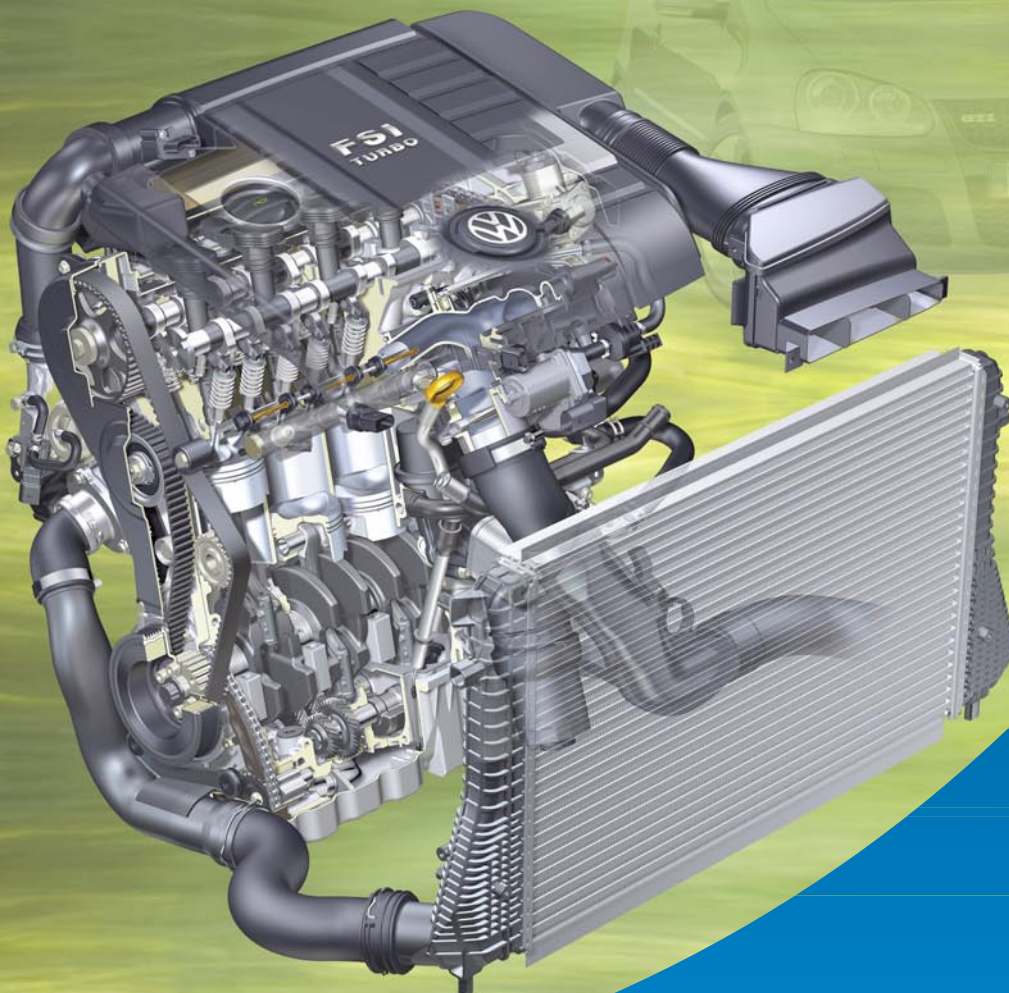




## Self-study programme 337

# The 2.0l FSI engine with turbocharger

Design and function

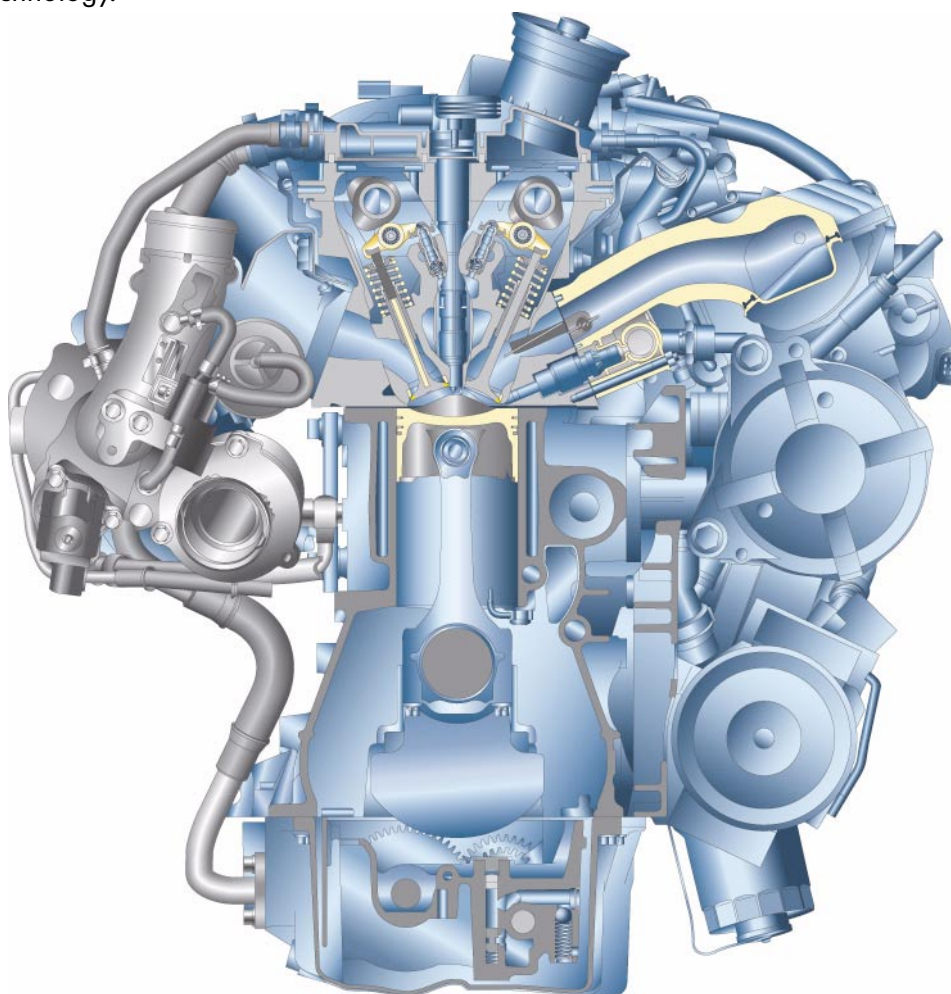


The new FSI engines from Volkswagen do without stratified injection and place greater emphasis on output and torque. Until now, FSI direct injection was always associated with stratification. On the turbocharged engine, the abbreviation FSI remains but there is no stratified charge. Doing without fuel stratification and NOx sensors represents a loss on one part, but also promises the finest driving enjoyment with high output and a torquey engine and great pulling power and economy.

In this self-study programme you can familiarize yourself with the technical highlights of this engine.

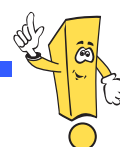


Further information can be found in self-study programme no. 322 - The 2.0l FSI engine with 4-valve technology.



S337\_002

**NEW**



**Warning Note**



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

For instructions on testing, adjusting and repairs, please refer to the relevant service literature.

# At a glance



|                                 |           |
|---------------------------------|-----------|
| <b>Introduction .....</b>       | <b>4</b>  |
| <b>Engine mechanics .....</b>   | <b>6</b>  |
| <b>Engine management.....</b>   | <b>12</b> |
| <b>Service .....</b>            | <b>24</b> |
| <b>Test your knowledge.....</b> | <b>26</b> |



# Introduction



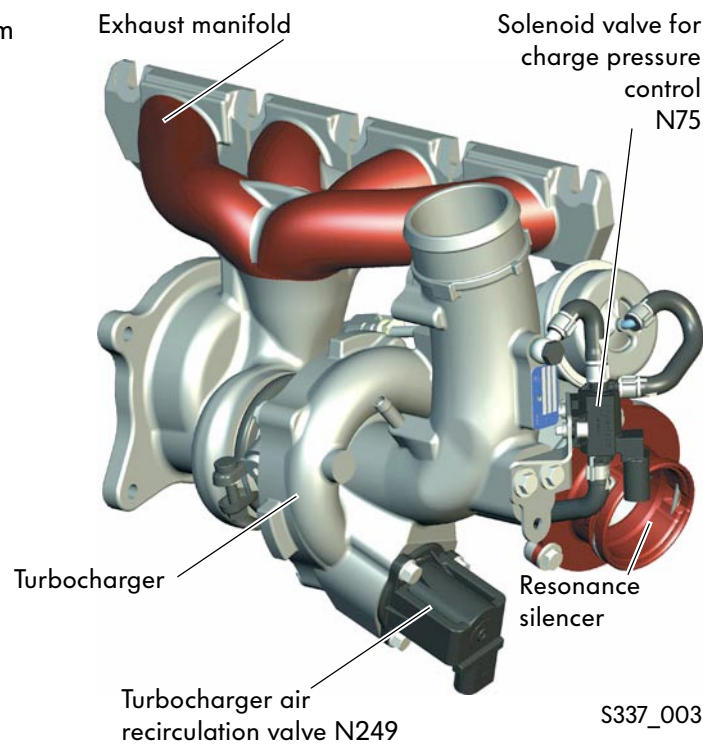
## Description of the engine

In terms of basic dimensions and design, the turbo FSI engine is derived from the 2.0l FSI with engine code AXW.

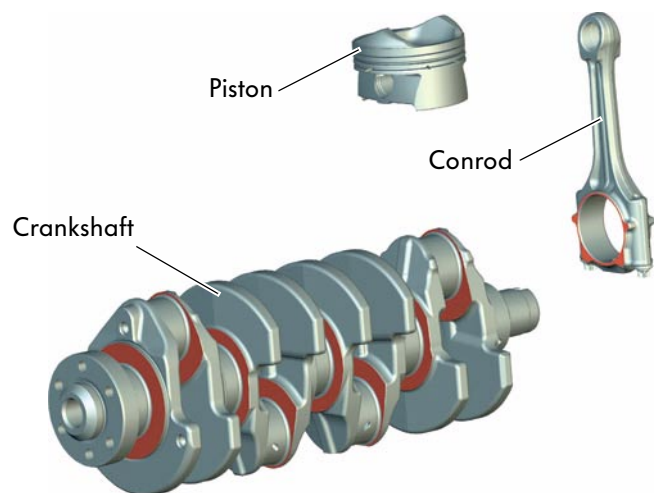
In order to meet the high expectations of a turbocharged engine, components of the engine had to be adapted to specific requirements.

The exhaust manifold and the turbocharger form one unit.

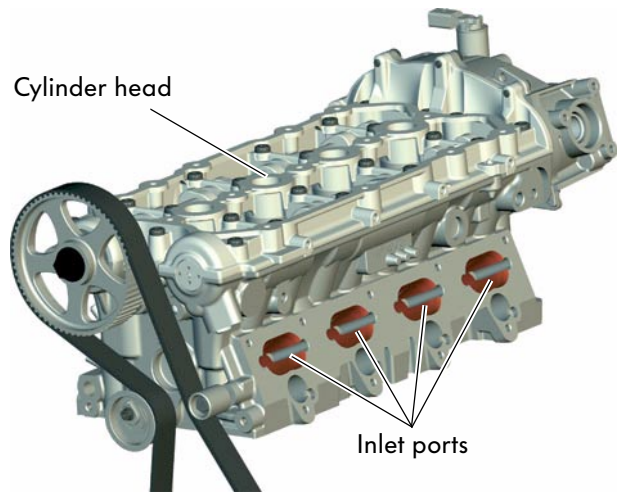
The exhaust and turbo module is customer service friendly and is attached to the cylinder head by a clamping flange.



