Reference Manual

B38 TOP ENGINE

Technical Taining

Technical training.
Product information.

B38 Top Engine

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BMW Group University
Technical Training
ST1405 1/1/2019

BMW Service

General information

Symbols used

The following symbol is used in this document to facilitate better comprehension or to draw attention to very important information:

⚠

Contains important safety information and information that needs to be observed strictly in order to guarantee the smooth operation of the system.

Information status and national-market versions

BMW Group vehicles meet the requirements of the highest safety and quality standards. Changes in requirements for environmental protection, customer benefits and design render necessary continuous development of systems and components. Consequently, there may be discrepancies between the contents of this document and the vehicles available in the training course.

This document basically relates to the European version of left-hand drive vehicles. Some operating elements or components are arranged differently in right-hand drive vehicles than shown in the graphics in this document. Further differences may arise as a result of the equipment specification in specific markets or countries.

Additional sources of information

Further information on the individual topics can be found in the following:

- Owner's Handbook
- Integrated Service Technical Application.

Contact: conceptinfo@bmw.de

The information contained in this document forms an integral part of the technical training of the BMW Group and is intended for the trainer and participants in the seminar. Refer to the latest relevant information systems of the BMW Group for any changes/additions to the technical data.

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Technical Training

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B38 Top Engine
1. Introduction

This document describes the special features of the new 3-cylinder top engine and serves to support technical service. The images shown relate to the 3-cylinder top engine.

- B38 = 3-cylinder gasoline engine

The B38K15T0 engine is used the first time in the I12. This 170 kW / 228 hp 3-cylinder gasoline engine. It is installed in the I12 as a transverse mounted mid-engine. Only the differences and special features are mentioned in this reference manual.

B38 Top engine

B38 Top Engine
1. Introduction

1.1. Engine designation

In the technical documentation, the engine designation is used to ensure proper identification of the engine. Frequently, however, only a short designation is used. This short form is used to assign an engine to an engine family.

Position	Meaning	Index	Explanation
1	Engine developer	M, N, B P S W	BMW Group BMW M Sport BMW M GmbH Bought-in engines
2	Engine type	1 2 3 4 5 6 7 8	4-cylinder in-line engine (e.g. N18) 4-cylinder in-line engine (e.g. N20) 3-cylinder in-line engine (e.g. B38) 4-cylinder in-line engine (e.g. N43) 6-cylinder in-line engine (e.g. N55) V8 engine (e.g. N63) V12 engine (e.g. N74) V10 engine (e.g. S85)
3	Change to the basic engine concept	0 1 – 9	Basic engine Changes, e.g. combustion process
4	Working method or fuel type and possibly installation position	A B C D H K	gasoline, transverse mounted gasoline, longitudinally mounted Diesel, transverse mounted Diesel, longitudinally mounted Hydrogen gasoline, horizontal mounting
5 + 6	Displacement in 1/10 liter	15	1.5 liters
7	Performance class	K U M O T	Lowest Lower Middle Upper Top
8	Redesign relevant to approval	0 1 – 9	New development Redesign

