Service Training

Self-study Programme 539

1.0-l 3-cylinder TSI Engine

Design and function

Volkswagen is consistently continuing its downsizing strategy with the new 1.0-litre 3-cylinder TSI engine. This engine will come in different output versions – initially in the Polo (70/81 kW) and in the Golf/Golf Estate (85 kW). It is also planned for the Golf SV, the Caddy and the up!.

S539_002

Over the following pages, we will introduce you to the design and function of the 1.0-l 3-cylinder TSI engine.

You will find further information on this engine in Self-study Programmes no. 508 “The 1.0-l 44/55 kW MPI Engine” and no. 511 “The New EA211 Petrol Engine Family”.

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

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

Important note

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The 1.0-l 3-cylinder TSI engine

The 1.0-l 3-cylinder TSI engine is another engine from the EA211 engine family. The engine mechanics are essentially the same for the two output versions for the Polo described in this book. The only difference is the sodium-filled exhaust valves and a more heat-resistant cast steel housing for the turbocharger in the 81-kW output version.

Technical features

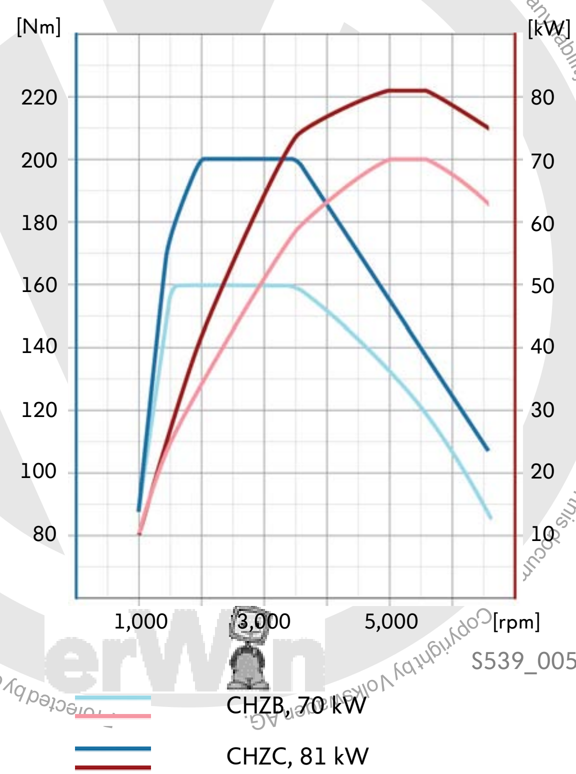
- Direct petrol injection
- Turbocharger with electric charge pressure positioner
- Camshafts driven via a toothed belt
- Cylinder head with integrated exhaust manifold
- Thermostat housing with integrated coolant pump
- Coolant pump driven by the exhaust camshaft via a toothed belt
- Variable inlet valve timing (50°CS)
- Variable exhaust valve timing (40°CS)
- Vane-type oil pump with continuously variable oil pressure control

S539_008

Technical data (Polo)

Engine code	CHZB	CHZC
Type	3-cylinder in-line engine	
Displacement	999 cm^3	
Bore	74.5 mm	
Stroke	76.4 mm	
Valves per cylinder	4	
Compression ratio	10.5:1	
Max. output	70 kW at 5,000–5,500 rpm	81 kW at 5,000–5,500 rpm
Max. torque	160 Nm at 1,500–3,500 rpm	200 Nm at 2,000–3,500 rpm
Engine management system	Bosch Motronic ME 17.5.21	
Fuel	Super unleaded at RON 95 (normal unleaded at RON 91 with slight reduction in performance)	
Exhaust gas treatment	Three-way catalytic converter with one step-type Lambda probe upstream of the catalytic converter and one downstream	
Emission standard	EU6	

Torque and power diagram (Polo)



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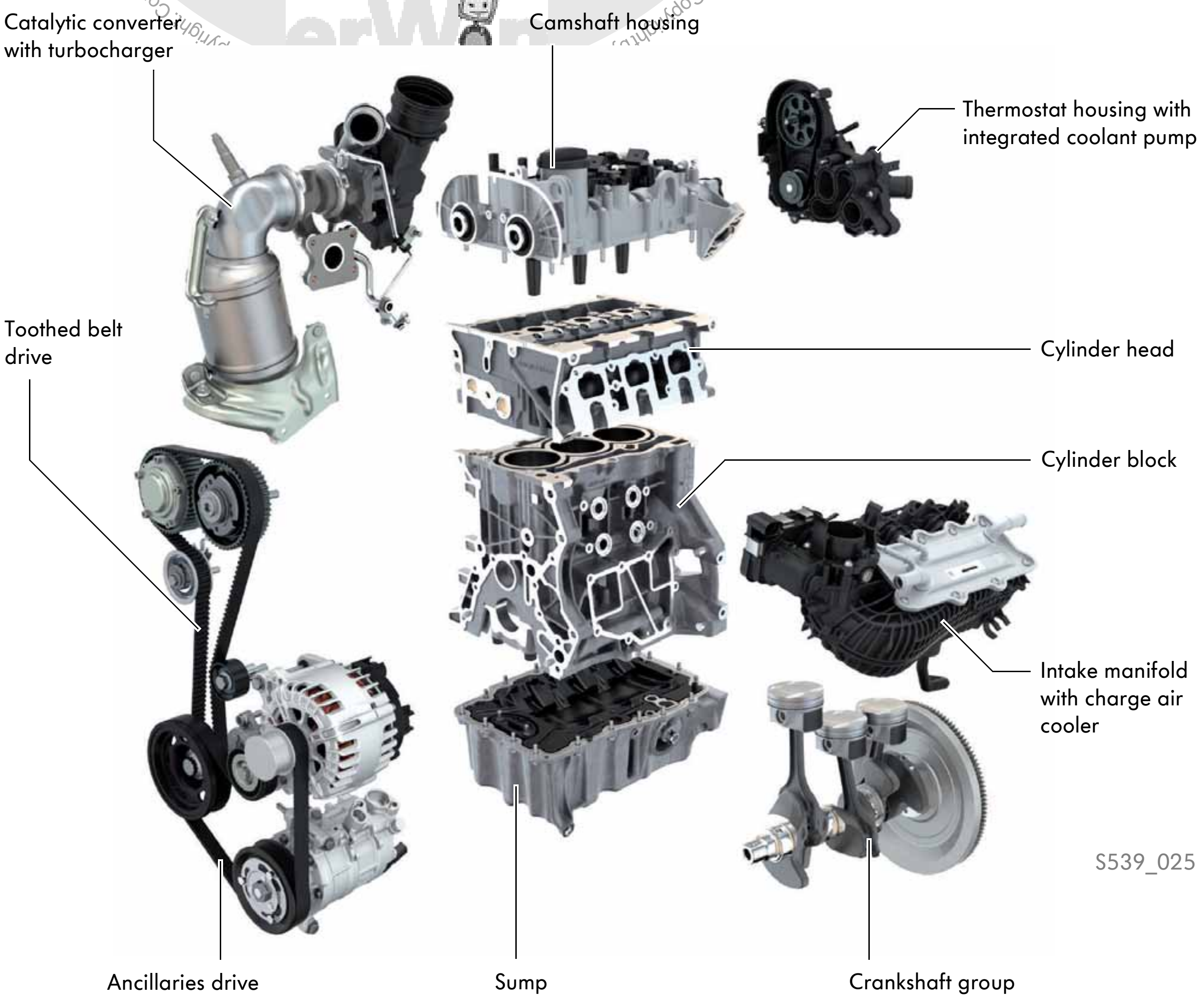
Overview of modular design

Like the other members of the EA211 engine family, this engine also uses a modular design.

The characteristics shared by all engines in the EA211 family are:

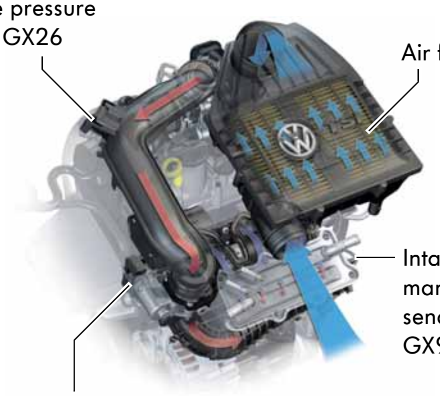
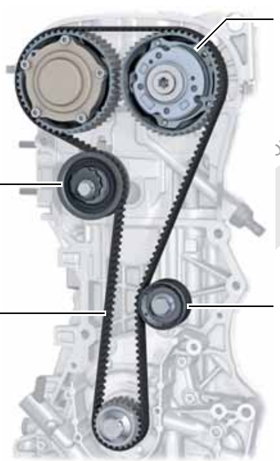
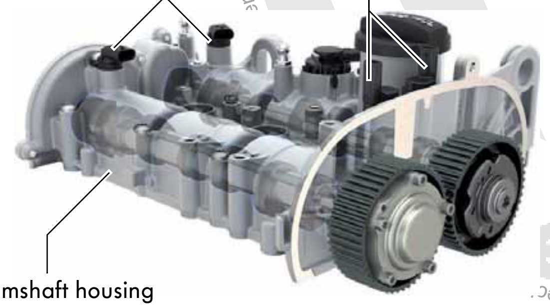
- Same engine mounting position
- Air conditioner compressor and alternator mounted directly on the sump, on the cylinder block and on the oil pump housing without additional brackets
- 4-valve technology
- Aluminium cylinder block
- Cylinder head with integrated exhaust manifold
- Camshafts driven via a toothed belt