The crankshaft mechanics have been adapted to the higher demands of a turbocharged FSI engine.

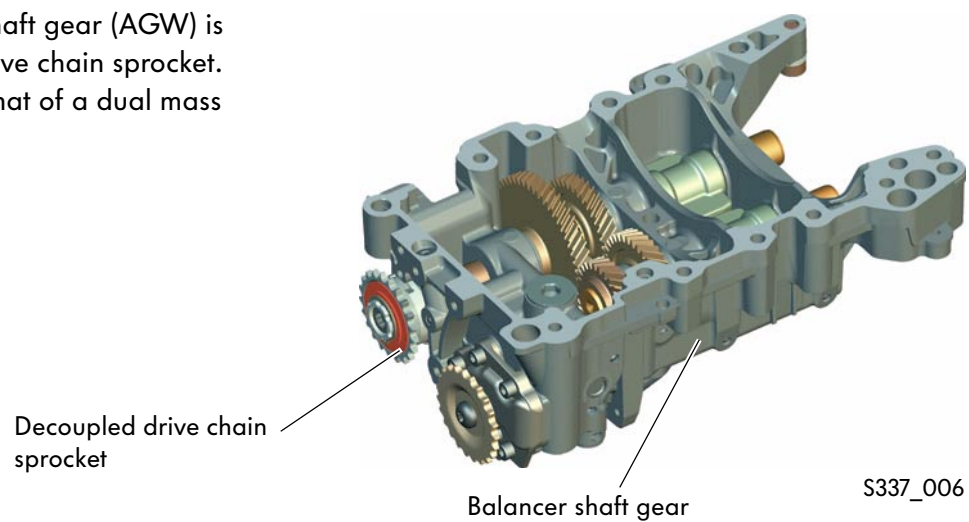


In order to meet the higher levels of power and heat transfer, the cylinder head has been adapted to the specific conditions. The inlet camshaft features continuously variable valve timing (adjustment range 42° crankshaft angle).



S337\_005

The optimised balancer shaft gear (AGW) is driven by a decoupled drive chain sprocket. The function is similar to that of a dual mass flywheel.



S337\_006

# Engine mechanics

## Technical data

The 2.0l turbocharged FSI engine was first installed in the Audi A3 Sportback. At Volkswagen, the engine finds its debut in the Golf GTI.



### Technical features

- Turbocharger in exhaust manifold
- Single pipe exhaust system with starter and underbody catalyst close to engine
- Hitachi high pressure pump resistant to ethanol
- Non-return fuel system
- Homogenous fuel injection

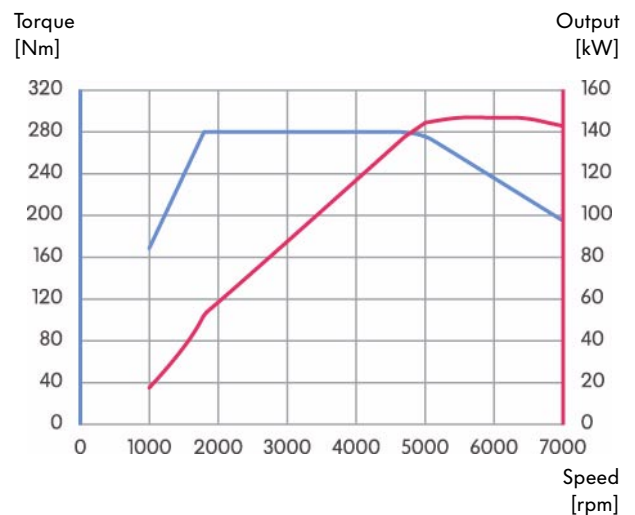


S337\_007

### Technical data

|                             |                                                                           |
|-----------------------------|---------------------------------------------------------------------------|
| Engine code                 | AXX                                                                       |
| Engine type                 | 4-cylinder in-line engine                                                 |
| Capacity [mm <sup>3</sup> ] | 1984                                                                      |
| Bore [mm]                   | 82.5                                                                      |
| Stroke [mm]                 | 92.8                                                                      |
| Compression ratio           | 10.5:1                                                                    |
| Max. output                 | 147 kW at 5700 rpm                                                        |
| Max. torque                 | 280 Nm at 1800-4700 rpm                                                   |
| Engine management           | Bosch Motronic MED 9.1                                                    |
| Variable valve timing       | 42° crankshaft angle                                                      |
| Exhaust gas recirculation   | Inner exhaust gas recirculation                                           |
| Fuel                        | Premium unleaded RON 98 (normal unleaded RON 95 with reduced performance) |
| Exhaust gas treatment       | 2 three-way catalytic converters with lambda control                      |
| Emissions standard          | EU 4                                                                      |

### Torque and performance graph

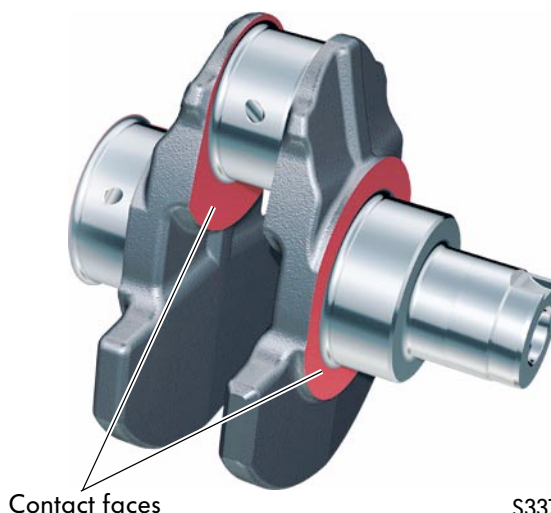


S337\_008

## The crankshaft

The component strength was adapted to the higher combustion pressures.

The contact faces of the main journals and conrod journals were made larger to improve strength.



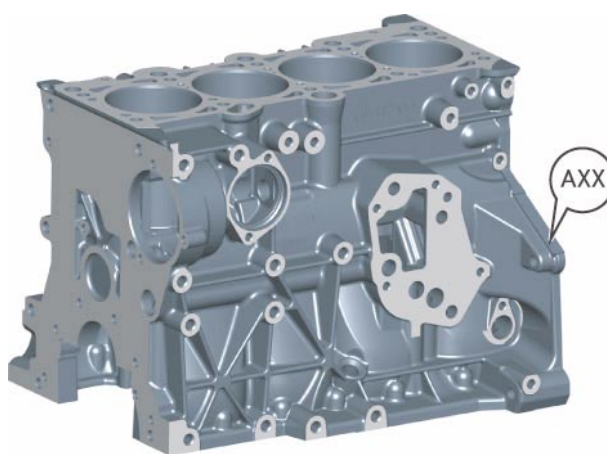
Contact faces

S337\_009

## Engine block

The cylinder contact surfaces of the cast iron engine block were honed by means of liquid blasting.

Liquid blasting and smooth honing are an extension of the familiar two-stage honing technique by two additional process stages. In the first new processing stage, any compacting of the bushing contact surface brought about from the high pressure procedure is removed, and scores and damage from honing and cracks from alloying are rectified. The resulting surface is thereby largely free of metallic imperfections. In the final honing operation, the rough edges arising from blasting and any remaining rough areas are smoothed out to the highest level. This type of honing shortens the running-in time of the engine and leads to lower oil consumption.



S337\_010

## Modified pistons

The piston crown of the T-FSI has been adapted to the homogenous combustion procedure.

2.0l 4V FSI

2.0l 4V T-FSI



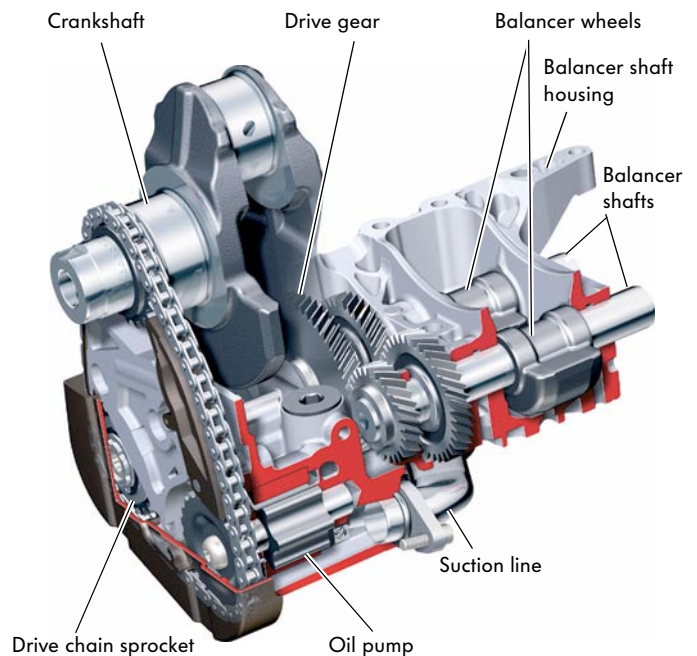
S337\_011



## The balancer shaft gear

The balancer shaft gear was taken over from the common FSI engine. However, it had to be modified as follows:

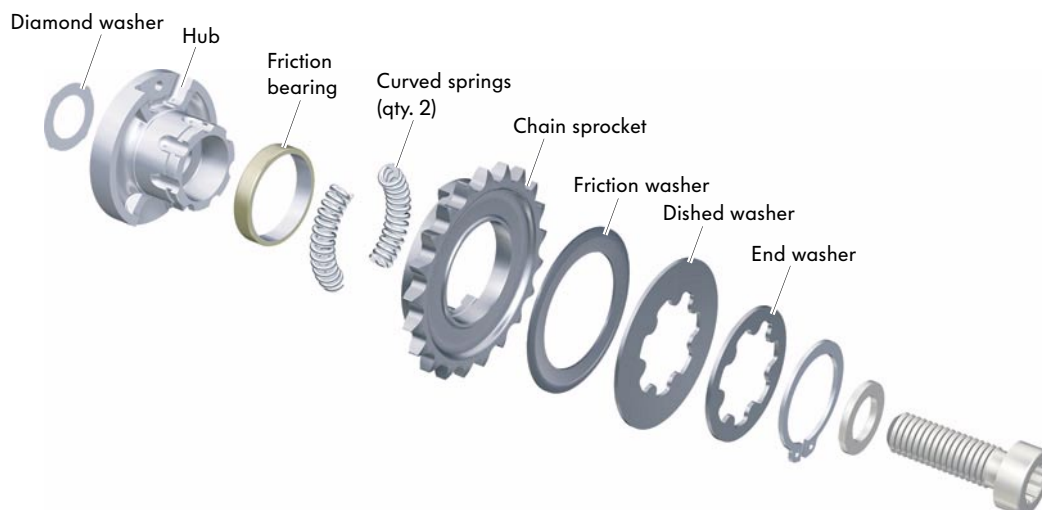
- Decoupled drive chain sprocket in balancer shaft mechanism
- Separation of splines and compensation weights to increase balancing efficiency
- Oil pump with greater gear width
- Pressure relief valve, controlled purely by oil, with oil control in vicinity of oil pump, integrated in balancer shaft housing
- Strength optimised pressure cast housing
- Bearings of balancer shafts located directly in aluminium housing



S337\_012

## The decoupled drive chain sprocket

The improved smooth running of the crankshaft in the lower speed range leads to a considerable increase in chain forces in the balancer shaft gear. With a relative crankshaft vibration angle of  $0.8^\circ$  on the normal FSI engine, the increased crankshaft vibration angle of  $2^\circ$  on the turbocharged FSI engine is much more noticeable. Due to the increased load of the chain drive, the chain would be subjected to increased wear if there were no countermeasures. Therefore, there are curved springs in the hub of the chain sprocket. These decouple the input shaft of the balancer shaft gear to the crankshaft.



