

Audi 3.0L V6 TDI Biturbo Engine

3.0l V6 TDI biturbo engine

Following the launch of the 2nd Gen 3.0l V6 TDI engine, Audi now introduces a biturbo version based on the 2nd Gen 3.0l V6 TDI engine.

The core of the unit is the compact two-stage charging system installed in the inner V of the engine and over the gearbox bell housing.

The two in-line chargers are subdivided into a high pressure exhaust turbocharger and a low pressure exhaust turbocharger. The high pressure exhaust turbocharger has a Variable Turbine Geometry with an electrical positioner. The low pressure exhaust turbocharger is regulated by a wastegate valve and designed for high air flow rates, with the result that the engine delivers high torque at low rpm combined with performance potential right up to the top end of the rev band.

The development goal was to build an engine that sets new standards for sporty diesel engines by its dynamic torque and revving ability. By adopting all efficiency measures from the basic engine, e.g. thermal management system, friction-reducing enhancements, weight reduction and start-stop system, the 3.0l V6 TDI biturbo engine strikes a good balance between high performance and fuel efficiency. Other premises for the development of the engine were that it was to be produced on the assembly line of the basic engine at the Győr engine plant, and that maximum use was to be made of common and synergetic parts shared with the 2nd Gen V6 TDI engine.



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Learning objectives of this Self Study Programme:

This Self Study Programme describes the design and function of the 3.0l V6 TDI biturbo engine. After you have worked your way through this Self Study Programme, you will be able to answer the following questions:

- ▶ Which aspects of the engine mechanicals have changed?
- ▶ How is the cooling system configured in the cylinder head?
- ▶ How is the biturbo system designed?
- ▶ How are both turbochargers controlled?

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► The Self Study Programme teaches a basic knowledge of the design and functions of new models, new automotive components or new technologies.

It is not a Repair Manual! Figures are given for explanatory purposes only and refer to the data valid at the time of preparation of the SSP.

For further information about maintenance and repair work, always refer to the current technical literature.



Note



Reference

Introduction

Brief technical description

Technical features based on the 3.0l V6 TDI engine (second generation)



Piston



Cylinder head



Oxidising catalytic converter

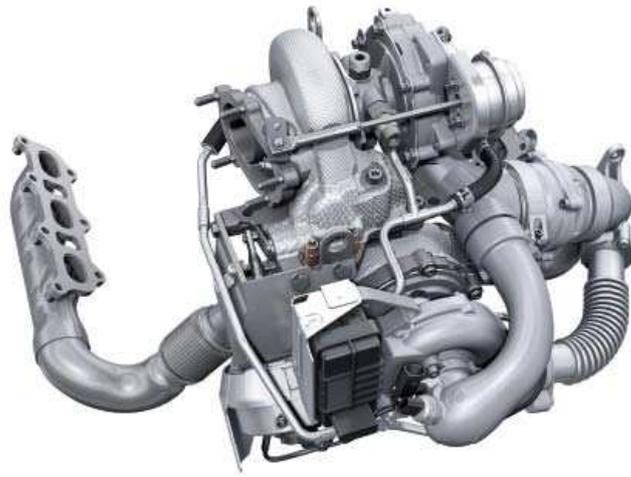


Reference

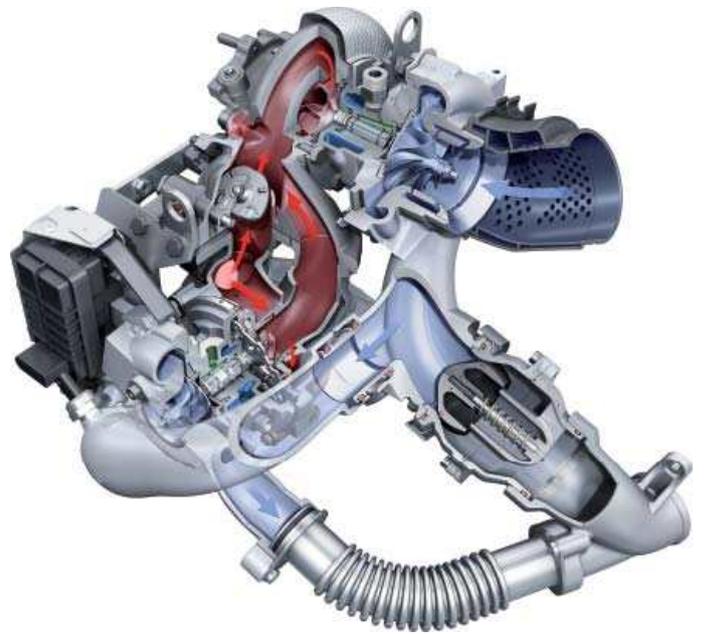
For further information about the design and operation of the basic engine, refer to Self-Study Programme 479 "Audi 3.0l V6 TDI Engine (second generation)".



Start-stop system and recuperation

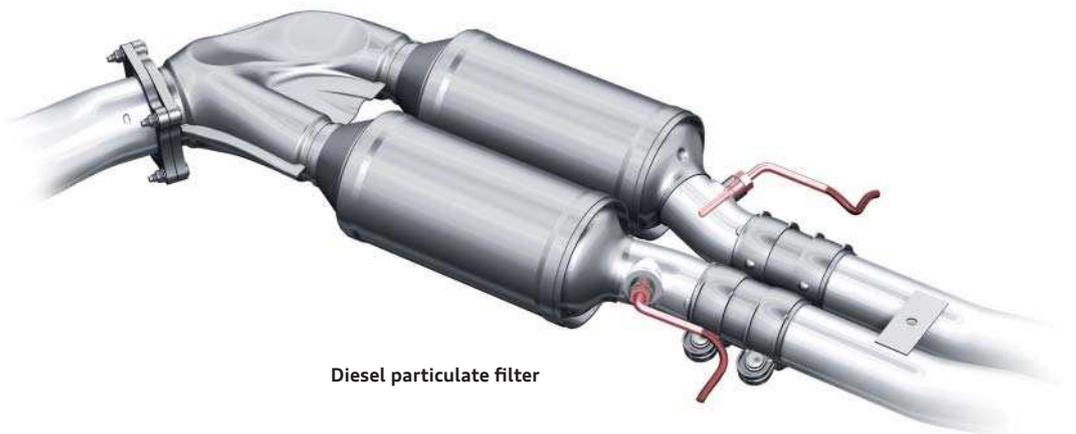


High and low pressure exhaust turbochargers



Compressor bypass valve

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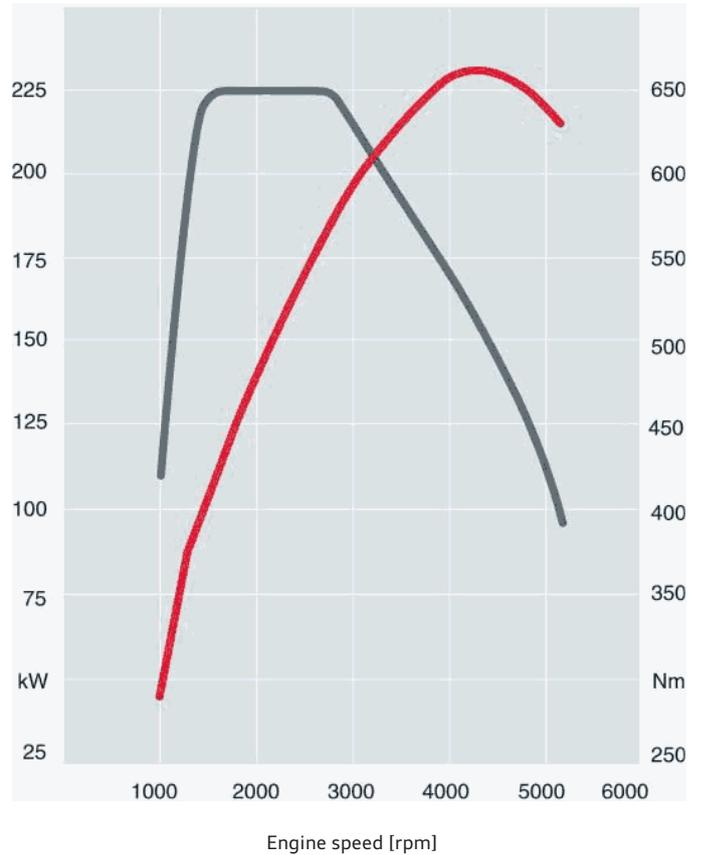


Diesel particulate filter

Specifications

Torque-power curve

- Power output in kW
- Torque in Nm



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Engine code	CGQB
Type	Six cylinder V engine with 90° V angle
Displacement in cm ³	2967
Power output in kW at rpm	230 at 4250
Torque in Nm at rpm	650 at 1500 – 2750
Number of valves per cylinder	4
Cylinder spacing in mm	90
Firing order	1-4-3-6-2-5
Bore in mm	83
Stroke in mm	91.4
Compression ratio	16 : 1
Engine management	Bosch CRS 3.3
Fuel	Diesel to EN 590
Maximum injection pressure in bar	2000
Emissions standard	EU V
CO ₂ emission in g/km	169

