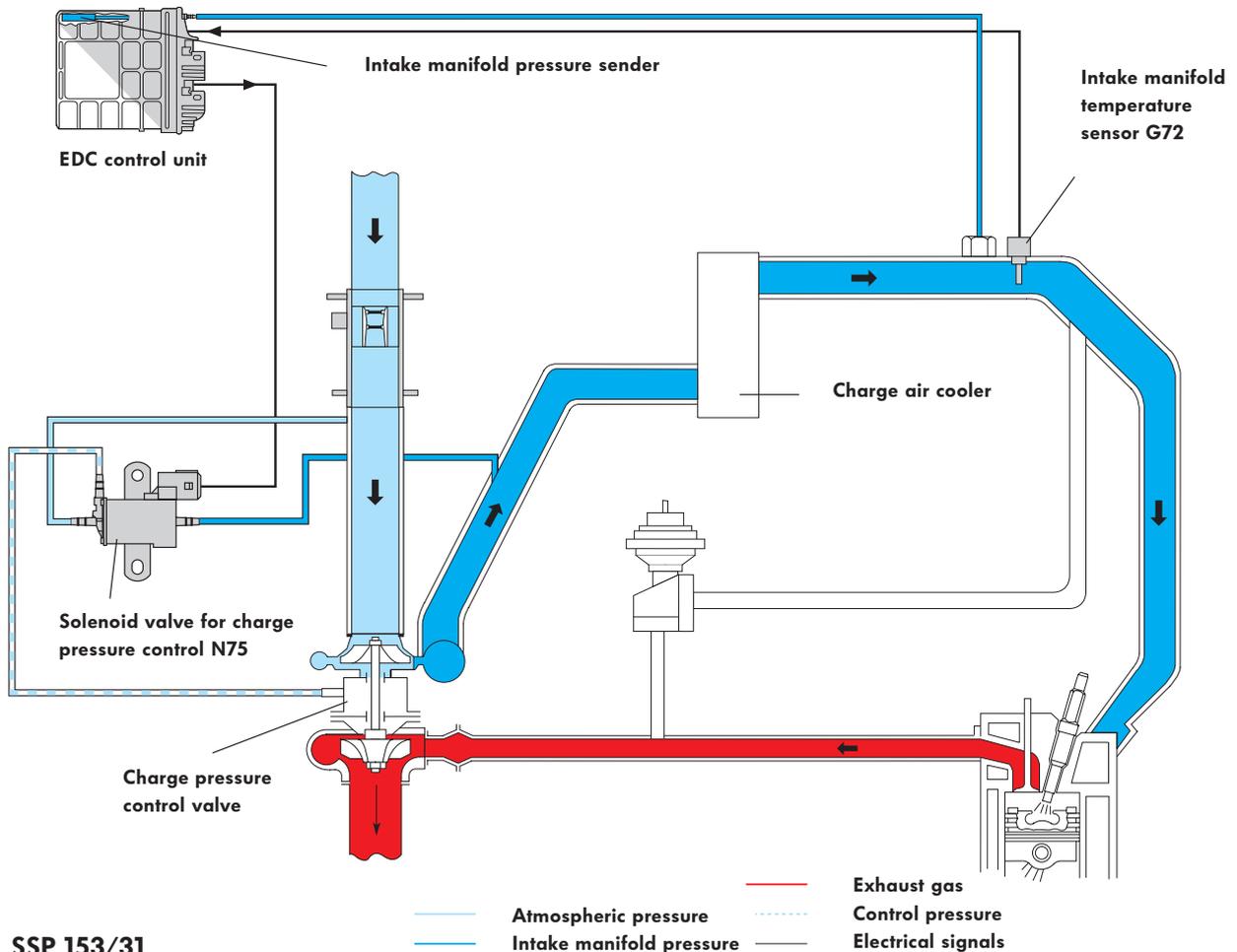
# Charge pressure control

The solenoid valve for charge pressure control N75 applies pressure to the charge pressure control valve on the exhaust gas turbocharger (waste gate). Valve N75 receives electrical signals (pulse duty factor) from the EDC control unit. Charge pressure is thus regulated according to a characteristic map.