S337\_013

## The toothed belt drive mechanism

As with all 4-cylinder in-line engines of series 113, the valve timing is designed as a toothed belt and direct exhaust camshaft drive system.

Due to considerably higher demands on the toothed belt drive mechanism, such as:

- higher valve spring forces due to turbo
- turbo-specific timing in conjunction with adjustment range of  $42^\circ$  CA from continuously variable valve timing (inlet camshaft).
- high pressure pump drive by means of 3 cams on inlet camshaft,

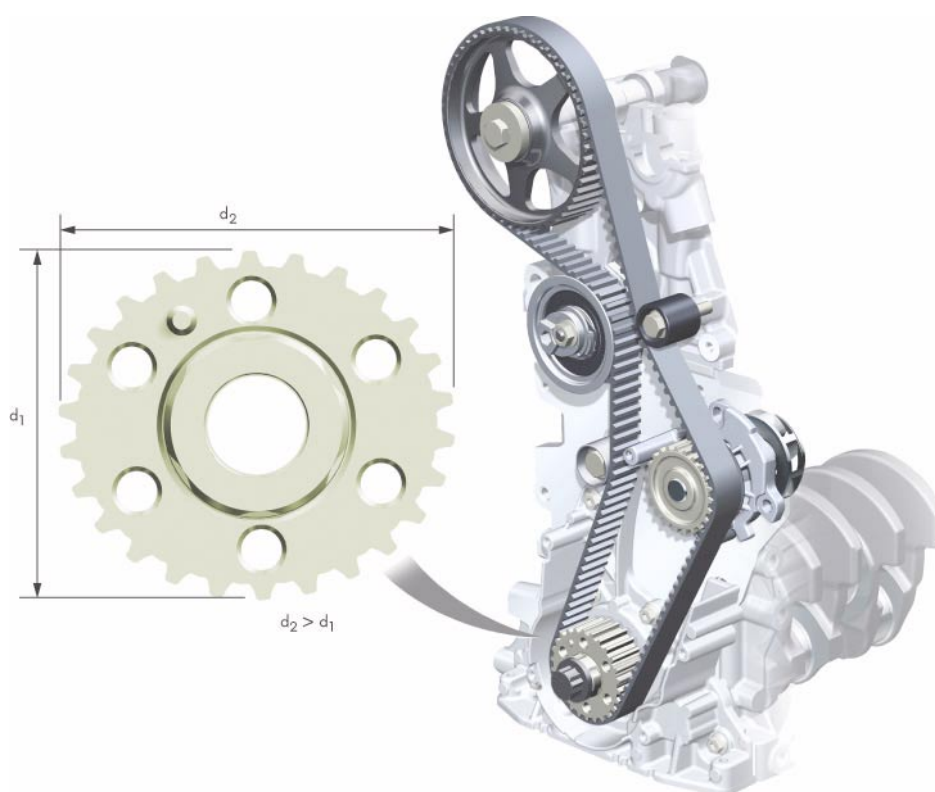
the toothed belt tensioning system, adopted from the naturally aspirated engine, was modified. This resulted in an elliptical toothed belt pulley on the crankshaft.

The CTC toothed belt pulley\*, used for the first time, reduces rotational vibrations on the camshaft and pulling forces on the toothed belt.

\* CTC toothed belt pulley = Crankshaft Torsionals Cancellation

### Function

The positioning of the toothed belt on the crankshaft is shown at TDC no. 1 cylinder, as in illustration 337\_014. Once the working stroke begins, extremely high pulling forces are imparted on the toothed belt. These are reduced by the elliptical shape of the toothed belt pulley, due to the fact that the flat side of the pulley allows slight detensioning of the toothed belt. The rotational vibrations that arise as a result counteract the rotational vibrations of the 2nd engine order in the resonance point of the timing mechanism, without causing excessive unrest in other speed ranges.



S337\_014



# Engine mechanics

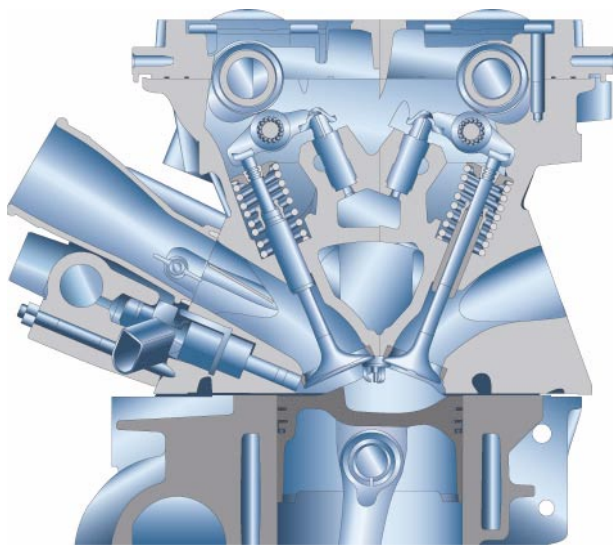
## The cylinder head

Turbo-specific changes were made to the cylinder head (with regards to the 2.0l FSI):

- Sodium filled exhaust valves
- Armoured inlet and exhaust valve seats
- Strength-optimised roller rocker fingers with reduction in web width from cams and rollers
- Valve springs with increased spring forces (same valve springs for inlet and exhaust valves)

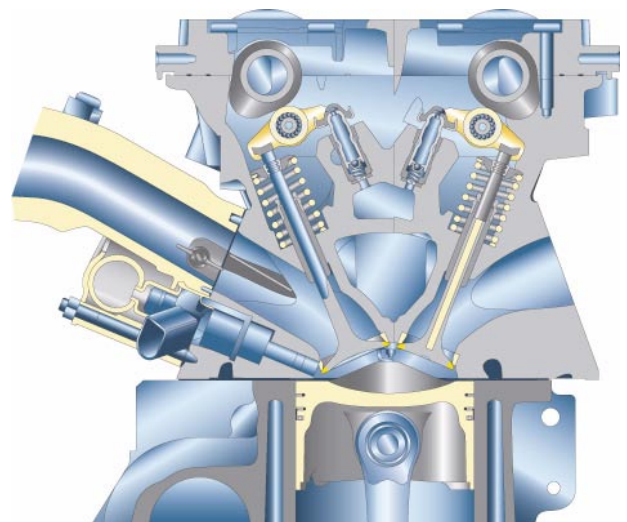
Furthermore, the inlet port geometry was modified. This enabled the tumble effect and thereby the knock resistance and smooth running properties to be improved.

**2.0l 4V FSI**



S337\_015

**2.0l 4V T-FSI**



S337\_016

## The crankcase breather system

The constant vacuum in the crankcase is assured by a separate breather system for crankcase and cylinder head.

The blow-by gases emerging from the crankcase are passed via the primary oil separator in the oil filter module to the cylinder head cover.

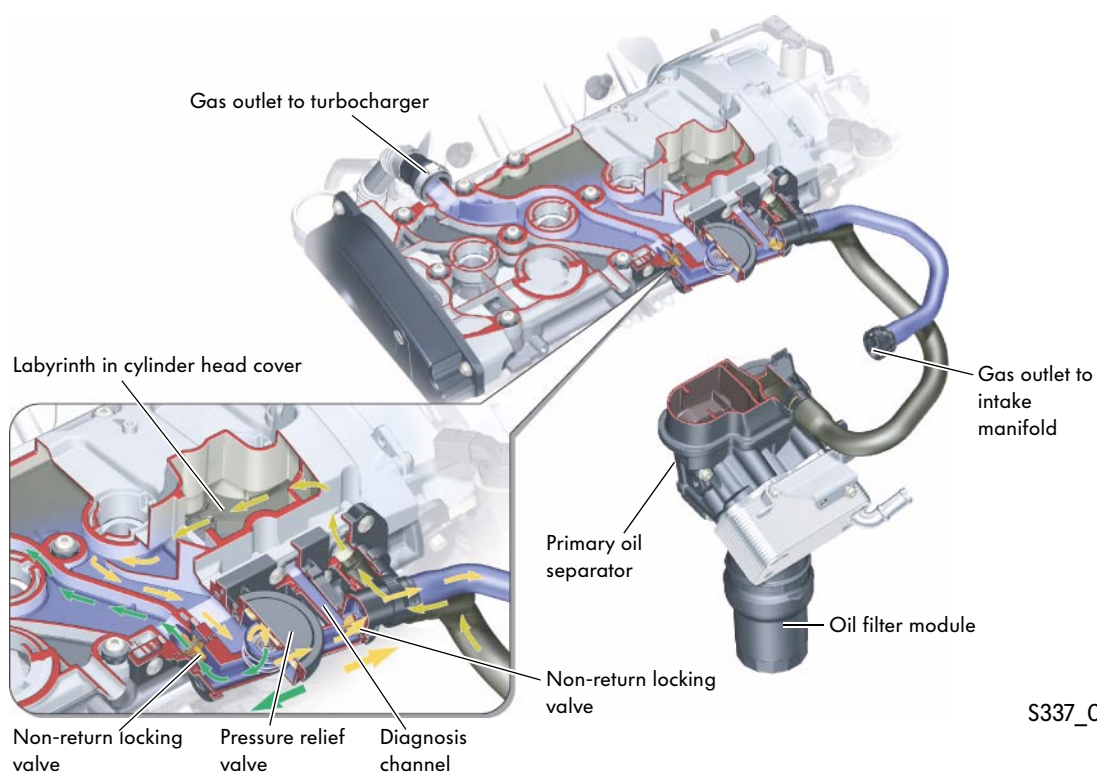
When this happens, the blow-by gases are mixed with those from the cylinder head and are passed through a labyrinth, where further oil separation occurs.

Since turbo operation requires more complicated pressure control, there is a two-stage pressure relief valve on the cylinder head cover, which channels the blow-by gases to the intake manifold or turbocharger. When there is vacuum in the intake manifold, the blow-by gases are fed directly to the intake manifold.

In the case of charge pressure, a non-return valve closes in the pressure relief valve housing. The blow-by gases are fed to the turbocharger via a channel in the cylinder head cover. To recognize an incorrectly installed pressure relief valve, a so-called diagnosis port has been integrated. Incorrect installation forces unmetered air via the sealing area of the pressure relief valve into the cylinder head cover. The reaction of the lambda probe results in diagnosis of the unmetered air and a fault is then stored in the memory.