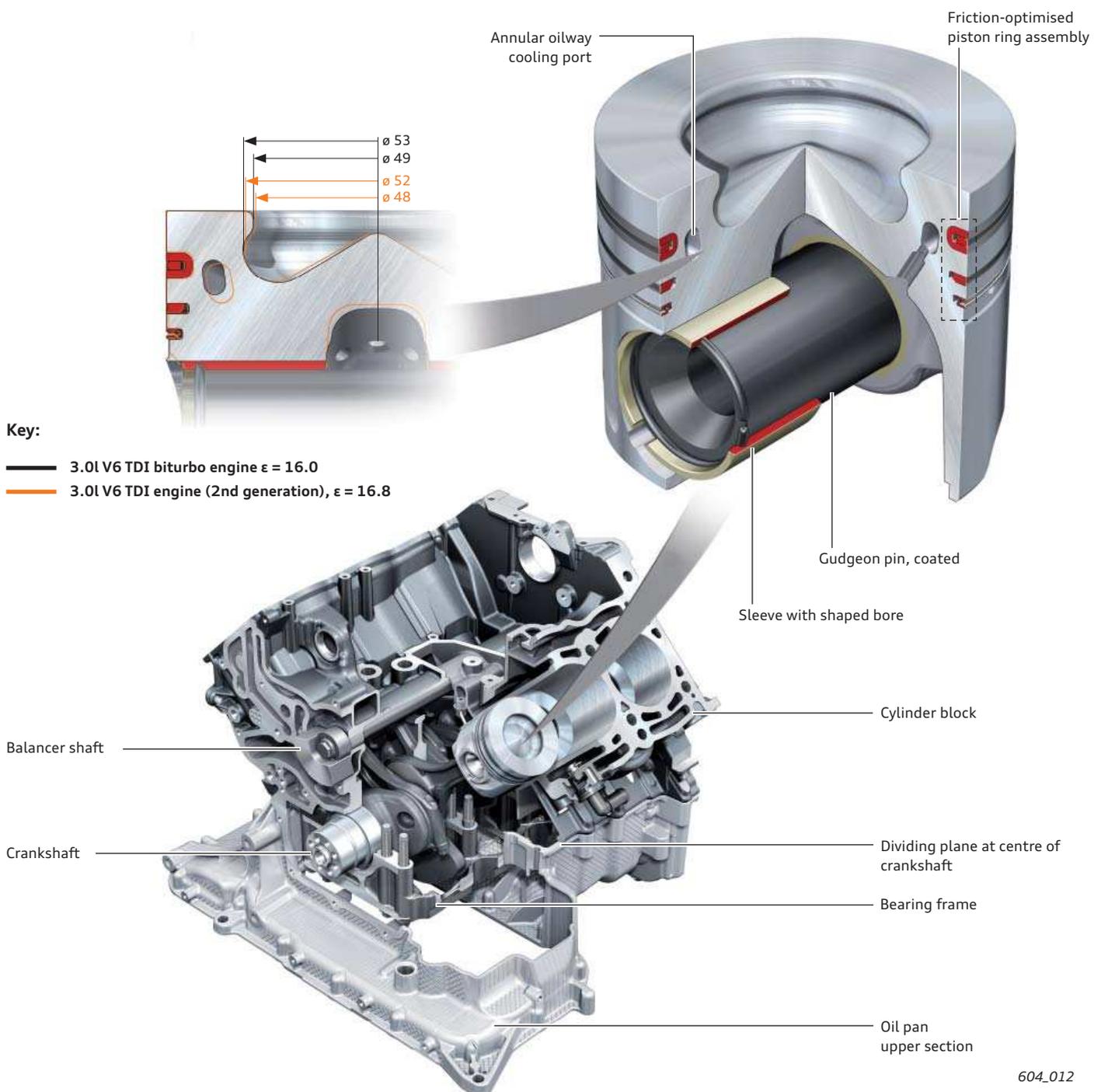
Cylinder block and crank drive

Due to the 46 kW increase in engine power output, it was also necessary to optimise the pistons.

As with the basic engine, the piston has a salt core cooling port for oil spray cooling. This salt core is washed out after it has been cast, producing an annular oilway with outlets. The compression ratio ϵ has been reduced from 16.8 : 1 to 16.0 : 1 by enlarging the piston recess, and the cooling port in the piston has been moved closer to the first piston ring groove. The recess edge temperature has been substantially reduced through the higher elevation of the cooling port and the optimised oil spray cooling system. To increase piston strength, the V6 TDI biturbo engine has a sleeve piston with a coated gudgeon pin (carbon-based coating).

The coating enhances the sliding properties of the gudgeon pin and reduces friction in this region. Using sleeves with a shaped bore ensures that the pressure is evenly distributed between the gudgeon pin and the piston. The shaped bore is incorporated into the piston sleeves. Basically, this bore is machined in such a way that it counteracts ovalisation of the piston and deformation during engine operation, thus ensuring that the gudgeon pin runs smoothly. These measures have made it possible to retain the gudgeon pin diameter of the basic engine and to design the conrod as a common part.

The piston ring assembly is optimised for minimum friction like in the basic engine. The crankshaft has been adopted unchanged from the basic engine.

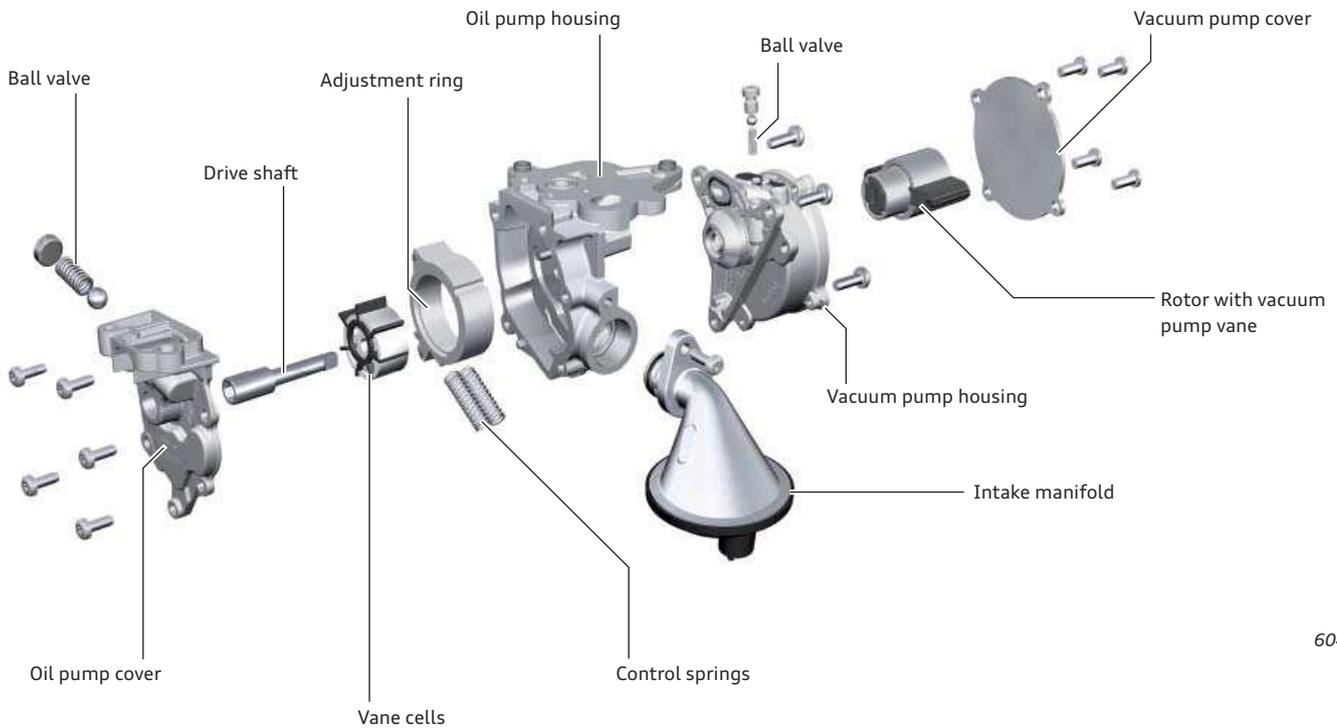


Oil vacuum pump and coolant pump

It was also necessary to revise the oil and coolant pumps. The oil pump was adapted to meet the increased engine oil demand resulting from improved oil spray cooling of the pistons and the second turbocharger.

As with the basic engine, the oil pump is a two-stage volume-controlled vane cell pump with an increased flow rate achieved by widening the adjusting ring and the vane cells.

Oil pump with vacuum pump



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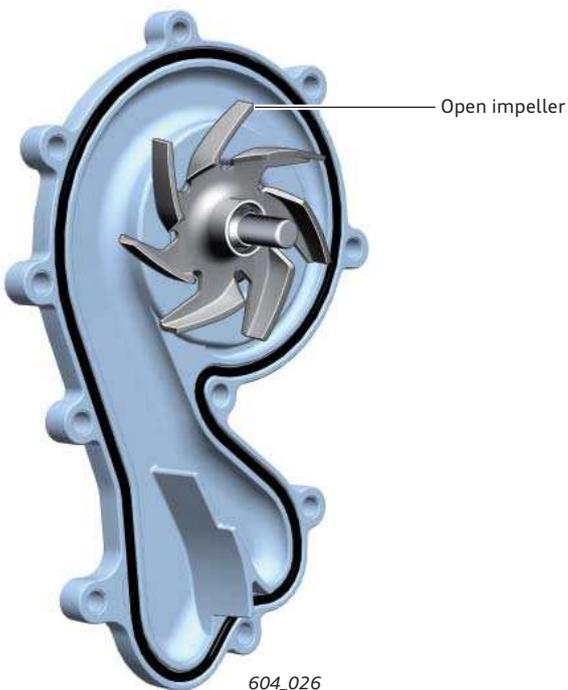
Coolant pump

A higher capacity coolant pump is used to meet the increased engine cooling requirements.

The V6 TDI biturbo engine uses an enclosed impeller optimised for maximum efficiency.

2nd Gen V6 TDI engine

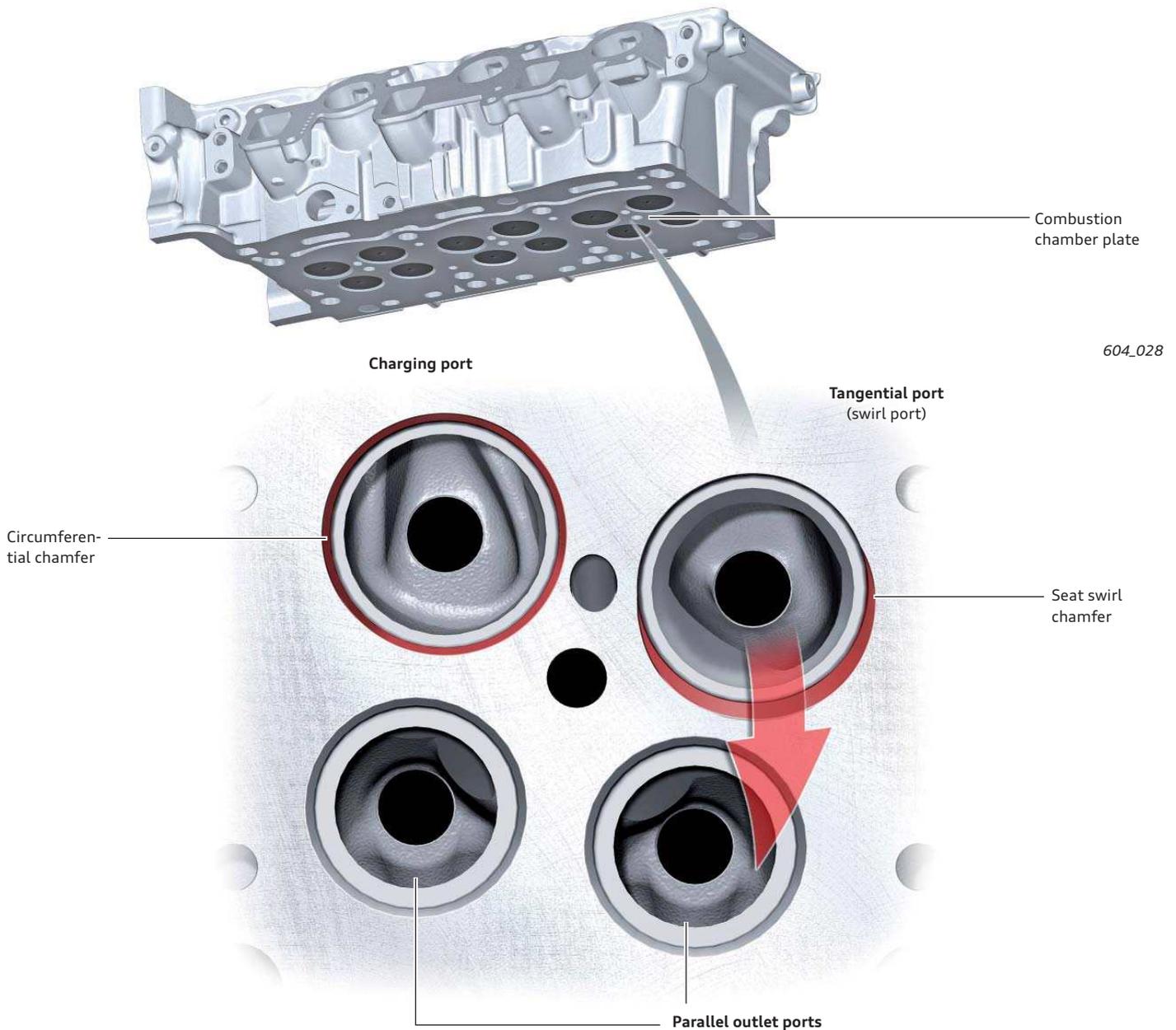
V6 TDI biturbo engine



Cylinder head

During engine operation the cylinder head is subjected to dynamic loading by the cylinder pressure, as well as thermo-mechanical loading by the changes in temperature. Peak combustion pressure has been increased by up to 185 bar compared to the basic engine. However, this pressure is utilised across a wider range of engine speeds at full throttle, resulting in increased material stress and thermal load.

