Service Training

5.2 litre V10 FSI engine

Self-Study Programme 376

For the first time in its history, Audi presents a high-performance ten-cylinder engine - the V10 FSI engine. Fitted in the Audi S6 and S8 models, it underscores the specific attributes of pronounced sportiness and supreme comfort. This combination of ten cylinders and FSI technology gives Audi a unique technological position on the market.

The V10 belongs to the next generation of Audi V-engines, all of which have a 90-degree included angle and a spacing of 90 millimetres between cylinder centres. Compared to the engine in the Lamborghini Gallardo, which has a spacing of 88 millimetres between cylinder centres, the Audi engine has several new features in key areas.

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Reference

Content-wise, this SSP supplements SSP 377.

Table of contents

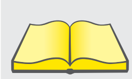
5.2 litre V10 FSI engine

The self-study programme teaches the design and function of new vehicle models, new automotive components or new technologies.

The Self-Study Programme is not a Repair Manual!
The values given are intended as a guideline only and refer to the software version valid at the time of publication of the SSP.

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

Reference



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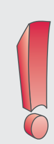

Performance features

The engine code is located at the front above the vibration damper on the right-hand side adjacent the oil pressure switch.

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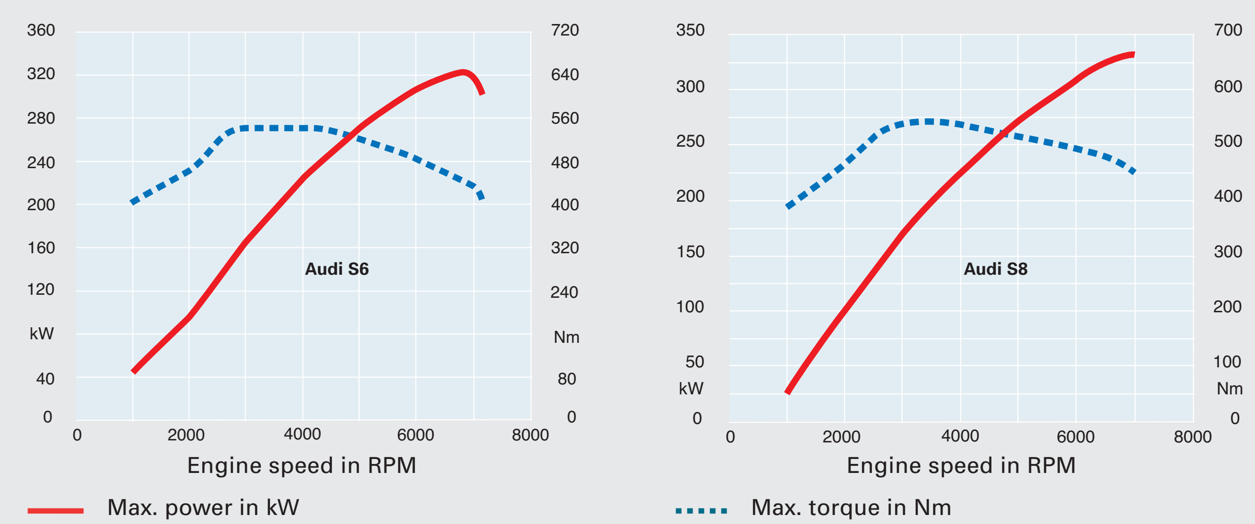
Torque/power curve



Specifications

	S6	S8
Engine codes	BXA	BSM
Type of engine	V10 engine with 90° included angle	
Displacement in cm^3	5204	
Max. power in kW (bhp)	320 (435)	331 (450)
Max. torque in Nm	540 at 3000 - 4000 rpm	
Cylinder spacing in mm	90	
Bore in mm	84,5	
Stroke in mm	92,8	
Compression ratio	12,5 : 1	
Firing order	1–6–5–10–2–7–3–8–4–9	
Engine weight in kg	approx. 220	
Engine management	Bosch MED 9.1 - master-slave principle	
Exhaust gas recirculation	internal	
Exhaust gas treatment system	4 main catalysts, 4 pre-catalytic converters and 4 post-cat sensors	
Exhaust emission standard	EU IV/LEV II	

Basic engine

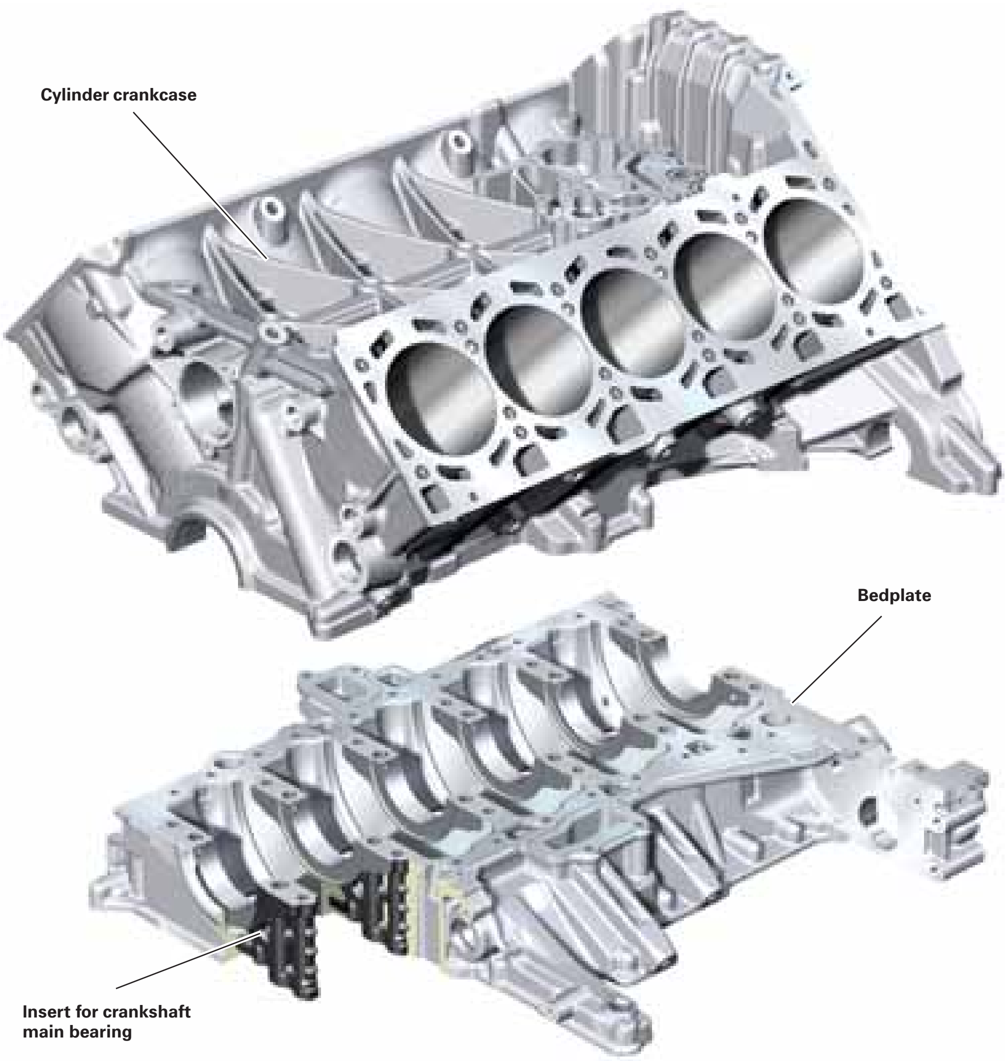
The V10 FSI engine is based on the V8 FSI engine, which has, in principle, "only" been upgraded to include an additional pair of cylinders.
The basic concept of the cylinder crankcase and the cylinder heads, as well as the timing gear, the fuel system and the intake manifold concept, have been adopted unchanged.

On the other hand, the crankshaft with balancer shaft, the double-chambered intake with dual throttle valves, the exhaust manifold and the ECU concept are features specific to the V10.

Crankcase

The cylinder crankcase with 90° included angle is a bedplate construction and, with a length of 685 mm and a width of 80 mm, it sets new standards for compact design and overall length. The cylinder crankcase, inclusive of bearing bushings and bolts, weighs only approx. 47 kg.
The cylinder crankcase upper section is manufactured as a homogeneous monoblock from AlSi17Cu4Mg using the low pressure chill casting method.

The benefits of this combination of materials are high strength, minimal cylinder distortion and good heat dissipation.
This technology made has it possible to dispense with separate cylinder liners because the cylinder liners are manufactured by mechanically stripping the hard silicon crystals directly from the aluminium alloy.



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The AlSi12Cu1 bedplate has been reinforced with cast-in GGG50 inserts which are attached with four screws and through which the majority of the power flow from the engine is transmitted.

These inserts also reduce thermal expansion and play in the main crankshaft bearings at high temperatures.

Crankshaft drive

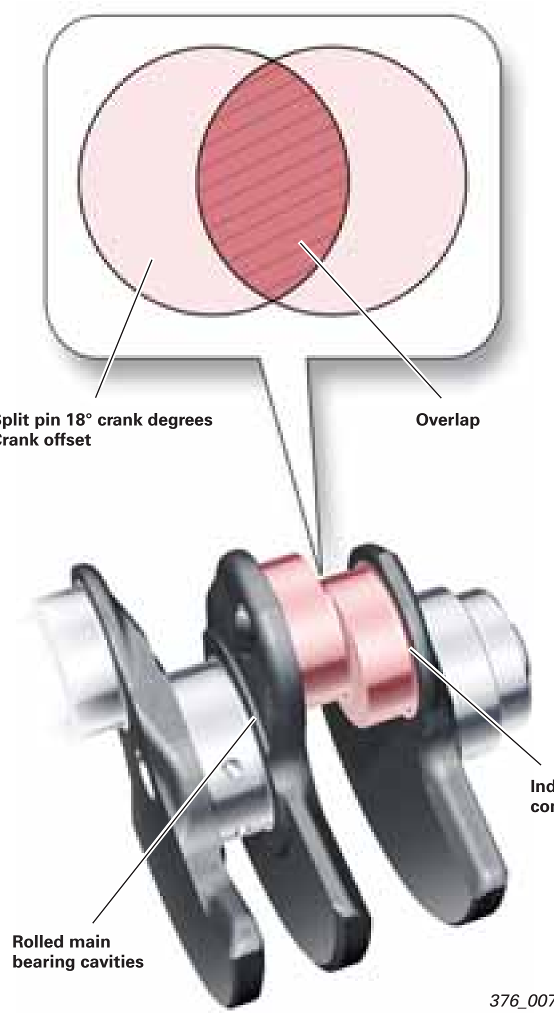
Due to the 90° included angle, the crankshaft has been forged as a split-pin shaft with a crank offset of 18° in order to achieve an even firing interval of 72° crank degrees.
The split pin offset requires special strength treatment because the crankshaft is most susceptible to breaking at this so-called "overlap".

This was achieved by toughening measures such as *rolling** the main bearing cavities and *induction hardening** of the conrod journal cavities.

A viscous damper lessens the torsional vibration at the free end of the crankshaft facing the belt drive.

* *Rolling: a roller under high pressure which rolls off the rotating part of the workpiece. This produces a high quality surface finish and simultaneously strengthens the material.*

* *Induction hardening: heating of the workpiece edge zone by means of induced eddy currents whereby the core is not heated and remains soft and ductile.*



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The first-order free moments of inertia are compensated by a balancer shaft counter-rotating at crankshaft speed.

This spheroidal cast iron balancer shaft runs in two bearings and ensures a high level of engine refinement. It is integrated in the chain drive D of the ancillary units and is disposed in the vee space between the cylinder banks.

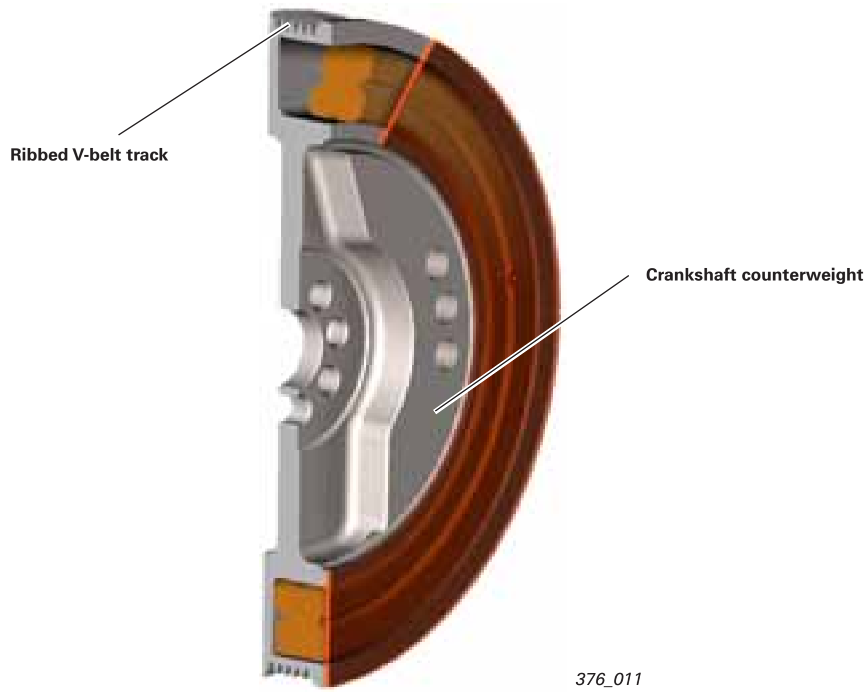
376_009

Viscous vibration damper

So-called vibration dampers are used to dampen the torsional vibrations which occur at the free end of the crankshaft due to the firing order of the cylinders.

These vibration dampers usually have two metal rings connected by a damping medium (elastomer-rubber). A viscous damper is fitted in the V10 FSI engine to absorb torsional vibration in the crankshaft.

A viscous oil filled ring on the belt pulley is used as a damping medium. This viscous oil buffers the relative movement between the damping element and the belt pulley housing.
The result is a reduction in the torsional vibration of the crankshaft and hence also the torsional irregularity of the belt wheel.
At the same time, it reduces the load on the ribbed V-belt.