Feedback on the actual pressure in the intake pipe is provided along a hose connection routed from the intake pipe to a sensor in the control unit. If a deviation from the setpoint occurs, the pressure is corrected accordingly. The charge pressure is also corrected in the control unit by the intake pipe temperature to make allowance for the effect of temperature on the density of the charge air.

To ensure that the air mass supplied to the engine stays almost constant, the charge pressure specified map is corrected in dependence on the air pressure using the information supplied by the altitude sender F96. The charge pressure is reduced above an altitude of approx. 1500 m to prevent the turbocharger overspeeding in excessively thin air.

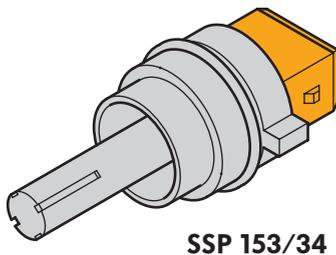
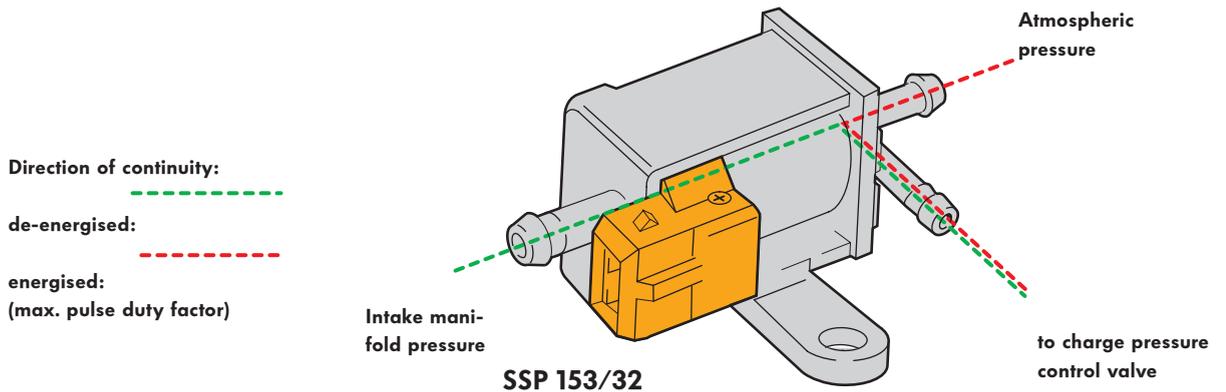
## Charge pressure control (schematic diagram)



## Solenoid valve for charge pressure control N75

The EDC control unit sends output signals to the solenoid valve for charge pressure control N75 according to the charge pressure specified map. By changing the signal pulse duty factor, more or less intake manifold pressure is applied to the charge pressure control valve on the exhaust gas turbocharger.

The charge pressure can thus be varied between the minimum and maximum permissible values.



## Intake manifold temperature sender G72

The charge pressure is also corrected in the control unit by the intake pipe temperature to make allowance for the effect of temperature on the density of the charge air.

# Glow plug system

A glow plug controller is integrated in the EDC control unit of the 1.9-ltr. TDI engine. This process is divided into the following phases:

- **Glow phase**
- **Afterglow phase**

## Glow phase

Thanks to the good starting response of this direct injection diesel engine, a glow phase is only necessary below + 9°C. The control unit receives the corresponding temperature signal from coolant temperature sender G62.