The temperature in the V7 TDI biturbo would rise to a critical level without the modifications to the cylinder head. This could result in crack formation due to thermo-mechanical fatigue in the combustion chamber plate after lengthy periods of use.



Intake ports

To achieve high performance, special emphasis was placed on the charge cycles. The intake ports have been optimised for this purpose. To achieve a further improvement in volumetric efficiency, the charging ports in the V6 TDI biturbo engine have a circumferential chamfer instead of a seat swirl chamfer.

The seat swirl chamfer is now implemented in the tangential port only. The improved volumetric efficiency results in higher engine charging capacity. The slight reduction in swirl compared to the basic engine can be compensated by controlled use of the central swirl flap.

Coolant flow

A cylinder head with a two-piece coolant chamber has been developed for the biturbo engine to counteract the higher thermal loads. The coolant chamber is subdivided into upper and lower sections, and the volumetric flow rate in the upper coolant chamber is reduced by means of restrictor ports in the cylinder head gasket. Both coolant chambers are supplied via separate intakes from the cylinder block.

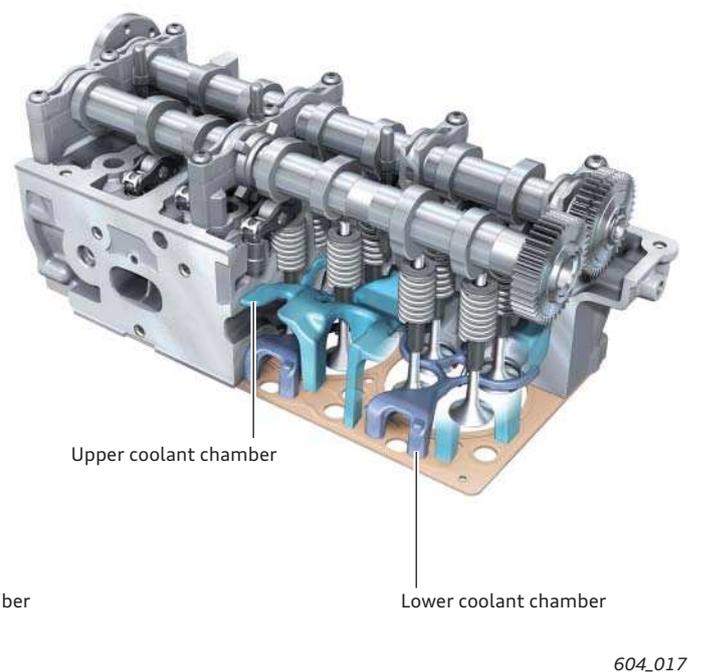
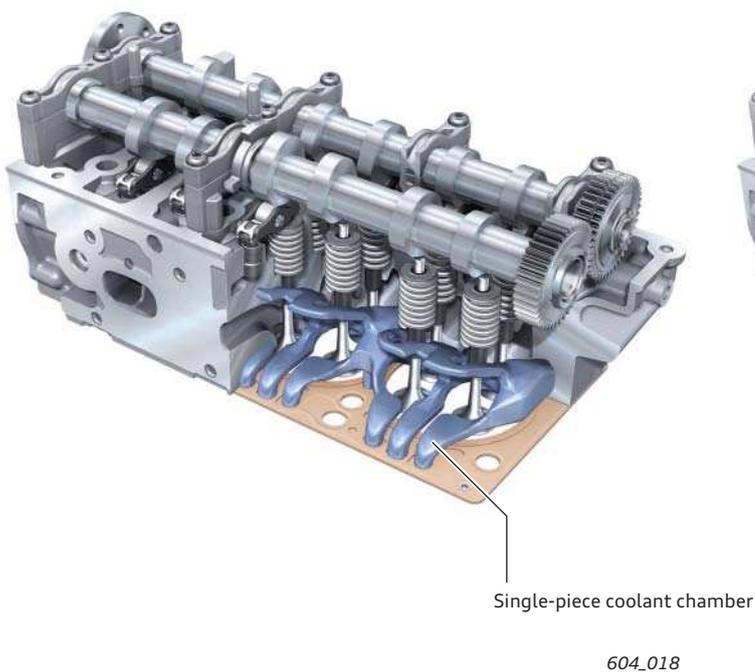
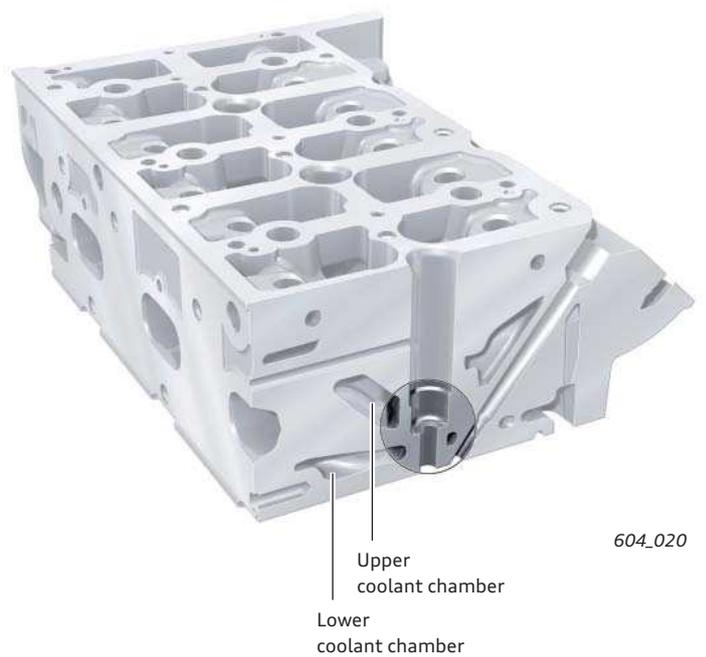
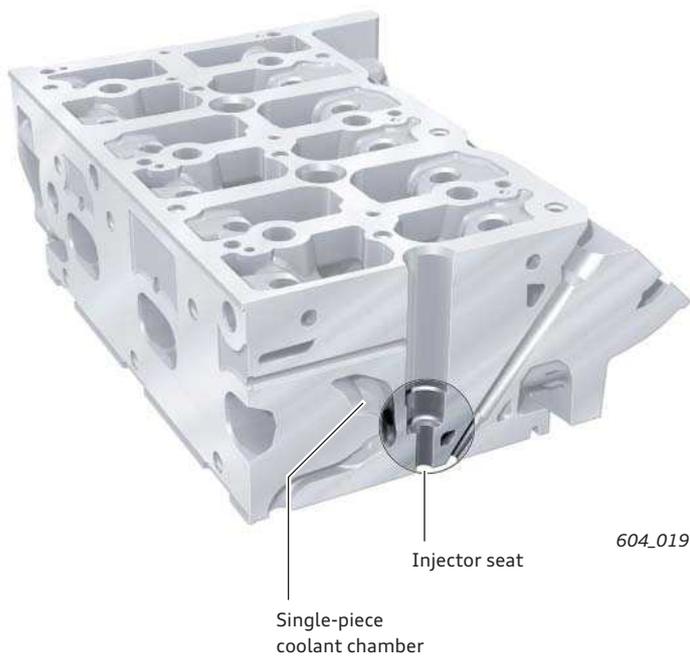
This configuration allows a larger volume of coolant to be directed through the lower coolant chamber, cooling the areas between the valves and the injector seat.

As in the basic engine, the webs between the cylinders are cooled by the cylinder head by utilising the pressure differential between the upper and lower coolant chambers as the driving gradient.

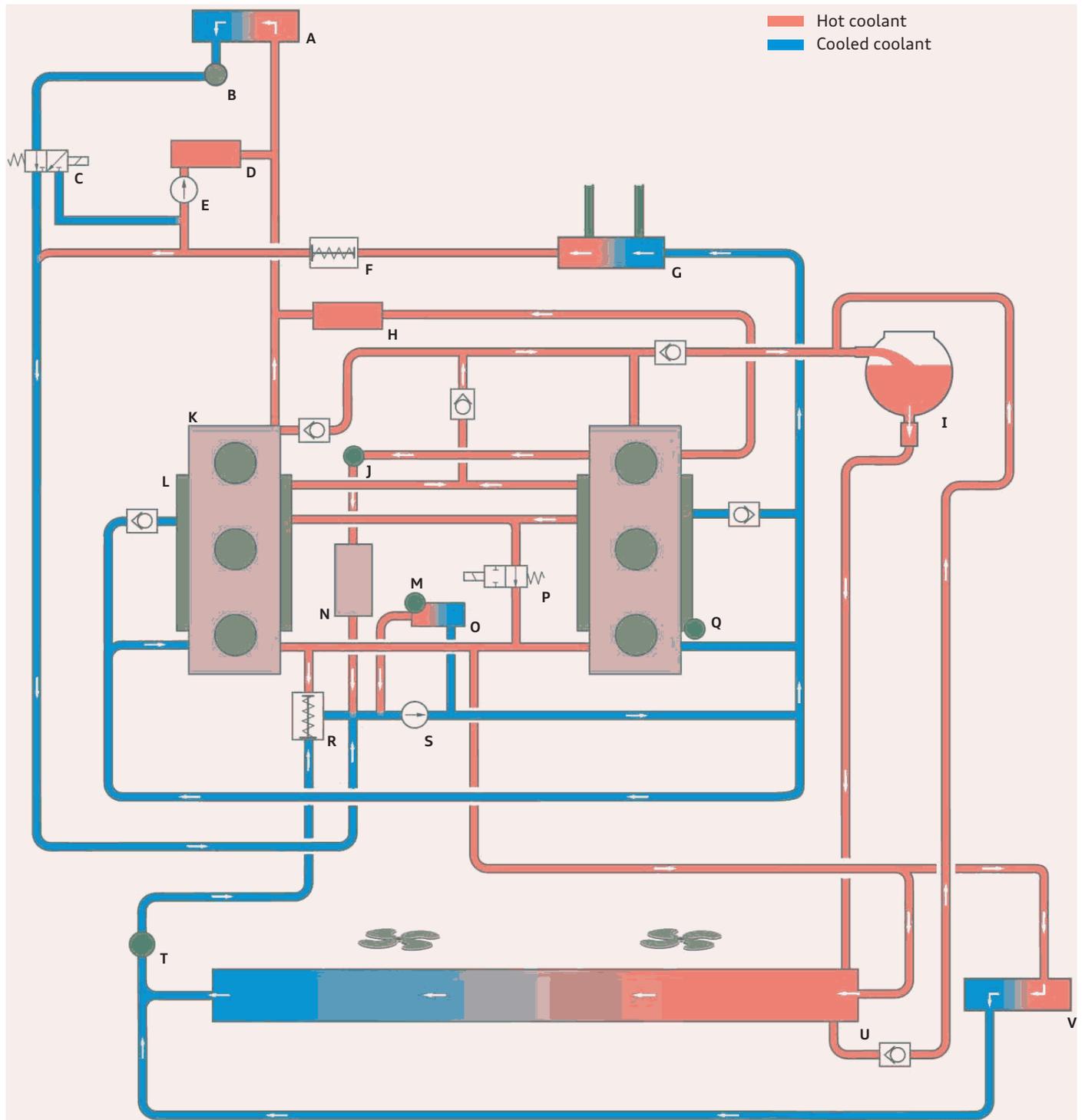
The principle of transverse flow cooling has been retained, and likewise the separate head block cooling system of the basic engine controlled by the thermal management system.