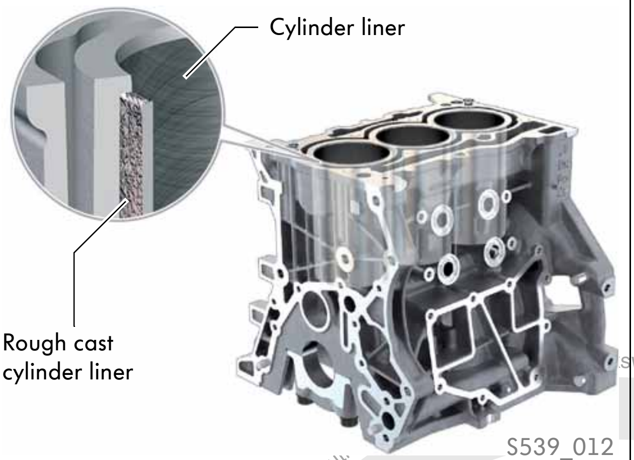
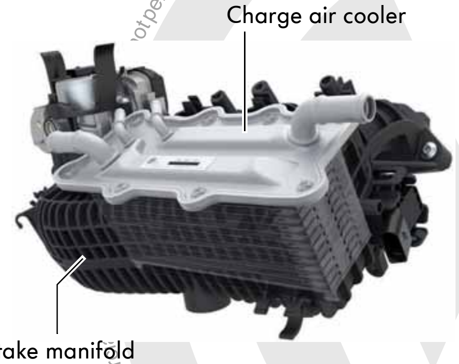
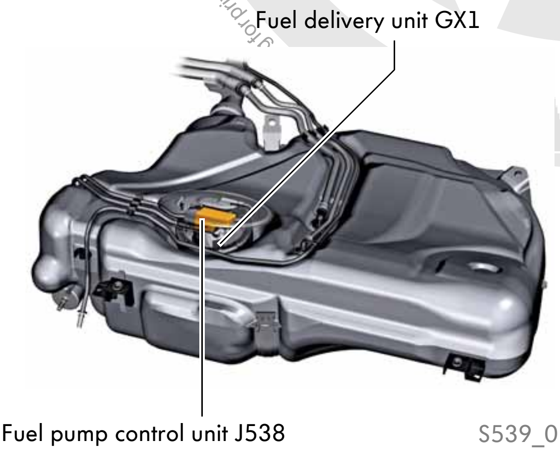
Modular design of 1.0-l 3-cylinder TSI engine



Features of the engine mechanics

The table below provides an overview of the mechanical features.

Component	Features
Intake system  S539_011	The intake system runs from the air filter via the turbocharger, the throttle valve module GX3 and the intake manifold to the inlet valves. The design has been made as compact as possible so that the turbocharger responds even at low revs. Two pressure sensors with intake air temperature senders are fitted in the intake system. They are located in front of the throttle valve module and on the intake manifold behind the charge air cooler.
Toothed belt drive  S539_014	The camshafts are driven by a toothed belt. It is tensioned by an automatic tensioning roller. This roller has contact shoulders to also ensure that the toothed belt is guided correctly. An idler roller on the tension side and tri-oval camshaft pulleys ensure that the toothed belt runs smoothly.
Camshaft housing  S539_013	The camshaft housing is made from die-cast aluminium and, together with the two camshafts, forms an integral module. This means the camshafts, which are mounted in four bearings, cannot be removed. On both camshafts, a grooved ball bearing is used as the first bearing, which is subjected to the highest loading by the toothed belt drive, to reduce friction. Furthermore the camshaft housing is used to mount the camshaft control valves on the inlet side N205 and on the exhaust side N318 as well as the Hall senders G40 and G300.

Component	Features
Aluminium cylinder block  S539_012	The cylinder block is made from die-cast aluminium and has as an open-deck design. A shallow coolant jacket and individually rough-cast cylinder liners ensure a high level of stiffness in the cylinder block. The cylinder liners have been honed with a honing tool to reduce cylinder distortion. This allows the piston ring tension to be decreased and thus reduces friction. Furthermore, the reduced cylinder distortion lowers the oil consumption.
Charge air cooling  S539_010	The charge air cooler is part of the separate charge air cooling system. The air, which is heated greatly during compression, flows through the charge air cooler and transfers a large part of its heat to the charge air cooler and the coolant.
Low-pressure fuel system  S539_015	The low-pressure fuel system without a return line consists of the fuel pump control unit J538, the fuel tank with the fuel delivery unit GX1, the activated charcoal filter with the activated charcoal filter solenoid valve 1 N80 and the fuel lines. The electrical fuel pump is activated by the fuel pump control unit with a pulse-width modulation signal (PWM signal) and delivers the fuel to the high-pressure fuel pump. In normal operation, the fuel pressure is between 2 and 5 bar. During cold or hot starts, the pressure is briefly raised to between 5 and 6 bar depending on the engine temperature.

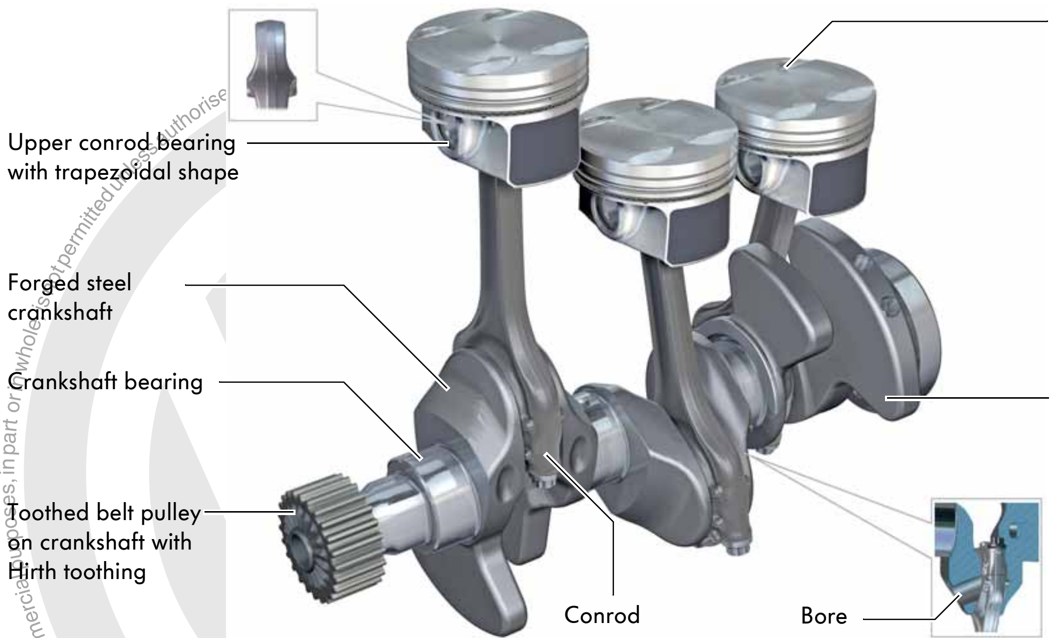
Crankshaft group

The crankshaft group is designed for low, moving masses and low friction. The weight of the forged conrods and the aluminium pistons has been optimised to such an extent that a balance shaft is not required. Together with the small crankshaft bearings (diameter 45 mm) and conrod bearings (diameter 47.1 mm), the weight of the engine and the engine friction have been reduced even further in this way.

Technical features

Pistons, piston rings, piston pins and conrods

- The pistons have a shallow piston bowl. This leads to a lower weight and even temperature distribution on the piston crown.
- The installation tolerance of the piston has been increased and friction has therefore been reduced.
- The piston pins are highly wear-resistant thanks to a special carbon coating. In addition, the surfaces of the small conrod bearings have been smoothed in a so-called rolling process. Thanks to these two measures, a bearing bush is not required in the small conrod bearings.
- The conrods are fracture-split. The small conrod bearing has a trapezoidal design in the area subject to lower loads. This reduces the weight and the friction even further.
- The first crankshaft bearing has a polymer coating to increase wear resistance during start/stop operation.



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Crankshaft

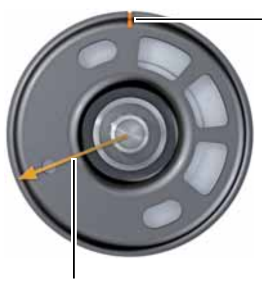
The steel crankshaft, which is mounted in four bearings, has four counterweights that reduce the inner forces of the crankshaft and therefore the load on the crankshaft bearings. The conrod journals are hollow-bored to reduce the weight even further.

Measures to reduce vibrations

The engine already has generally good vibration behaviour thanks to its basic design with a stiff engine structure, light crankshaft group and the installation position perpendicular to the direction of travel.

The vibration damper (specific material reinforcement) and the flywheel (specific drilled holes) have vehicle-specific intentional imbalances to further improve the vibration behaviour of the 3-cylinder engine. The intentional imbalances are configured differently for each vehicle model.

Vibration damper



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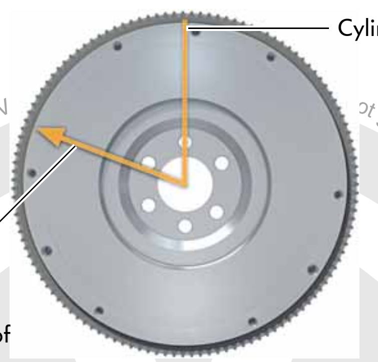
Flywheel



S539_043

In the installation position, the effective directions of the two imbalances are positioned approximately opposite each other. Together with the optimised engine mounting, the vibration behaviour of the engine is improved and fewer vibrations are transferred to the vehicle interior.

S539_037

The vibration damper fits on the crankshaft pulley in all positions. Please observe the instructions in ELSA Pro.