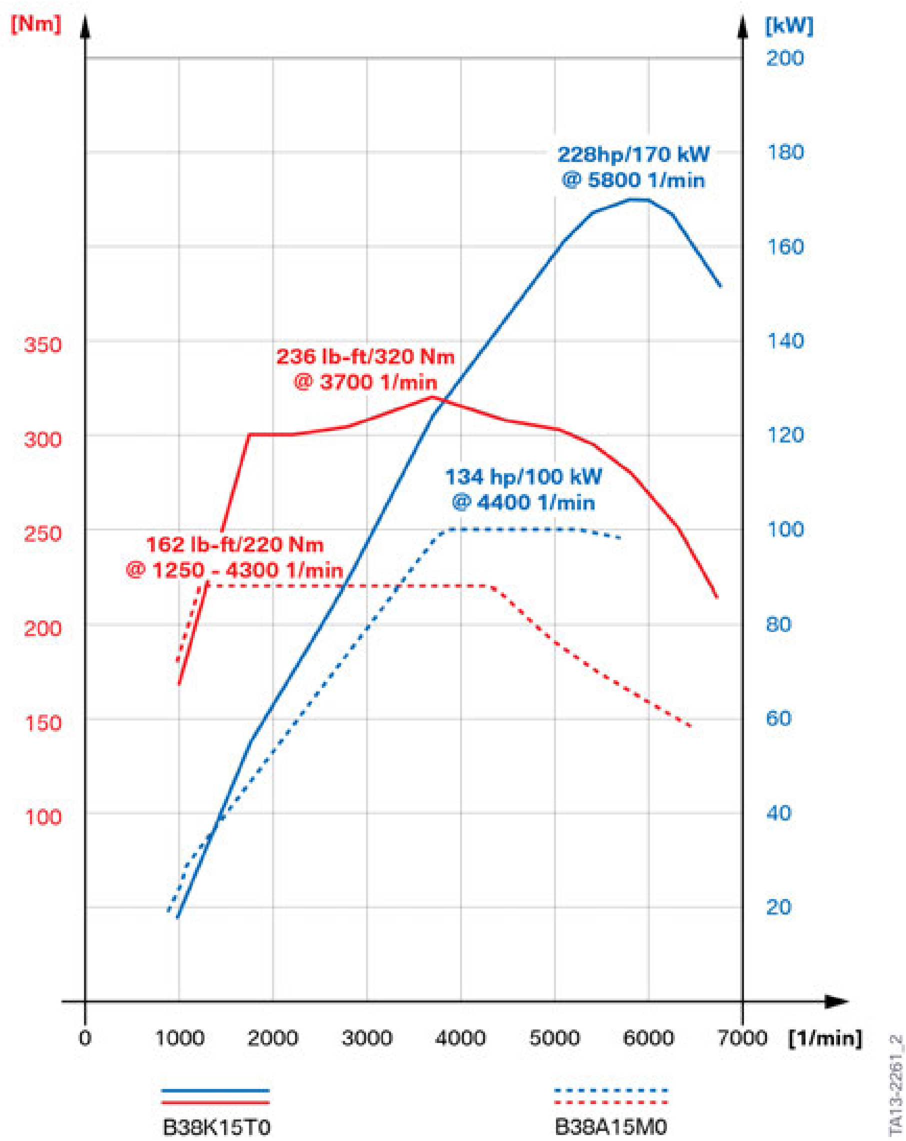
1.2. Technical data

	Unit	B38K15T0
Design		In-line engine
Cylinder		3
Displacement	[cm^3]	1499
Stroke/Bore hole	[mm]	94.6/82
Power at engine speed	[kW (HP)] [rpm]	170 (228) 5800

B38 Top Engine

1. Introduction

Power output per liter	[kW/l]	113.4
Torque at engine speed	[Nm] [rpm]	320 3700
Compression ratio	[ε]	9.5:1
Valves per cylinder		4
Fuel rating	[RON]	91 - 100
Fuel	[RON]	98
CO_2 emissions	[g/km]	49
Digital Engine Electronics		DME 17.2.3
Exhaust emission standards		ULEV II



I12 Torque and performance diagram for B38K15T0 engine in comparison to the B38A15M0 engine

1.3. Highlights

The following list provides an overview of the B38 top engine.

Engine mechanics

- The crankcase was adapted to the front installation position of the mechanical coolant pump. This is necessary for space reasons as the high-voltage starter motor generator and the intake air system require more space.
- The diameters of the main bearings and connecting rod bearings were increased to 50 mm.
- The cylinder head is manufactured in the gravity casting procedure. As a result, the cylinder head has a higher density and a higher stability.
- The shaft diameter of the exhaust valves was increased to 6 mm. This prevents valve vibrations which would otherwise occur due to the high charging pressure with the valve overlap.

Oil supply

- A 1 kg / 2.2 lbs lighter oil pump, as the function of the integrated mechanical vacuum pump is assumed by the electrical vacuum pump.
- The anti-roll bar link is connected on the front oil sump side.

Belt drive

- Newly developed belt drive. The combustion engine is started via a high-voltage starter motor generator. A conventional pinion style starter motor is not installed.
- The bearings of the drive shaft in the housing of the mechanical coolant pump were reinforced due to the greater forces in the belt drive.
- The air conditioning compressor in the belt drive is also not installed. It is replaced with an EKK at the electrical machine.
- Newly developed belt tensioner.
- Drive belt was widened from six to eight ribs.
- Adapted vibration damper with disconnected belt pulley.

Intake air and exhaust emission systems

- Twin-pipe unfiltered-air intake, actuator depending on the situation. Which can be switched by a Local Interconnect Network (LIN)
- First use of a water-cooled throttle valve.
- The charge air cooling is carried out using an indirect charge air cooler, which is integrated in the intake air system.
- The turbine housing of the exhaust turbocharger was integrated in the steel manifold.
- The charging pressure of up to 1.5 bar is reached by modified variable turbine geometry and controlled by an electrical wastegate valve.
- The cooling of the exhaust turbocharger is done via the bearing seat.

B38 Top Engine
1. Introduction

1.4. Features

1.4.1. Advantages

Benefits due to lower number of cylinders:

- less weight
- fewer moving masses
- less spatial requirement
- reduction of internal engine friction

The familiar TVDI[1] technology is used in all new engines.