- With charge pressure before turbocharger
- With vacuum to intake manifold

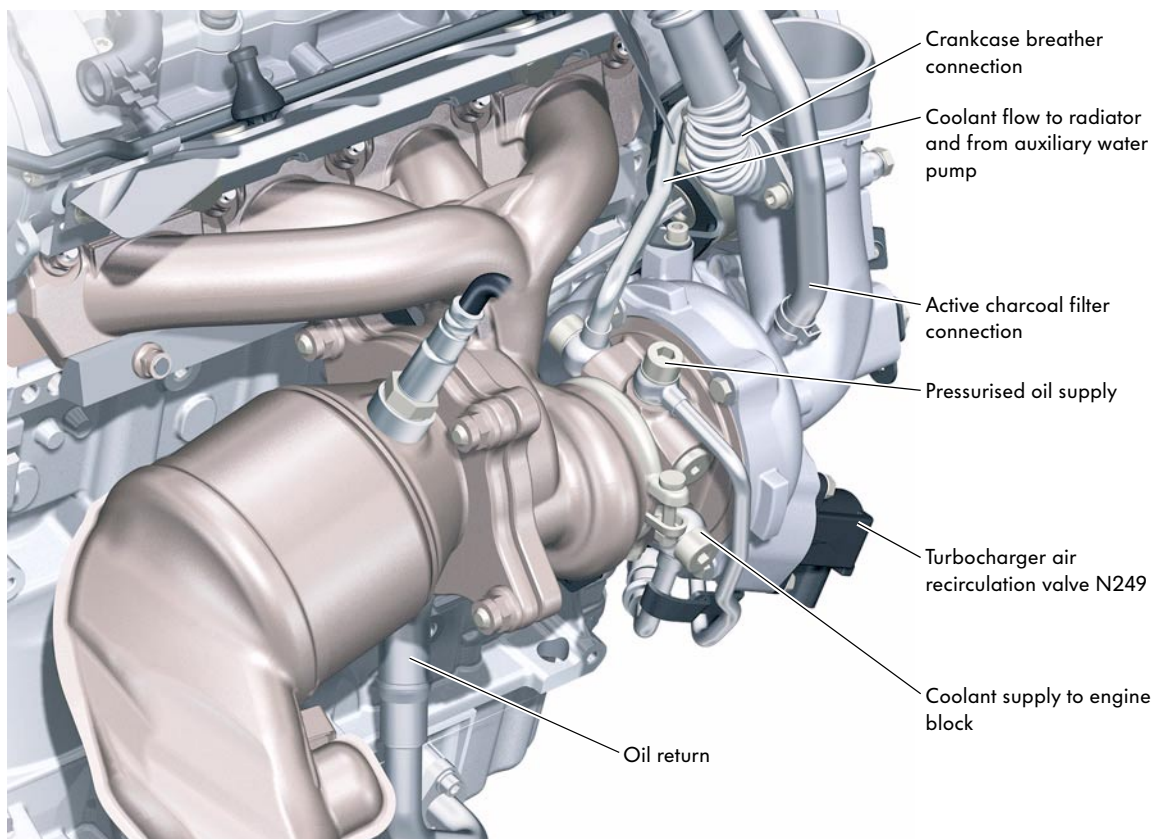


S337\_017

# Engine management

## The turbocharger/exhaust manifold module

To save space, an exhaust manifold/turbocharger housing was developed, which can be installed with all engine variations in longitudinal or transverse configuration. Importance was also placed on realising a customer service orientated solution to allow the exhaust manifold to be removed and installed easily, and for a catalytic converter to be included close to the engine.



S337\_018

The bearing of the turbine shaft is integrated in the compressor housing. The cylinder head cover houses the crankcase and active charcoal breather connections. Screwed into the pressure connection is an individually tuned resonance silencer to reduce the pressure pulsation noises.

The required charge pressure is adjusted via the charge pressure control solenoid valve N75 (pressure relief control as on 1.8 l turbocharged engine) and the so-called wastegate.

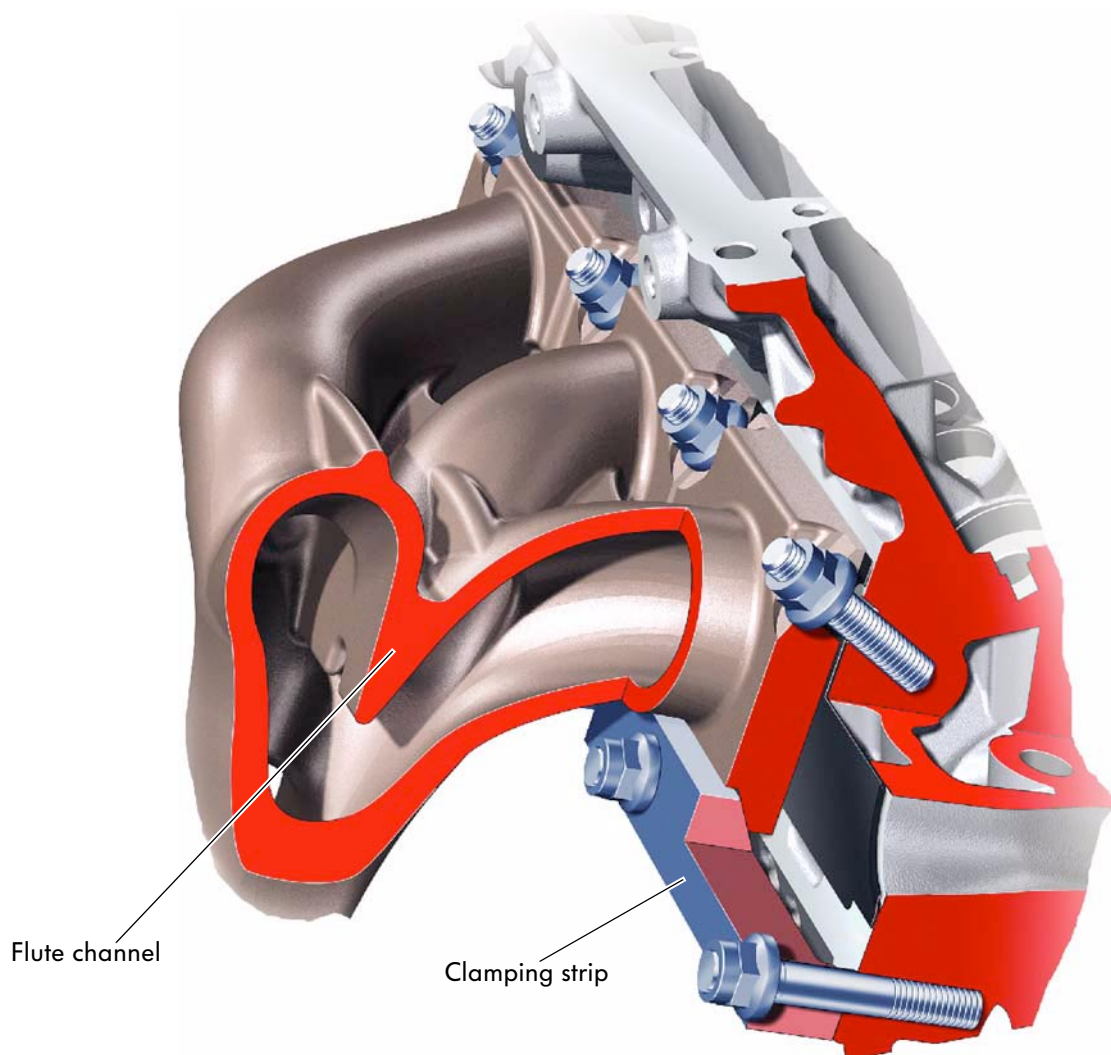
The charge pressure control solenoid valve N75 and the turbocharger air recirculation valve N249 can be found on the turbocharger.

## The turbocharger with new flange fixture

The turbocharger module is easy to fit and is attached to the cylinder head by five threaded connections. For removal and installation, the clamping strip need not be loosened.

The exhaust manifold is designed to take advantage of the firing order. The manifold is fluted to channel the exhaust gases equally over the turbine. In this way, the exhaust ports are separated in line with the firing order. Furthermore, the flute channel prevents the exhaust gas pressure from expanding into other cylinder ports.

This means that the required turbine speed is maintained and the response of the turbocharger could be optimised.



S337\_019

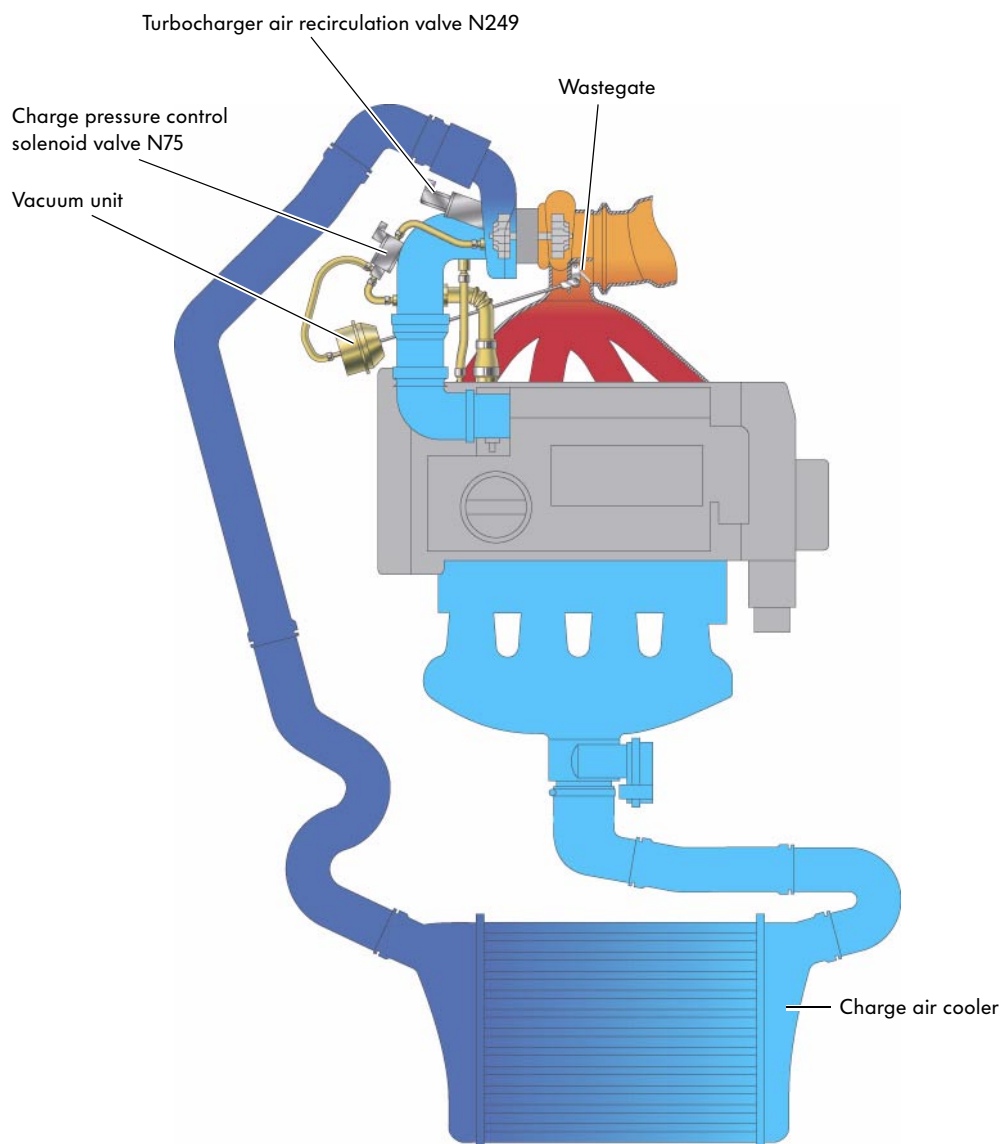
# Engine management

## Charge pressure flow and charge pressure control

Control pressure is formed from the charge pressure and intake pressure via the energised charge pressure control solenoid valve N75. The control pressure affects the vacuum unit, which actuates the wastegate valve via a linkage. The wastegate valve opens a bypass channel to allow part of the exhaust gases past the turbine into the exhaust gas system. This control feature allows the speed of the turbine to be controlled and the maximum charge pressure can thereby be regulated.