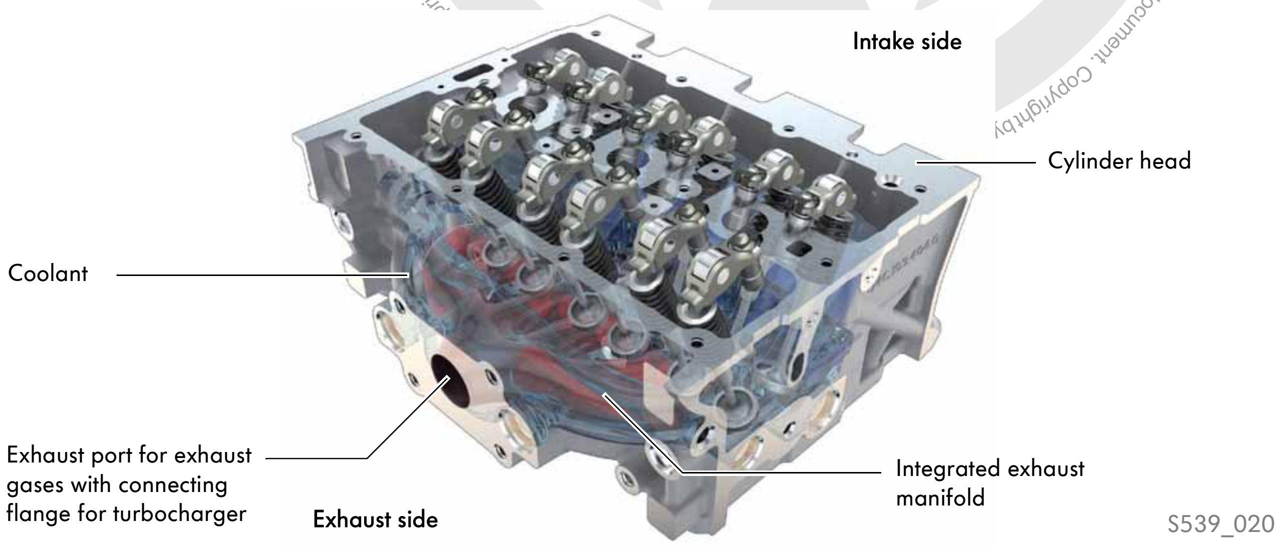
Due to the uneven arrangement of one of the securing holes, the flywheel only fits in one position on the crankshaft.

Cylinder head

Thanks to the integrated exhaust manifold, the aluminium cylinder head ensures fast usage of the exhaust gas energy and allows the engine to warm up quickly. Improving the mixture formation was one of the main focuses during the enhancement of the aluminium cylinder head.

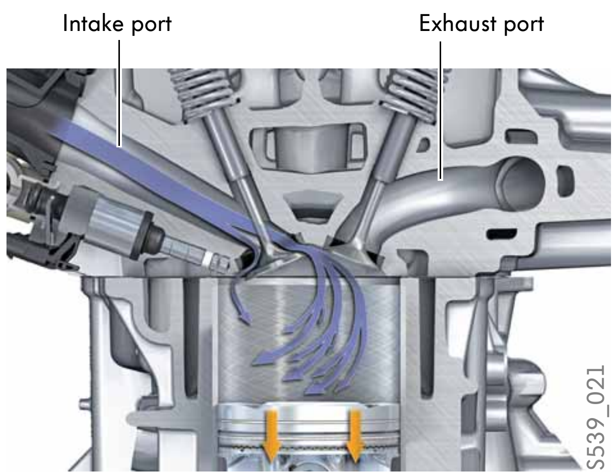
Technical features

- 4-valve technology with roller rocker fingers and hydraulic compensation elements
- Cross-flow cooling
- Integrated exhaust manifold
- Designed for alternative fuels



Mixture formation

The intake port has been designed so that a high flow rate is achieved without affecting the flow quantity. The swirling flow of intake air into the cylinder at a high rate ensures very good mixture formation.

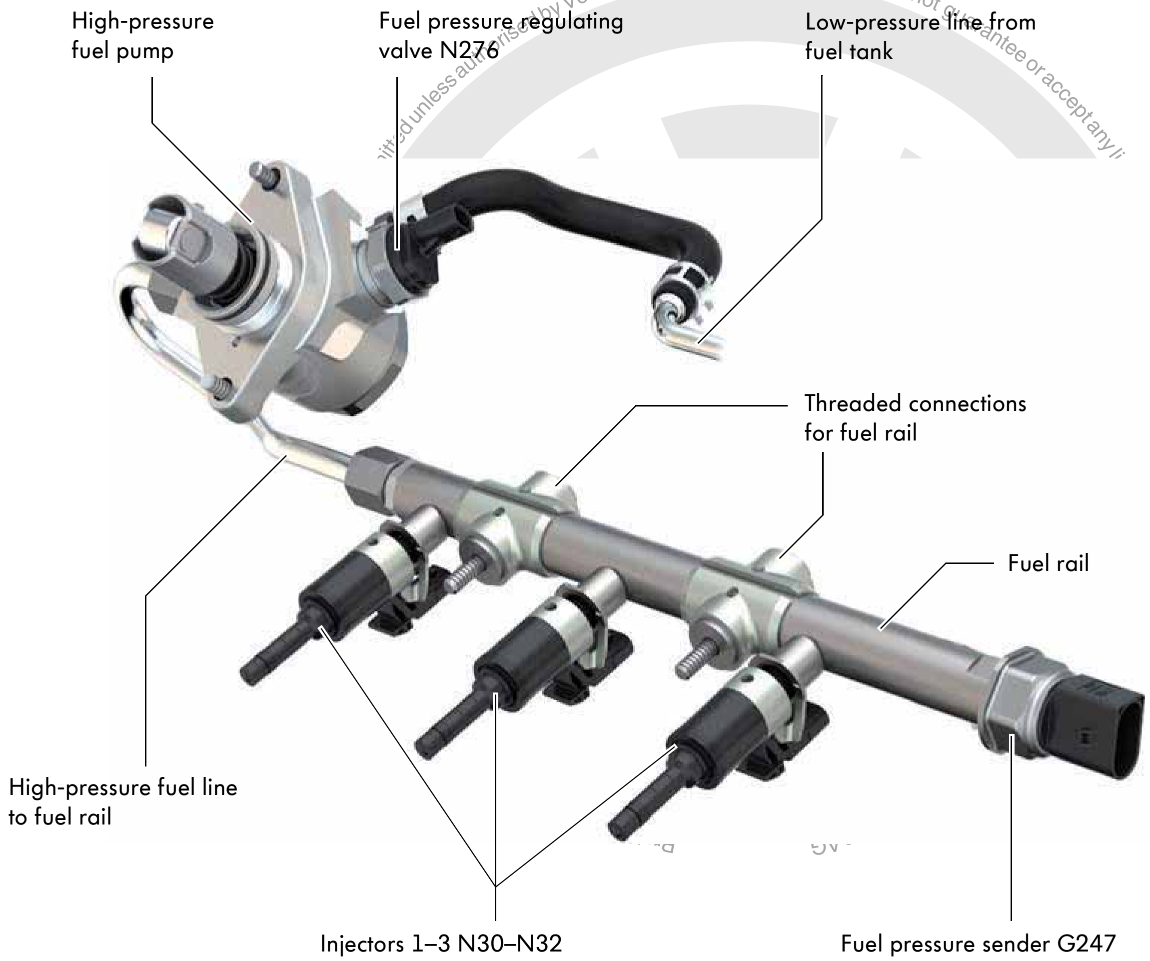


High-pressure fuel system

The high-pressure fuel system basically corresponds with the system used on the EA211 TSI engines. However, for the first time, it works with an injection pressure of up to 250 bar. Together with the optimised injection pattern of the injectors, a very good mixture formation results in all load and speed conditions. This reduces the fuel consumption, the exhaust emissions and contamination of the engine oil with fuel.

Technical features

- High-pressure fuel pump with fuel pressure regulating valve N276
- Injection pressure between 120 and 250 bar
- Stainless steel fuel rail, bolted
- 5-hole injectors N30–N32
- Fuel pressure sender G247
- Multiple injection (up to three injections at engine start, for heating up the catalytic converter and for full load up to 3,000 rpm)