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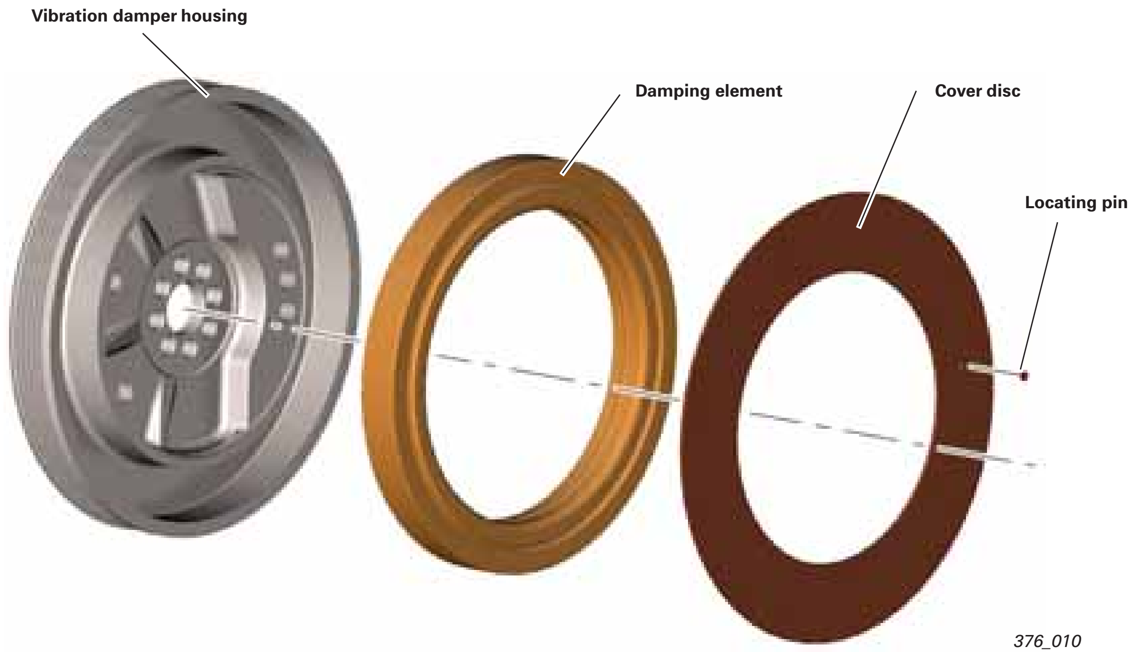

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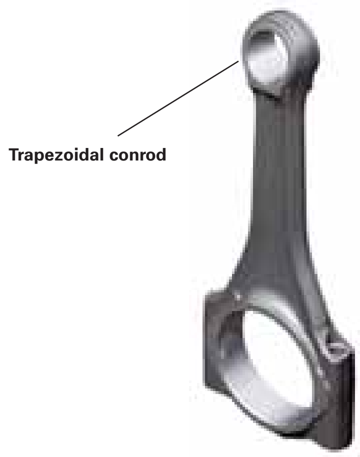
Conrods

The trapezoidal-type conrods are manufactured from a high-strength cracked material (36MnVS4) and broken at a predetermined position in the production process.

This produces a structural break at the parting point and ensures a high degree of joining accuracy whereby only these two parts fit together perfectly. The conrods and their bearing bushings are lubricated through oil bores running from the main bearing to the conrod journal.



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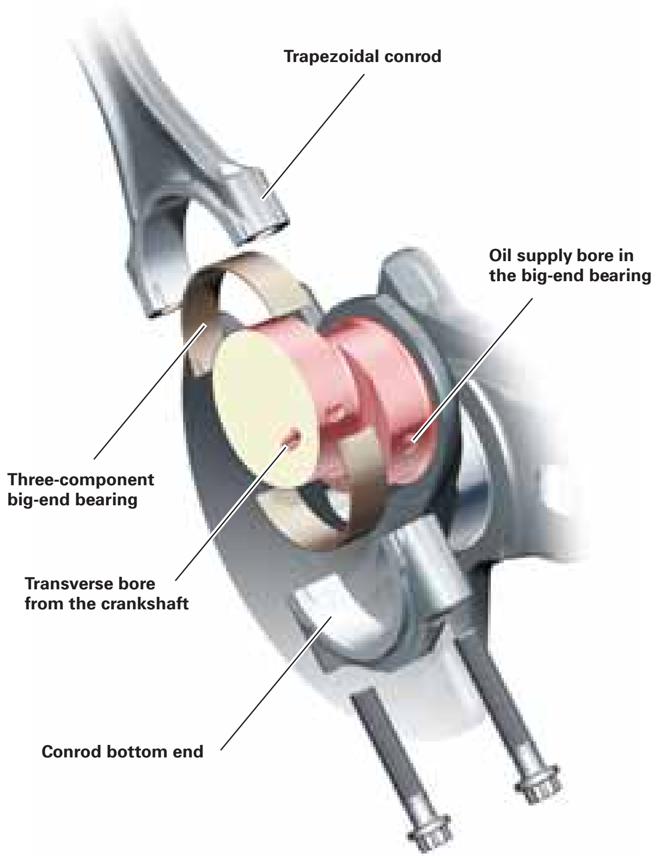

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Pistons

The cast aluminium pistons, made by Kolben Schmidt, have a special crown shape that has been adapted to the FSI combustion process in order to promote charging (tumble effect) and impart a tumbling motion of the air-fuel mixture induced in homogeneous-charge mode.

The piston skirt is coated with a wear-resistant iron anti-friction liner which minimises the wear of the piston bearing surface under compressive load. Oil spray nozzles cool the piston crown from beneath and simultaneously lubricate the gudgeon pin bearings.

376_024

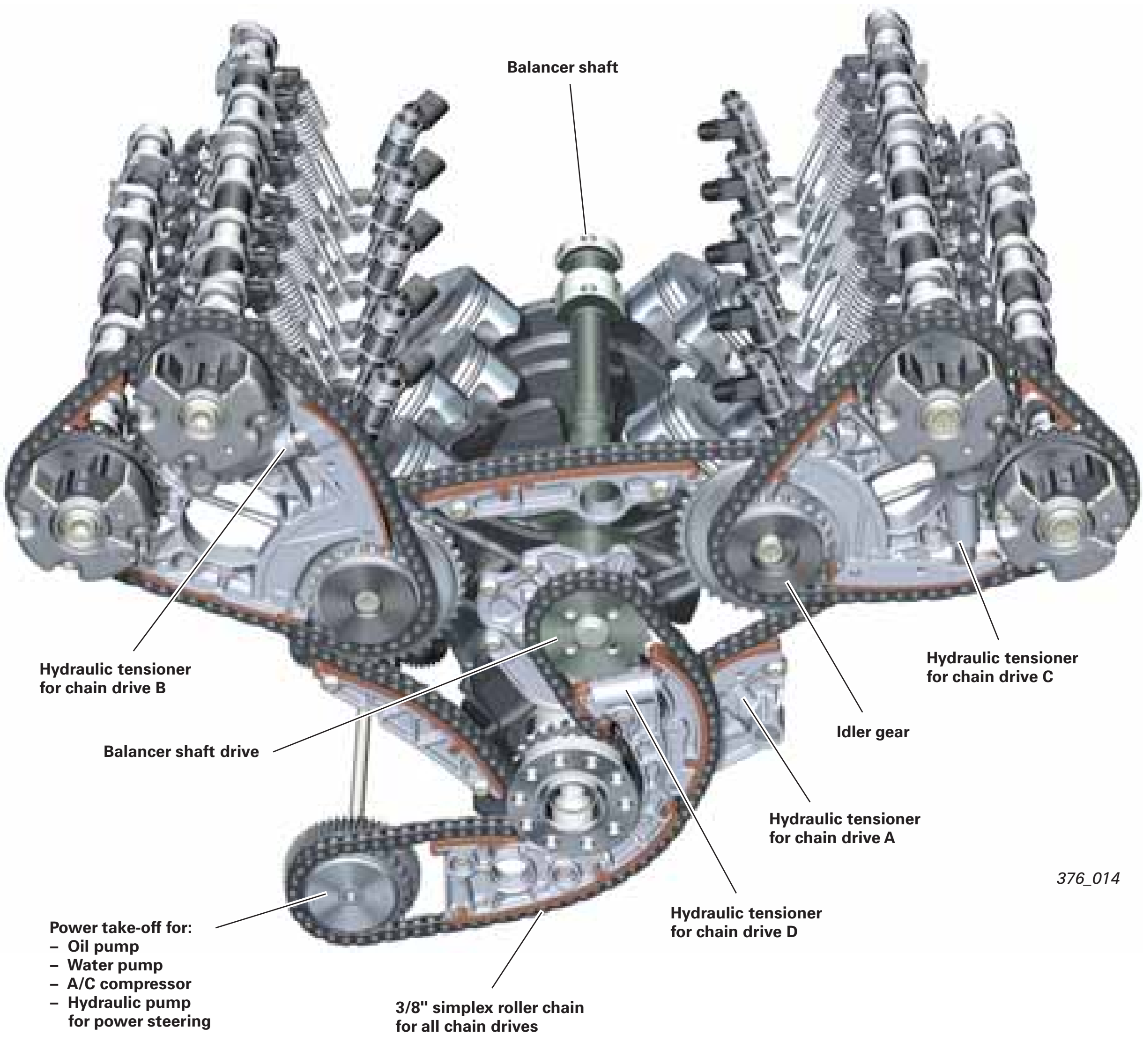
Chain drive

The timing gear with flywheel side chain drive is a key building block with synergy potential within the vee engine family due to its advantages in terms of compactness.

Chain drive is provided by four 3/8" roller chains arranged on two planes.
Chain drive A, acting as a distributor drive, from the crankshaft to the idler gears, and chain drives B and C, acting as cylinder head drives, from the idler gears to the camshafts.
Chain drive D, acting as an ancillary units drive, drives not only the oil and water pumps, air conditioner compressor and power steering pump, but also the balancer shaft.

The balancer shaft is mounted in the vee space between the cylinder banks and rotates in the opposite direction at engine speed in order to counteract first-order mass moments of inertia. The latter evidence themselves as vibrations, noises and uneven running of the engine in certain speed ranges.

The balancer shaft, adapted to the V10 engine, ensures a high level of engine refinement and must be installed in the correct position in the chain drive after repair work has been done.
Hydraulic tensioners with non-return valves are used as a tensioning system and, like the chains, they are designed for lifetime use.



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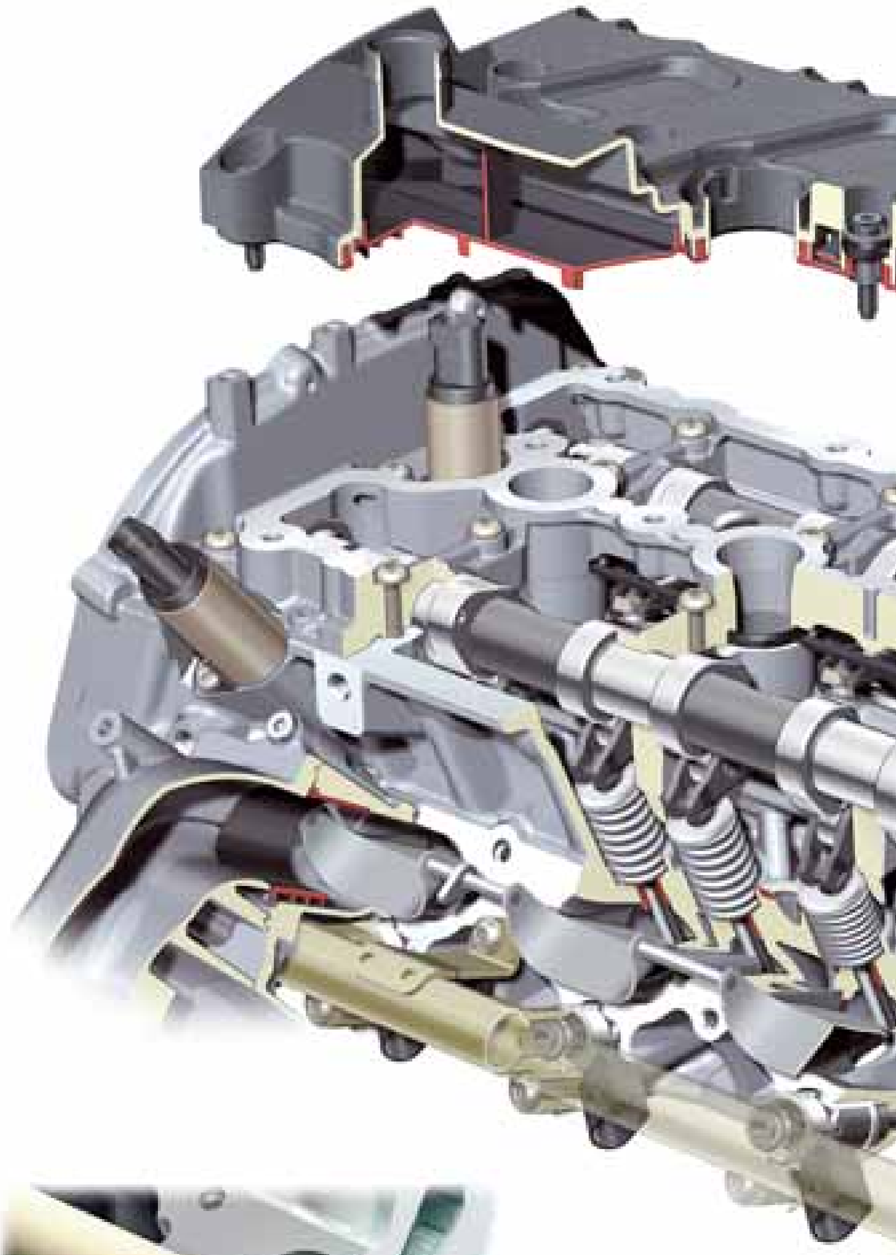
Cylinder head

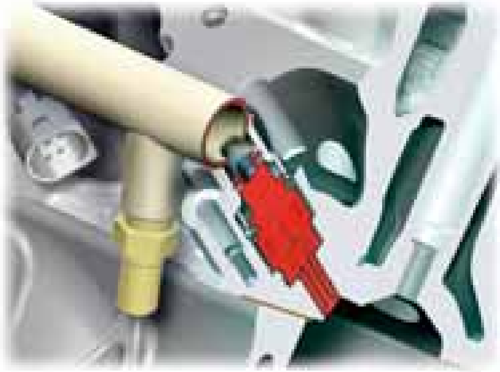
The cylinder head of the new V10 FSI engine is based on the identically designed Audi 4V FSI cylinder head concept.
Design features are spark plugs mounted at the centre of the cylinder heads and solenoid controlled injection nozzles at the intake end. The built-up hollow camshafts rotate in bearings in the cylinder head and are bolted to a ladder frame.