If the control features fails, the vacuum unit is affected directly by the charge pressure, which imparts pressure against the spring. The maximum charge pressure is thereby restricted to a basic operating charge pressure.



S337\_020

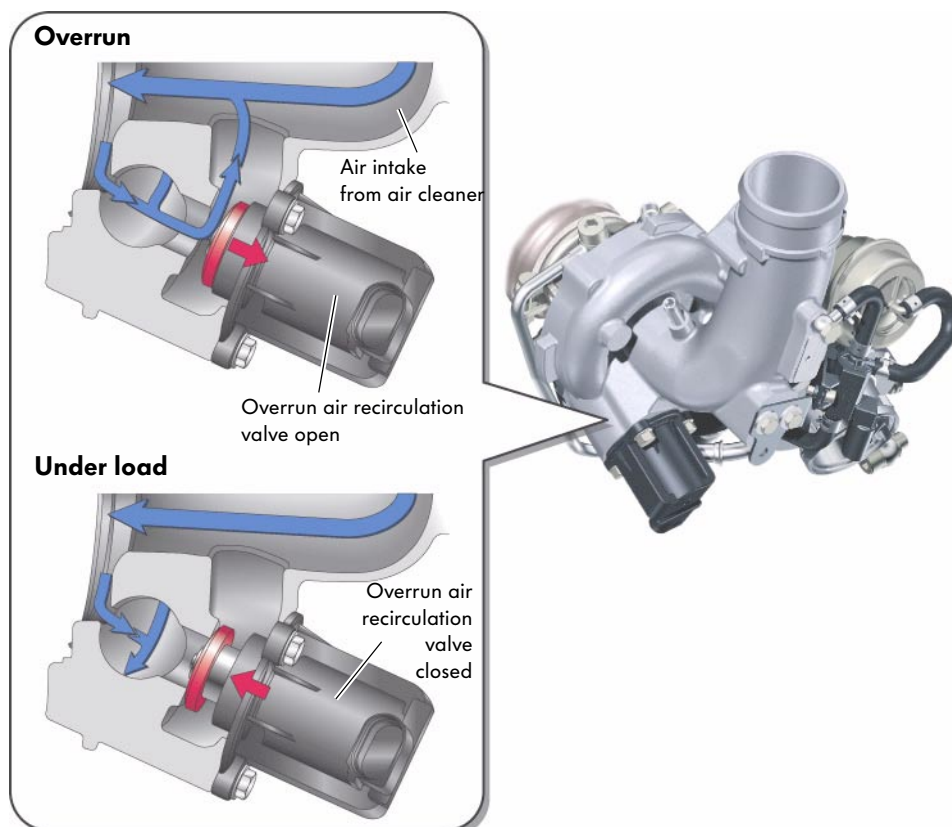
## The electric overrun air recirculation control (previously pneumatic)

In order to prevent the turbocharger from braking too heavily in overrun and between gear changes, an electric turbocharger air recirculation valve N249 is installed.

The electric overrun air recirculation control is much more durable than the pneumatic one.

In overrun, the vacuum unit is completely closed. The overrun air recirculation control is open, even between gear changes.

During overrun, pressure is built up in the compressor housing due to the prevailing charge pressure. This pressure build-up causes the compressor wheel to brake heavily, which leads to a reduction in the prevailing charge pressure (turbo drop). To prevent this from happening, the turbocharger air recirculation valve N249 is opened by an electric servomotor. It opens a bypass channel to pass compressed air via the compressor wheel back to the suction side of the compressor circuit. This keeps the turbine at a constant speed. When the throttle valve is opened, the turbocharger air recirculation valve N249 is closed and charge pressure is immediately available again.

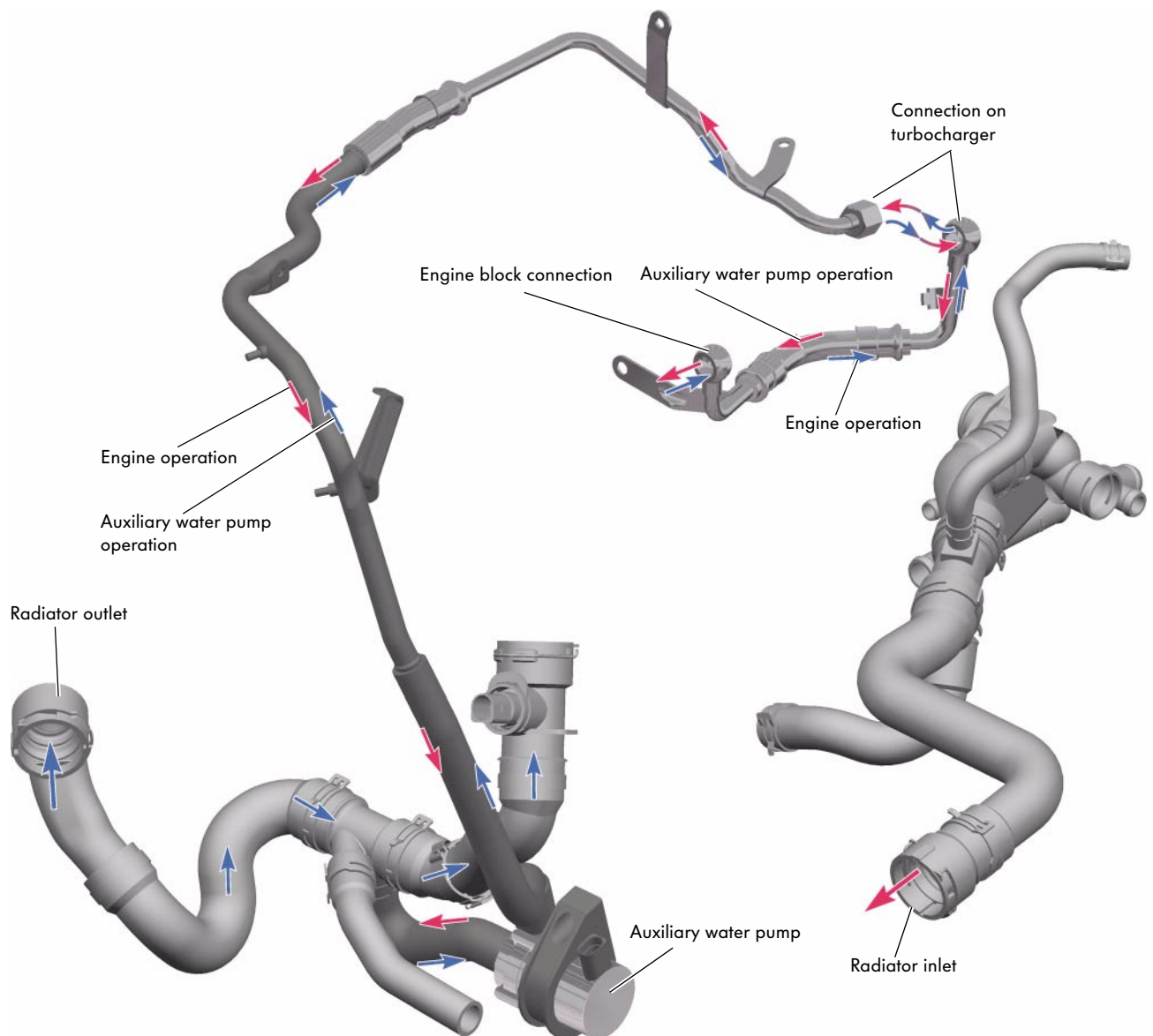


S337\_027

# Engine management

## The cooling system with coolant run-on pump and radiator run-on

To prevent oil deposits from burning onto the turbine shaft in the turbocharger, an auxiliary water pump runs-on for up to 15 minutes after the engine has been switched off. It transports the cooler coolant against the direction of normal flow. As it does this, coolant drawn in from the auxiliary pump flows from the radiator via the turbocharger in the engine block and back to the radiator to break down the residual heat.



S337\_021

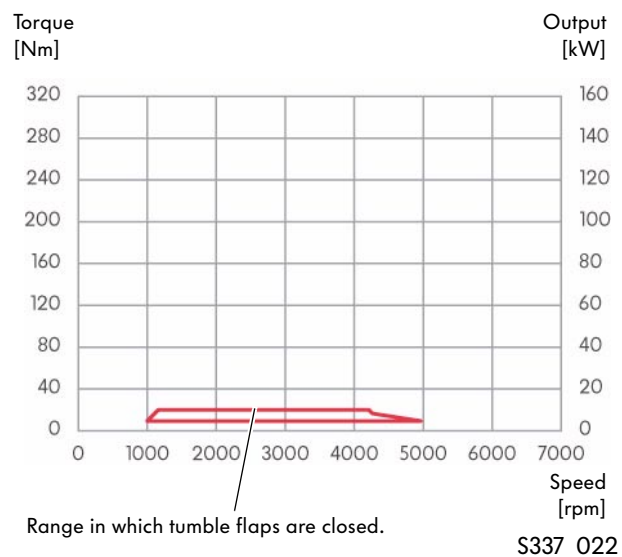
## The tumble flaps

Since the engine is operated in homogenous mode, the tumble flaps are used to improve the internal mixture formation.