2nd Gen V6 TDI engine

V6 TDI biturbo engine



Cooling circuit



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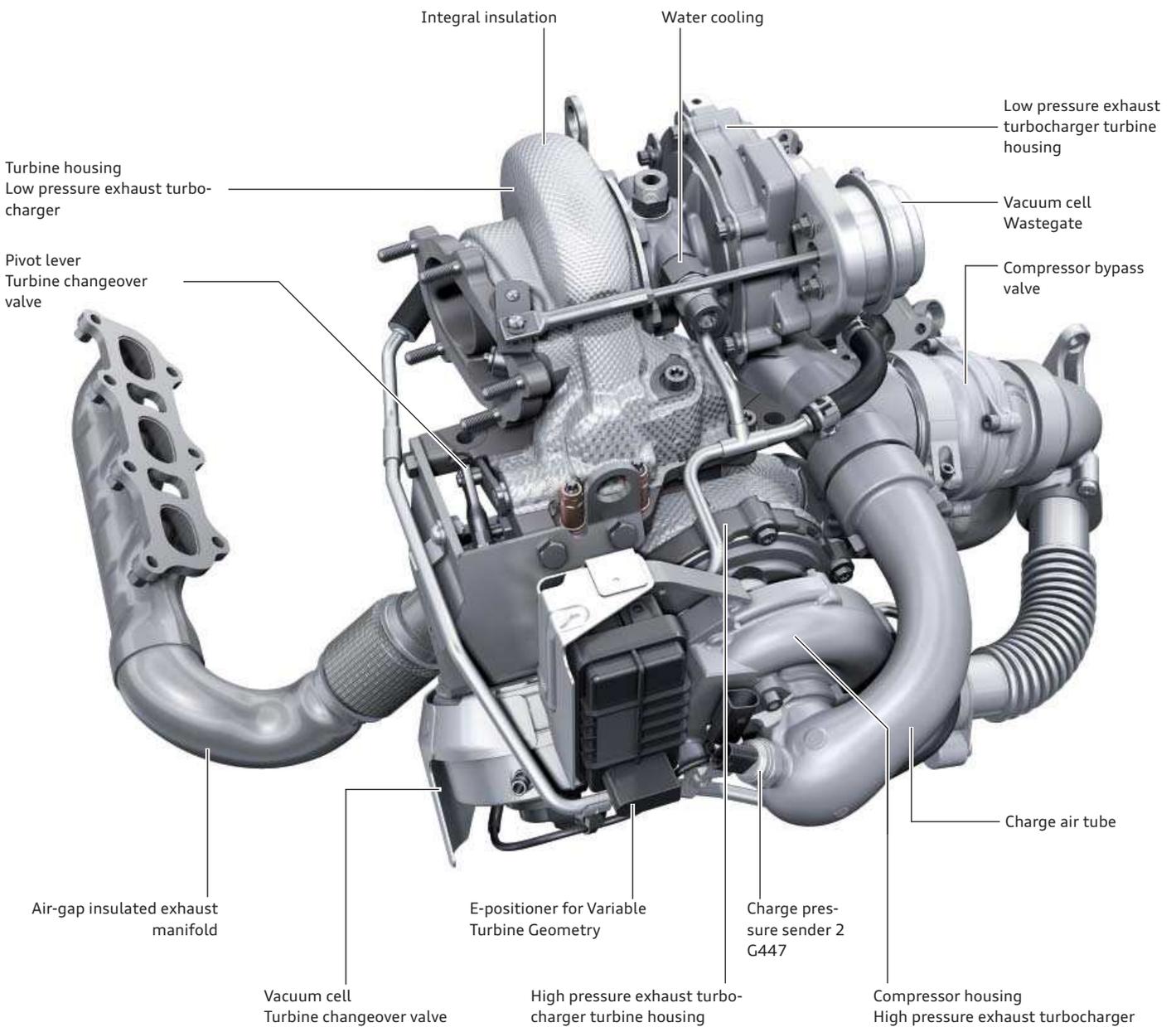
- | | | | |
|----------|------------------------------------|----------|--|
| A | Heater heat exchanger | L | Cylinder block |
| B | Vent screw | M | Oil temperature sender G8 |
| C | Heater coolant shut-off valve N279 | N | EGR cooler |
| D | Auxiliary heater | O | Engine oil cooler |
| E | Coolant circulation pump V50 | P | Coolant shutoff valve |
| F | Coolant thermostat for ATF cooling | O | Engine temperature control temperature sender G694 |
| G | ATF cooler | R | Thermostat for mapped engine cooling F265 |
| H | Exhaust turbocharger module | S | Coolant pump |
| I | Coolant expansion tank | T | Radiator outlet coolant temperature sender G83 |
| J | Coolant temperature sender G62 | U | Radiator |
| K | Cylinder head | V | Auxiliary radiator |

Charging

Biturbo charging

The concept of two-stage charging is implemented here for the first time on Audi diesel V engines. It provides outstanding throttle response at low engine speeds and a very high specific power output at high engine speeds.

High pressure and low pressure turbines are connected in series on the exhaust side. The low pressure exhaust turbocharger is housed in the rear section of the inner V, while the high pressure exhaust turbocharger is positioned at 90° behind the engine over the gearbox.



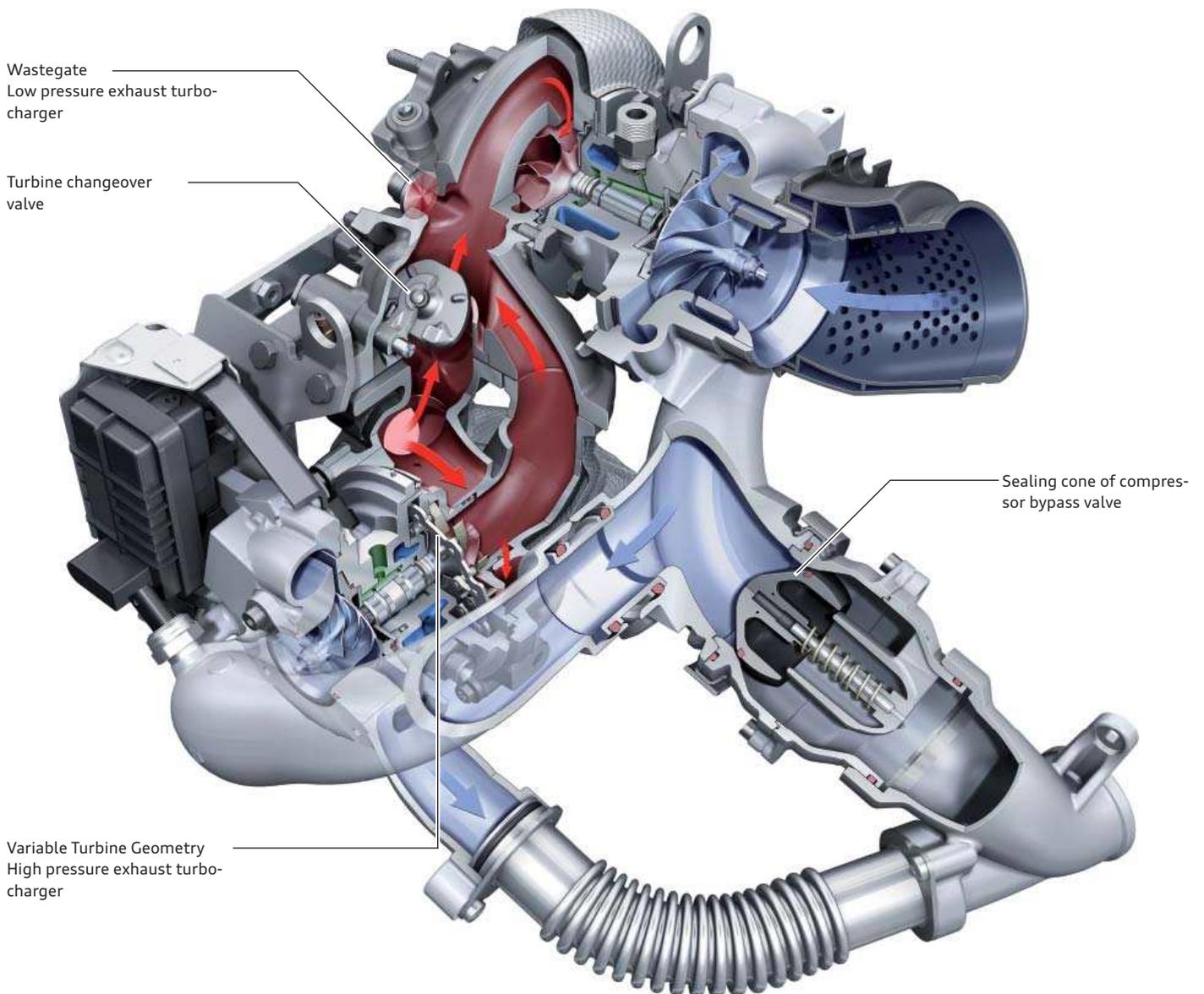
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Supercharger module

The central component of the charging system is the high pressure exhaust turbocharger turbine housing which is used for distributing the exhaust gas mass flows within the system. It includes the flange for connecting the exhaust manifold via a Y-piece, as well as the flanges for the high pressure turbine bypass, the low pressure exhaust turbocharger and the exhaust gas recirculation line. The turbine changeover valve with changeover flap mounted on one side is integrated in the low pressure exhaust turbocharger turbine housing.

The compressor bypass valve is designed in such a way that it quickly opens the cross section under heavy acceleration. The resulting pressure losses in the compressor bypass have been reduced to a minimum by geometric enhancement of the sealing cone.

The housings of both turbochargers are water-cooled. Coolant and oil are supplied by externally laid lines or directly from the cylinder block.



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Note

The exhaust turbocharger and positioner can be replaced separately. The current Workshop Manuals apply.