The camshaft is adjusted by means of vane adjusters, whereby the actuators are locked mechanically by lokking bolts at engine start until the required oil pressure level is reached.

The adjustment range of the variable camshaft adjuster is 42° at the intake and exhaust ends.

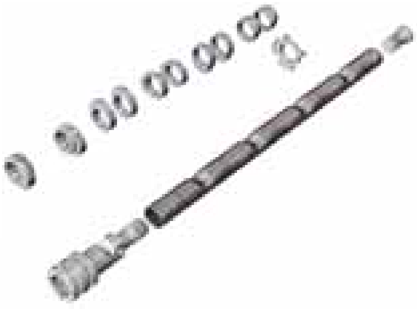


An inserted partition plate divides the intake port into an upper half and a lower half.

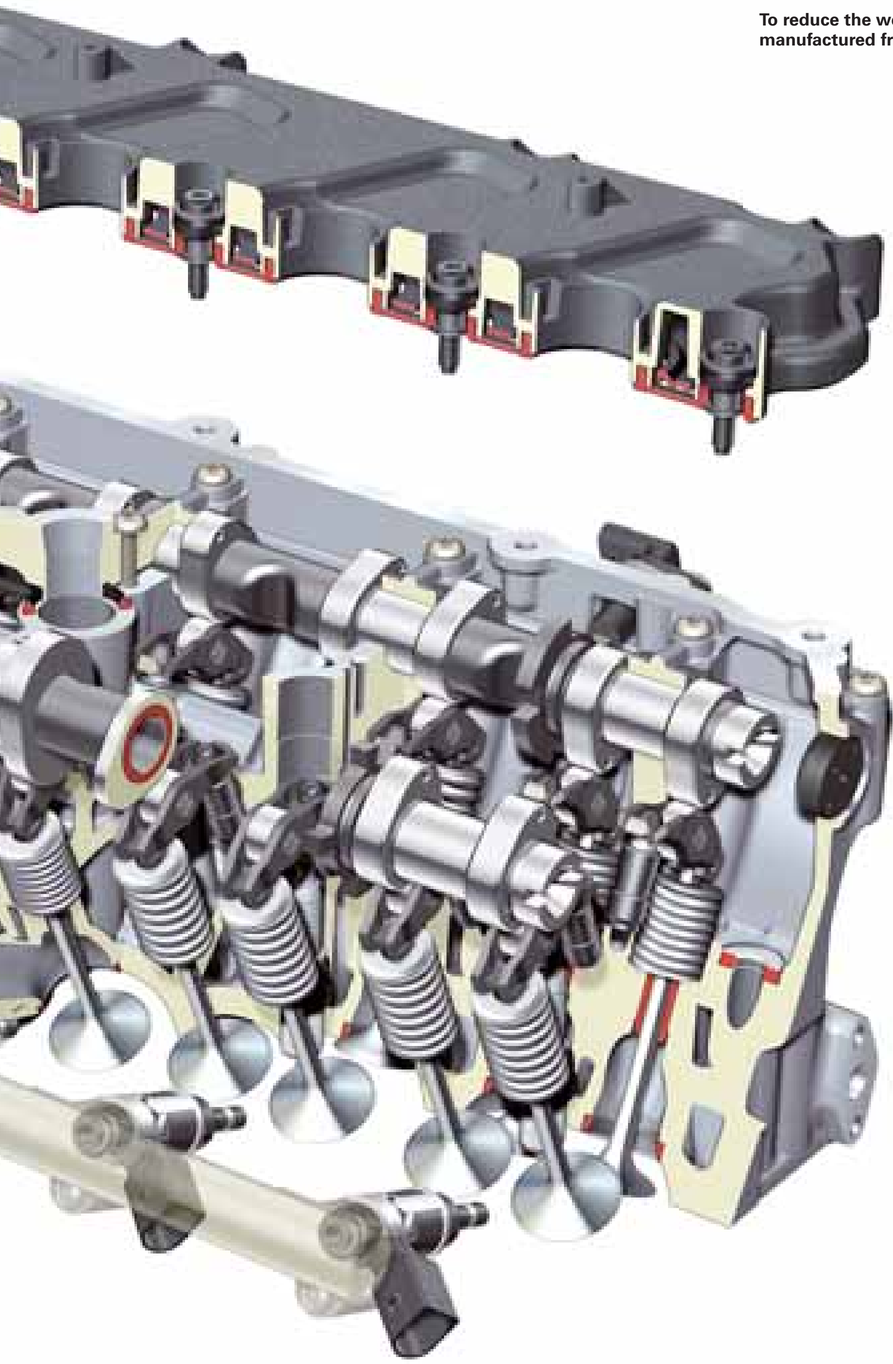


The injectors and the injection nozzle are mounted directly in the cylinder combustion chamber so that fuel is injected at an angle of 7.5°.

They actuate roller cam followers with hydraulic valve clearance compensation, as well as the intake valves and the sodium cooled exhaust valves.
The intake ports have baffle plates to enhance the tumble effect.



To reduce the weight of rotating parts, the camshafts are manufactured from a hollow tube and mount-on cams.



Hydraulic valve clearance compensation elements are supplied with hydraulic oil through transverse bores in the cylinder head and provide backlash free valve actuation.

Additional air flows through a port in the cylinder head to each exhaust port in order to burn the rich fuel-air mixture downstream of the exhaust valves after cold starting (catalytic converter start).

376_013

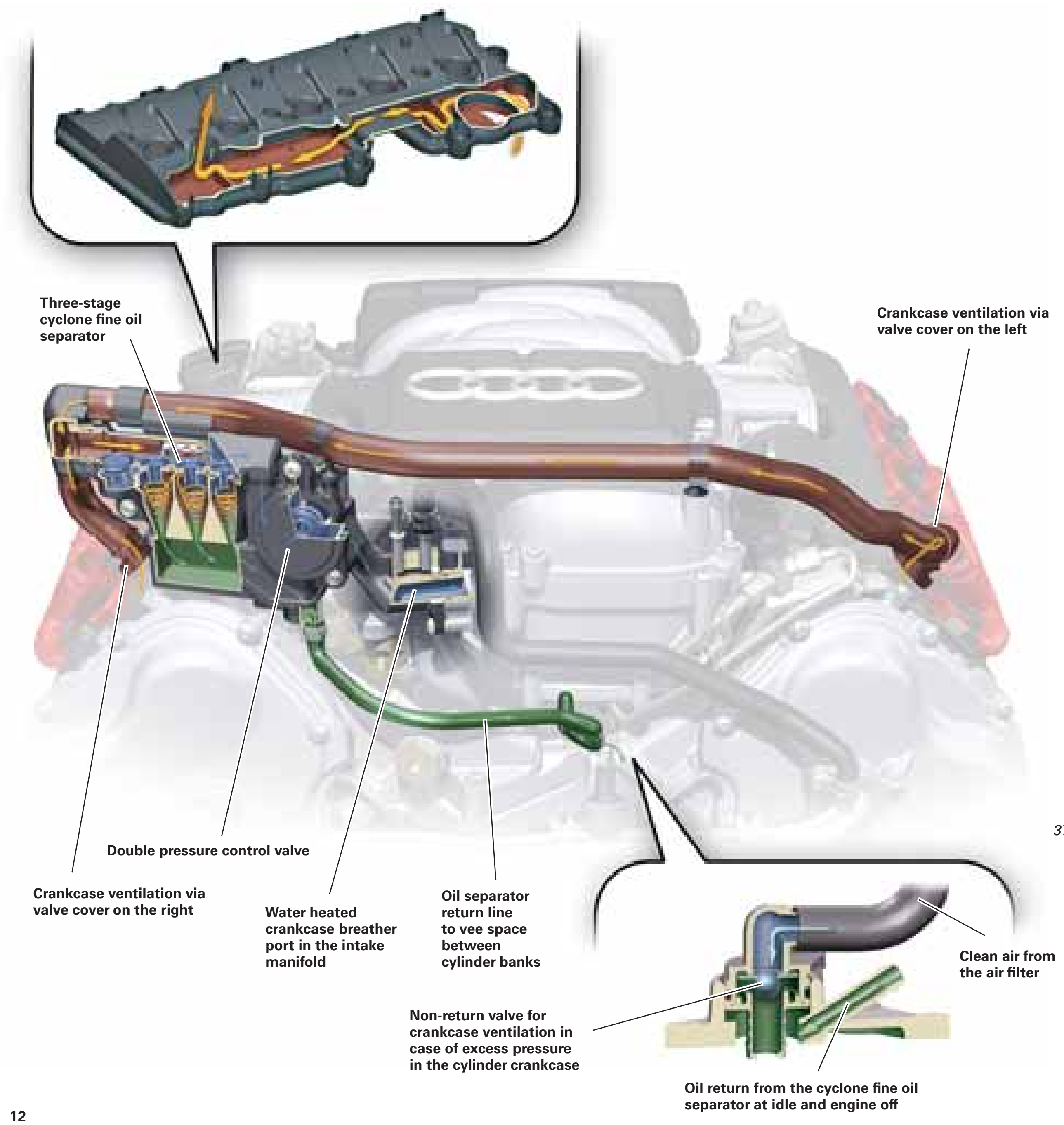
Crankcase ventilation

The blow-by gases produced by the combustion process flow through the cylinder heads and into the valve covers.
Both valve covers channel the blow-by gases internally to the fine oil separator via baffles acting as gravity oil separators and via a system of hoses.

The fine oil separator takes the form of a three-stage cyclone with bypass whereby the oil content in the blow-by gases is approx. 0.1 g/h after passing through the cyclone. This method of fine oil separation effectively prevents coking of the intake valves.

After leaving the throttle valve the blow-by gases flow to the combustion chamber via a two-stage pressure limiting valve. The inlet is heated via the coolant system in order to prevent freezing in extremely cold weather.

Additional air for the PCV system (Positive Crankcase Ventilation) is extracted downstream of the air filter and flows via a non-return valve into the crankcase in the vee space between the cylinder banks.
Mixing the blow-by gases with clean air ensures a low water and fuel content in the engine lubricating oil and reduces oil nitration.



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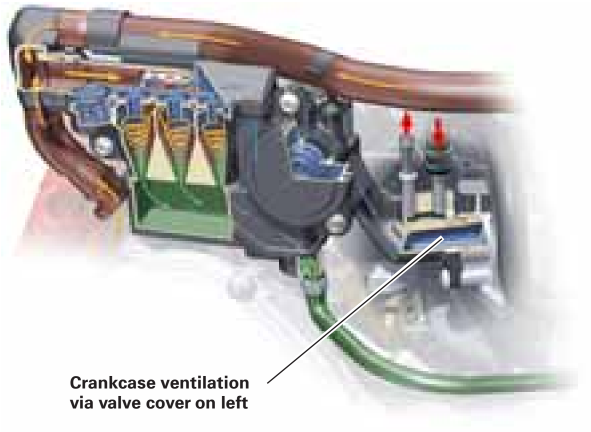
Three-stage cyclone fine oil separator

The quantity of gas in the blow-by gas is dependent on engine load and speed.
Fine oil separation is achieved by means of a three-stage cyclone.

One, two or three cyclones are operated in parallel depending on gas flow since cyclone oil separators can only separate efficiently a small proportion of the volumetric flow.



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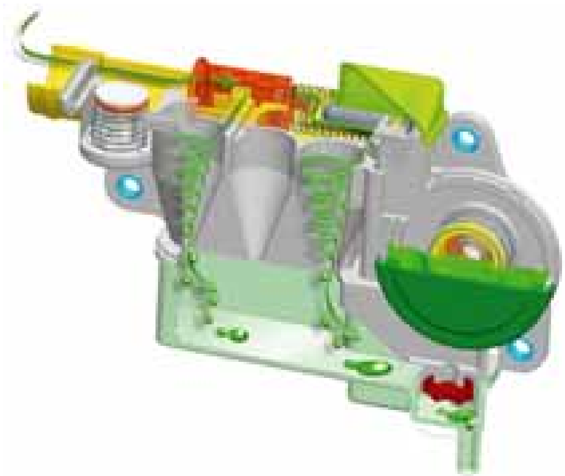
The mass flow rate of the blow-by gases increases with increasing engine speed. The higher the mass flow rate, the higher the force acting on the control piston.

The control piston therefore pushed against the pressure of the spring and opens up access to one or more cyclones.



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Piston ring wobble can occur at very high engine speeds and low engine loads, causing the pressure inside the crankcase to increase, which can result in very high gas flow rates.
This cyclones cannot cope with this pressure increase, and the pressure would continue to rise due to backpressure.
The bypass valve in the fine oil separator opens as a result of the pressure increase. A proportion of the blow-by gases is able to bypass the cyclones and flows directly to the intake manifold via the pressure limiting valve.