The new engine generation is mainly characterized by lower fuel consumption and fewer exhaust emissions (ULEV 2). To achieve low fuel consumption, a map-controlled oil pump, characteristic map thermostat and injection system with direct-rail and electric arc wire-sprayed cylinder barrels, among others, are used. All engines also receive the automatic start-stop function and intelligent alternator control as a further EfficientDynamics measure.

[1]TVDI technology consists of:

- T = Turbocharger
- V = Valvetronic
- DI = Direct-Injection (direct fuel injection)

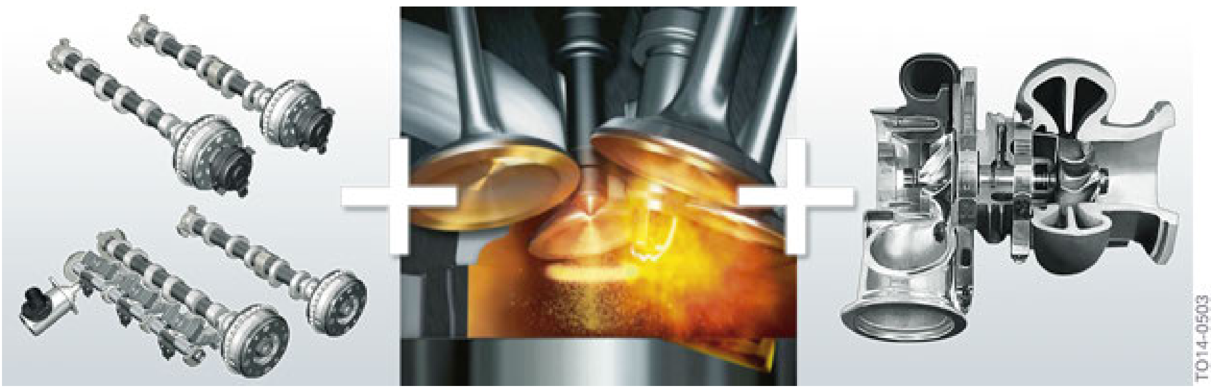
1.4.2. Overview of technical features

	B38K15T0
Map-controlled oil pump	YES
Electric arc wire-sprayed cylinder barrels	YES
Twin-scroll exhaust turbocharger	NO
Electronically controlled wastegate valve	YES
Direct fuel injection	YES
VANOS	YES
Valvetronic	YES

1.5. Design

1.5.1. TwinPower Turbo

The B38 engine is equipped with the established TwinPower Turbo Technologies.



TwinPower Turbo Technology, B38 engine

In the context of gasoline engines, TwinPower Turbo means that the following technologies are used:

- VANOS
- Valvetronic
- Direct fuel injection
- Turbocharging

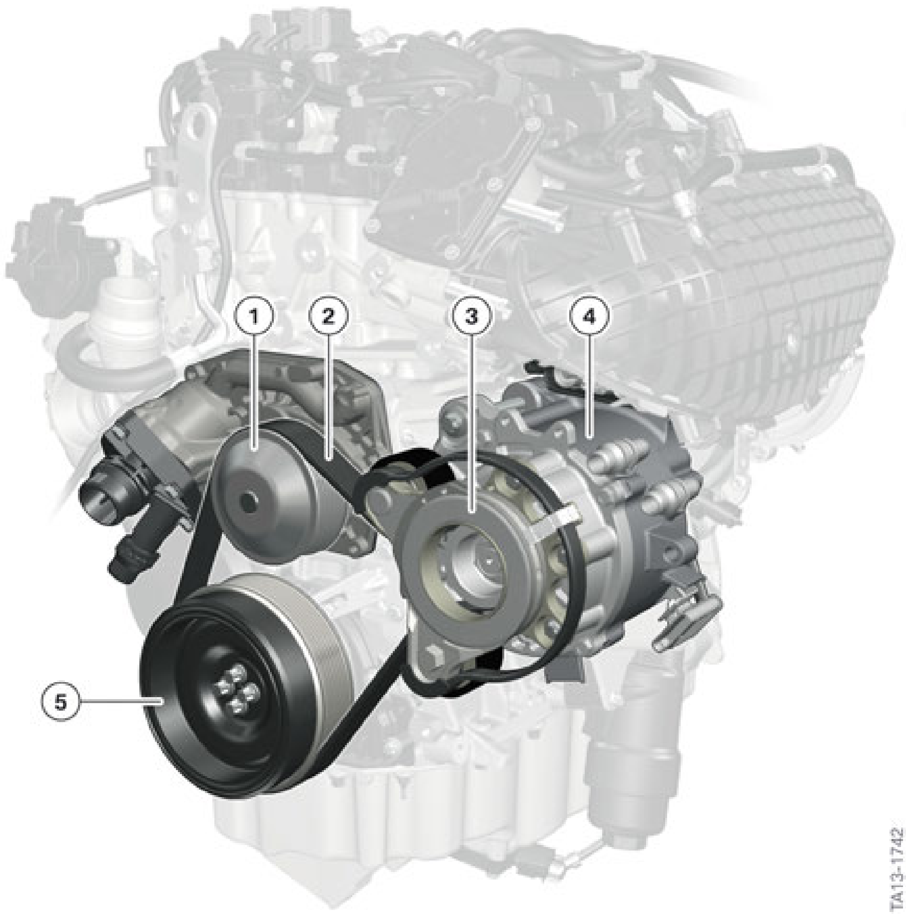
1.6. Belt drive

The belt drive of the B38 Top engine is different to that of the traditional engine. Instead of the alternator, in the I12 a high-voltage starter motor generator is used which can provide sufficient electrical energy to the high-voltage battery for charging. Other tasks of the high-voltage starter motor generator include:

- Vehicle electrical system supply
- Starting the combustion engine
- Load point increase of the combustion engine
- Boost function of the combustion engine

There is no longer a conventional starter motor in the I12.

The belt drive of the I12 had to be adapted for the integration of the high-voltage starter motor generator and the modified loading. A new belt tensioner is used in order to be able to safely transfer the maximum torque of 50 Nm / 37 lb ft in the belt drive which the starter motor generator produces during engine operation. As a result of the greater forces, the drive shaft bearing of the mechanical coolant pump was reinforced, the drive belt widened and the vibration damper with disconnected belt pulley adapted to the modified requirements.



I12 Belt drive

Index	Explanation
1	Mechanical coolant pump
2	Ribbed V-belt
3	Pendulum belt tensioner
4	High-voltage starter motor generator
5	Vibration damper with disconnected belt pulley

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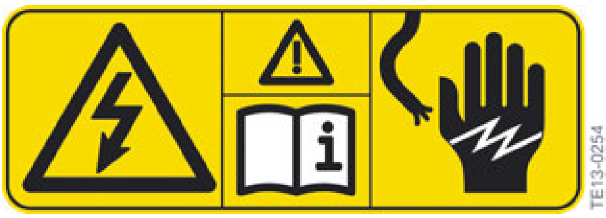
The high-voltage starter motor generator is a high-voltage component. Work on the high-voltage starter motor generator can only be carried out by Service employees that attended ST1408 I12 Complete Vehicle training with the relevant certification.

High-voltage components are marked with the following warning stickers:

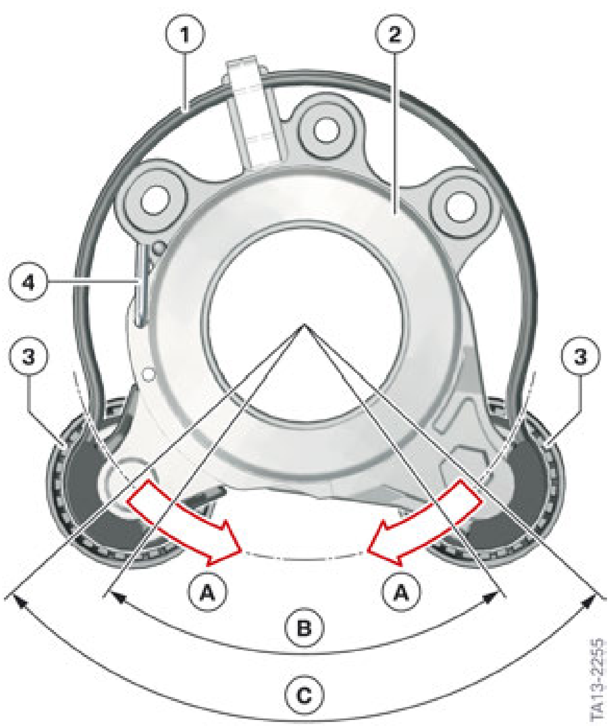


High-voltage component warning sticker

More information on the structure and function of the high-voltage starter motor generator can be found in the "I12 High-voltage Components" training manual.

1.6.1. Pendulum belt tensioner

The housing of the pendulum belt tensioner is mounted directly to the housing of the high-voltage starter motor generator using three bolts. A tension spring generates the clamping force and transmits this to the drive belt via two tensioning pulleys. The two tensioning pulleys can be turned towards each other **and** towards the housing via a radial bearing. Thanks to this intelligent design the pendulum belt tensioner is always adapted to the drive belt depending on the load, ensuring sufficient tension in the belt drive.