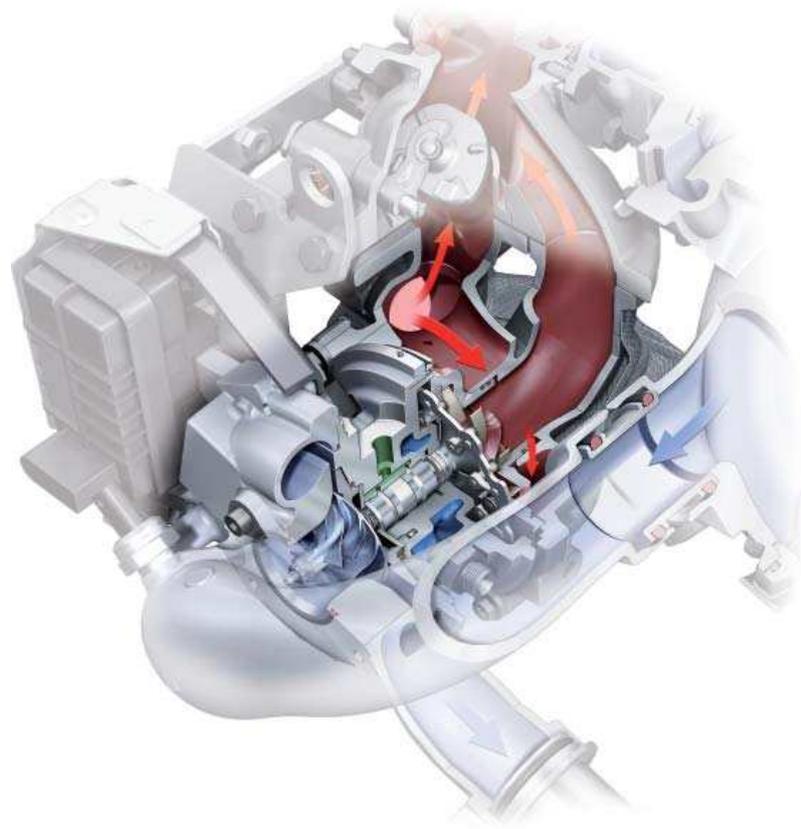
High pressure exhaust turbocharger

The high pressure exhaust turbocharger has a Variable Turbine Geometry (VTG). Depending on charge pressure requirements up to approx. 2300 rpm, the guide vanes are set in such a way that the exhaust gas flow drives the turbine optimally.

The high pressure exhaust turbocharger is seated on the flange of both exhaust manifolds. It produces the required charge pressure of up to 3.2 bar (absolute) very quickly and is supplied with pre-compressed air from the low pressure exhaust turbocharger.

Components of the high pressure exhaust turbocharger

- ▶ Turbine housing
- ▶ Bearing housing
- ▶ Compressor housing
- ▶ Guide vane unit with servomotor and exhaust turbocharger control unit 1 J724
- ▶ Connection for exhaust gas recirculation



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Low pressure exhaust turbocharger

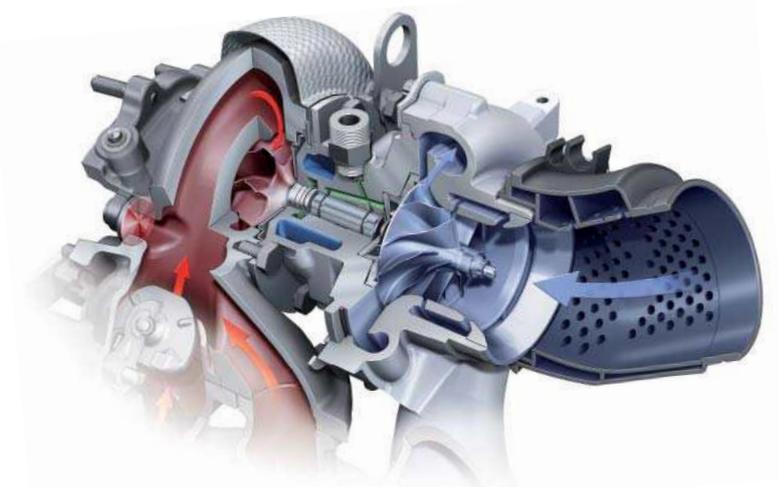
The low pressure exhaust turbocharger is a turbocharger with a fixed turbine geometry and is installed downstream of the high pressure exhaust turbocharger. The turbine changeover valve is located between the two turbochargers. When the turbine changeover valve is fully open, the flap is no longer in the exhaust gas flow, allowing swirl-free inflow into the turbine.

Components of the low pressure exhaust turbocharger:

- ▶ Turbine, bearing and compressor housing
- ▶ Turbine changeover valve
- ▶ Wastegate
- ▶ Vacuum cell

The low pressure exhaust turbocharger is equipped with a wastegate flap for charge pressure control at engine speeds of approx. 3400 rpm and higher. This wastegate flap is actuated by a vacuum cell and counteracts the charge pressure until it is attained.

In the event of loss of vacuum, a low charge pressure is set, and this counteracts a spring integrated in the vacuum cell.



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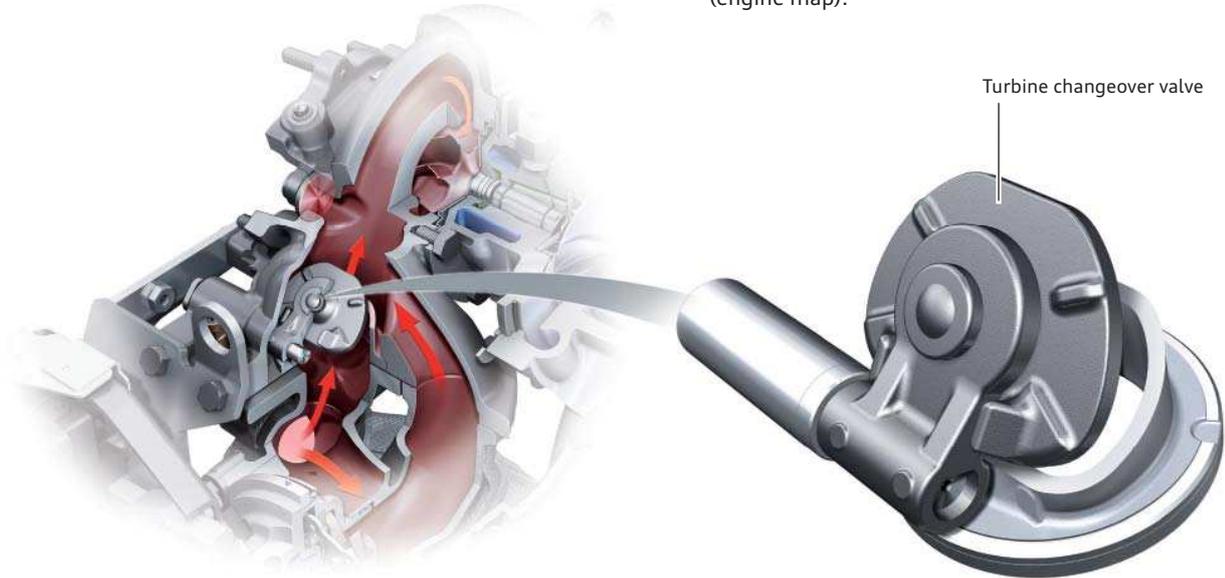
Note

The wastegate vacuum cell can be replaced separately.

Turbine changeover valve

The turbine changeover valve is seated in the low pressure exhaust turbocharger housing and is actuated via a vacuum cell. It controls the exhaust gas flow to both turbochargers depending on load requirements. At low rpm, the turbine changeover valve directs the exhaust gases to the high pressure exhaust turbocharger.

If the turbine changeover valve is minimally open, the partial exhaust gas flow is immediately channelled to the low pressure exhaust turbocharger, with the result that the low pressure exhaust turbocharger always feeds pre-compressed air to the high pressure exhaust turbocharger. The turbine changeover valve serves as a charge pressure control actuator and regulates the charge pressure in the 2300 – 3400 rpm engine speed range (engine map).



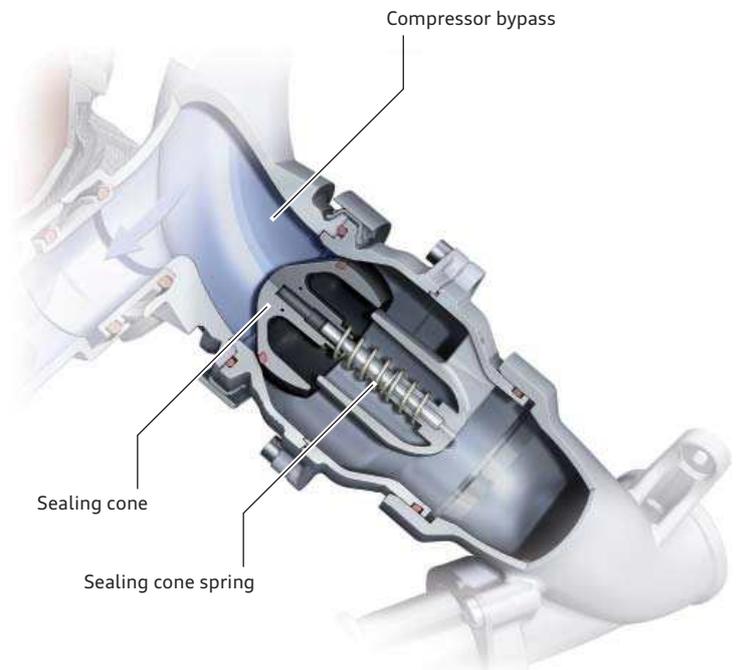
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Compressor bypass valve

A self-regulating compressor bypass valve is arranged in parallel with the high pressure compressor. When the turbine changeover valve is fully open, the compressor bypass valve opens on account of the pressure differences between the low and high pressure exhaust turbochargers and frees up the path directly to the intake manifold. The compression work of the low pressure stage is then sufficient to set the required charge pressure.

Components of the compressor bypass valve:

- ▶ Spring-loaded sealing cone
- ▶ Sealing cone with flow-optimised contour



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Note

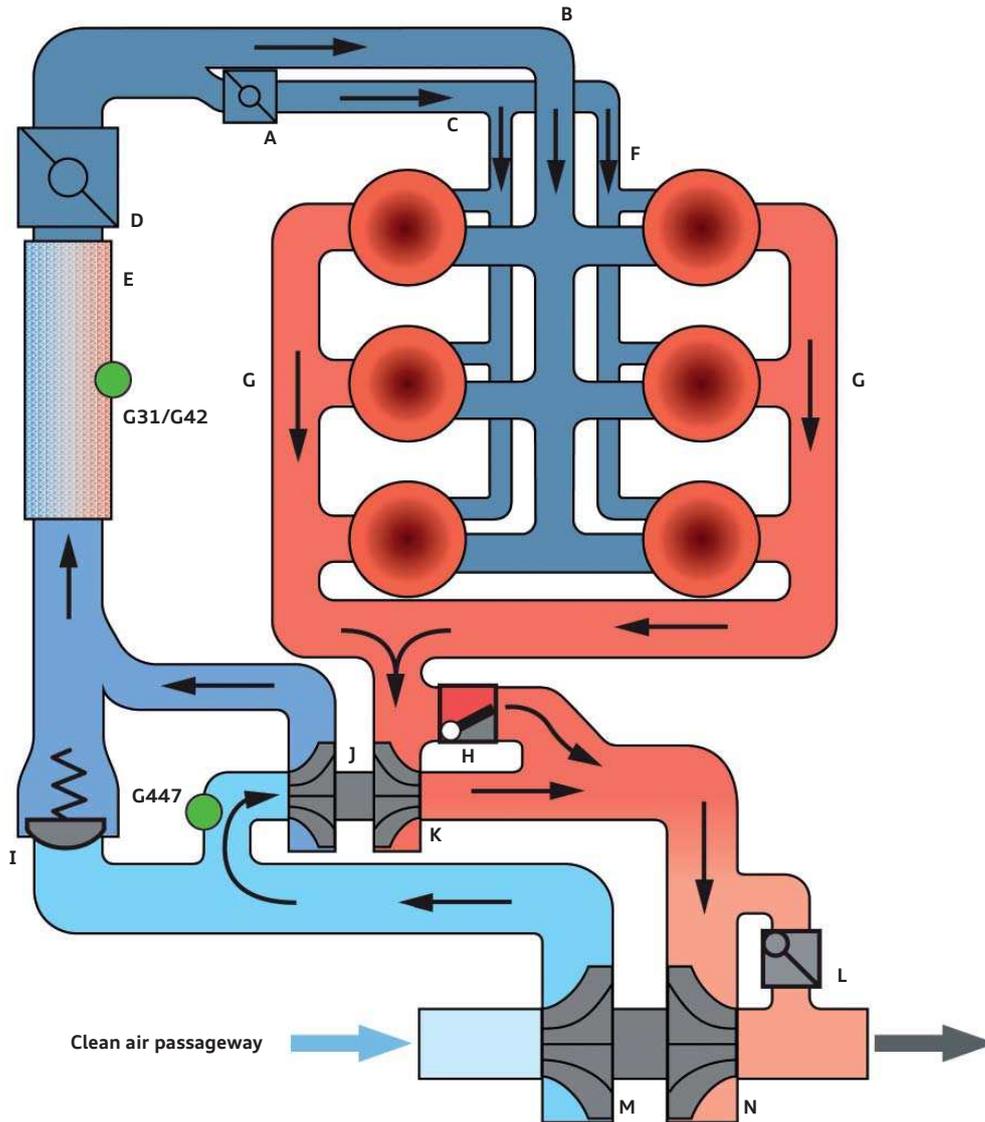
The turbine changeover valve vacuum cell including the mount and compressor bypass valve can be replaced separately.

System design

On the air side, the fresh air flowing via air filters and the clean air passageway is pre-compressed by the low pressure compressor across the entire mapped range. The pressure of the air mass flow is increased still further inside the high pressure compressor. The air mass flow is then cooled in the charge air cooler and channelled to the engine via the throttle flap, the central swirl flap and the intake manifold. A self-regulating compressor bypass valve is arranged in parallel with the high pressure compressor.

This valve opens depending on the compressor rating of the low pressure exhaust turbocharger and the resultant pressures ratio upstream and downstream of the high pressure compressor. The compression work of the low pressure stage is now sufficient to set the required charge pressure.

Depending on load requirements, the charge pressure of both chargers is adjusted to approx. 3.2 bar (absolute).



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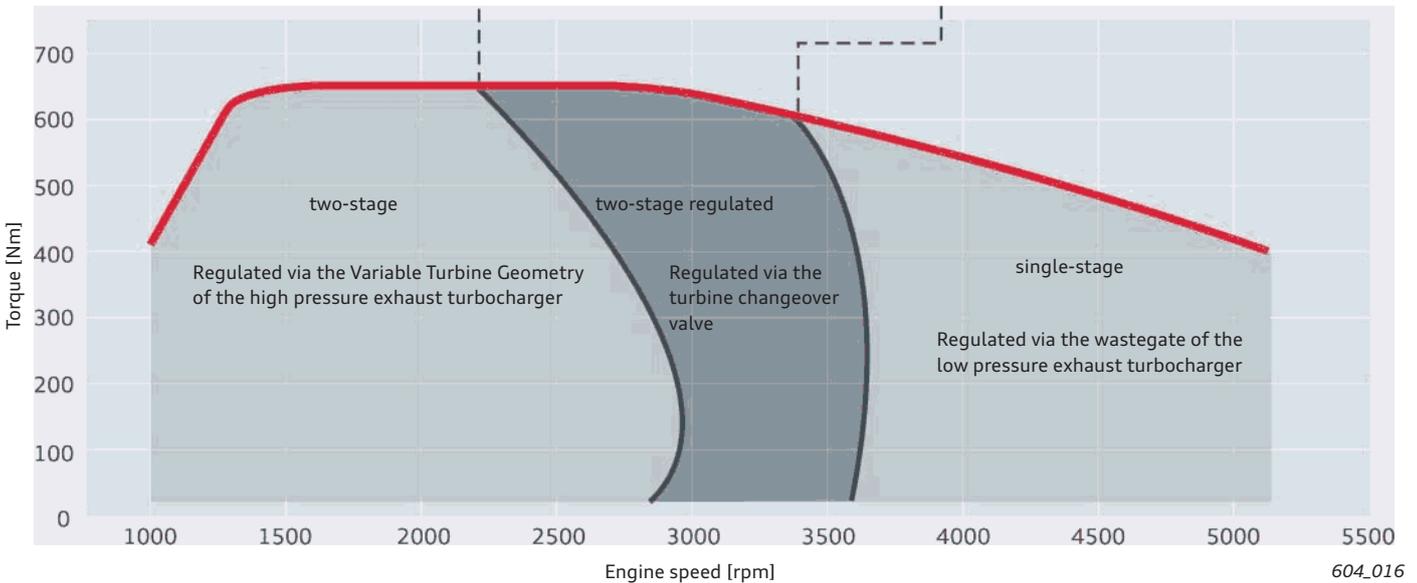
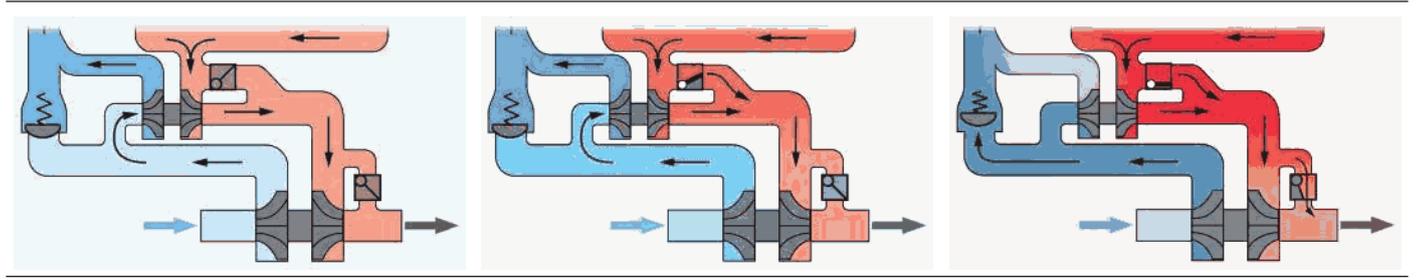
A	Central swirl flap	J	High pressure compressor
B	Swirl port (tangential port)	K	High pressure turbine with Variable Turbine Geometry
C	Charging port	L	Wastegate
D	Throttle flap	M	Low pressure compressor
E	Charge air cooler	N	Low pressure turbine
F	Intake manifold	G31	Charge pressure sender
G	Exhaust manifold	G42	Intake air temperature sender
H	Turbine changeover valve	G447	Charge pressure sender 2
I	Compressor bypass valve		

Function in map

The various operating modes of the system are shown here in the engine map.

The pneumatically activated turbine changeover valve controls the power outputs of the turbines.

Low engine speed (up to 2300 rpm)	Medium engine speed (2300 – 3400 rpm)	High engine speed (over 3400 rpm)
<p>The turbine changeover valve is fully closed, with the result that the exhaust gas flows completely through the smaller high pressure exhaust turbocharger. The nominal charge pressure is set by VTG adjustment. This ensures spontaneous system response even at very low engine speeds.</p>	<p>The power output of the large, continuous-flow low pressure exhaust turbocharger starts to rise when the wastegate is closed. The charge pressure control system begins to adjust the charge pressure with the pneumatic turbine changeover valve by opening in a defined manner the turbine bypass to circumvent the small high pressure exhaust turbocharger. Even a reduction in the surface pressure of the turbine changeover valve in its seat results in significant bypassing of high pressure exhaust turbocharger due to the pressure conditions upstream and downstream of the changeover valve.</p>	<p>The turbine changeover valve and the turbine bypass of the small high pressure exhaust turbocharger are fully opened. The charge pressure is controlled solely via the wastegate of the low pressure exhaust turbocharger. The low pressure charger design provides outstanding revving ability up to 5200 rpm and high performance over a wide engine speed range.</p>



The described engine speed ranges in the various control modes shift under changing temperature and altitude conditions. The charge pressure control application factors this in when activating the actuators.

When two-stage charging is employed, engine response is determined by the leak-tightness of the turbine changeover valve. Even the smallest of leaks can lead to high pressure losses in the high pressure turbine.

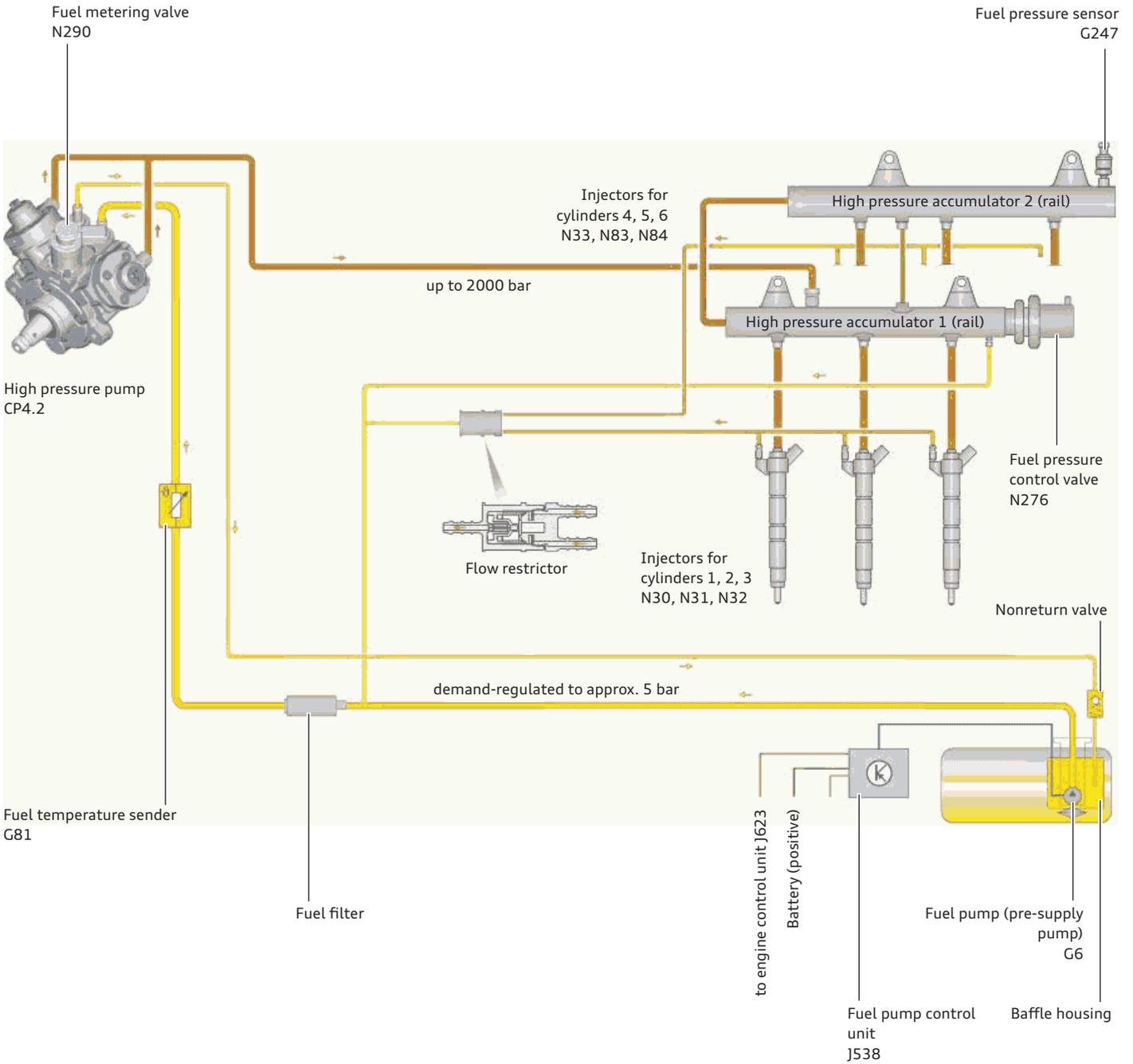
Fuel system

Common rail injection system

The rail pressure (up to 2000 bar) is produced by a CP4.2 twin piston high pressure pump. To deliver the amount of fuel needed to produce the required power output, the pump stroke has been extended from 5.625 mm to 6.0 mm compared to the basic engine.