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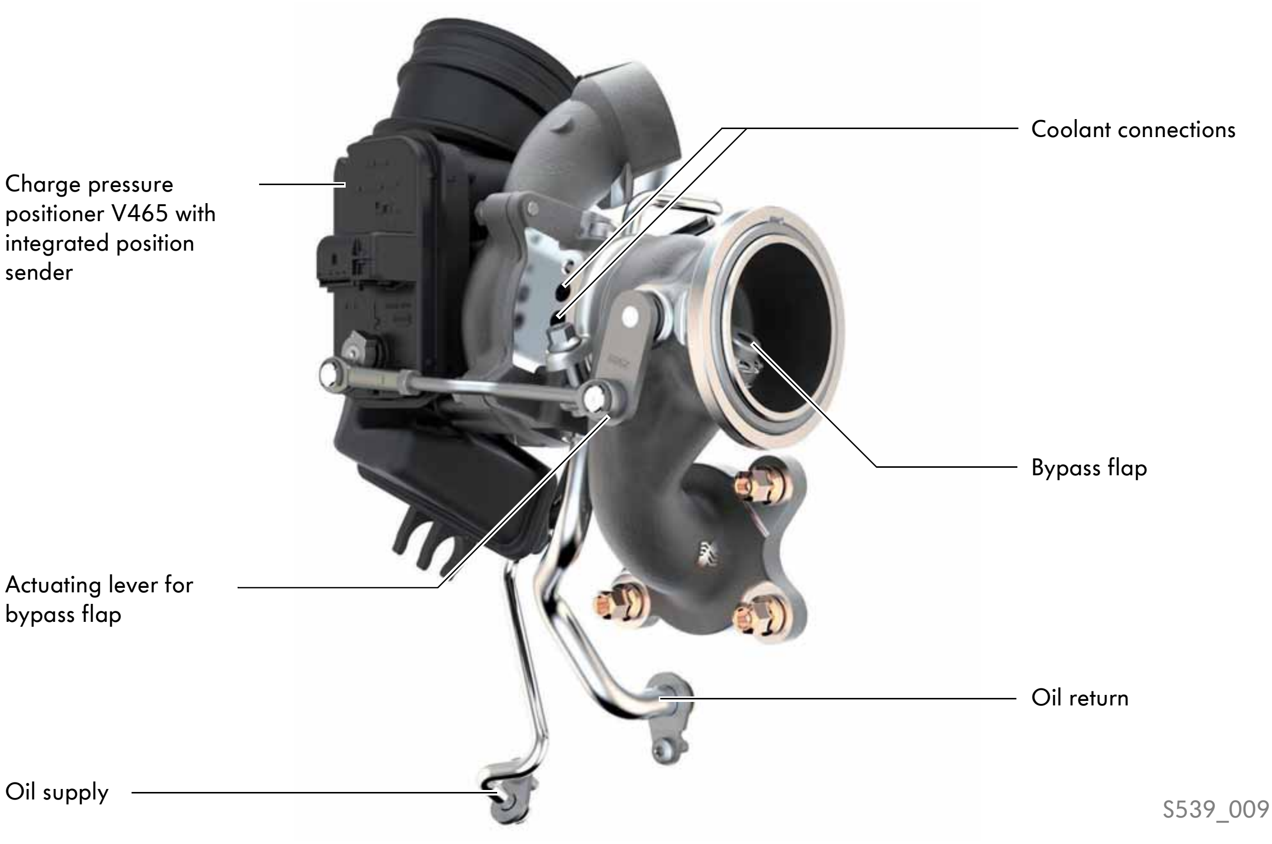
Turbocharger

Typical TSI performance is the requirement from the turbocharger. This includes early response and high torque at low engine speeds. In addition to the compact configuration of the intake manifold, further modifications were made to the turbocharger to achieve the required performance:

- The angle at which the exhaust gas flows onto the turbine was calculated so that the turbine wheel's inertia torque is easily overcome. This allows the turbine to quickly reach a high speed.
- The bypass flap is adjusted via an electric charge pressure positioner, which responds very quickly and has a high actuating force.

Technical features

- Charge pressure up to 1.6 bar (relative)
- Electric charge pressure positioner with rotary output
- Heat-resistant cast steel housing for exhaust gas temperatures up to 1,050°C (from outputs above 70 kW)

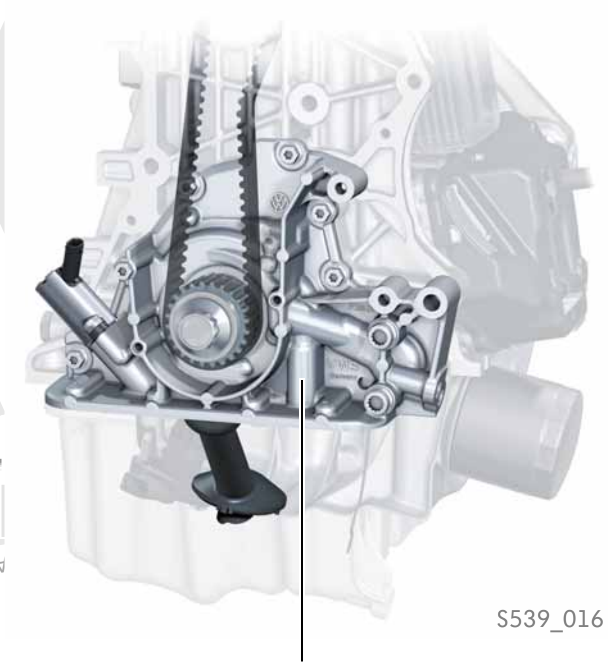


You will find further information on the basic function of the charge pressure positioner V465 in Self-study Programme no. 443 "The 1.2l 77kW TSI engine with turbocharger".

Continuously variable oil pressure control

Vane-type oil pump

Volkswagen is using continuously variable oil pressure control for the first time in the 1.0-l 3-cylinder TSI engine.
The oil pressure is controlled in accordance with the load, engine speed and oil temperature by means of a vane-type oil pump. It is driven directly by the crankshaft.


S539_016

Vane-type oil pump

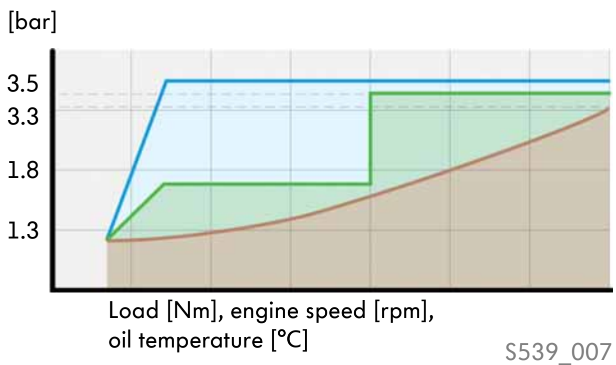
During the first 1,000 km, the vane-type oil pump delivers the maximum oil pressure of 3.3 bar (relative). This balances out the increased thermal loading of the components when the engine is run in.

Advantages of continuously variable oil pressure control

While the 1.4-l 4-cylinder TSI engines switch between two pressure stages, the oil pressure in this engine is controlled continuously between 1.3 and 3.3 bar (relative).
As a result, the drive power of the pump is even better suited to the operating conditions of the engine.
The drive power of the oil pump is thus reduced considerably, above all, in the load cycles preferred by customers, like city or long-distance driving.

The advantages compared with two-stage oil pressure control are:

- Internal engine friction is further reduced.
- The power consumption of the oil pump is lowered further because the oil pump only pumps as much oil as is required.
- The oil wear in the oil circuit is further reduced as less oil is being circulated.



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Key

Continuously variable oil pressure control (1.0-l TSI engines)
Two-stage oil pressure control (1.4-l engines)
No oil pressure control (1.0-l and 1.2-l engines)

Oil pressure sender G10

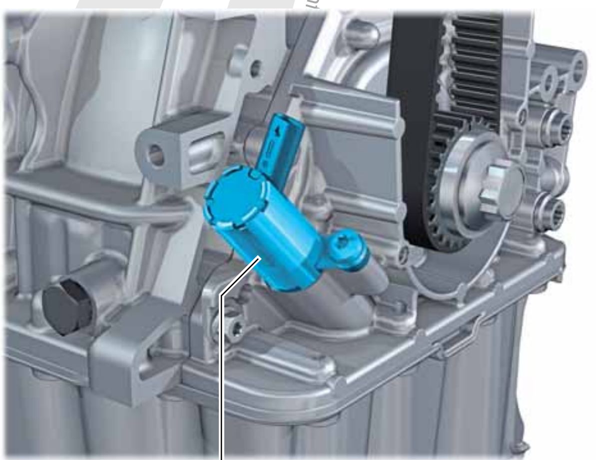
The oil pressure sender constantly measures the oil pressure and transmits it to the engine control unit with a data log.
The engine control unit uses the signals to activate the valve for oil pressure control and to change the oil delivery quantity. The oil pressure rises or falls.

S539_017

Oil pressure sender G10

Valve for oil pressure control N428

The valve for oil pressure control N428 is activated by the engine control unit by means of a map with a pulse-width modulation signal (PWM signal) between 20 and 80 per cent. Depending on the activation signal, it opens a continuously variable cross-section to the channel by using a control surface. The oil pressure is increased or decreased in relation to how much oil is guided onto the control surface.



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Valve for oil pressure control N428

Design of the vane-type oil pump

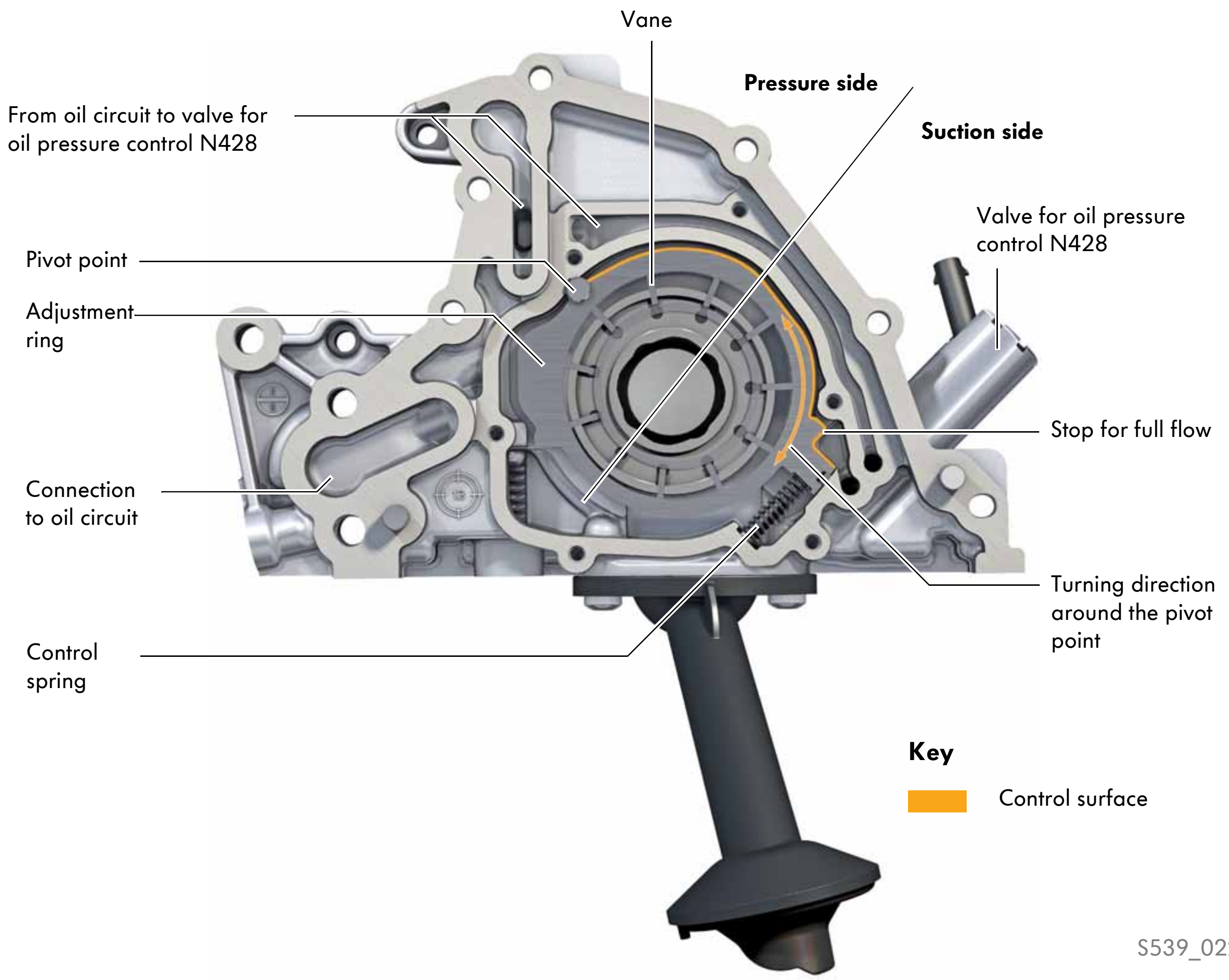
The vane-type oil pump has an eccentrically mounted adjustment ring. Turning the adjustment ring enlarges or reduces the space between the vanes on the suction and pressure sides. This changes the oil delivery quantity.