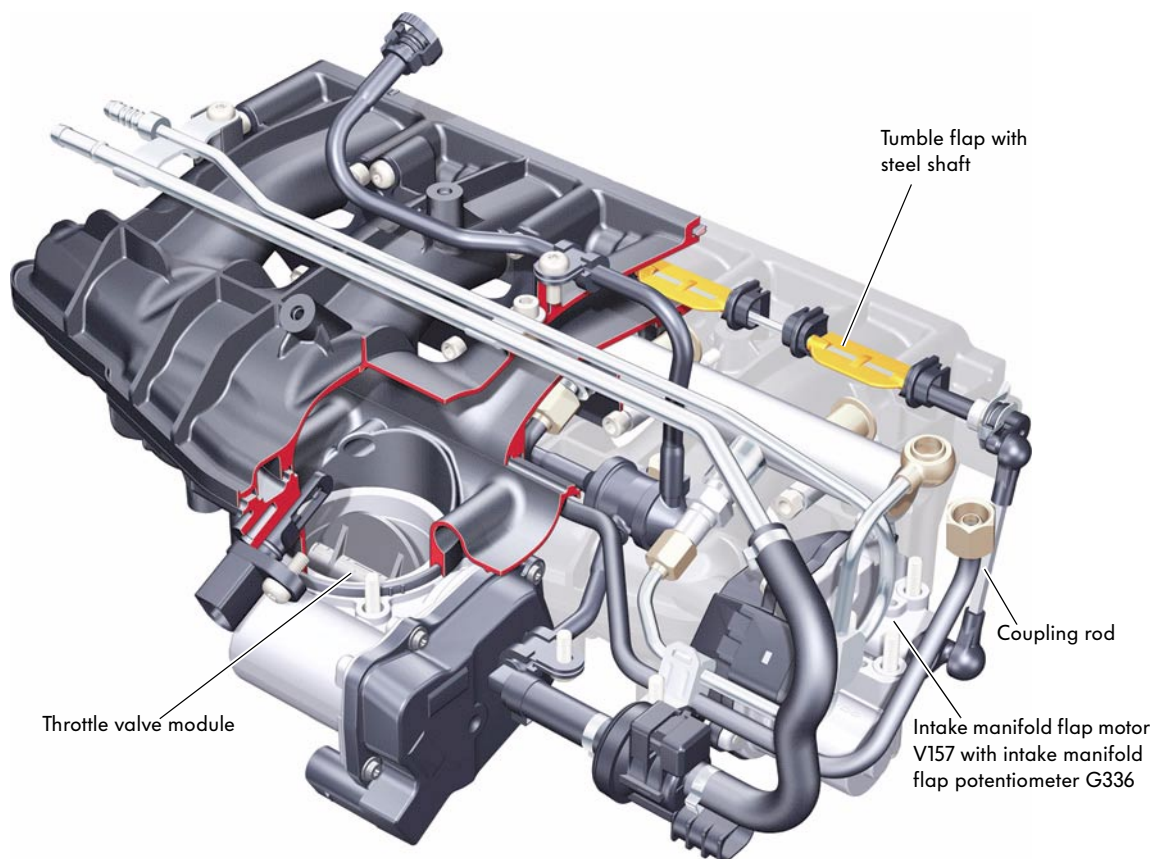
At low loads, in a speed range from 1000 rpm to 5000 rpm, the tumble flaps are closed:

- to improve idling speed quality on a cold engine
- to increase the tumble effect and thereby improve smooth running of the engine
- in overrun to prevent engine jolts

In other speed ranges, the tumble flaps are open to avoid any resistance to flow and thereby a reduction in performance.



S337\_022



S337\_023



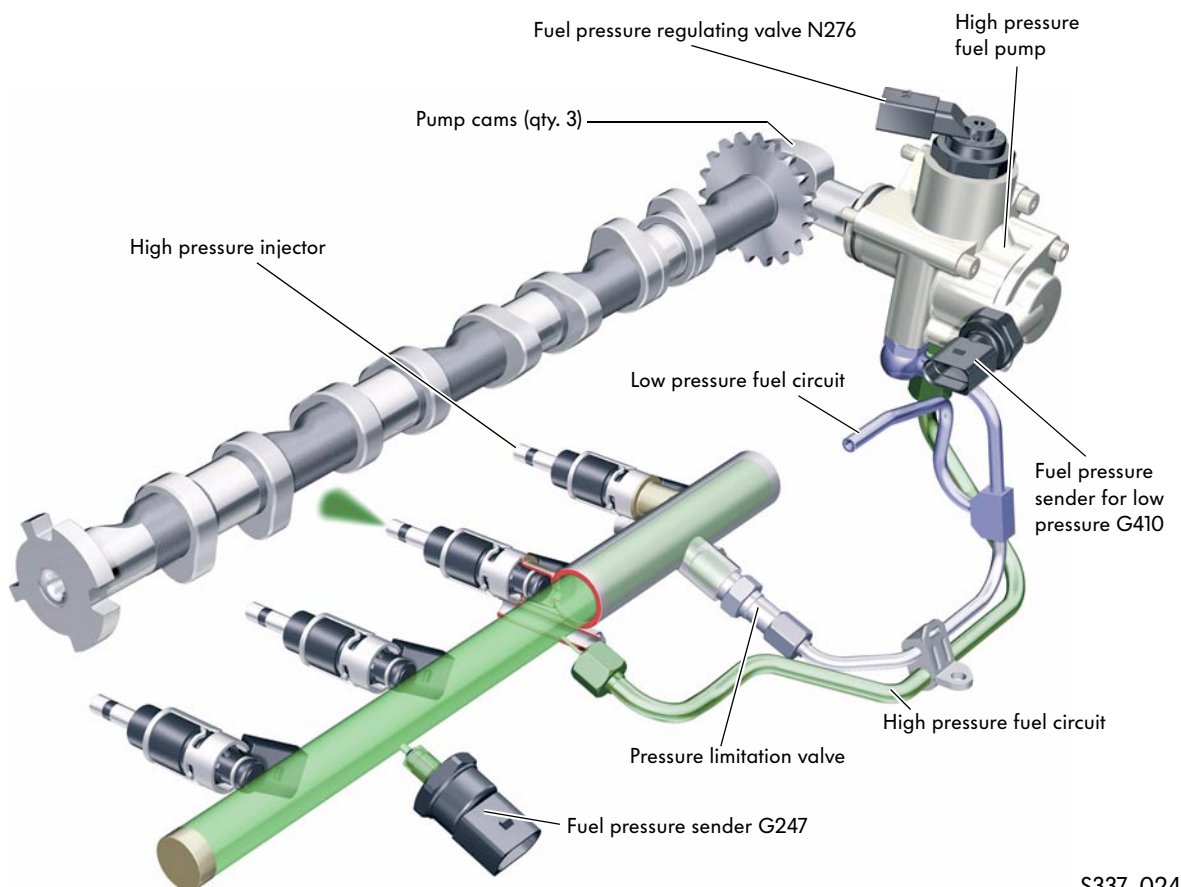
# Engine management

## The fuel supply

The direct injection petrol engines are supplied with fuel via a demand-controlled fuel pump. This demand-control feature was developed to bring the energy requirement of the fuel pump to a low level and thereby to save fuel.

To achieve increasingly high pressures, the pump is driven by 3 cams (2 cams on AXW).

The electric fuel pump provides just the amount of fuel required by the engine at a prescribed system pressure. This is controlled by the engine control unit and an electronic system that regulates the speed of the fuel pump via pulse width modulation.



S337\_024

## Modes of operation

The turbocharged engine is driven in two modes of operation.

### Dual injection with cold start

Dual injection is a special mode of operation for rapid heating of the catalytic converter.

To do this, a quantity of fuel is injected on the intake stroke at approx 300° before TDC of ignition. The fuel distributes itself homogeneously due to the long gap before ignition. The second injection occurs at approx. 60° before TDC of ignition in the compression phase.

The rich mixture that thereby forms around the spark plug means that timing can be retarded to a considerable degree without affecting stability of the engine.

Both injection periods result in lambda 1. Since the exhaust valves are already open, the exhaust gas temperature rises rapidly. This brings the catalytic converter to operating temperature (350°C) in a short space of time (30-40 seconds).

When the driver door is opened, the electric fuel pump is energised by means of the door contact switch. The prestart serves as a means of shortening the start time and to build-up pressure more rapidly. A maximum counter is installed to prevent the pump from becoming damaged.

### Main mode of operation with catalytic converter at operating temperature

Only homogenous injection occurs in the area of the spark plugs, as no additional heating of the catalytic converter is necessary.

The engine sets to lambda 1.

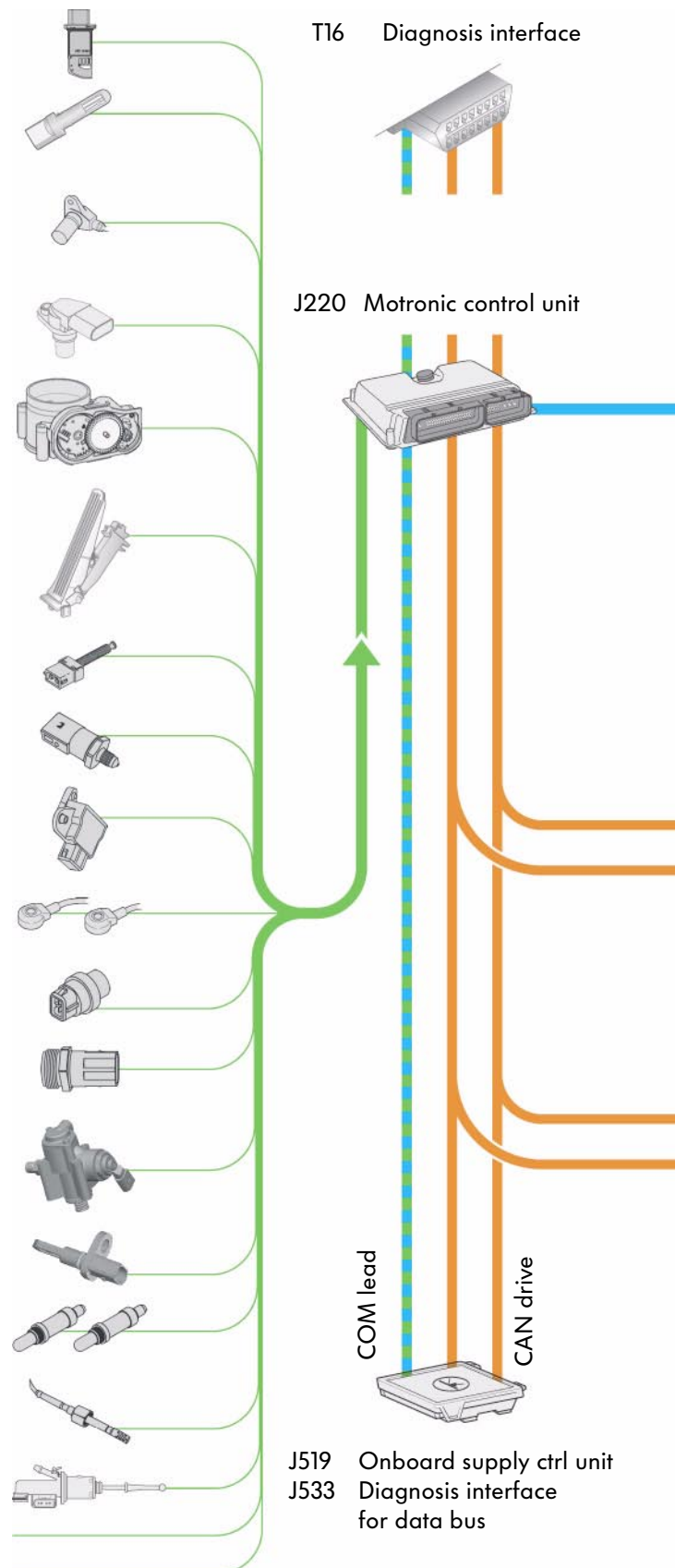
To prevent heat bubbles forming in the fuel line, the electric fuel pump is actuated even when the engine is at operating temperature.