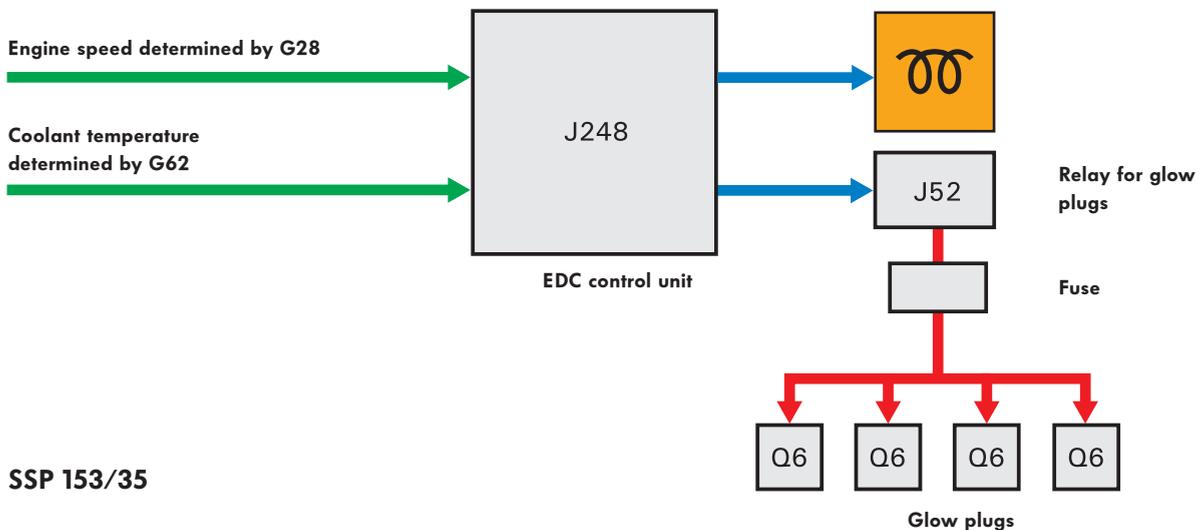
The duration of the glow period is dependent on the size of this temperature signal. The warning lamp for glow period K29 on the instrument panel indicates to the driver when the glow phase is in progress.

**Please note:** The warning lamp for glow period has dual functions. If it comes on during vehicle operation, it serves as a fault warning lamp and provides the driver with information regarding a fault in the engine management system.

## Afterglow phase

The glow phase follows the afterglow phase after starting the engine. This improves combustion efficiency shortly after the engine is started, and dampens engine noise, improves idling quality and reduces hydrocarbon emissions.

The afterglow phase always takes place irrespective of glow phase. The afterglow phase is interrupted at an engine speed of 2,500 rpm.



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# Emission characteristics

Minimising environmental pollution demands a great deal of co-ordination and design work. This frequently involves reconciling conflicting demands such as low nitrogen oxide emission and high engine performance. The 1.9-ltr. TDI engine easily achieves the 1998 EU exhaust emission limits and offers high fuel efficiency at the same time.

## Pollutants in the exhaust gas

The pollutants which mainly occur in the exhaust gases of diesel engines are

- carbon dioxide (CO)
- gaseous hydrocarbons (HC)
- particles
- nitrogen oxides (NO<sub>x</sub>).

Other noxious components such as sulphur hydrides also occur in smaller quantities.

Carbon dioxide, particles and hydrocarbons in exhaust gas are primarily due to incomplete combustion of the fuel.

Nitrogen oxides - chemical compounds of oxygen and nitrogen - form at high combustion chamber temperatures, provided that sufficient excess air is available.

## Pollution control

The proportion of nitrogen oxides (NO<sub>x</sub>) normally increases due to the measures to reduce particle and HC formation. Reducing nitrogen oxide emission means accepting higher emissions of other exhaust gas constituents, and possibly even higher fuel consumption. It is also necessary to find the best possible compromise.

The components involved in the combustion process, e.g. injectors, piston recess, combustion chamber shape, etc, were designed with a view to minimising exhaust emissions in particular.

The complete engine management system has been adapted in such a way as to optimise the combustion process.

Above all the point of commencement of injection and the exhaust gas recirculation affect the composition of the exhaust gas.