Adjustment mechanism

The adjustment ring is turned and the oil delivery quantity varied under the following conditions:

- The valve for oil pressure control is activated and the oil from the oil circuit is guided onto the control surface. The oil pressure applied turns the adjustment ring clockwise against the force of the control spring. The space between the vanes becomes smaller and the oil pressure falls.
- The valve for oil pressure control is activated so that less oil from the oil circuit is guided onto the control surface. The oil pressure applied falls and the adjustment ring is turned anti-clockwise by the force of the control spring. The space between the vanes becomes larger and the oil pressure rises.

The extent to which the adjustment ring is turned depends on the activation of the valve for oil pressure control.



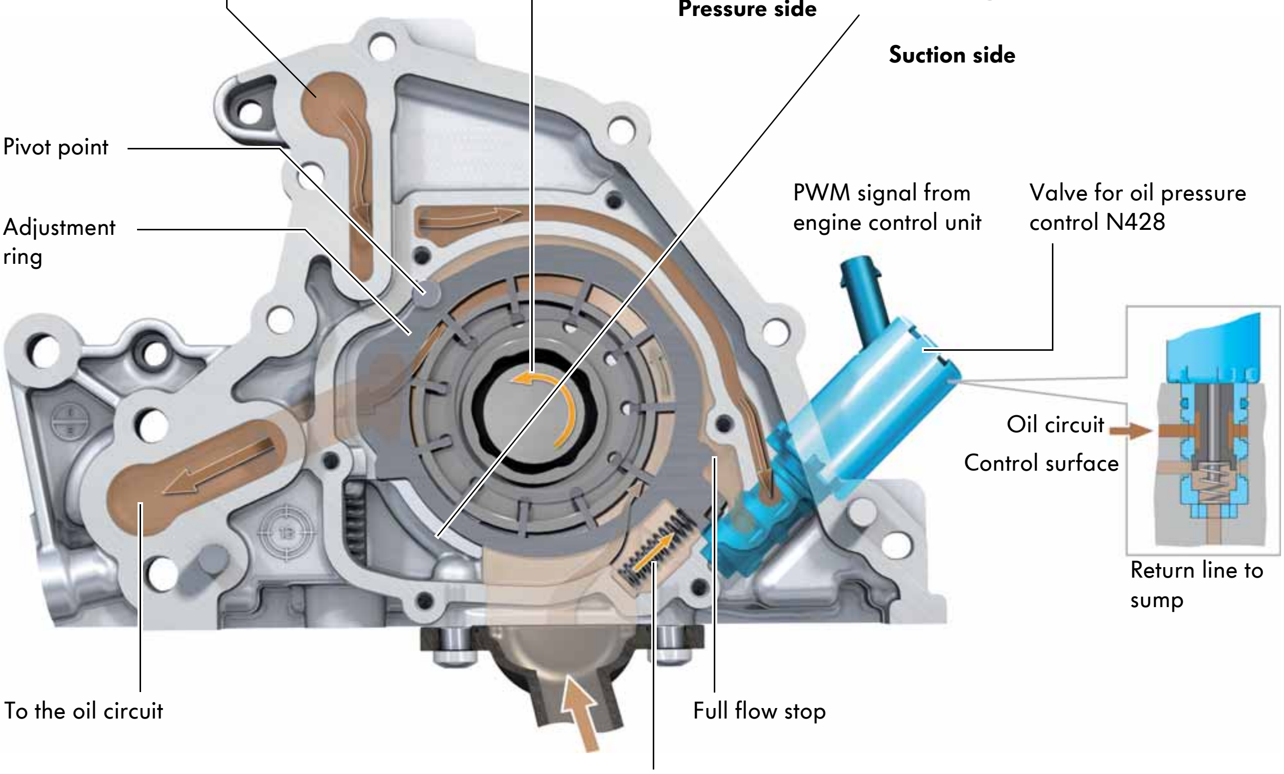
S539_022

Function

Engine start

The oil pressure needs to be built up as quickly as possible when the engine is started.

- The valve for oil pressure control N428 is activated by the engine control unit with a PWM signal.
- Since no pressure is applied yet to the control surface, the control spring pushes the adjustment ring anti-clockwise against the full flow stop.
- The spaces between the vanes on the suction and pressure sides are fully open. The oil pump delivers the maximum oil quantity for the respective engine speed to the oil circuit.



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Key

Vacuum

Oil pressure (up to 3.3 bar)

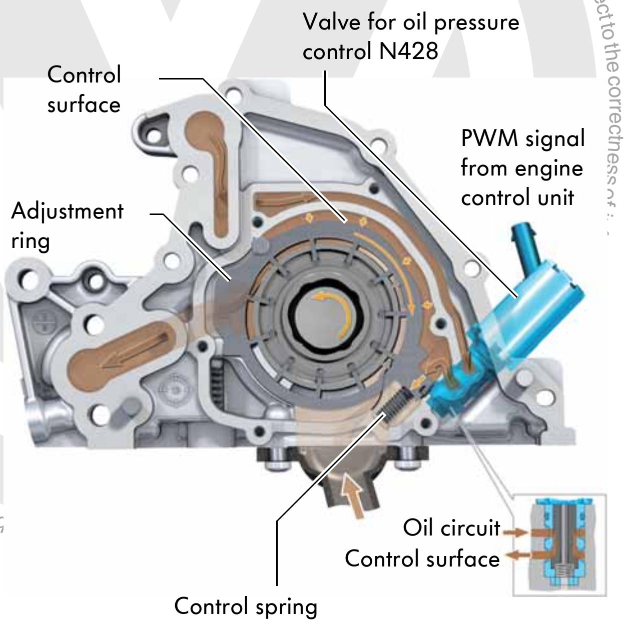
The return to the sump is only open if the valve for oil pressure control is not activated.

Engine running

While the engine is running, the oil pressure is continuously variably controlled in relation to the load, engine speed and oil temperature by means of a map. The valve for oil pressure control N428 is activated with a PWM signal and opens the corresponding flow cross-section for the oil from the oil circuit. The oil reaches the control surface, turns the adjustment ring and adjusts the oil pressure accordingly.

Reducing the oil delivery quantity and the oil pressure

- The valve for oil pressure control N428 is activated by the engine control unit using a PWM signal with a large pulse width. A larger flow cross-section is opened to the control surface on the adjustment ring.
- The oil pressure acts on the control surface.
- The resulting force is greater than that of the control spring and turns the adjustment ring clockwise to the centre of the vane-type oil pump. The delivery chamber on the suction and pressure sides becomes smaller and less oil is delivered to the oil circuit.



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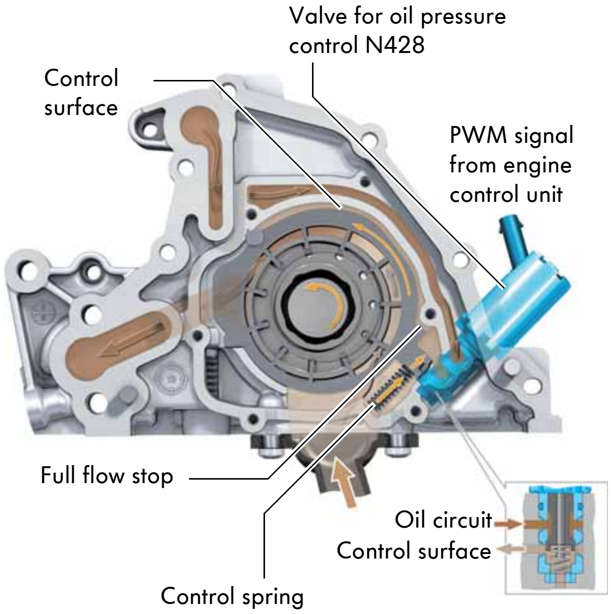
Increasing the oil delivery quantity and the oil pressure

- The valve for oil pressure control N428 is activated by the engine control unit using a PWM signal with a small pulse width. The flow cross-section to the control surface of the adjustment ring is reduced.
- A lower oil pressure acts on the control surface.
- The resulting force is smaller than that of the control spring and turns the adjustment ring anti-clockwise towards the full flow stop. The delivery chamber on the suction and pressure sides becomes larger and the oil pump delivers a larger quantity of oil to the oil circuit.