I12 Pendulum belt tensioner, installation position

Index	Explanation
A	Clamping force
B	Neutral position
C	Installation position
1	Tension spring
2	Housing
3	Tensioning pulleys
4	Assembly bolt

In Service the pendulum belt tensioner can be relaxed using an open-end wrench, and retained using an assembly bolt. This is the installation position in which the pendulum belt tensioner is supplied.

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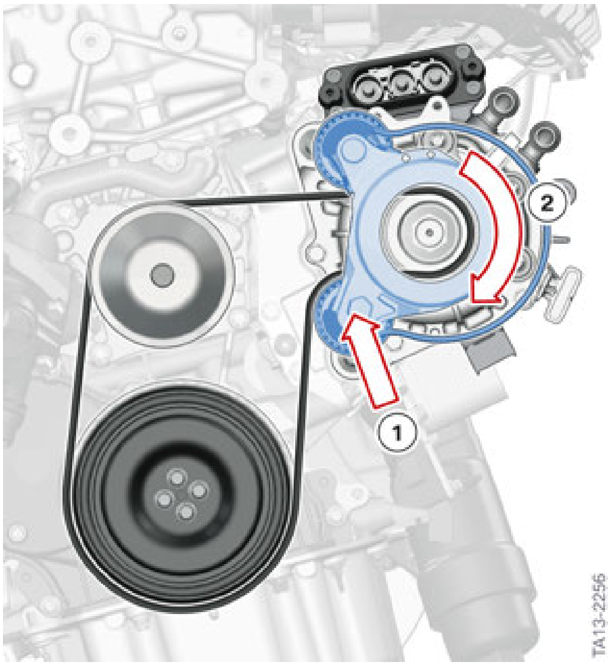
After the pendulum belt tensioner is secured at the housing and the drive belt has been properly installed, the assembly bolt must be removed. Using the open-end wrench relax the pendulum belt tensioner in an counter-clockwise direction until the assembly bolt can be removed.

Start and Boost function

BMW engines are typically right-turning engines. When looking at the engine from the front (opposite end of the output side) the crankshaft rotates in a clockwise direction. To start the combustion engine after a start-stop phase or during an electric drive, the high-voltage starter motor generator has to rotate the combustion engine. The upper part of the drive belt is pulled taut and the lower part is relaxed. To prevent the drive belt from slipping, the movable pendulum belt tensioner keeps the lower part under tension. The operating principle of the pendulum belt tensioner during the Boost function is identical to the operating principle applied during start-up.

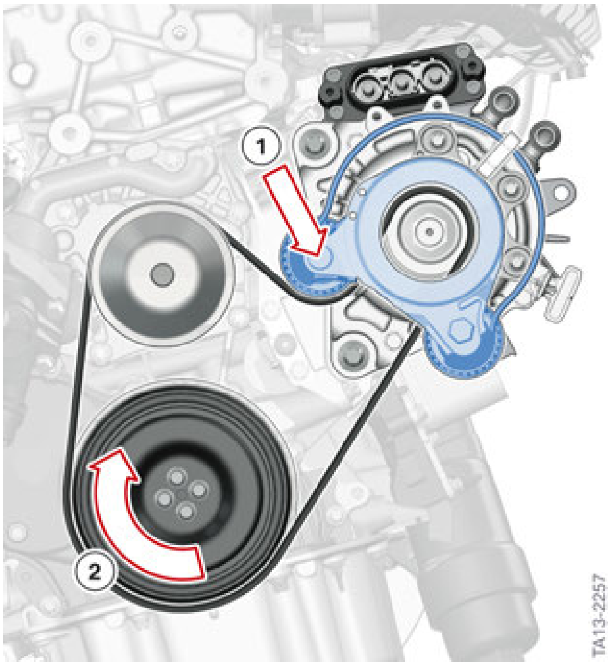


I12 Belt drive in starting mode of the high-voltage starter motor generator

Index	Explanation
1	Direction of force of the pendulum belt tensioner
2	Direction of force when the high-voltage starter motor generator powers the combustion engine

Energy recovery

When energy is recovered via the high-voltage starter motor generator, it extracts the energy from the combustion engine. The combustion engine now powers the high-voltage starter motor generator. The lower part of the drive belt is pulled taut and the upper part is relaxed. To prevent the belt slipping during energy recovery, the moveable pendulum belt tensioner keeps the upper part under tension.