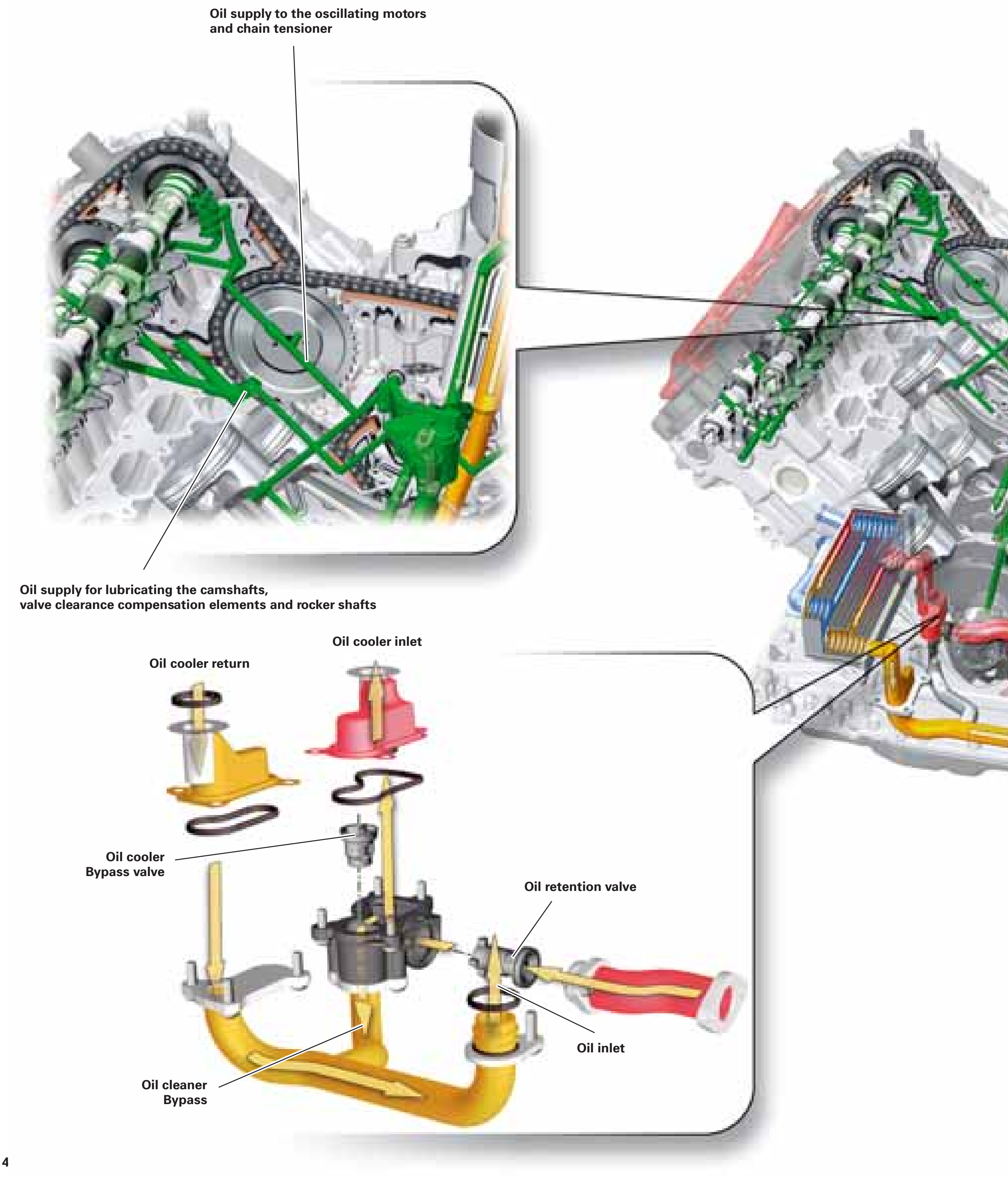
The separated oil which has been collected flows into the vee space between the cylinder banks via a valve which opens under the weight of the oil.

376_036

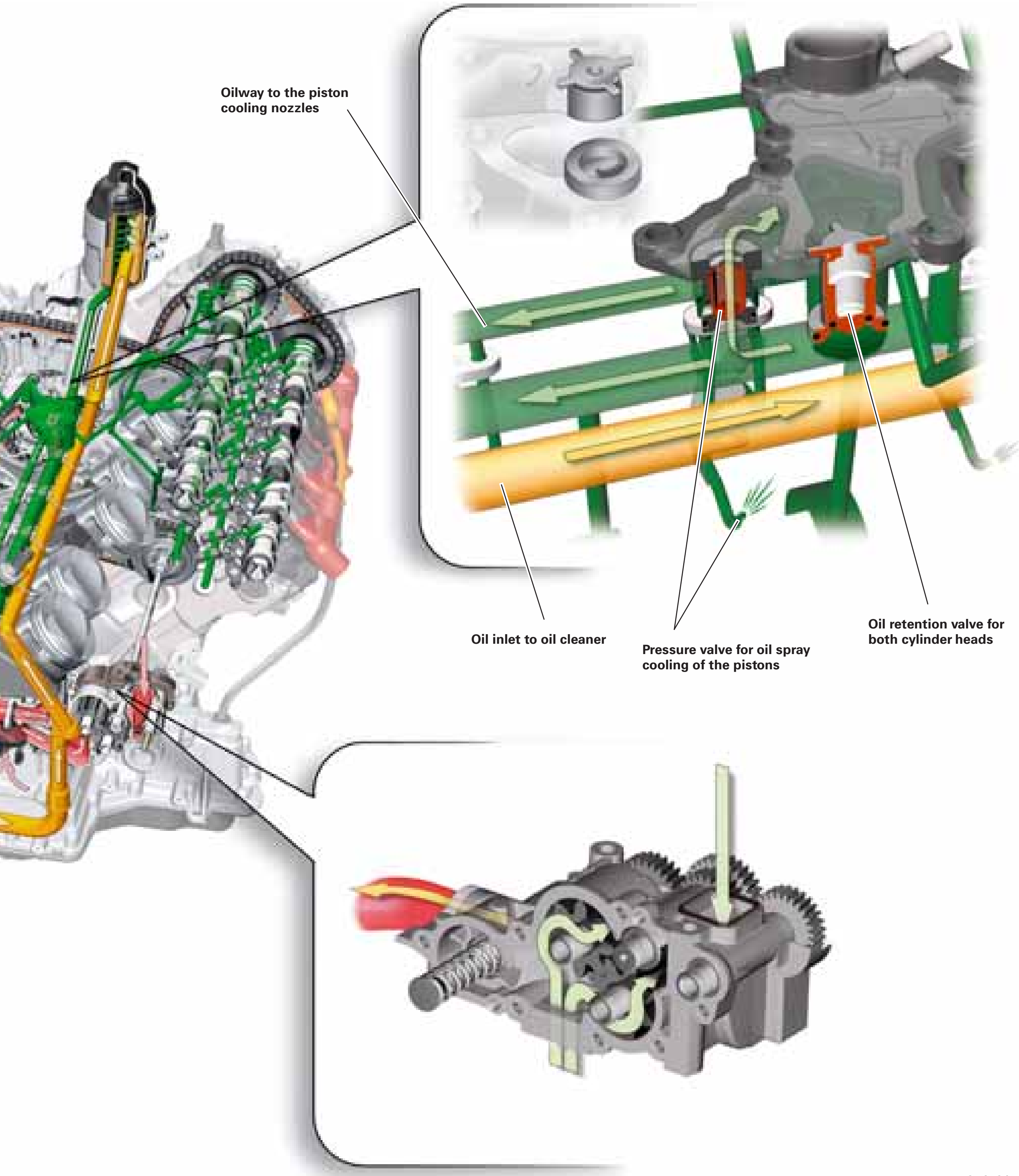
Oil circulation system

Design - component overview

The oil circulation system of the V10 FSI engine is of classic wet sump construction. The oil flow rate, approx. 55 l/min at 7000 rpm and 120 °C, and hence also the power consumption of the oil pump, have been reduced by optimising the clearance of the low-friction bearings.



In addition, the oil supply to the camshaft adjusters and the chain modules on the cylinder head side was separated from the oil supply to the camshaft bearings and the hydraulic elements in order to reduce the oil pressure in the cylinder head and optimise oil supply to the camshaft adjusters.



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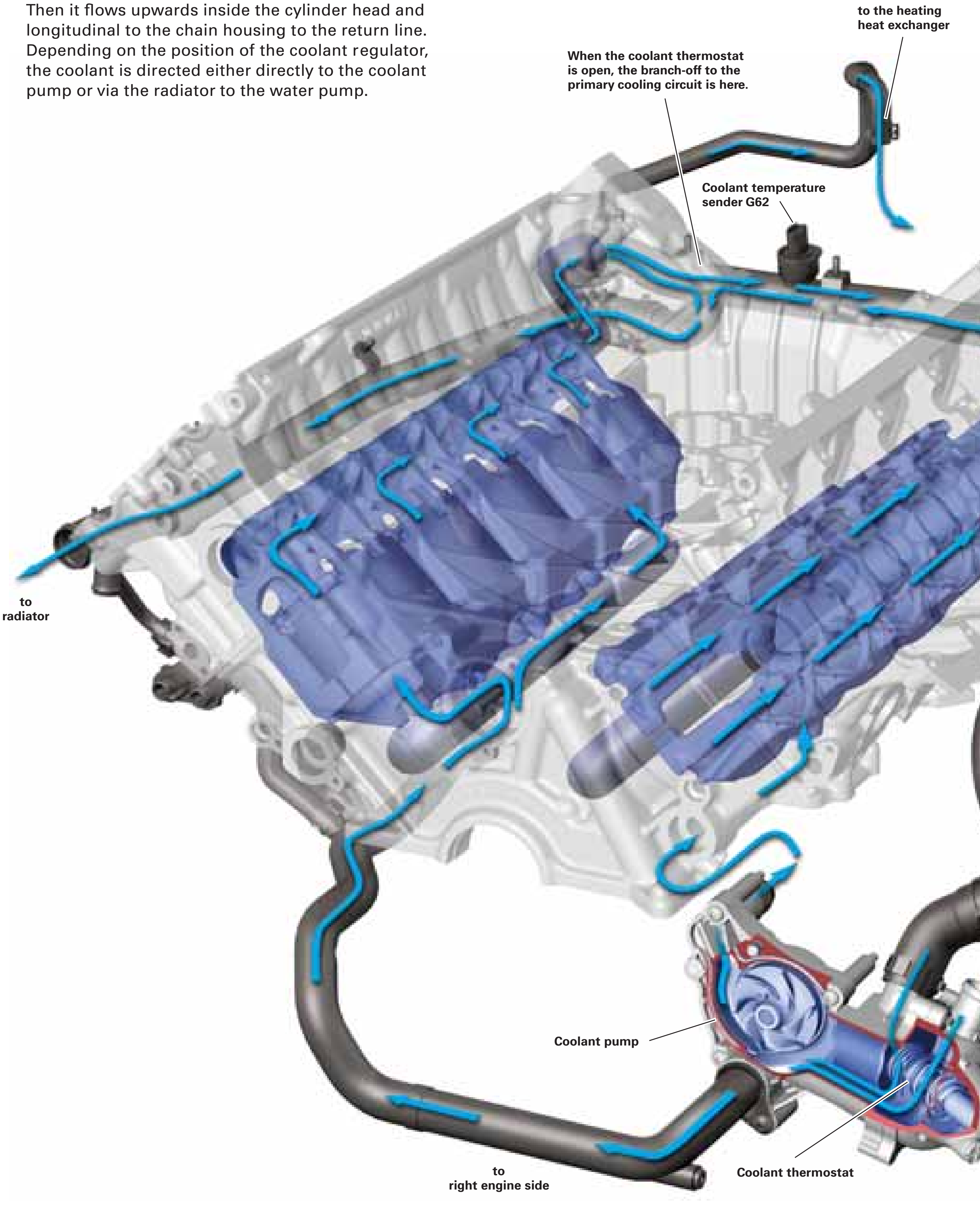
Water circulation system

The cooling system in the 5.2 litre V10 FSI engine is configured as a longitudinal flow cooling system. Coolant flows from the coolant pump to the engine block on the left and right-hand sides and around the cylinders.
Then it flows upwards inside the cylinder head and longitudinal to the chain housing to the return line. Depending on the position of the coolant regulator, the coolant is directed either directly to the coolant pump or via the radiator to the water pump.

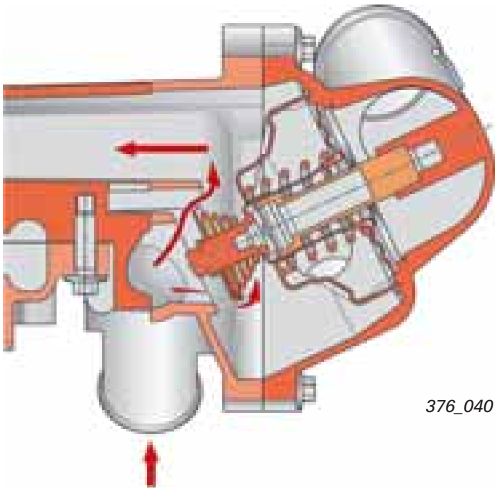
Due to the high power density, the intake valves - which are subject to high thermal stresses - are cooled via additional bores between the intake valves.



The coolant temperature is regulated to between 90 °C and 105 °C by the engine control unit via an electrically heated coolant thermostat.

Coolant thermostat deenergised, coolant cold

The coolant thermostat closes the inlet from the radiator completely and opens the return port, activating the secondary cooling circuit.



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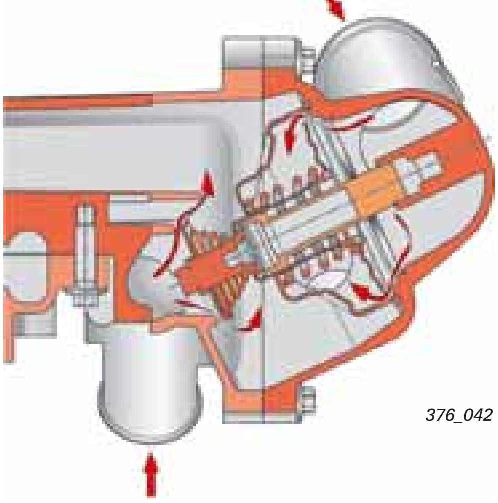
Coolant thermostat deenergised, coolant hot - coolant thermostat is in an intermediate position

The inlet from the radiator is partially open and the return line from the engine is partially closed. The coolant temperature is regulated to approx. 105 °C in part-load operation to allow the engine to run at reduced friction (the oil temperature rises).



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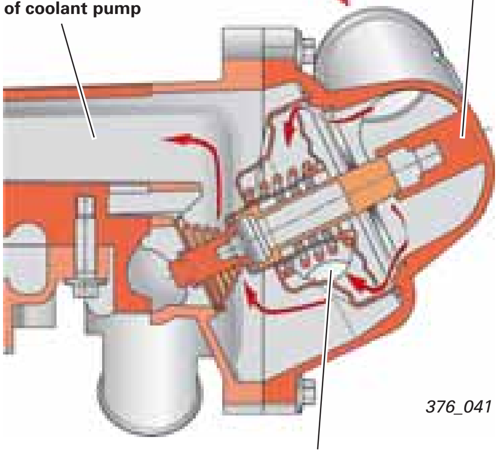
Coolant thermostat is energised at full throttle by a PWM signal

The coolant thermostat opens the inlet by fully opening the radiator and simultaneously closes the engine's return port.
Due to the large cooling surface of the radiator, coolant temperature can be reduced to 90 °C at full throttle in order to reduce the knock tendency of the engine (lower combustion chamber temperature). Furthermore, better carburetion is achieved due to the reduced intake air temperature.