Piezo inline injectors with 8 port nozzles and a hydraulic flow rate of 400 ml / 30 s inject the fuel into the combustion chamber in order to achieve the maximum power output of 230 kW.

Fuel system



Common rail injector

Whereas a ZI needle seat with midi sac hole is used in the basic engine, a ZK needle seat with i-midi sac hole is used for the first time in the V6 biturbo engine. These modifications have made it possible to reduce the detrimental volume relevant to HC formation by approx. 32 %.

Sac hole injectors

Here, the injection ports start from a sac hole below the seat cone. On completion of the injection cycle, the volume below the needle seat is filled with fuel which may then be admitted, badly carburated, to the combustion chamber and have a detrimental effect on HC emissions (uncombusted hydrocarbons) in the exhaust gas.

i-midi sac hole injector

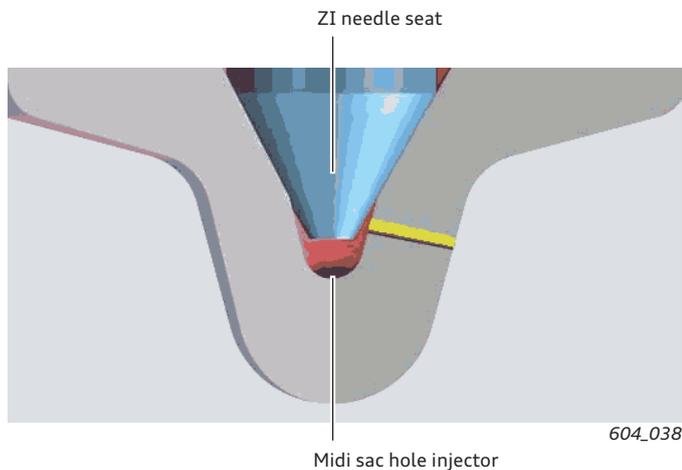
This type of injector is a compromise between detrimental volume and spray pattern symmetry. Minimising the volume below the needle seat results in lower HC emissions compared to the midi sac hole.

The relatively smooth flow of fuel to the injector ports produces a symmetrical spray pattern.

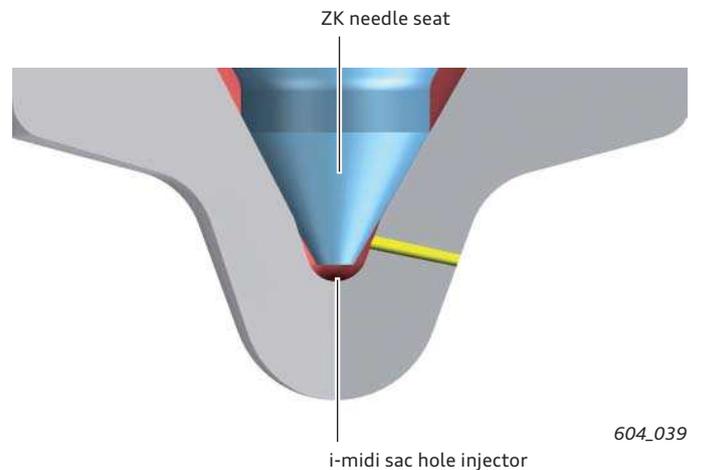
Result: a reduction of approx. 30 % in sac hole detrimental volume reduces HC emissions by approx. 15 %.



2nd Gen V6 TDI engine



V6 TDI biturbo engine



Diesel particulate filter regeneration

Whereas three post-injections were employed in the 2nd Gen 3.0l V6 TDI engine for regeneration purposes, as many as five post-injections are performed in the biturbo engine:

- ▶ Two post-injections close to the main injection
- ▶ Three partial post-injections remote from main injection

These post-injections produce exothermy¹⁾ which is released via the oxidising catalytic converter. Therefore, up to eight partial fuel injections are performed per combustion cycle across a wide mapped range during the regeneration phase of the particulate filter.

¹⁾ Exothermy: here a chemical reaction takes place on the surface of the oxidising catalytic converter, additionally heating the exhaust gas.

Engine management

System overview

Sensors

Air mass meter G70

Engine speed sender G28

Hall sender G40

Coolant temperature sender G62

Radiator outlet coolant temperature sender G83

Fuel temperature sender G81

Temperature sender for engine temperature control G694

Oil level/oil temperature sensor G266

Fuel pressure sender G247

Accelerator pedal sensor and accelerator pedal position sender G79 and G185

Exhaust gas recirculation potentiometer G212

Brake light switch F

Charge pressure sender G31 and Intake air temperature sender G42
Charge pressure sender 2 G447

Oxygen sensor G39

Oil temperature sender 2 G664

Oil pressure switch F22

Oil pressure switch for reduced oil pressure F378

Exhaust gas temperature sender 3 (after cat) G495

EGR temperature sensor G98

Exhaust gas temperature sender 1 G235

Exhaust gas temperature sender 2 G448

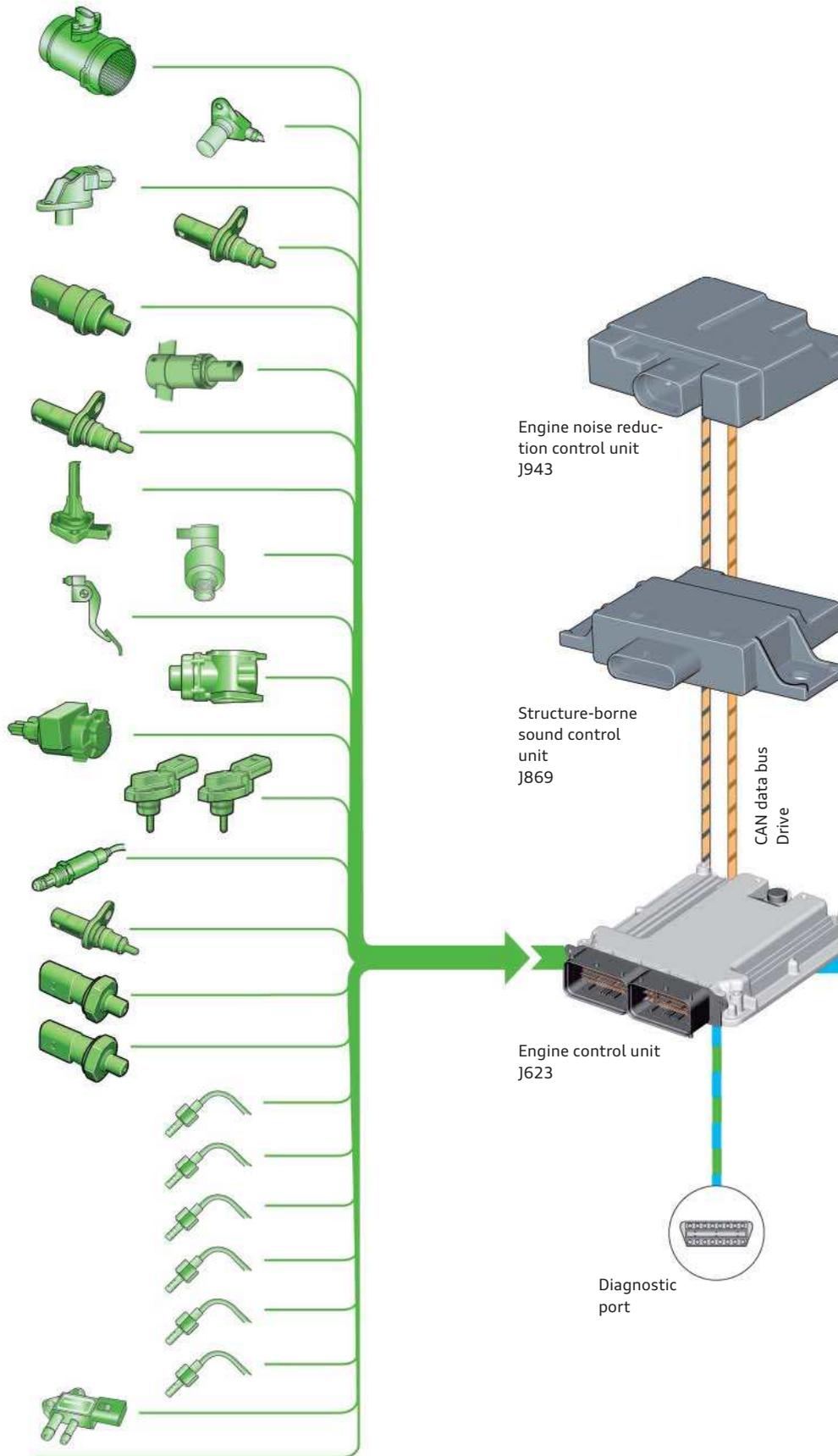
Exhaust gas temperature sender 4 (after particulate filter) G648

Exhaust temperature sender 4 for bank 2 G649

Differential pressure sender G505

Auxiliary signals:

- Cruise control system
- Speed signal
- Start request to engine control unit (Kessy 1 + 2)
- Terminal 50
- Crash signal from airbag control unit



Actuators

Piezoelectric element for injector for cylinders 1 – 3
N30, N31, N32

Piezoelectric element for injector for cylinders 4 – 6
N33, N83, N84

Automatic glow period control unit for J179
Glow plugs 1 – 3 Q10, Q11, Q12

Glow plugs 4 – 6 Q13, Q14, Q15

Oil pressure control valve N428

Throttle valve control unit J338

Fuel metering valve N290

Fuel pressure regulating valve N276

Exhaust gas recirculation servomotor V338

Intake manifold flap motor V157

Exhaust gas recirculation cooler change-over valve N345

Cylinder head coolant valve N489

Turbine changeover valve N529

Charge pressure limitation solenoid valve N75

Exhaust turbocharger control unit 1 J724

Thermostat for mapped engine cooling F265

Fuel pump control unit J538

Electro/hydraulic engine mounting solenoid valve, left N144
Electro/hydraulic engine mounting sol. valve, right N145