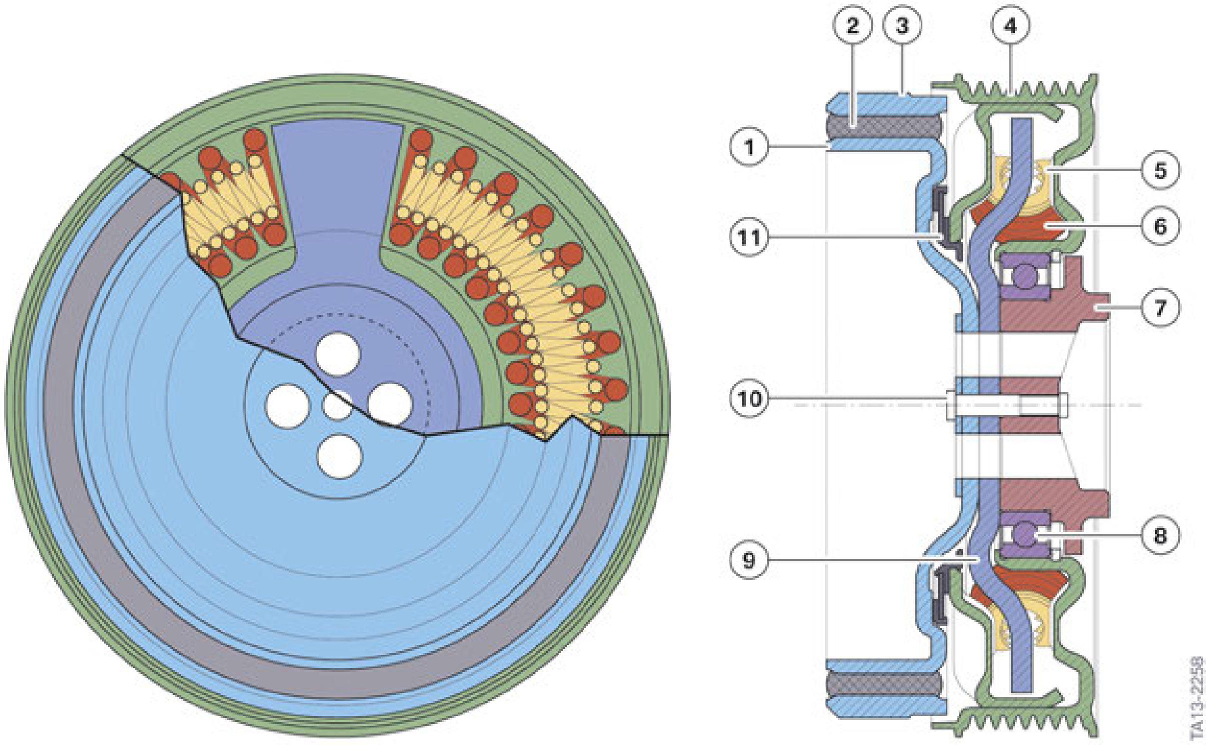


I12 Belt drive in charge mode of the high-voltage starter motor generator

Index	Explanation
1	Direction of force of the pendulum belt tensioner
2	Direction of force when the combustion engine powers the high-voltage starter motor generator

1.6.2. Vibration damper with disconnected belt pulley

Due to the 3-cylinder design, in the belt drive the torsional vibrations of the B38 Top engine must be counteracted. For this reason a vibration damper with disconnected belt pulley is used in the I12. Its operating principle is similar to that of a dual-mass flywheel.



I12 Vibration damper with disconnected belt pulley

Index	Explanation
1	Fixed pulley
2	Damping element (made from elastomer)
3	Flywheel
4	Belt pulley
5	Bow spring (small diameter)
6	Bow spring (large diameter)
7	Connection hub
8	Ball bearing
9	Connecting flange
10	Rivet
11	Friction rings

Similar to other BMW models, the vibration damper consists of a fixed pulley (1, small mass) and a flywheel (3, large mass). These are connected by a damping element (2) and can rotate freely by a few angular degrees. The fixed pulley (1) is bolted to the front end face of the crankshaft.