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Air intake in the Audi S8

Intake system

The air intake on the V10 engine is double-chambered on account of the engine's high power output.
The left and right hand air filters have switchable flaps to induce extra air from the engine bay at high air flow rates and reduce the pressure loss in the system.

After passing through the flow optimised air filter, the intake air flows via two hot-film air mass meters seated directly on the air filters and through two throttle valves with a diameter of 68 mm into central intake manifold headers.

A soundpipe accentuates the sound typical of the V10 at high engine loads.
This soundpipe transmits the intake noise produced by charge cycles into the vehicle interior through a special membrane-foam composite filter.

376_019

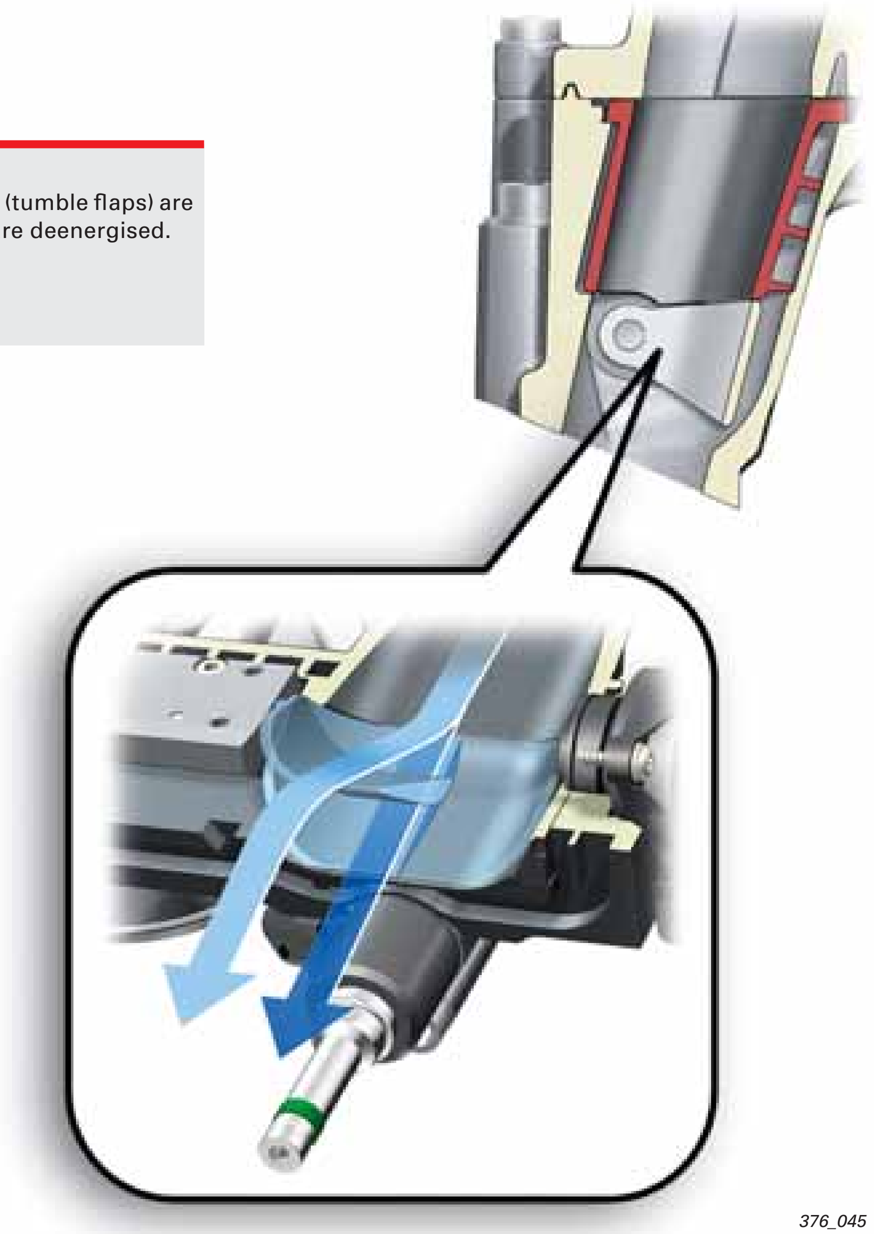
Intake manifold flaps

Like the variable inlet manifold, the intake manifold flaps are map-controlled in both engine variants. The intake manifold flaps in both engines are activated at the bottom end of engine load and speed ranges.
They are brought into abutment with the baffle plates in the cylinder head and thereby close of the bottom section of the intake port. The induced air mass now flows through the upper section of the intake port and creates a tumbling charge motion within the cylinder.
The intake manifold flaps are open while inactive, thus allowing air to flow through the full port cross-section. All flaps in a cylinder bank are attached to a common shaft.

In the basic engine the intake manifold flaps are activated by an electrical actuator.
A Hall sensor monitors the position of the intake manifold flaps for each cylinder bank.
In the high revving engine, the intake manifold flaps are switched by a vacuum actuator, with there being a separate actuator for each cylinder bank. Again, feedback on flap positions is provided by Hall sensors.

Note

The intake manifold flaps (tumble flaps) are always open when they are deenergised.



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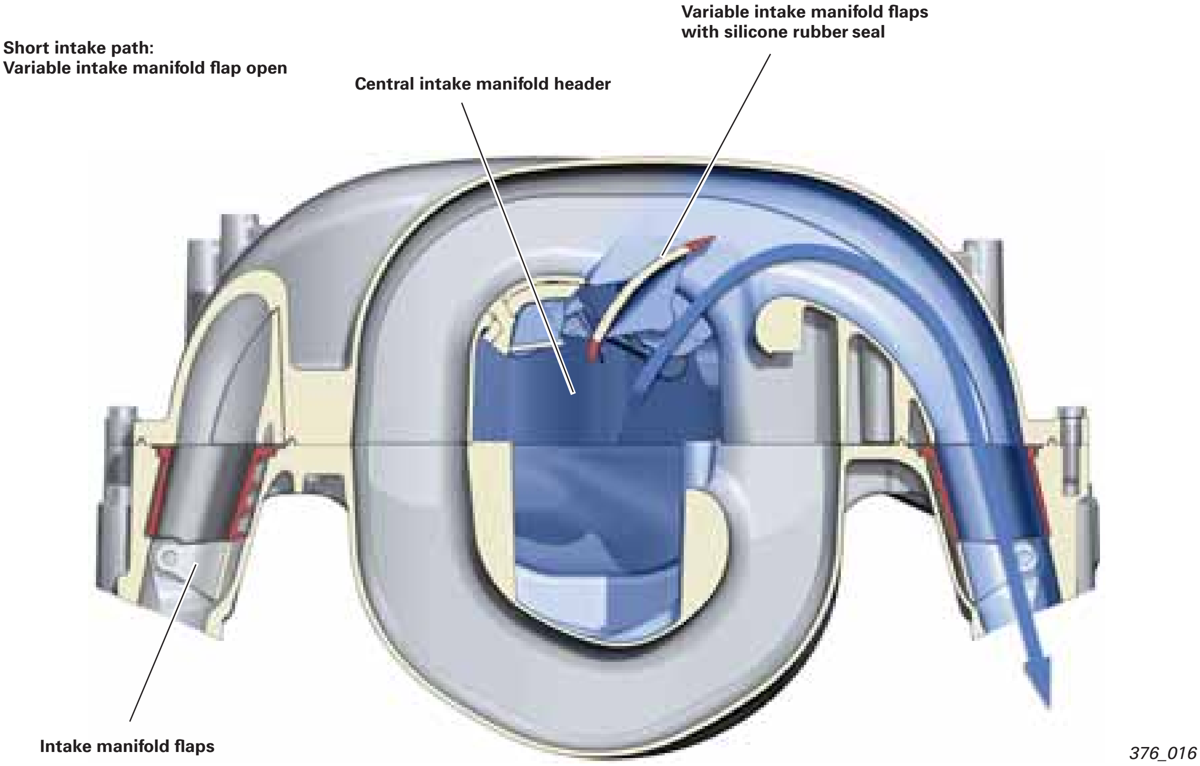
Variable inlet manifold

The V10 FSI engine has a four-piece variable intake manifold made from die-cast magnesium.
The control shafts are operated by an electric motor, whereby the switching of the intake manifold lengths is map-controlled.
To minimise inner leakage, the intake manifold flaps have silicone rubber lip seals.

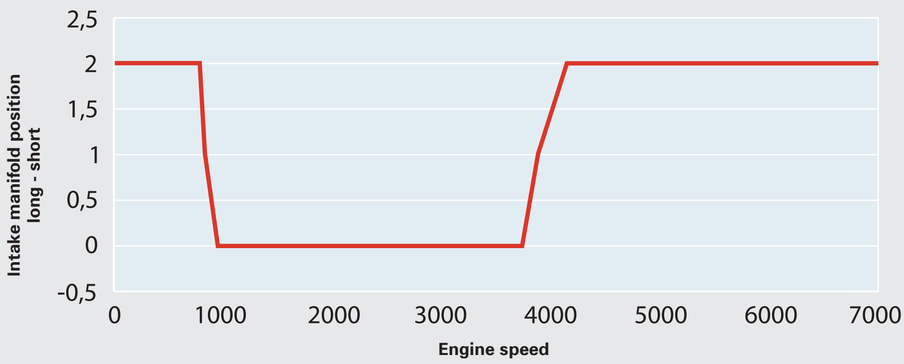
The flap system is integrated in the upper section of the intake manifold. The intake manifold flaps are positioned based on a characteristic map by the engine control unit by an electric motor.

At low engine loads/speeds, the intake manifold is switched to the short intake path. The flaps are positioned flush against the intake manifold in order to avoid flow losses due to vorticity.

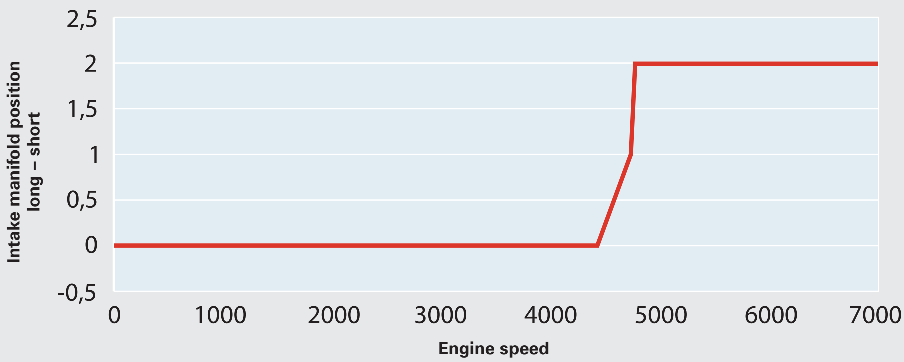


The variable intake manifold length in the power position (short path) is 307 mm.

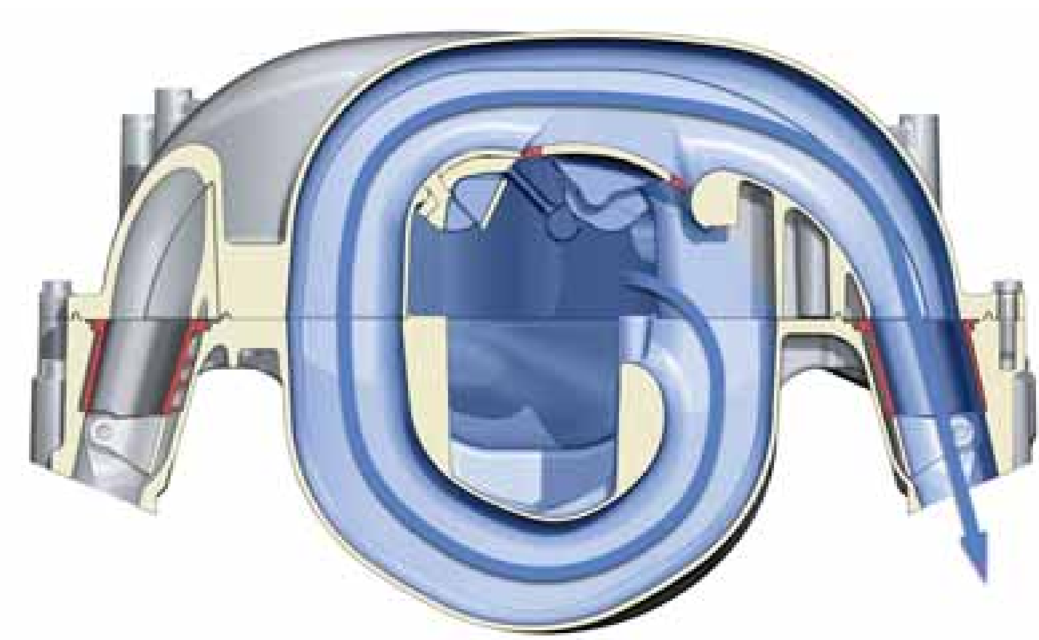
Variable intake manifold switching at low engine loads