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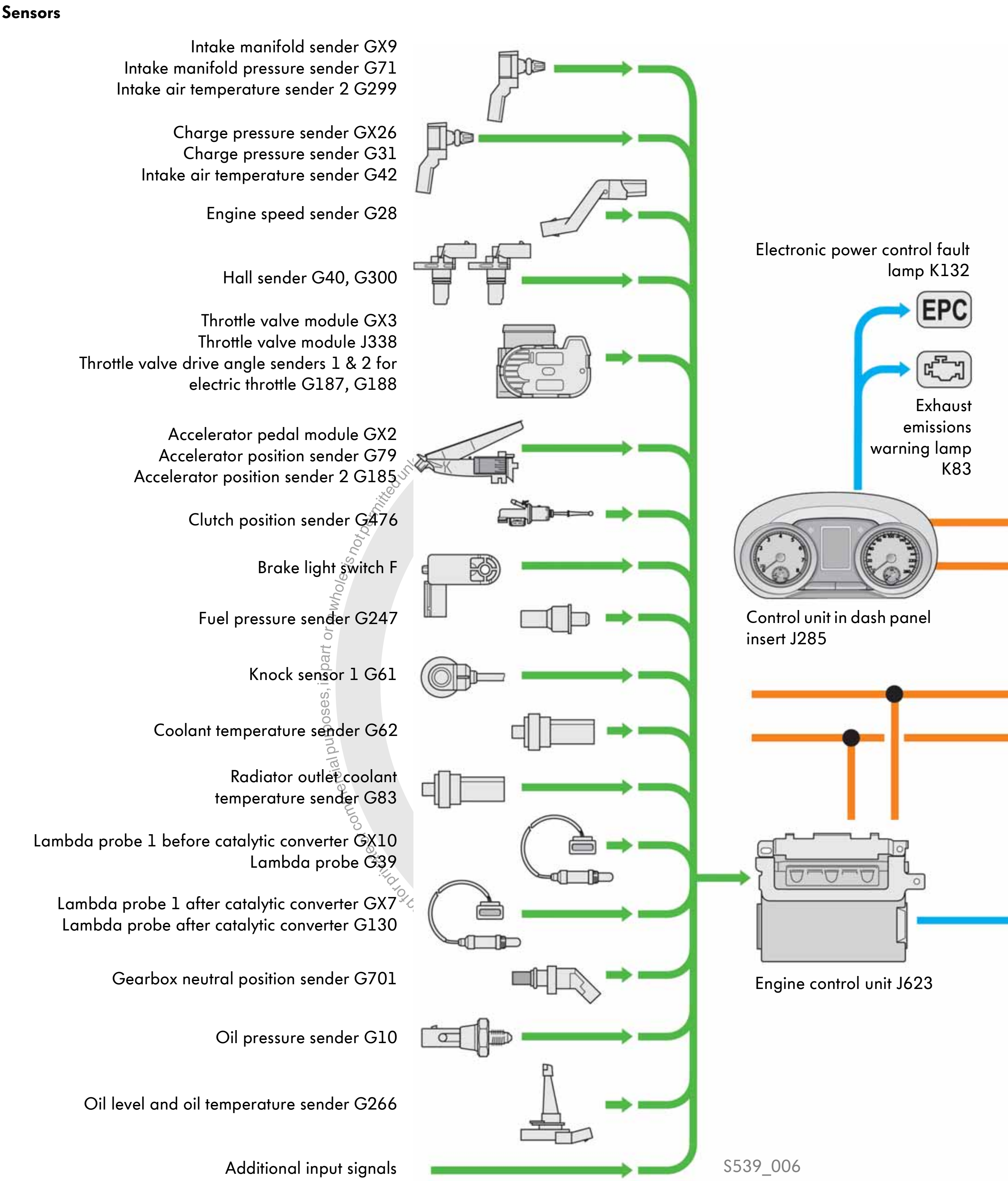
System overview

1.0-l 3-cylinder TSI engine



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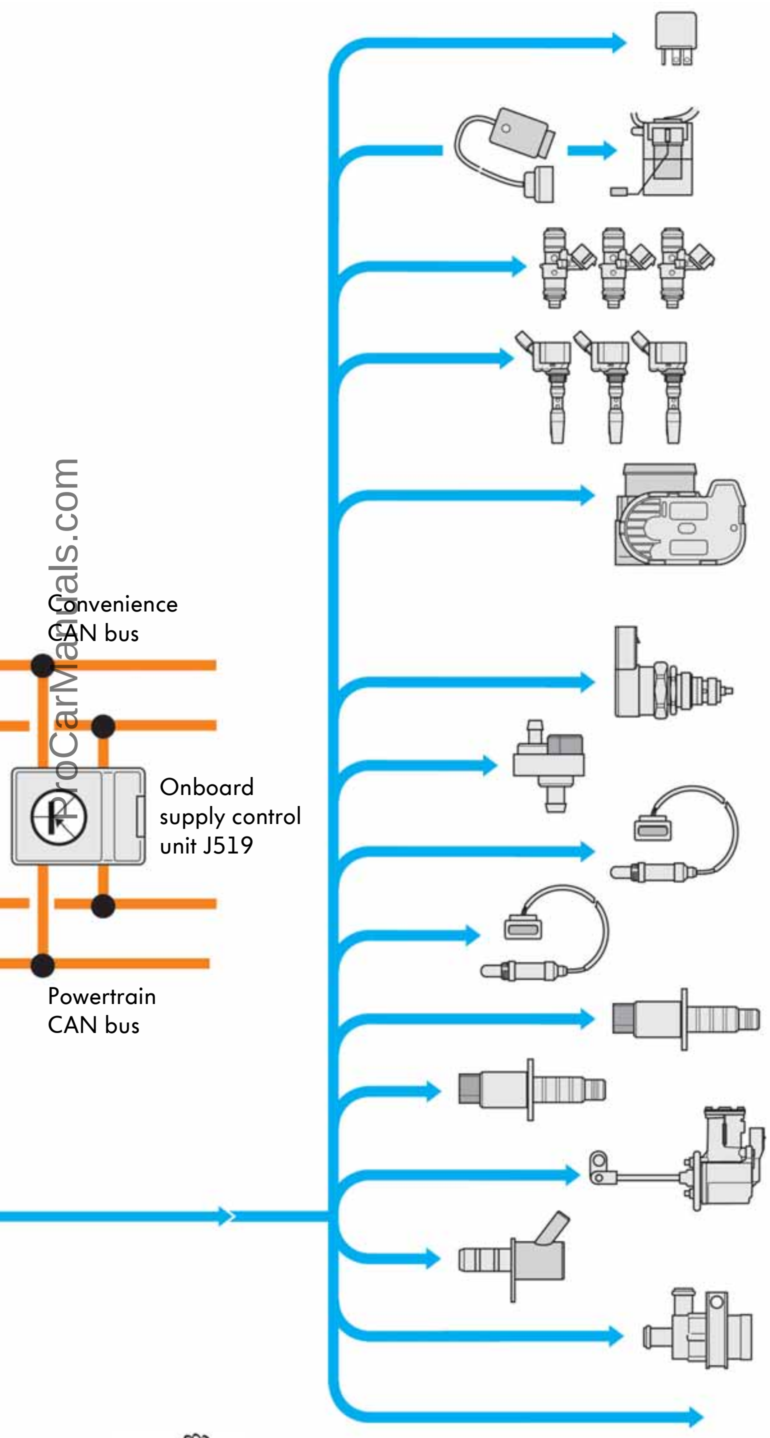
Actuators



Main relay J271

Fuel pump control unit J538
Fuel delivery unit GX1
Fuel system pressurisation pump G6

Injectors, cylinders 1–3 N30–N32

Ignition coils 1–3 with output stages N70, N127, N291

Throttle valve module GX3
Throttle valve module J338
Throttle valve drive for electric throttle G186

Fuel pressure regulating valve N276

Activated charcoal filter solenoid valve 1 N80

Lambda probe 1 before catalytic converter GX10
Lambda probe heater Z19

Lambda probe 1 after catalytic converter GX7
Lambda probe 1 heater after catalytic converter Z29

Camshaft control valve 1 N205

Exhaust camshaft control valve 1 N318

Charge pressure positioner V465

Valve for oil pressure control N428

Charge air cooling pump V188

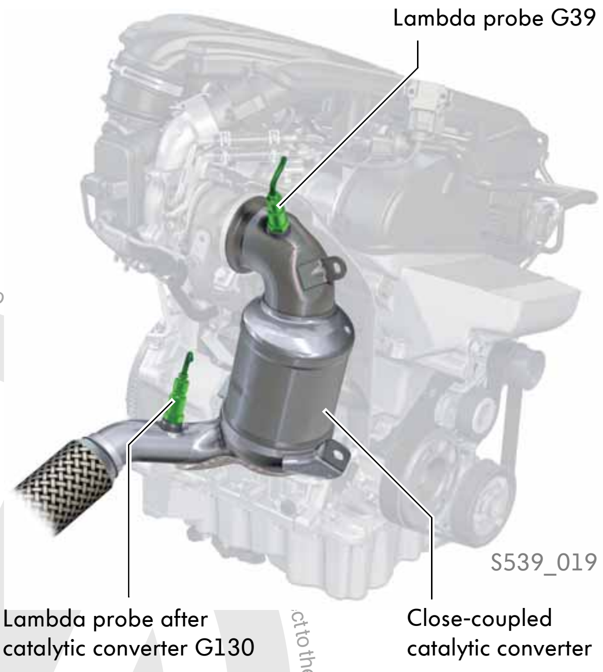
Additional output signals

Components with an X in the short designation contain several sensors, actuators or switches in one housing, such as the intake manifold sender GX9 with the intake manifold pressure sender G71 and the intake manifold temperature sender 2 G299.