Oxygen sensor heater Z19

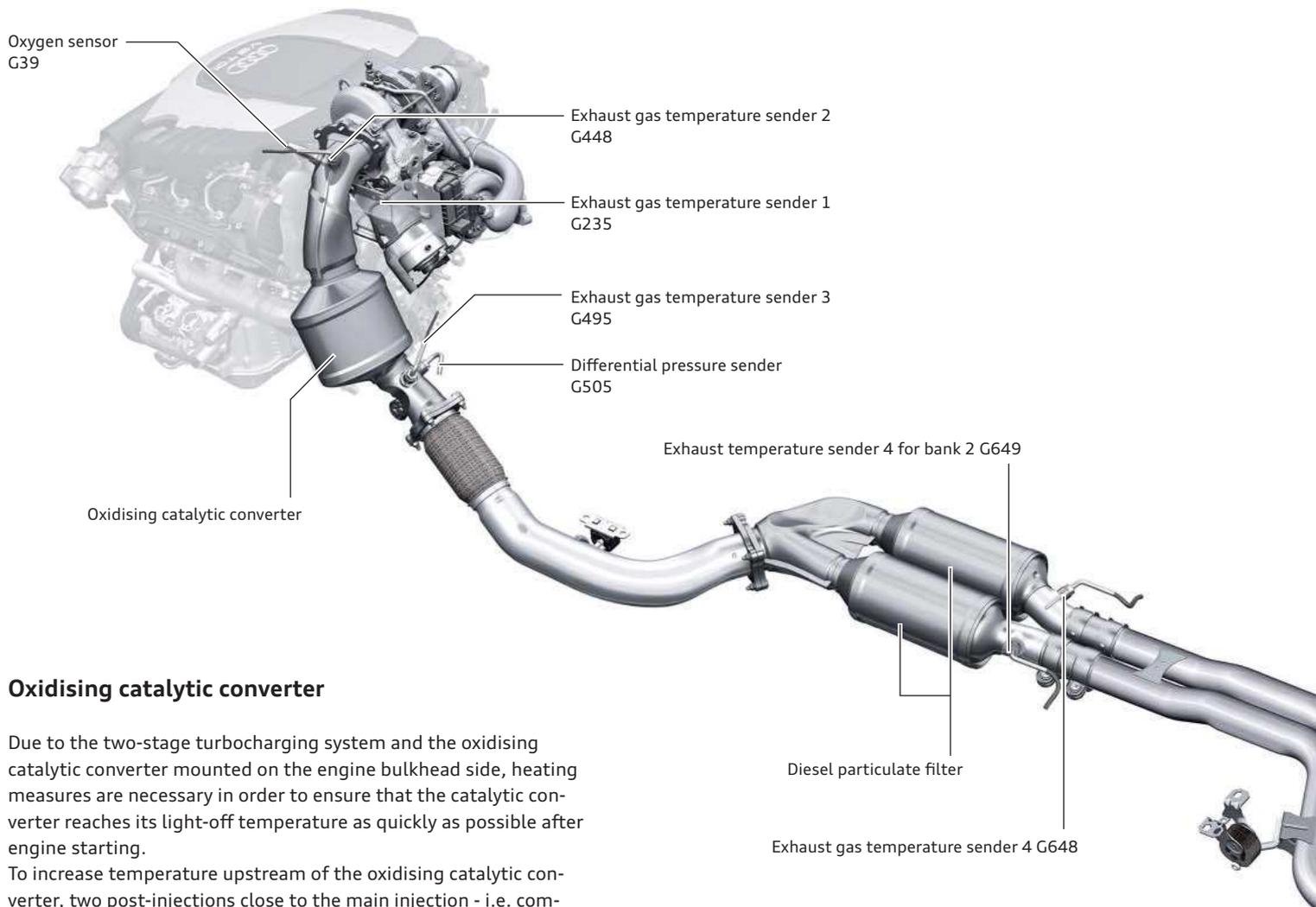
Fuel pump relay J17
Fuel predelivery pump G6

Auxiliary signals:

A/C compressor
Auxiliary coolant heater
Fan setting 1 + 2
Auxiliary air heater element Z35

Exhaust system

Overview



Oxidising catalytic converter

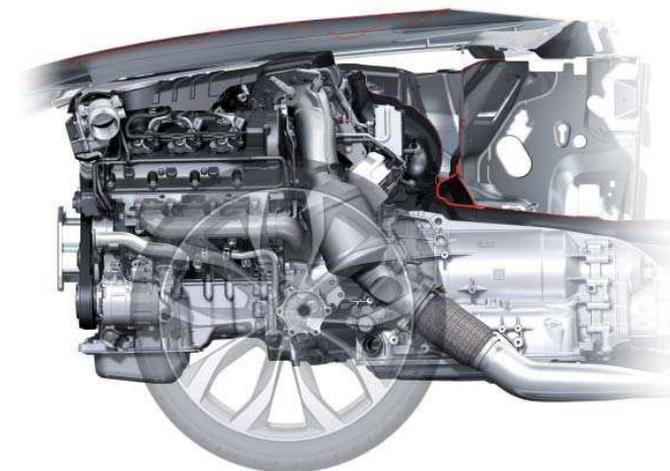
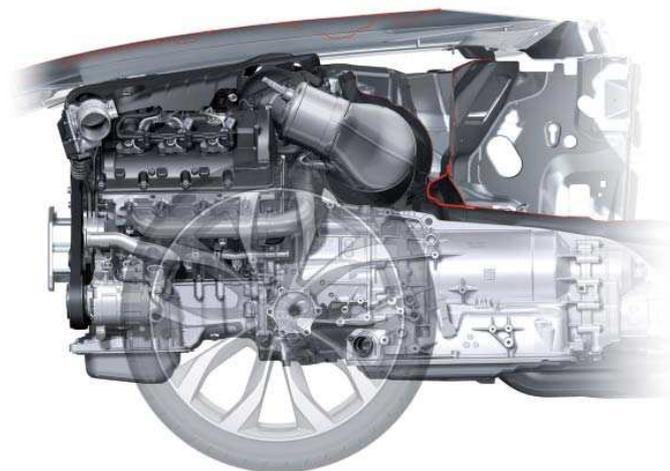
Due to the two-stage turbocharging system and the oxidising catalytic converter mounted on the engine bulkhead side, heating measures are necessary in order to ensure that the catalytic converter reaches its light-off temperature as quickly as possible after engine starting.

To increase temperature upstream of the oxidising catalytic converter, two post-injections close to the main injection - i.e. combustible injections - are activated for a period of 400 seconds after cold starting.

Installation position of the oxidising catalytic converter

2nd Gen V6 TDI engine

V6 TDI biturbo engine



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Sound actuator and active sound exhaust system

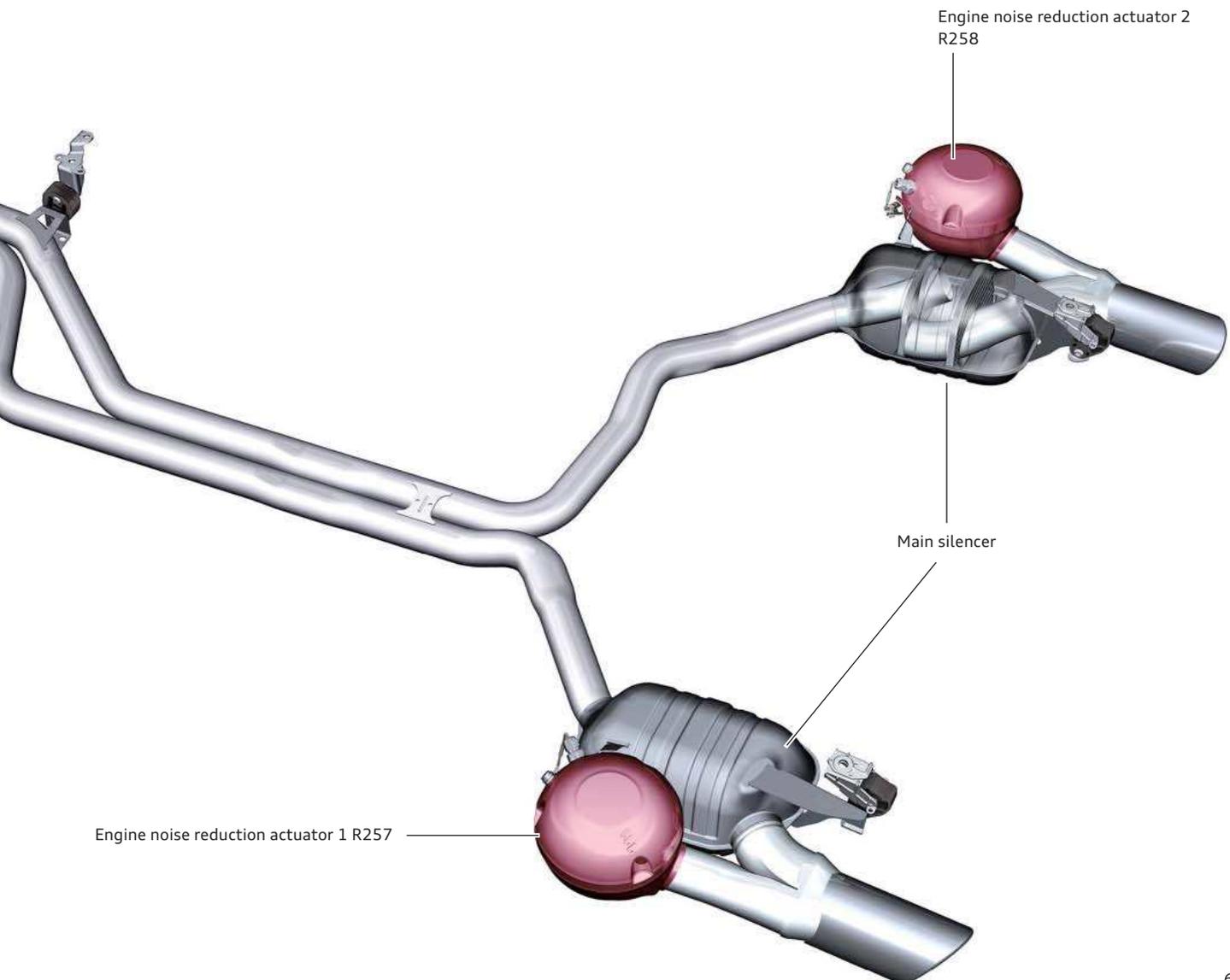
The sound actuator system and the active sound exhaust system are used on models with the 3.0l V6 TDI biturbo engine in order to enhance the acoustics.

Sound actuator

The structure-borne sound generated by the sound actuator is transmitted to the cabin via the vehicle body and the windscreen, which acts as a loudspeaker membrane.

Active sound exhaust system

The active sound exhaust system comprises an exhaust system with mounted loudspeaker housings capable of producing defined frequencies (engine orders) in order to create a desired sound pattern (sound design).



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Reference

For further information about the sound actuator and the active sound exhaust system, refer to Self Study Programme 603 "Audi A6 Avant '12".

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