Variable intake manifold switching at high engine loads



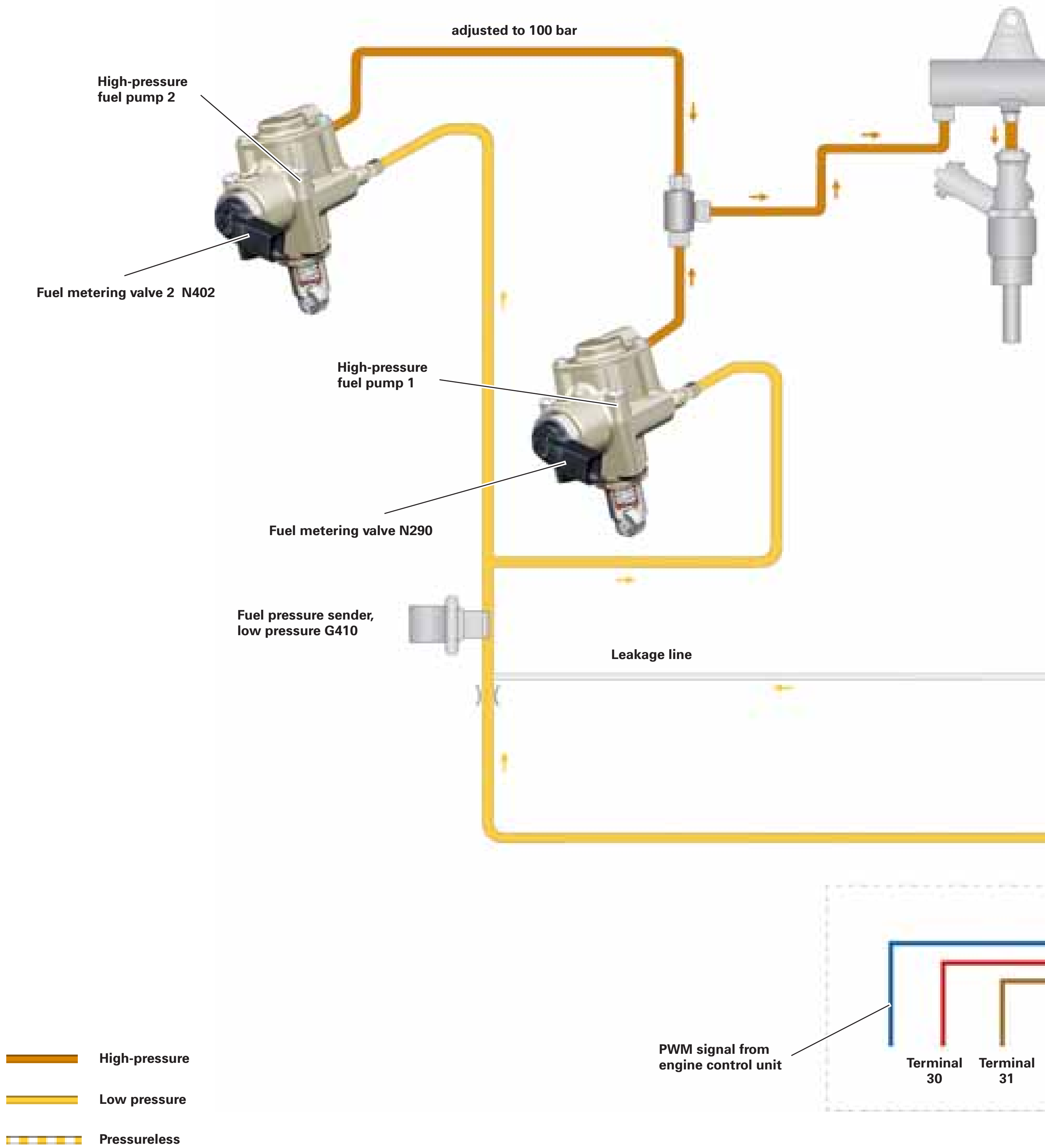
Long intake path:
Variable intake manifold flaps closed

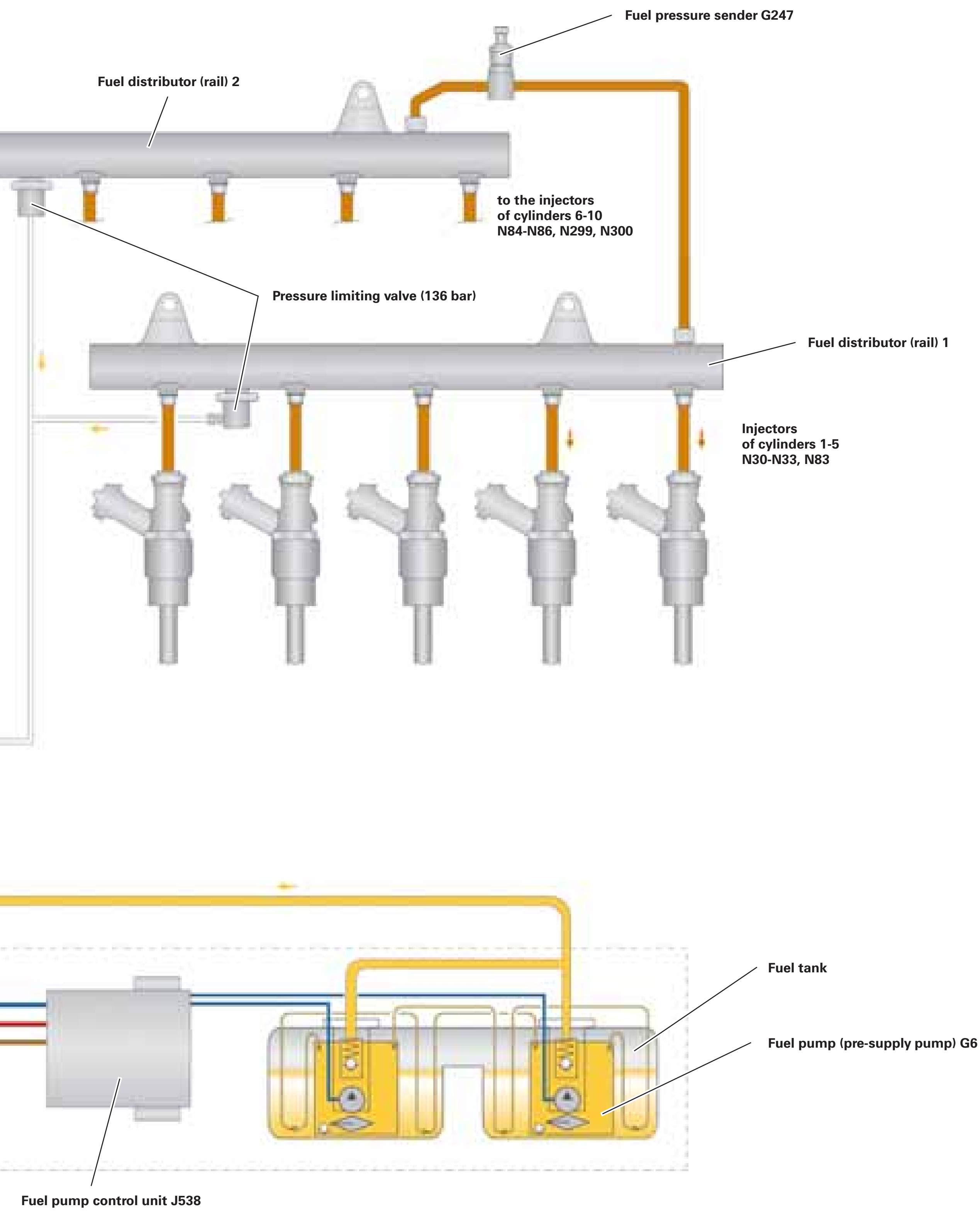


The variable intake manifold is 675 mm long in the torque position (long distance).

In the medium engine load/speed range the flaps are switched to the long intake path. The induced air is routed in a wide arc in order to provide increased air charging of the cylinders.

Fuel system in the Audi S8



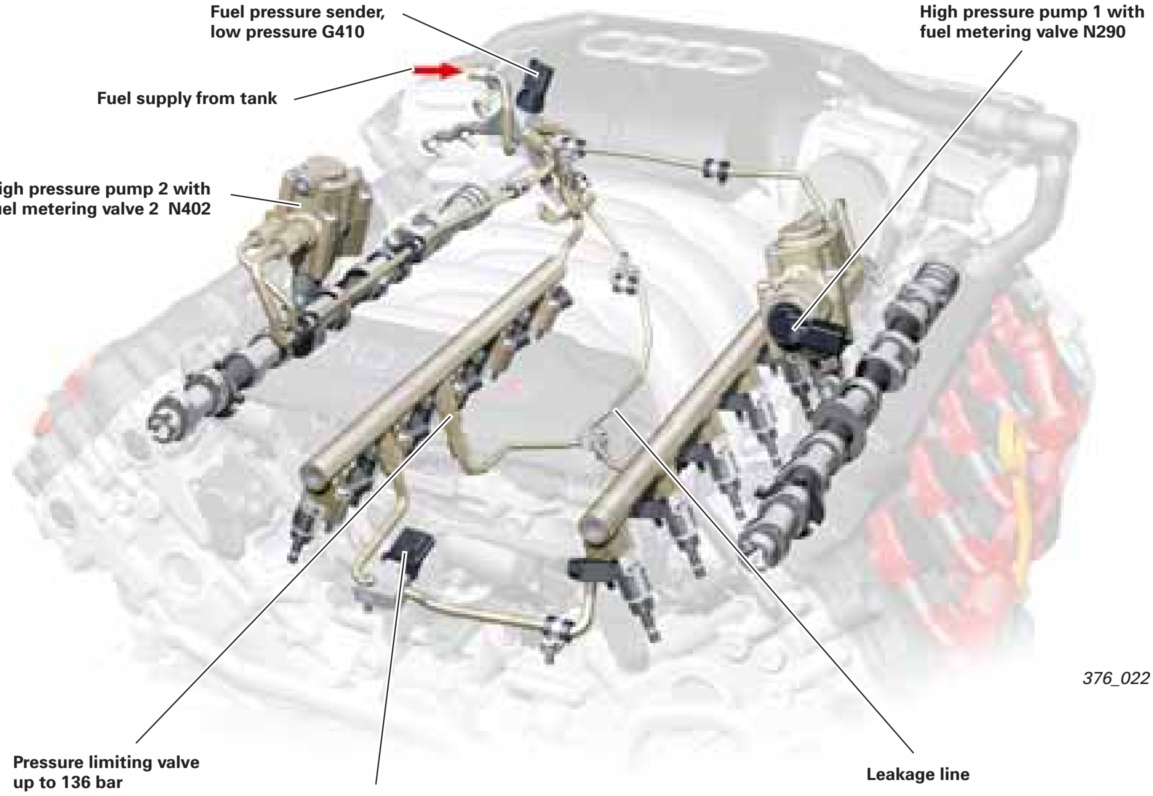

Fuel pressure sender G247
Fuel distributor (rail) 2
to the injectors
of cylinders 6-10
N84-N86, N299, N300
Pressure limiting valve (136 bar)
Fuel distributor (rail) 1
Injectors
of cylinders 1-5
N30-N33, N83
Fuel tank
Fuel pump (pre-supply pump) G6
Fuel pump control unit J538

376_027

High-pressure fuel circuit

The FSI high-pressure injection system is also employed in the V10 engine.
Central elements of the fuel system are two demand controlled single-piston high-pressure pumps, each of which is driven by a double cam on each intake camshaft.
The pump is regulated according to demand by an integral electrical quantity control valve.

The necessary max. fuel pre-supply pressure of 6 bar in the return system is provided by a demand-controlled fuel pump integrated in the fuel tank.
To reduce fuel pressure pulsation, the pumps are connected on the high-pressure side via the two rails. In addition, high-pressure fuel feed is configured in such a way that both pumps do not compress the fuel simultaneously, but in a staggered fashion.



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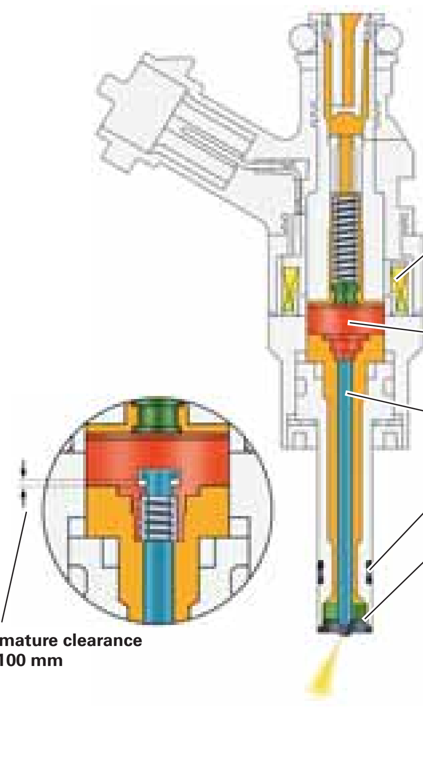
The solenoid controlled high-pressure injectors are operated at approx. 65 volts via capacitors in the engine control units.
They are configured as single-hole tumble valves having an injection angle (bend angle) of 7.5°.
The injection jet is designed to minimise cylinder wall wetting.

In addition, the fuel evaporating in the combustion chamber extracts heat from the cylinders which results in a reduced knock sensitivity and a higher charge density than in the MPI combustion process.
The FSI combustion process thereby permits a compression ratio of 12.5 : 1.



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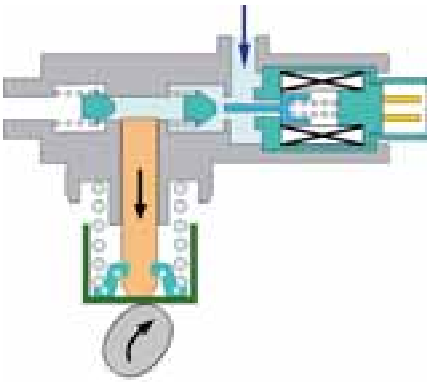
High-pressure fuel pump with fuel metering valve N290/N402

376_023

Pump functions

Suction stroke

The shape of the cam and the force of the piston spring move the pump piston downwards.
The increase in space inside the pump provides additional fuel flow. The low pressure valve is held open by the quantity control valve.
The quantity control valve is deenergised.



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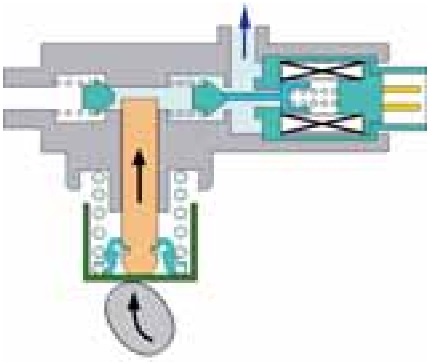
Working stroke

The cam moves the pump piston upwards.
Pressure cannot be developed yet because the quantity control valve is deenergised.
It prevents the low pressure intake valve from closing.