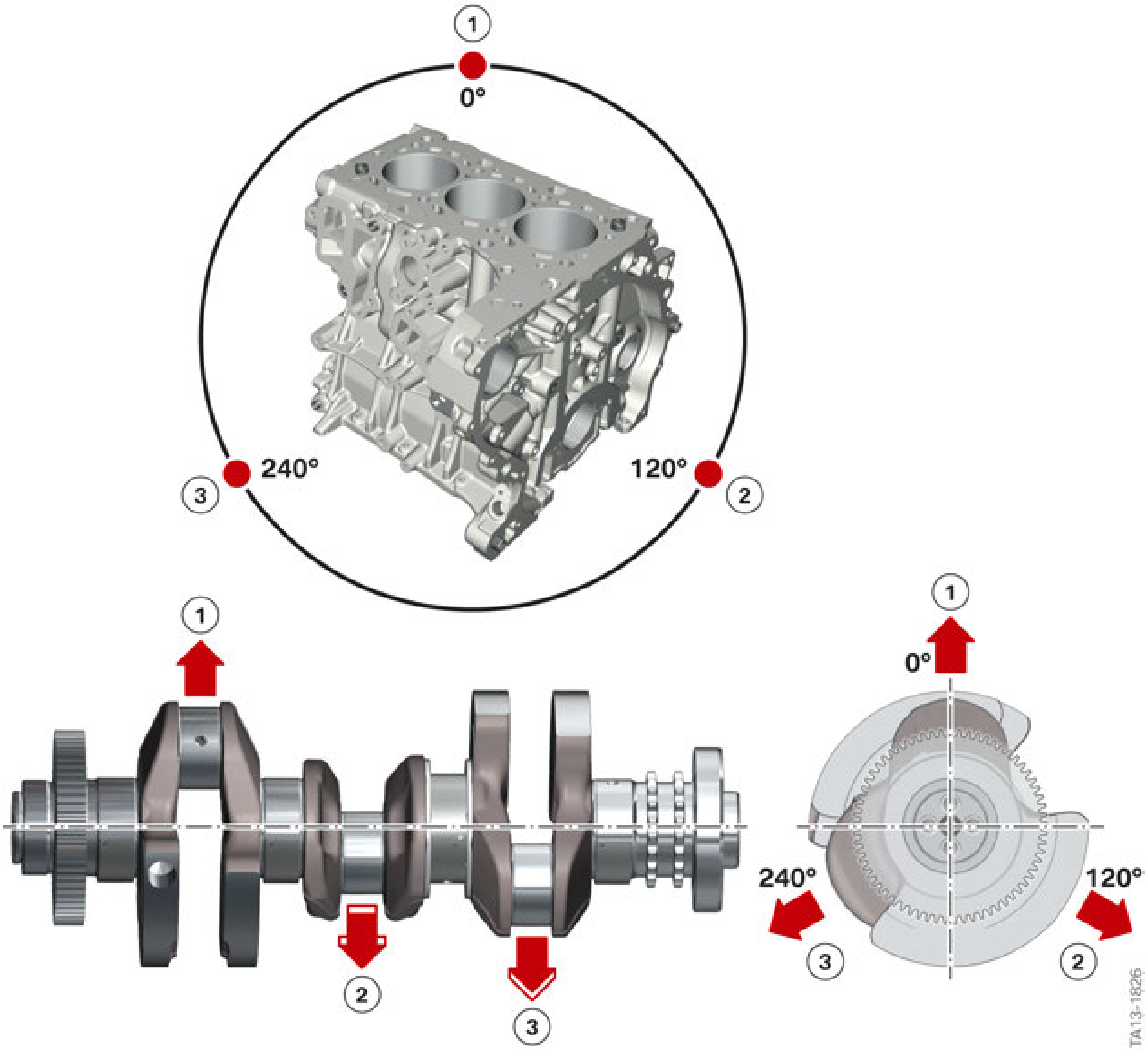
To avoid a transmission of the torsional vibrations from the engine or the crankshaft to the belt drive, a disconnected belt pulley (4) is used. This is positioned on the connection hub using a ball bearing (8) and rotates opposite the crankshaft. Two bow springs (5, 6) with different diameters counteract this rotation in the inside of the belt pulley (4). They are supported at a connecting flange (9) and thus reduce the arising oscillations. The space in the belt pulley where the bow springs are located is filled with a grease filling. This grease filling increases the service life of the bow springs and reduces their noise emissions. Friction rings (11) between the vibration damper and the belt pulley seal the belt pulley, thus protecting the interior from contamination.

In the event of emerging grease, the vibration damper with disconnected belt pulley must be replaced.

1.7. Engine acoustics

A special feature of the new 3-cylinder engine is their acoustics. For instance, the 3-cylinder engine fires the enthusiasm of drivers with their surprisingly sporty sound. In order to understand the origin of the acoustic differences, we must take a look at the engine mechanics. The following graphics illustrate the origin of the acoustics.