## **Effect of the point of commencement of injection**

To reduce the proportion of nitrogen oxides in the exhaust gas, the injection cycle commences slightly later than would otherwise be necessary to develop maximum power output. This causes an increase in HC and particle formation. Fuel consumption increases by approx. 4% because of the delay in commencement of the injection cycle.

## **Effect of the exhaust gas recirculation**

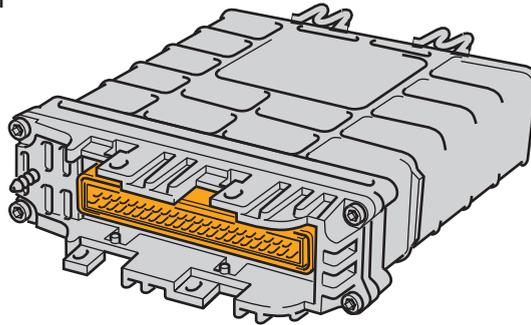
The supply of exhaust gases to the combustion chamber reduces the oxygen component in the combustion chamber.

This reduces the emission of nitrogen oxides, but it increases particle emission in certain operating states.

The addition of the recirculated exhaust gas quantity is therefore adapted precisely.

# Internal functions in the control unit

In the control unit, several auxiliary functions take place continuously during vehicle operation



## Idling speed control

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From the engine speed signal, which is supplied 4 times per revolution, the control unit recognises deviations from the set idling speed at an early stage. The quantity adjuster in the injection pump then receives a signal immediately. The idling speed is thus kept constant in every operating state, e.g. when electrical current consumers are switched on.

## Even running control

To ensure the engine runs very evenly, the injection quantity of every cylinder is regulated in such a way that the engine speed signal is uniform.

## Shudder damping

To avoid shudder, which occurs when marked load changes occur, the information regarding the accelerator pedal position is electronically "damped" when the pedal is moved too quickly.

## Maximum speed cut off

When the maximum engine speed is reached, the control unit reduces the injection quantity to protect the engine against overspeeding.

## Starting quantity regulation

The injection quantity necessary for starting the engine is dependent on the coolant temperature. The control unit determines the correct quantity to keep the exhaust emissions low.

## Signal monitoring

The control unit monitors itself and the functions of sensors and actuators during vehicle operation. The glow plug warning lamp indicates when major faults occur.

# Self-diagnosis

## The self-diagnosis and safety concept of the EDC (Electronic Diesel Control)

The control unit assumes the following functions during vehicle operation:

- It continuously cross-checks the measured values supplied by the sensors for plausibility.
- It monitors the electrical and mechanical functional capability of the final control elements (actuators) by observing system reactions. The self-diagnosis carries out actual value/setpoint comparisons; the results of these comparisons must meet the given requirements (maps).
- The self-diagnosis monitors the electrical connectors and cable connections for cable breakage (open circuit) and short circuit.

If faults occur in the system, the EDC reacts according to the significance of the fault.

Fault detection

- Stage 1: Should any sensors with a correcting function fail, the EDC uses default substitute values or accepts information from other sensors. The actions of this correcting function usually stay unnoticed by the driver.
- Stage 2: Major faults - i.e. faults leading to the failure of subfunctions - result in a reduction in performance, and a warning is issued to the driver via the fault warning lamp.
- Stage 3: If the driver can no longer control engine power output with the accelerator pedal, the EDC switches the engine to high idling speed mode. In this way, servo functions of the vehicle are preserved and vehicle operability is retained.
- Stage 4: If reliable engine operation can no longer be ensured, the quantity adjuster turns the engine off. If this is not possible on account of the fault, the engine is turned off via the fuel cut off valve (redundant system).

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# Performance diagram

## Engine performance and torque

The maximum power output of the new 1.9-ltr. TDI industrial engine is 60 kW (84 bhp) at 3,300 rpm.

The engine is notable for its very good torque curve. Maximum torque is 205 Nm at only 1800 rpm.