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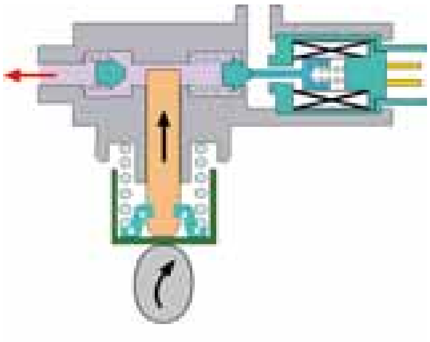
Compression stroke

The engine control unit now energises the quantity control valve. The solenoid armature is actuated.
The pressure inside the pump presses the low pressure intake valve down into its seat.
When the pressure inside the pump exceeds the rail pressure, the non-return valve opens and fuel is admitted to the rail.



376_030

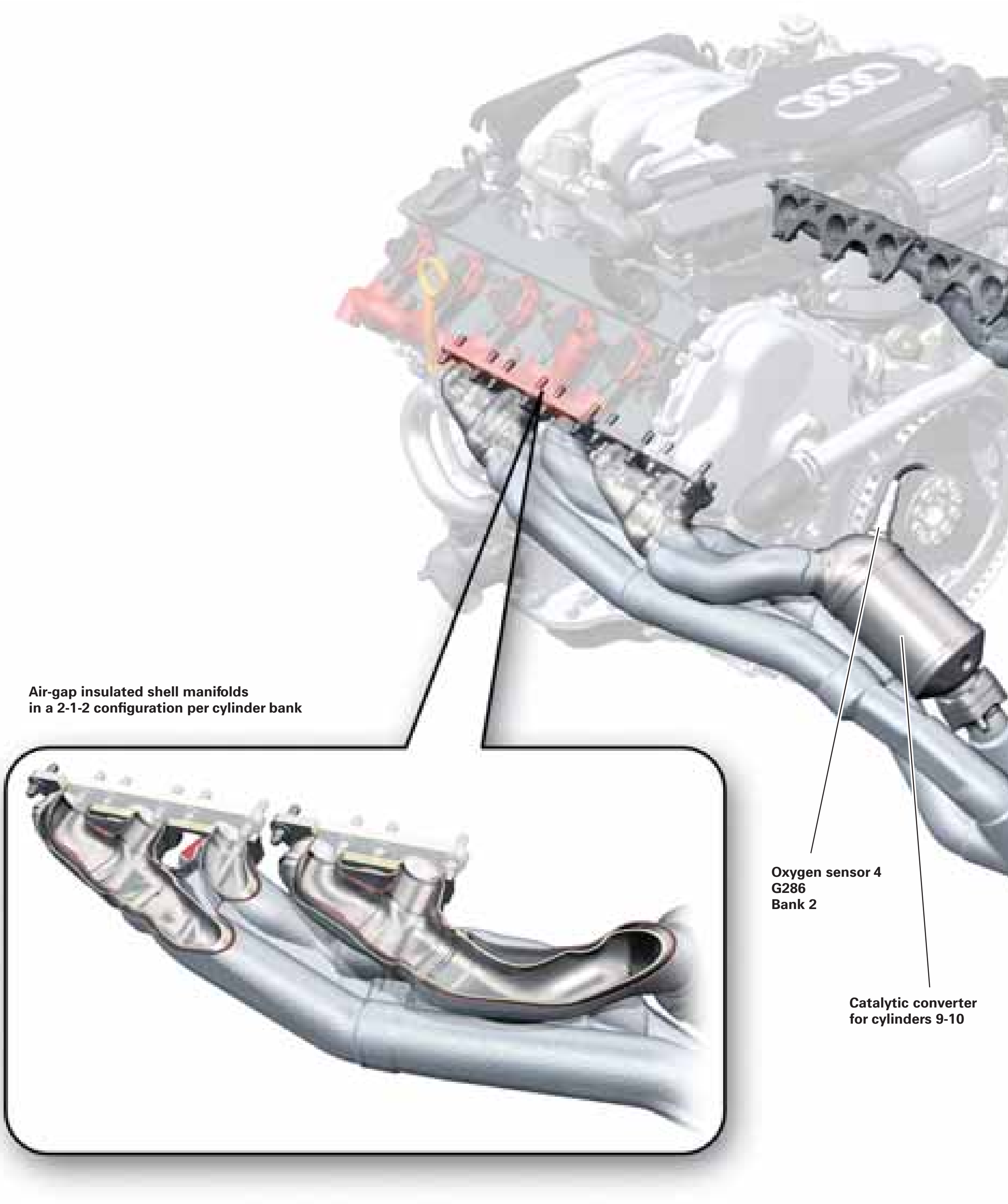
Exhaust system

Exhaust manifold

A V10 engine, in which the cylinders are opposed at 90°, puts the same demands on the exhaust-side charge cycle components as a five-cylinder in-line engine.

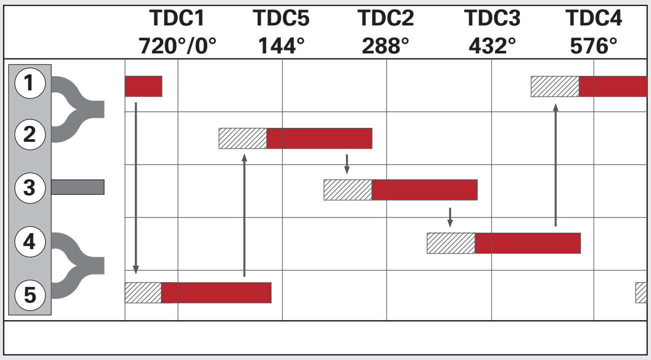
Each bank of cylinders is fired at a uniform firing interval of 144°, which, with exhaust opening periods of 210°, leads to a partial overlap between the exhaust phases.

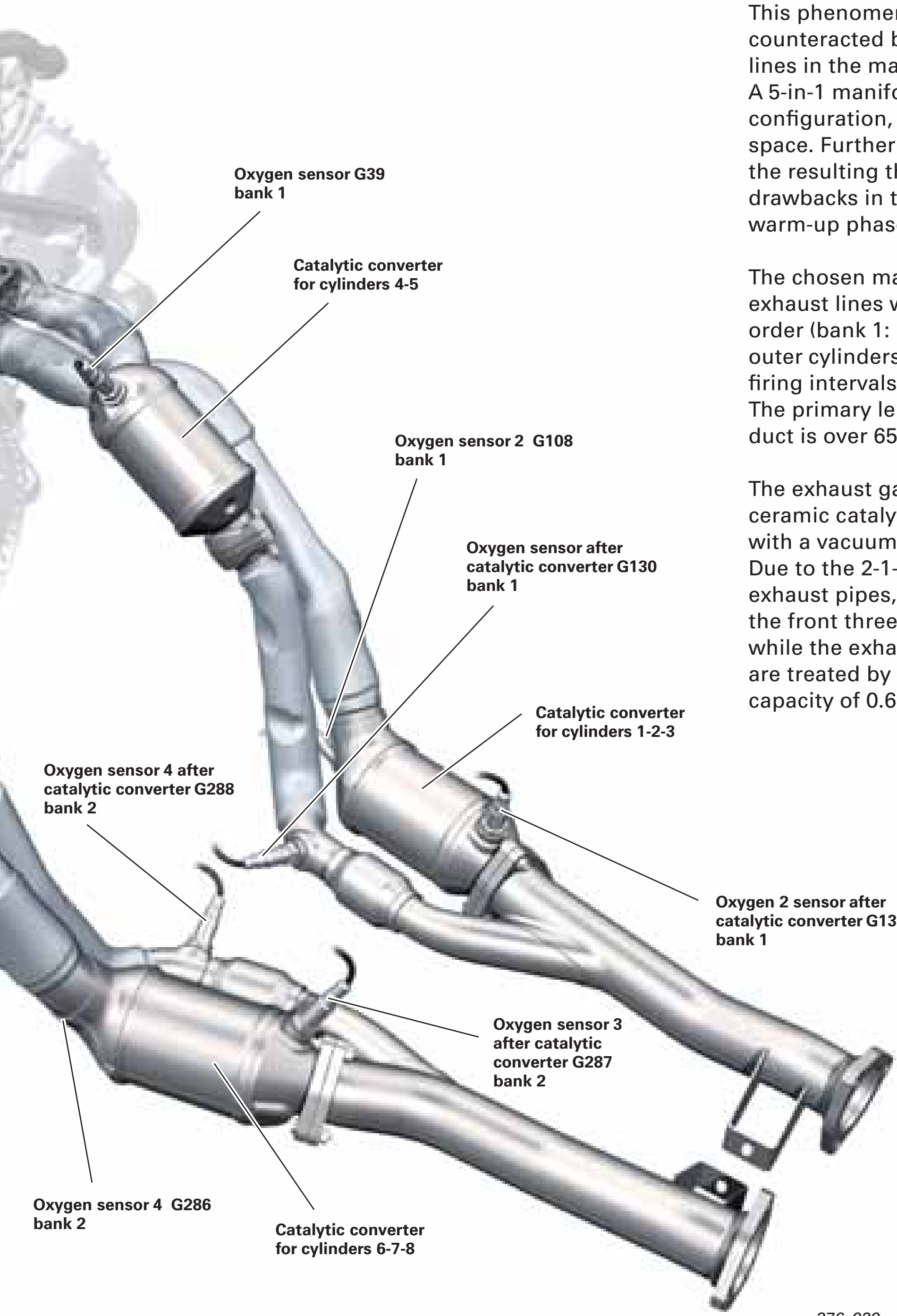
In the worst case, the exhaust pulse of a cylinder can cause reverse pulsation of expelled exhaust gases in the still-open exhaust port of a different cylinder.
This will result in a higher residual gas content in the cylinder and corresponding mean pressure losses in the combustion process due to insufficient fresh gas charging.



Exhaust valve open

Overlap
Exhaust opening periods





376_020

This phenomenon of exhaust-gas flow pulsation is counteracted by separating the individual exhaust lines in the manifold for as long as possible.
A 5-in-1 manifold would be the obvious choice of configuration, but requires a great deal of design space. Furthermore, due to its large surface area and the resulting thermal inertia, this configuration has drawbacks in terms of emission control during the warm-up phase (cat heating).

The chosen manifold configuration comprises three exhaust lines whereby, in accordance with the firing order (bank 1: 1-5-2-3-4 or bank 2: 6-10-7-8-9) the two outer cylinders are combined due to their non-critical firing intervals and the middle cylinder is separate.
The primary length of the middle cylinder exhaust duct is over 650 mm.

The exhaust gases are treated by four 600-cell ceramic catalytic converters working in combination with a vacuum controlled secondary air system.
Due to the 2-1-2 exhaust configuration into two exhaust pipes, the catalytic converter assigned to the front three cylinders has a capacity of 0.76 litres, while the exhaust gases from the two rear cylinders are treated by a single catalytic converter with a capacity of 0.62 l.

System overview (Bosch MED 9.1) in the Audi S8

Sensors

Air mass meter G70
Intake air temperature sensor G42

Accelerator pedal position sender G79
Accelerator pedal position sender 2 G185

Engine speed sender G28

Knock sensors 1+2 G61, G66

Fuel pressure sender G247

Hall sender G40
Hall sender 3 G300

Throttle valve module J338
Angle senders 1+2 for throttle-valve drive with electric power control G187, G188

Coolant temperature sender G62

Fuel pressure sender, low pressure G410

Intake manifold flap potentiometer G336

Lambda probe G39
Lambda probe after catalytic converter G130
Oxygen sensor 2 G108
Oxygen sensor 2 after catalytic converter G131

Brake servo pressure sensor G294

Brake light switch F
Brake pedal switch F47

Auxiliary signals:
Cruise control system on/off
P/N signal
Terminal 50
Wake up door contact from convenience system central control unit J393

Air mass meter 2 G246

Hall sender 2 G163
Hall sender 4 G301

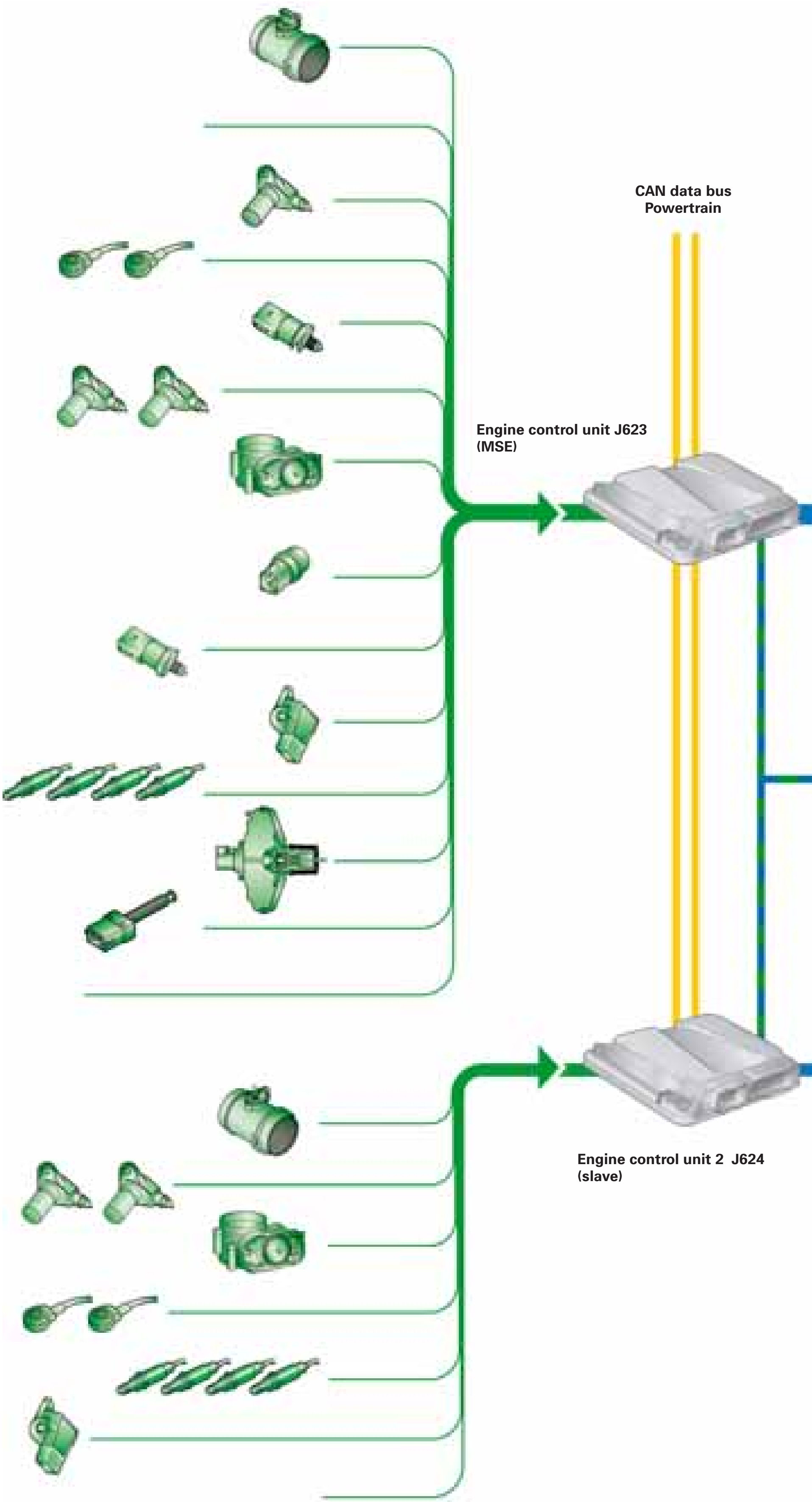
Throttle valve module 2 J544
Angle senders 1+2 for throttle valve drive 2 G297, G298