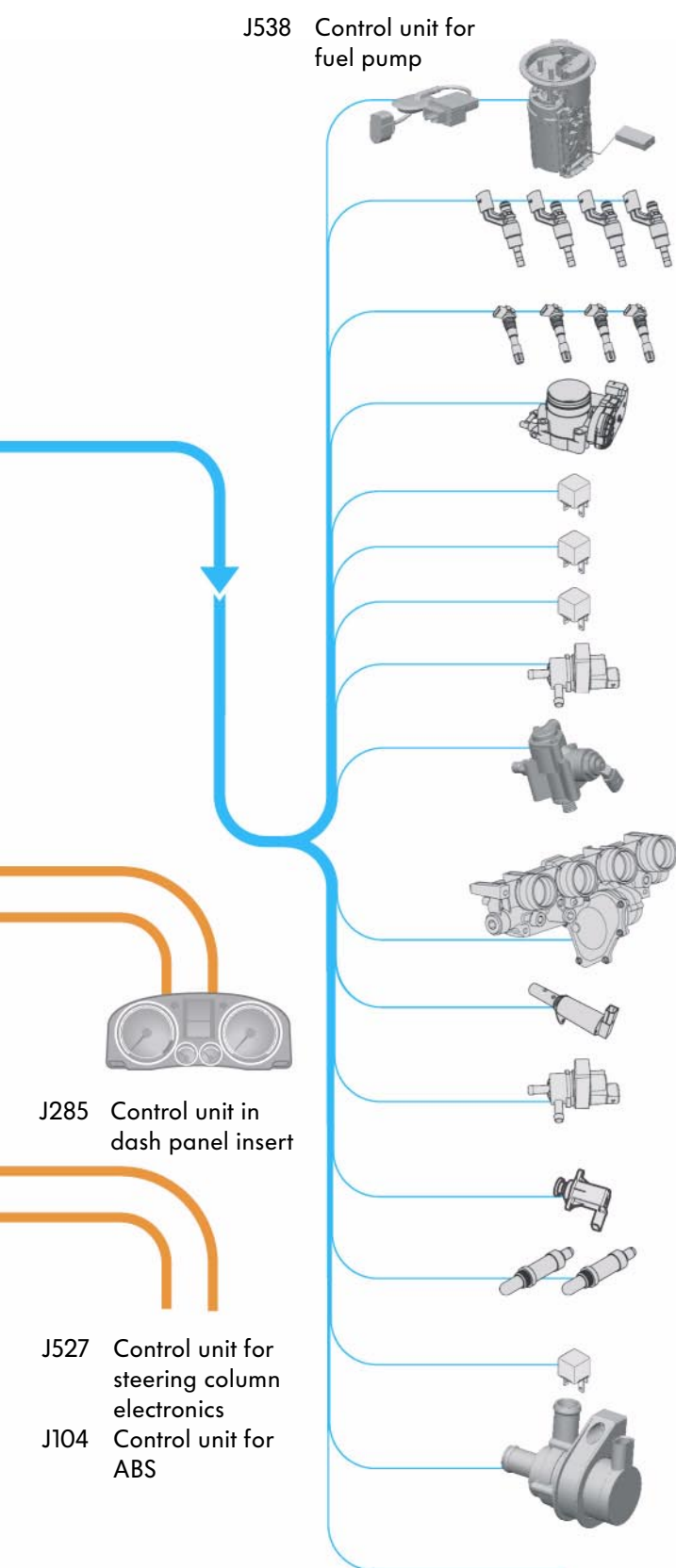


# Engine management

## The system overview

- G70 Air mass meter
- G31 Charge pressure sender
- G42 Intake air temperature sender
- G28 Engine speed sender
- G40 Hall sender
- J338 Throttle valve module
- G187 Throttle valve drive angle sender 1 for EPC
- G188 Throttle valve drive angle sender 2 for EPC
- G79 Accelerator pedal position sender
- G185 Accelerator pedal position sender 2
- F Brake light switch
- F47 Brake pedal switch
- G247 Fuel pressure sender
- G336 Intake manifold flap potentiometer
- G61 Knock sensor 1
- G66 Knock sensor 2
- G62 Coolant temperature sender
- G83 Coolant temperature sender at radiator outlet
- G410 Fuel pressure sender for low pressure
- G42 Intake air temperature sender
- G39 Lambda probe
- G130 Lambda probe after catalytic converter
- G476 Clutch position sender
- Alternator DF
- CCS on/off





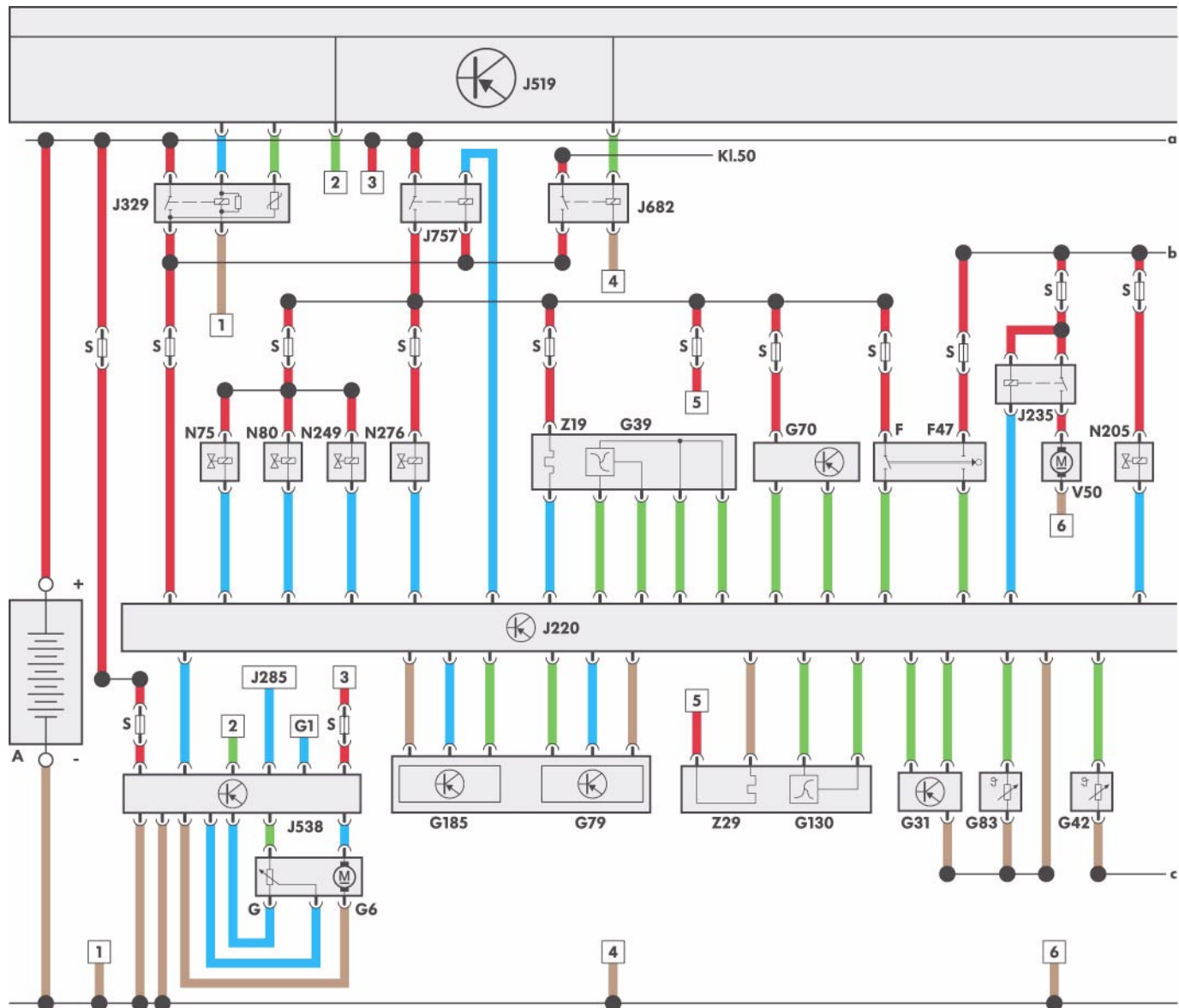
- G Fuel gauge sender
- G6 Fuel system pressurisation pump
- N30 - N33 Injectors for cylinders no. 1 - 4
- N70 Ignition coil 1 with final output stage
- N127 Ignition coil 2 with final output stage
- N291 Ignition coil 3 with final output stage
- N292 Ignition coil 4 with final output stage
- J338 Throttle valve module
- G186 Throttle valve drive for electronic power control
- J317 Voltage supply relay term.30
- J757 Voltage supply relay for engine components
- J329 Term. 15 voltage supply relay
- N80 Active charcoal relay solenoid valve 1
- N276 Fuel pressure control valve
- V157 Intake manifold flap motor
- N205 Inlet camshaft control valve 1
- N75 Charge pressure control solenoid valve
- N249 Turbocharger air recirculation valve
- Z19 Lambda probe heating
- Z29 Lambda probe 1 heater after catalytic converter
- J235 Coolant pump relay
- V50 Coolant circulation pump
- J293 Radiator fan control unit (PWM)



S337\_026

# Engine management

## Functional diagram

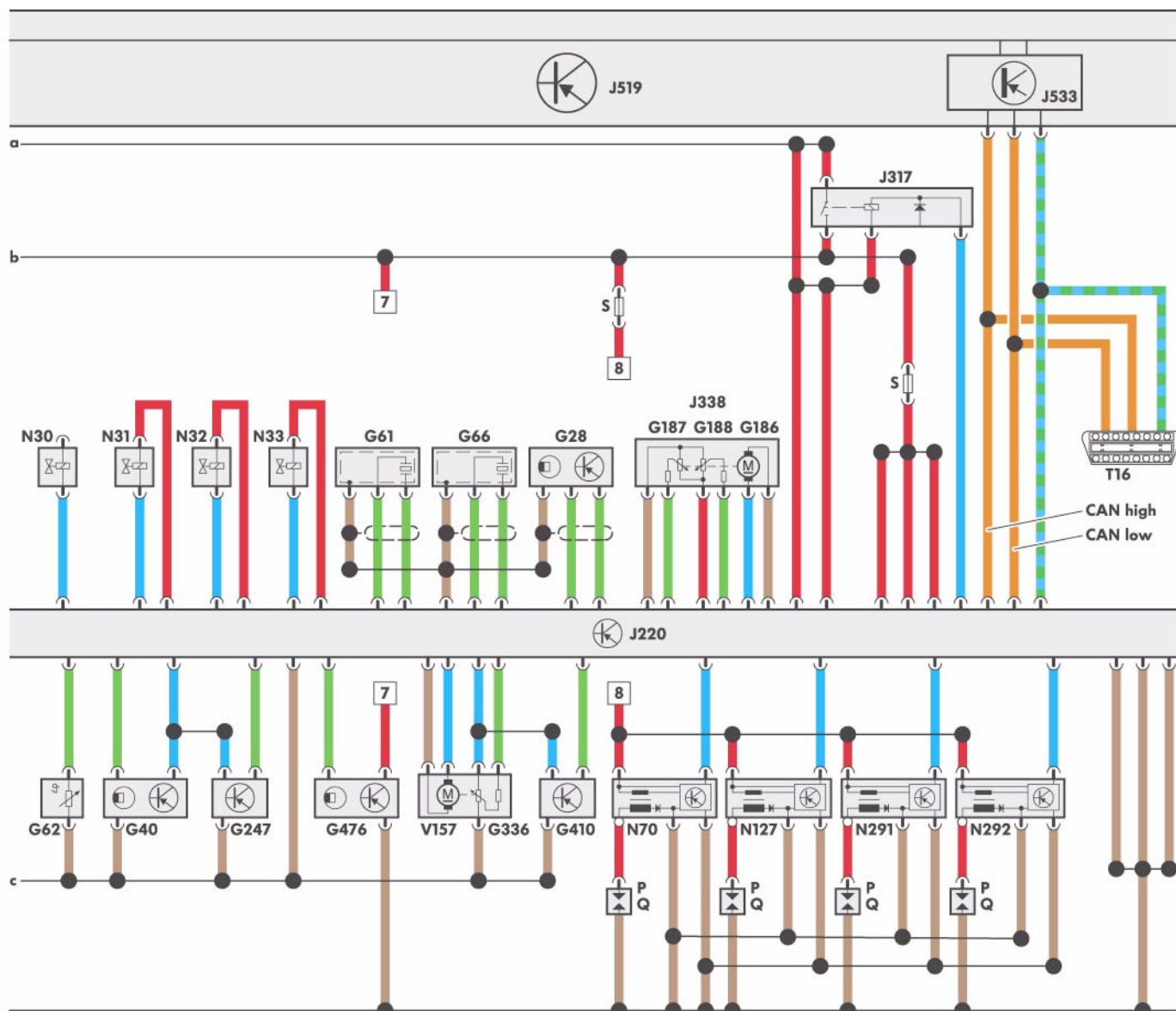


- A Battery
- F Brake light switch
- F47 Brake pedal switch
- G Fuel gauge sender
- G1 Fuel gauge
- G6 Fuel pump
- G28 Engine speed sender
- G31 Charge pressure sender
- G39 Lambda probe
- G40 Hall sender
- G42 Intake air temperature sender
- G61 Knock sensor 1
- G62 Coolant temperature sender
- G66 Knock sensor 2
- G70 Air mass meter
- G79 Accelerator pedal position sender
- G83 Coolant temperature sender at radiator outlet
- G130 Lambda probe after catalytic converter