Lambda control

The lambda control system uses one step-type lambda probe before the catalytic converter and one after.

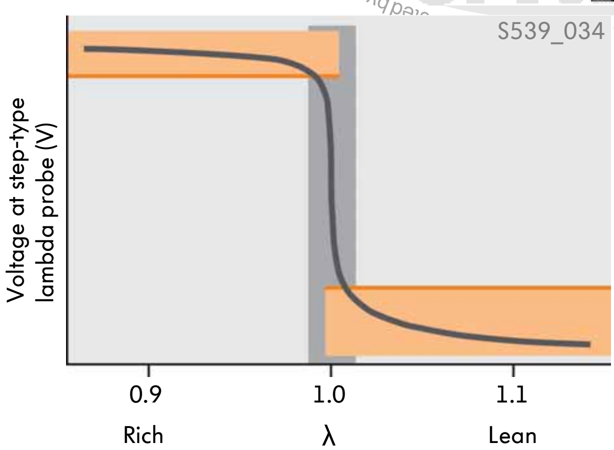
- The signals from the lambda probe before the catalytic converter G39 are used to regulate the fuel/air mixture.
- The signals from the lambda probe after the catalytic converter G130 are used to check the catalytic converter function and to adapt the lambda probe before the catalytic converter.



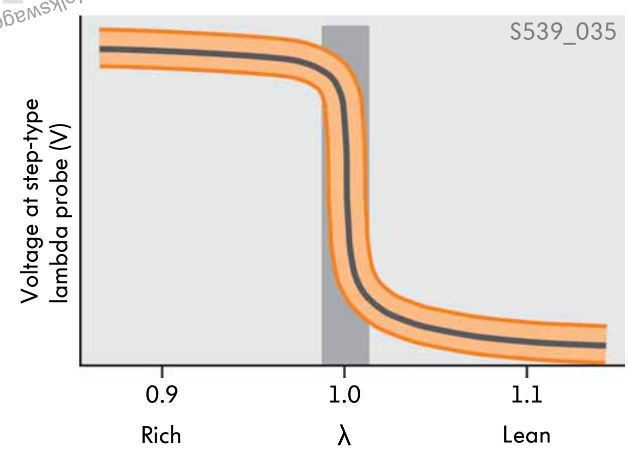
Engine control unit J623

A continuous lambda controller is installed in the engine control unit J623 instead of a two-point lambda controller in all engines from the EA211 engine family with a step-type lambda probe before the catalytic converter. The controller constantly evaluates the signal from the step-type lambda probe. This means it not only evaluates the step from a lean to a rich mixture and vice versa, but also the step itself. The lambda control is consequently much more precise with a step-type lambda probe.

Two-point lambda controller



Continuous lambda controller



Key

This region is evaluated by the lambda control system in the engine control unit.

Step-type lambda probe G39 before catalytic converter

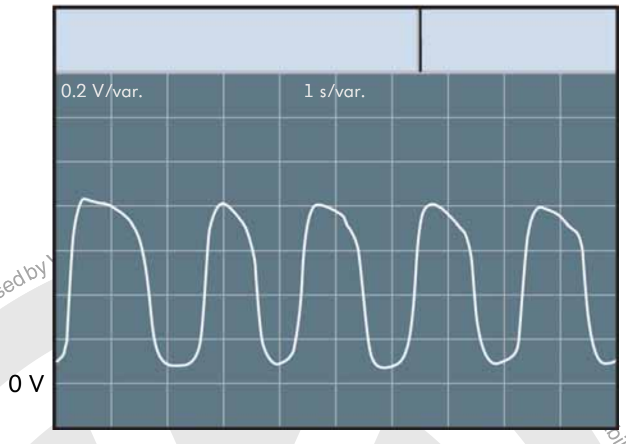
In both variants, the step-type lambda probes are of the same type and have the same functions. Only the evaluation process in the engine control unit differs. As a result, the signal patterns appear differently on the digital storage oscilloscope:

- The lambda value is 1.0 with a signal voltage of 450 mV.
- The lambda value is below 1.0 with a higher voltage.
- The lambda value is above 1.0 with a lower voltage.

Signal pattern of step-type lambda probe G39 before the catalytic converter in EA111 engine family

The engine control unit only detects a mixture that is too rich (signal voltage approximately 800 mV) or too lean (signal voltage approximately 100 mV) with the two-point lambda controller.

If the mixture is too rich, the injection quantity is reduced until a mixture that is too lean is detected via the signal voltage. The injection quantity is then increased again.



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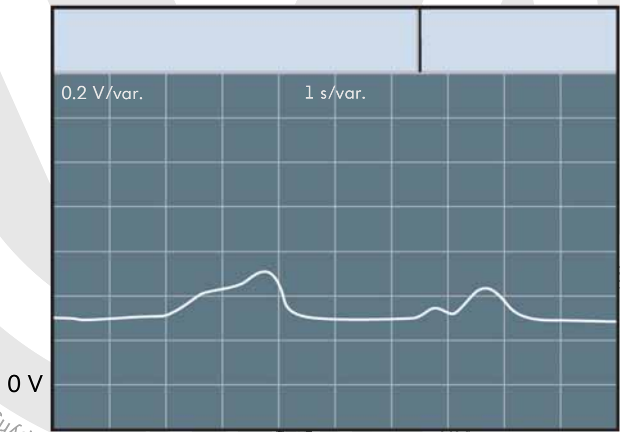
Signal pattern of step-type lambda probe G39 before the catalytic converter in EA211 engine family

The signal from the step-type lambda probe appears almost linear on the digital storage oscilloscope with the EA211 engines. Since the engine control unit constantly evaluates the signals, the signal runs almost steadily at a signal voltage of approximately 450 mV.



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The voltage values for the lambda probes may vary depending on the manufacturer.

Oil pressure control

Oil pressure sender G10

The oil pressure sender G10 is screwed into the cylinder head on the toothed belt side below the intake manifold. It constantly measures the oil pressure and sends the reading to the engine control unit with a data log.

The advantages of the sender are:

- The oil pressure is transmitted at short intervals and adjusted accordingly.
- The signals are not sensitive to electromagnetic interference.

Signal use

The signal from the oil pressure sender is used to regulate the oil pressure between 1.3 and 3.3 bar by means of a map. Furthermore it is used to check whether the minimum oil pressure is present.

Effects of signal failure

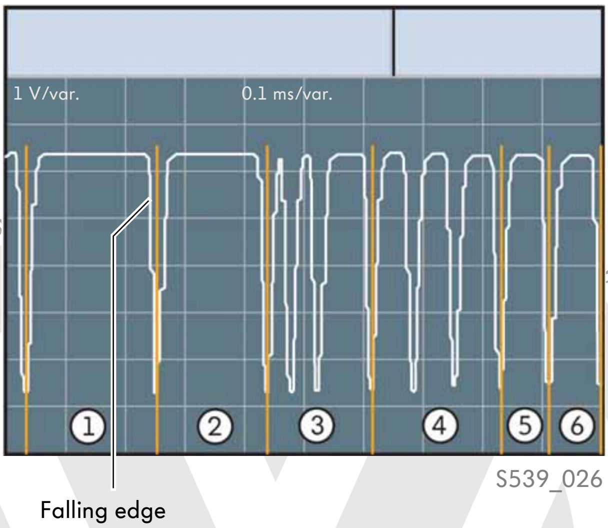
If the oil pressure sender fails, the engine control unit calculates a substitute PWM signal with which the oil pressure is kept constant at approximately 3.3 bar. An entry is made in the event memory.

Signal pattern of oil pressure sender

The oil pressure sender transmits a SENT data log with the current oil pressure to the engine control unit at short intervals.

The SENT data log consists of six information units.

1. Start of the data transmission, information on the oil pressure sender is transferred
2. Start of the data transmission
3. Signal 1 (oil pressure)
4. Signal 2 (currently not used)
5. Plausibility check of sent data
6. Pause until next data transmission

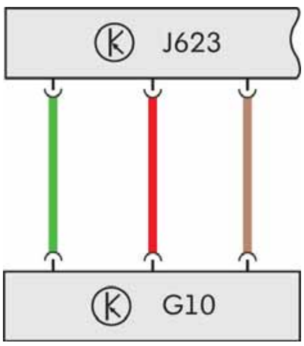


S539_026

Signal evaluation

The evaluation electronics in the oil pressure sender convert the voltage measured (in relation to the oil pressure) into a SENT data log and transmit it to the engine control unit. The engine control unit evaluates the time between two falling edges and recognises the content of the different information units from this – including the oil pressure.

Electrical circuit



S539_039

Key

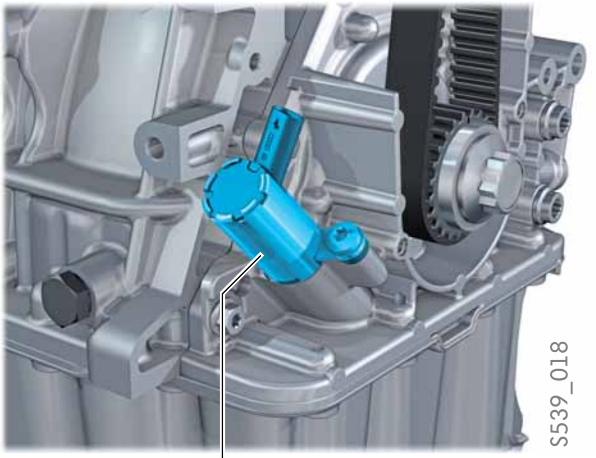
J623 Engine control unit
G10 Oil pressure sender

Signal from oil pressure sender
5-volt supply voltage
Sensor earth

Engine management system

Valve for oil pressure control N428

The valve for oil pressure control N428 is screwed into the vane-type oil pump housing on the toothed belt side.