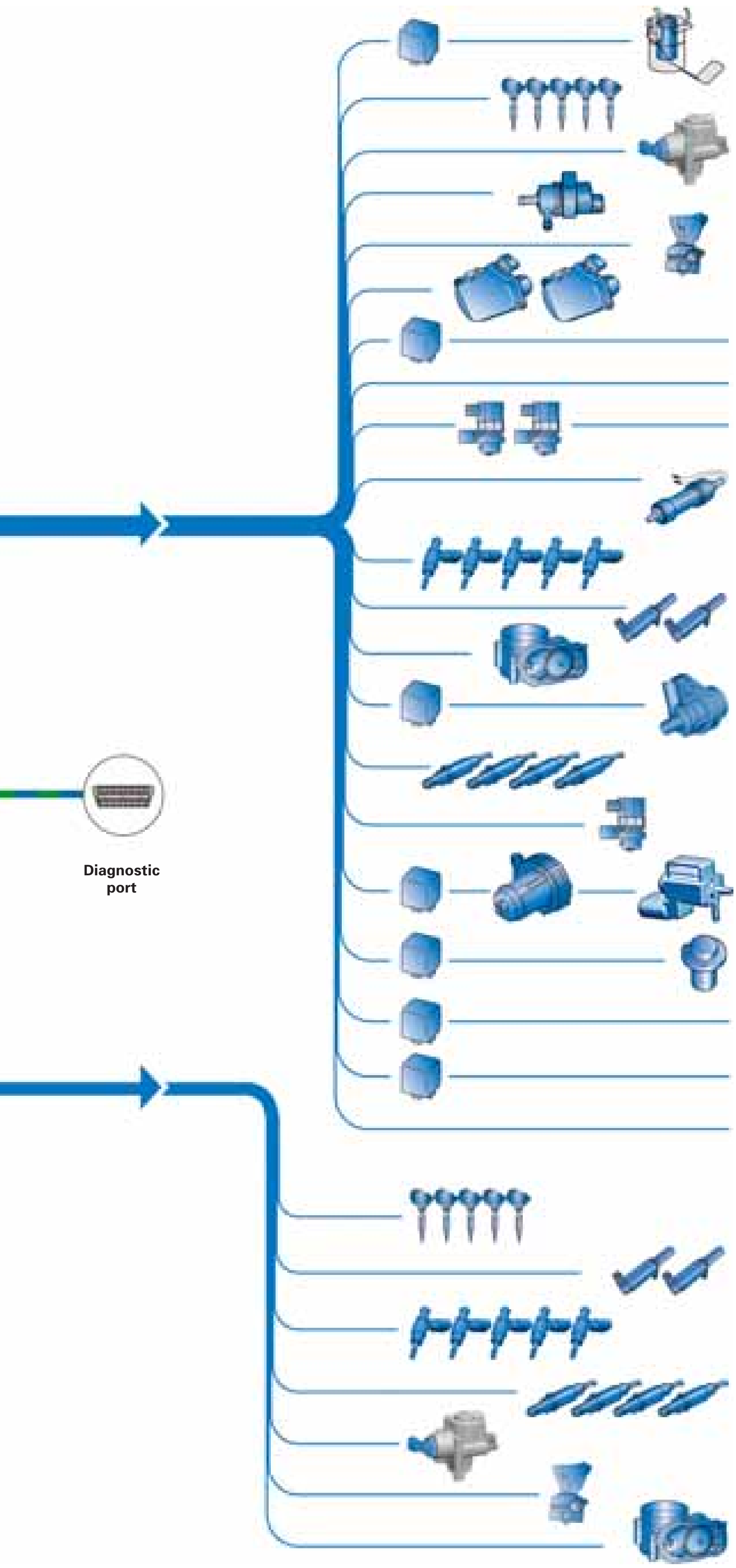
Knock sensors 3+4 G198, G199

Oxygen sensor 3 G285
Oxygen sensor 3 after catalytic converter G287
Oxygen sensor 4 G286
Oxygen sensor 4 after catalytic converter G288

Intake manifold flap 2 potentiometer G512

Auxiliary signals:
Wake up door contact from convenience system central control unit J393





Actuators

Fuel pump control unit J538
Fuel pump (pre-supply pump) G6

Ignition coils N70, N127, N291, N292, N323
Cylinders 1–5

Fuel metering valve N290

Activated charcoal filter solenoid valve 1 N80

Electro/hydraulic engine mounting solenoid valve, right N145

Intake manifold flap motor V157
Variable intake manifold motor V183

Starter motor relay J53
Starter motor relay 2 J695

Fuel system diagnostic pump (USA) V144

Exhaust flap 1 valve N321
Exhaust flap 2 valve N322

Mapped-controlled engine cooling thermostat F265

Injectors, cylinders 1-5
N30–N33, N83

Inlet camshaft timing adjustment valve 1 N205
Exhaust camshaft timing adjustment valve 1 N318

Throttle-valve drive for electric power control G186

Continued coolant circulation relay J151
Coolant run-on pump V51

Lambda probe 1 heater Z19
Lambda probe 1 heating, after catalytic converter Z29
Lambda probe 2 heater Z28
Lambda probe 2 heater, after catalytic converter Z30

Variable intake manifold change-over valve N335

Secondary air pump relay J299
Secondary air pump motor V101
Secondary air inlet valve N112

Brake servo relay J569
Vacuum pump for brakes V192

Engine component current supply relay J757

Motronic current supply relay J271

Auxiliary signals:
Engine speed
Radiator fan control units J293 and J671

Ignition coils N324–N328
Cylinders 6–10

Inlet camshaft timing adjustment valve 2 N208
Exhaust camshaft timing adjustment valve 2 N319

Injectors, cylinders 6-10
N84–N86, N299, N300

Lambda probe 3 heater Z62
Lambda probe heater 3, after catalytic converter Z64
Lambda probe 4 heater Z63
Lambda probe 4 heater, after catalytic converter Z65

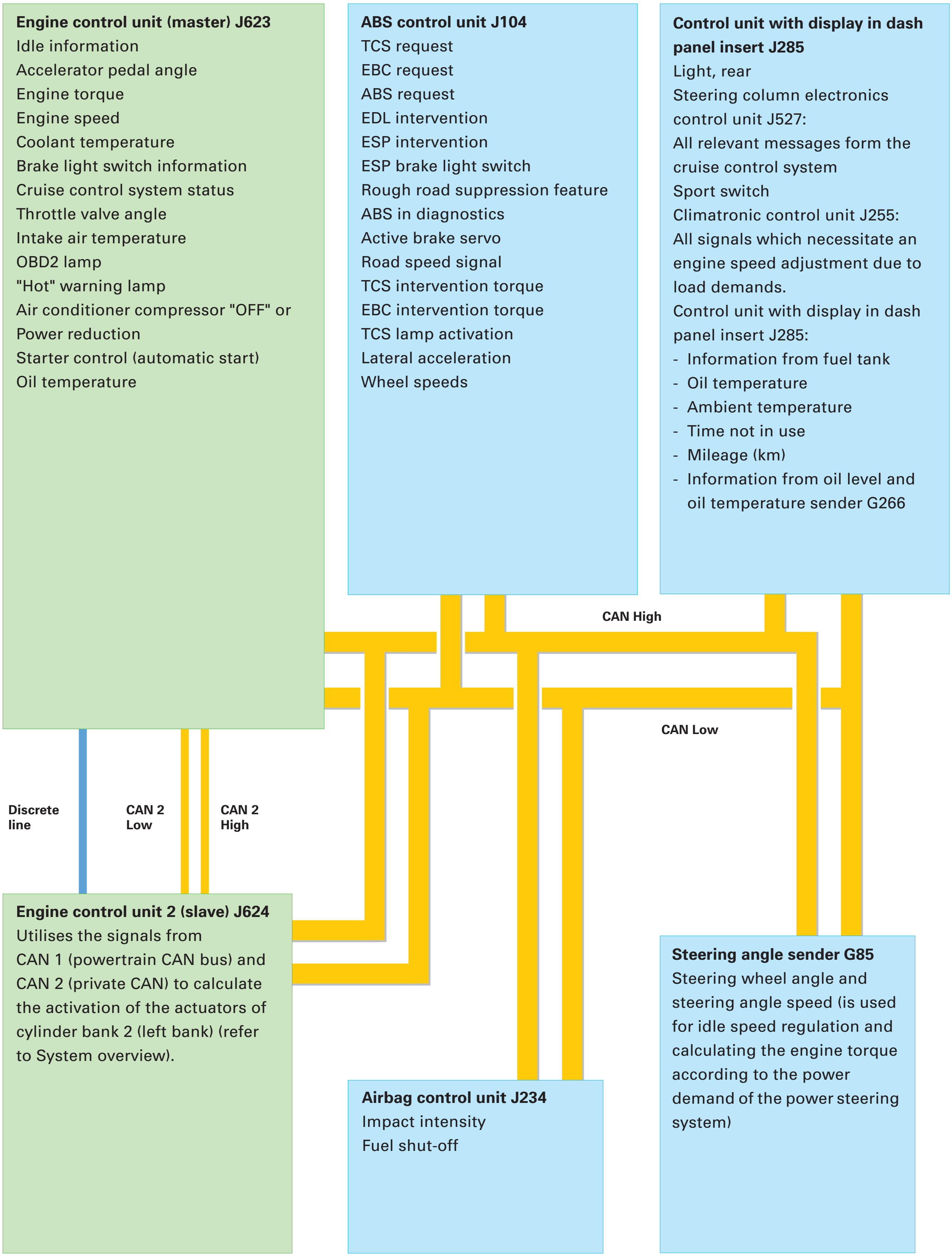
Fuel metering valve 2 N402

Electro/hydraulic engine mounting solenoid valve, left N144

Throttle valve drive 2 G296

376_032

CAN data bus interfaces



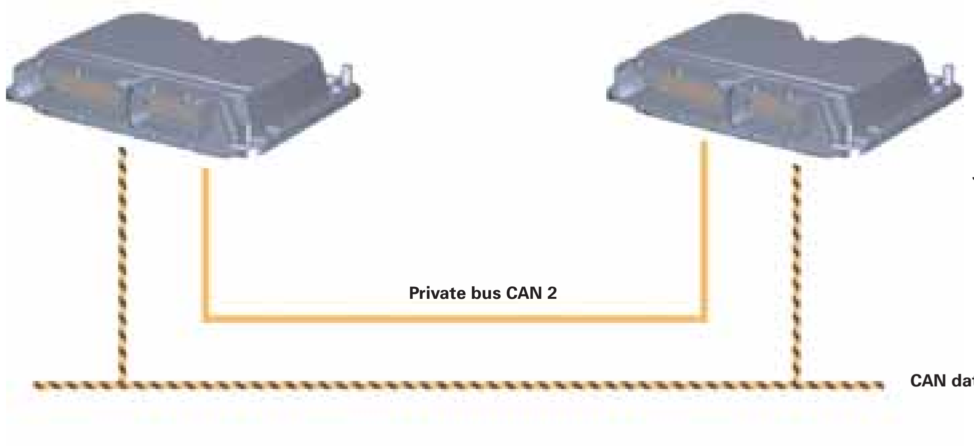
Communication between the master/ slave control units

The engine control unit (MSE) J623 calculates and controls the signals from the actuators for cylinder bank 1.
Most sensors are connected to the engine control unit (refer to System overview, page 28/29). Both control units are connected to the CAN data bus. The slave control unit functions as a receiver only.

The load signals required for calculation and control of the signals for the cylinder bank 2 actuators are transmitted across the private bus.

The slave control unit performs the task of misfire detection for all ten cylinders. It also processes the signal from engine speed sender G28.

The master and slave control units are identical in design and have the same part number. A voltage code in the control unit determines whether the control unit is working as a master or as a slave.
If a positive signal is present at the encoding pin, the control unit assumes the master function.



376_043

With one close-coupled catalytic converter and one downstream catalytic converter to be heated per cylinder bank, the engine runs in individual-cylinder lambda control mode at start-up. This means that the metered fuel and secondary air mass flows between the individual cylinders are varied, firstly, to heat the downstream catalytic converters with a rich air-fuel mixture. On the other hand, the close-coupled catalytic converters must not be allowed to overheat during secondary operation. For this reason, the air-fuel mixture is set to a leaner value.

Operating modes

Start phase - high pressure stratified charge start

Injection of the metered fuel mass commences during the compression stroke phase and ends shortly before the firing point.

Compared to the low pressure start, homogenisation is greatly improved and HC emissions are reduced by utilising the heat of compression for carburetion purposes.

After end of start phase - HOSP = homogeneous split

Application:
– Heating of the pre-catalysts to 300 °C in approx. 12 seconds; lambda value 1.05
– Intake manifold flap position: closed
– Throttle valve position: wide open

Injection:
– First injection approx. 300° before ignition TDC
– Second injection with small amount of fuel, approx. 60° before ignition TDC - firing ignition timing is retarded
– Mixture combusts very late
– Exhaust valve is already open

As a result, the catalytic converter reaches its operating temperature very quickly.

Normal operation homogeneous carburetion

(lambda 1) with intake manifold flap open or closed (map-dependent)

376

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