- G185 Accelerator pedal position sender 2
- G186 Throttle valve drive for electronic power control
- G187 Throttle valve drive angle sender 1 for electronic power control
- G188 Throttle valve drive angle sender 2 for electronic power control
- G247 Fuel pressure sender

### Colour coding/key

- Output signal
- Earth
- Input signal
- Positive
- CAN drive train

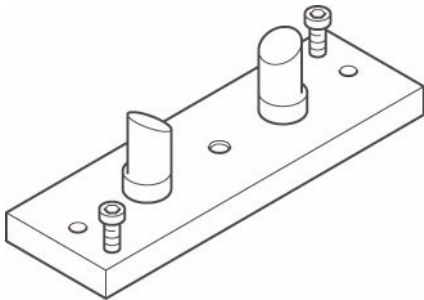
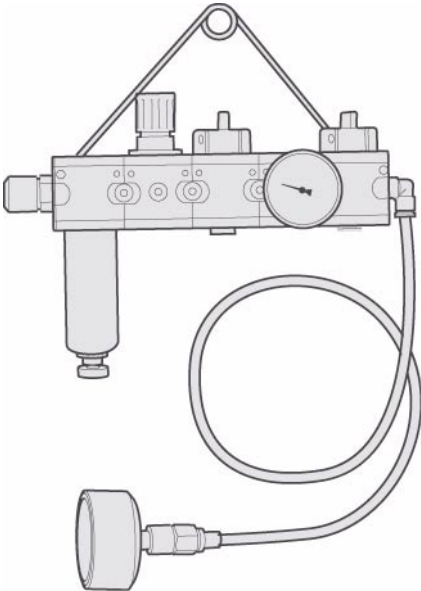


S337\_025

G336 Intake manifold flap potentiometer  
 G410 Fuel pressure sender for low pressure  
 G476 Clutch position sender  
 J220 Motronic control unit  
 J235 Coolant pump relay  
 J285 Control unit in dash panel insert  
 J317 Term. 30 voltage supply relay  
 J329 Term. 15 voltage supply relay  
 J338 Throttle valve module  
 J519 Onboard supply control unit  
 J533 Data bus diagnosis interface  
 J538 Control unit for fuel pump  
 J682 Term. 50 voltage supply relay  
 J757 Voltage supply relay for engine components  
 N30 Injector for cylinder no. 1  
 N31 Injector for cylinder no. 2  
 N32 Injector for cylinder no. 3  
 N33 Injector for cylinder no. 4

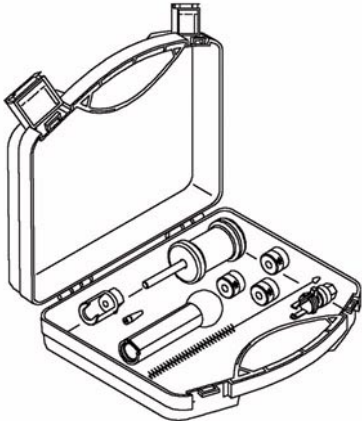
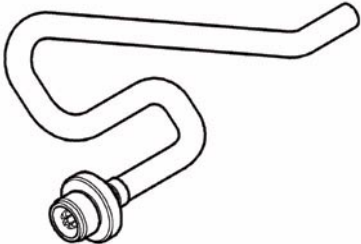
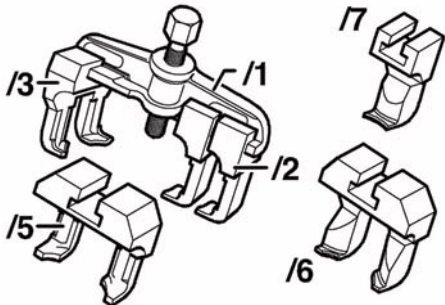
N70 Ignition coil 1 with final output stage  
 N75 Charge pressure control solenoid valve  
 N80 Active charcoal filter system solenoid valve 1  
 N127 Ignition coil 2 with final output stage  
 N205 Inlet camshaft control valve 1  
 N249 Turbocharger air recirculation valve  
 N276 Fuel pressure control valve  
 N291 Ignition coil 3 with final output stage  
 N292 Ignition coil 4 with final output stage  
 P Spark plug connector  
 Q Spark plugs  
 S Fuse  
 T16 Diagnosis interface  
 V50 Coolant circulation pump  
 V157 Intake manifold flap motor  
 Z19 Lambda probe heating  
 Z29 Lambda probe 1 heater after catalytic converter

## Special tools

| Designation                          | Tool                                                                               | Application                                |
|--------------------------------------|------------------------------------------------------------------------------------|--------------------------------------------|
| T10252<br>Camshaft bar               |   | To lock camshaft in order to remove pulley |
| VAG 1687<br>Charge air system tester |  | To check for leaks in charge air system    |
| With new adapter<br>1687/5           |                                                                                    |                                            |



## Special tools

| Designation                        | Tool                                                                                | Application                                                                            |
|------------------------------------|-------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| T10133<br>FSI special tool<br>case |    | Common special tools for repairs to FSI engines. Also used on turbocharged FSI engine. |
| T40057<br>Oil drain adapter        |  | To drain engine oil from oil filter housing                                            |
| T40001<br>Puller                   |  | To pull off camshaft pulley                                                            |
| T40001/1 - 7<br>Arms for puller    |                                                                                     |                                                                                        |



# Test your knowledge

## 1. In which mode of operation is the T-FSI driven?

- ☐ a) Homogeneous mode
- ☐ b) Homogeneous lean mode
- ☐ c) Stratified mode

## 2. When are the tumble flaps actuated?

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## 3. Where is the elliptical CTC toothed belt pulley used?

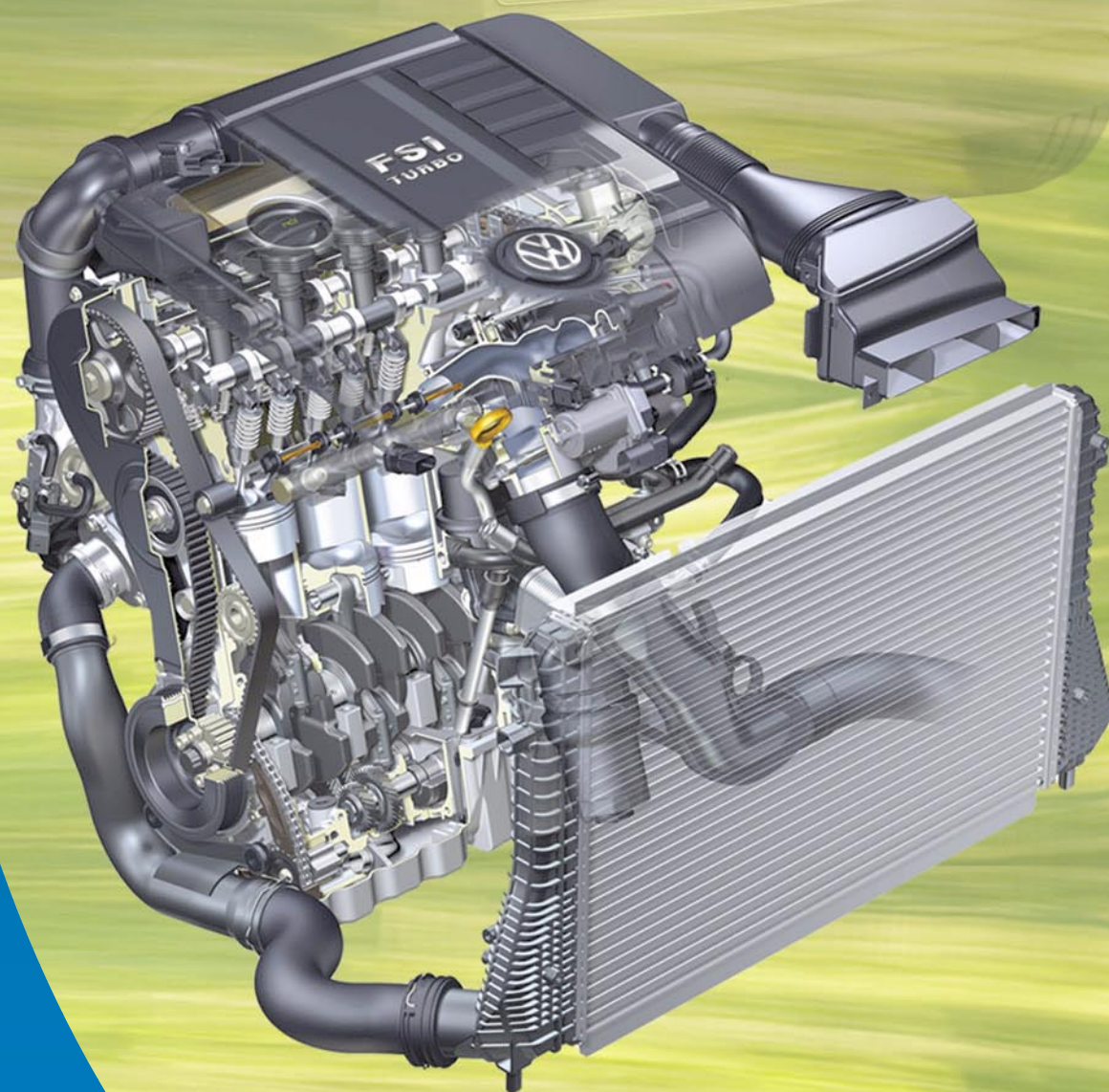
- ☐ a) Variable valve timing
- ☐ b) Balancer shaft drive
- ☐ c) Toothed belt drive

## 4. The flute channel in the exhaust manifold has the following tasks

- ☐ a) Equal flow of exhaust gases to turbocharger
- ☐ b) Prevents back flow of exhaust gases
- ☐ c) Turbocharger speed is maintained
- ☐ d) Response of turbocharger is optimised

Answers:  
1. a 2. At low load in a speed range of 1000 - 5000 rpm  
3. c 4. a, b, c, d





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