Valve for oil pressure control N428

Function

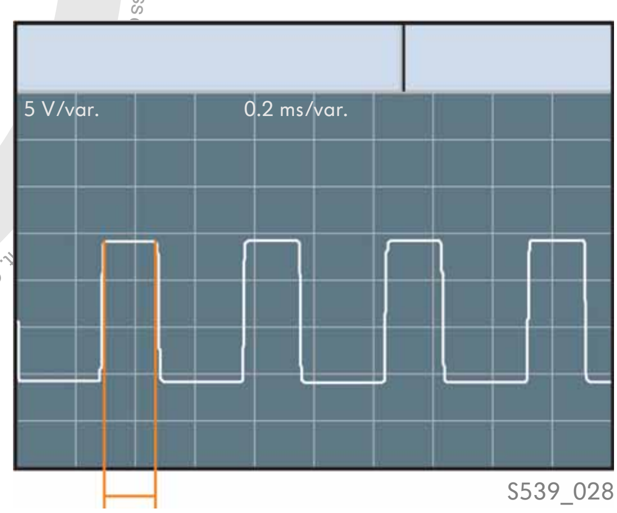
The valve for oil pressure control N428 is a hydraulic 3/2-way valve. It is activated by the engine control unit using a pulse-width modulated signal (PWM) on the basis of a map. Depending on the activation signal, it opens a specific flow cross-section to the control channel in the vane-type oil pump. The oil is guided directly to the control surface on the adjustment ring, moves it and adjusts the oil delivery quantity accordingly.

Effects upon failure

When the valve is not energised, the flow cross-section to the control channel of the vane-type oil pump is mechanically opened or closed depending on the oil pressure. The oil pressure is then approximately 4.5 bar at an oil temperature of 120°C. This mechanical control ensures that sufficient oil pressure is constantly present. If the oil pressure rises to over 4.5 bar, for example, during acceleration, the flow cross-section to the control channel is opened. The oil flows to the control surface and turns the adjustment ring so that the oil delivery quantity is reduced until the oil pressure is approximately 4.5 bar again.

Activating the valve for oil pressure control N428

The engine control unit activates the valve for oil pressure control with a PWM signal. The pulse width is between 20 and 80 per cent with continuously variable adjustment of the valve. The greater the pulse width, the greater the cross-section of the opening to the control channel.



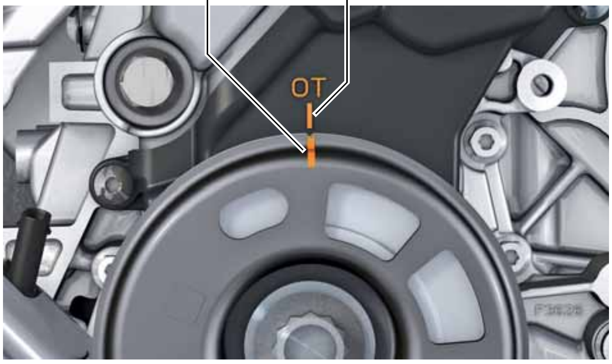
S539_028

Technical information

Assembly information for vibration damper

Due to the intentional imbalance on the vibration damper, you must ensure that it is installed in the correct position during assembly.

- Cylinder 1 needs to be at TDC.
- The TDC markings on the vibration damper (notch) and on the toothed belt cover (stamped mark) need to be lined up.



S539_038

Lining up the TDC markings

The Hirth toothing on the vibration damper and the crankshaft pulley does not have any mechanical coding. This means that the teeth on the vibration damper fit together with the teeth on the crankshaft pulley in any position. Therefore you need to ensure that the TDC markings are lined up before tightening the vibration damper to the specified torque.

Special tools

Description	Tool	Usage
T10476A Assembly tool	 S539_040	Assembly aid for precise positioning of the tri-oval camshaft pulleys.
T10527 Release tool	 S539_041	For releasing the fasteners on the air intake pipe between the air filter housing and the throttle valve module.
VAS 531 001 Release tool	 S539_042	For loosening and fastening hose clips on the cooling system.

Test your knowledge

Which answers are correct?

One or several of the given answers may be correct.

1. How is the oil pressure controlled in the 1.0-l 3-cylinder TSI engine?

❒ a) In two stages by means of two oil pressure switches that are actuated at different oil pressures.

❒ b) It is not controlled. An oil pressure switch is simply used to detect whether the minimum oil pressure is present.

❒ c) The oil pressure control is continuously variable. An oil pressure sender G10 transmits the oil pressure in a digital SENT signal to the engine control unit at short intervals.

2. What is the special feature of the lambda control for some EA211 engines?

❒ a) In the 1.2-l TSI and the 1.4-l TSI engines, a NO_x sender is used after the catalytic converter.

❒ b) A new variant of the broadband lambda probes is installed in engines with outputs above 90 kW. In this variant, the exhaust gas temperature is also transmitted via an additional signal line as a pulse-width-modulated signal. The new design can be recognised from the 7-pin compact connector.

❒ c) In engines with a step-type lambda probe before the catalytic converter, a “linear lambda controller” is used in the engine control unit J623. This controller constantly evaluates the voltage signal from the step-type lambda probe.

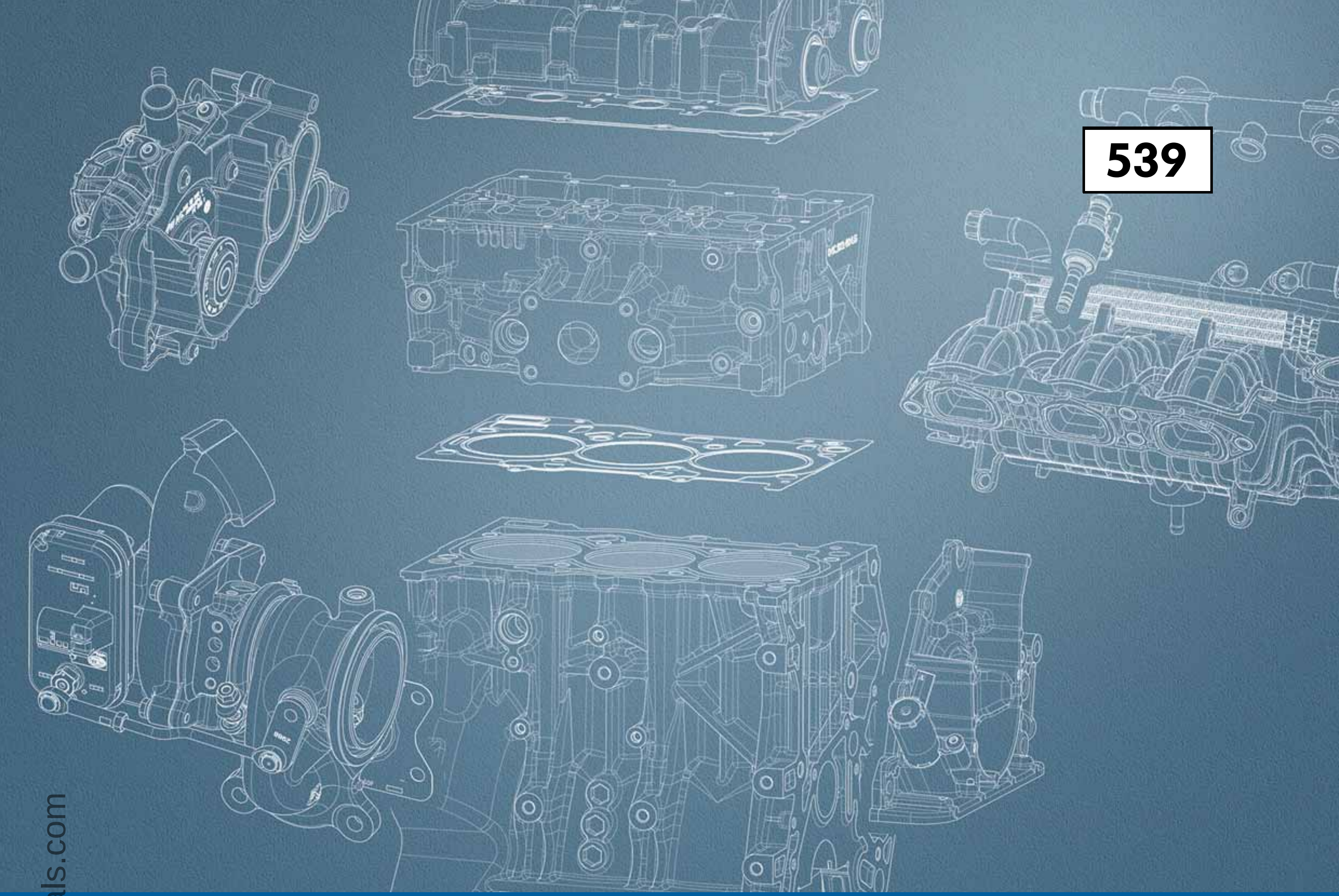
3. What should you observe when fitting the vibration damper and the flywheel on the crankshaft?

❒ a) The vibration damper and the flywheel may be fitted in any position.

❒ b) The vibration damper needs to be fitted in the correct position due to a specific unbalance. The flywheel fits on the crankshaft in only one position.

❒ c) The vibration damper and the flywheel can both be fitted only in one position.

Answers:
1.) c)
2.) c)
3.) b)



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