1.7.1. Comparison

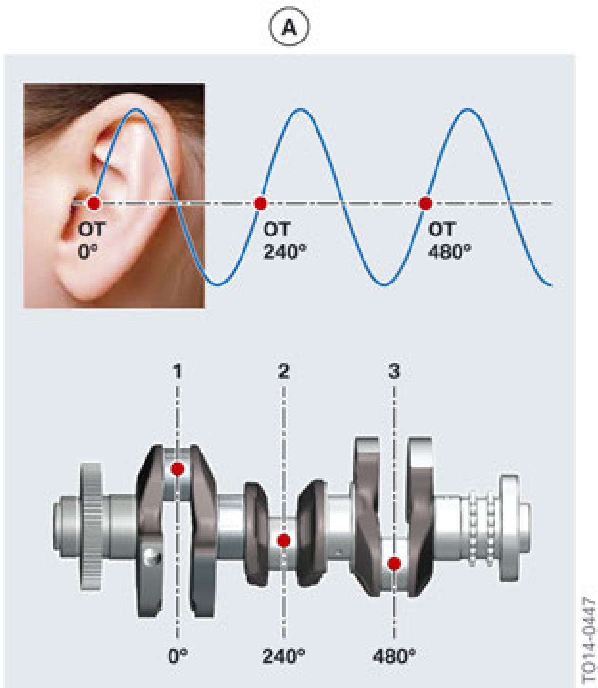


Firing interval of B38 engine

Index	Explanation
1	Connecting rod bearing journal, cylinder 1
2	Connecting rod bearing journal, cylinder 2
3	Connecting rod bearing journal, cylinder 3

The graphic shows a 3-cylinder in-line engine with a firing interval of 240° and a firing order of 1–2–3. A crankshaft revolution (360°) results in 1.5 work cycles for the 3-cylinder in-line engine.

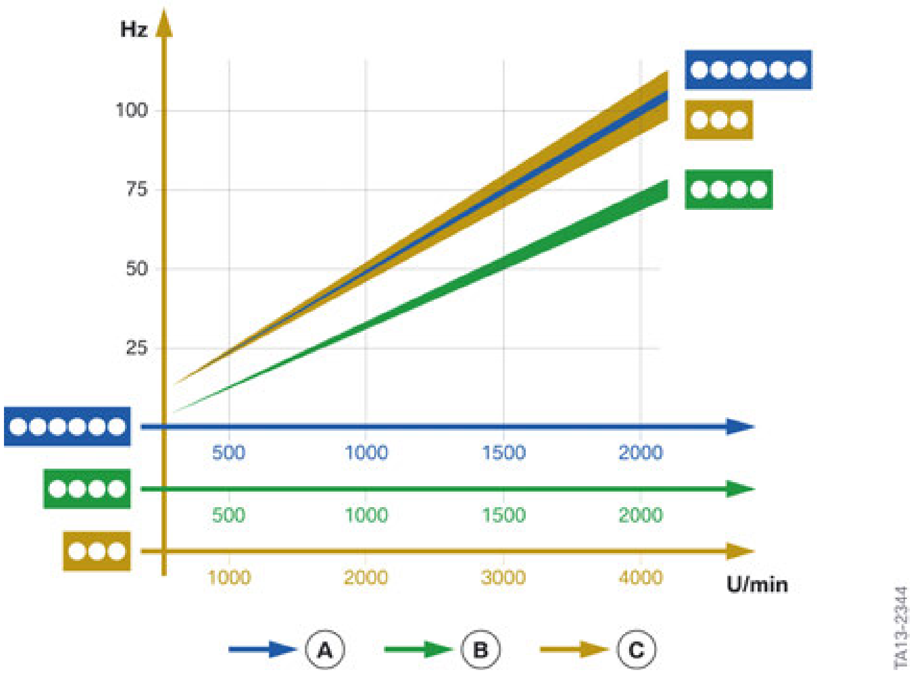
The acoustic differences therefore have their origin in the different firing intervals.



Acoustic oscillations of the B38 engine

Index	Explanation
A	Acoustic oscillation of the 3-cylinder in-line engine

The sound of the 3-cylinder in-line engine is rugged and sporty.



Acoustic diagram showing comparison between 3, 4 and 6-cylinder engine

Index	Explanation
A	6-cylinder in-line engine
B	4-cylinder in-line engine
C	3-cylinder in-line engine
Hz	Dominant firing frequency [f]
rpm	Revolutions per minute

The dominant firing frequencies [f] can be calculated as follows:

- 6-cylinder in-line engine (firing order 3)
  f = Engine speed : 60 · 3
- 4-cylinder in-line engine (firing order 2)
  f = Engine speed : 60 · 2
- 3-cylinder in-line engine (firing order 1.5)
  f = Engine speed : 60 · 1.5

The previous graphic shows the development of the acoustics across the entire engine speed range. It is interesting to note that the 3-cylinder in-line engine and the 6-cylinder in-line engine are similar. The reason for this is the uneven firing order of the two engines. As already described above, the 3-cylinder in-line engine performs 1.5 work cycles per crankshaft revolution. The 6-cylinder in-line engine performs three work cycles in the same period – i.e exactly twice as often. As they both have an uneven firing order, the 3-cylinder in-line engines have the acoustic fingerprint of a 6-cylinder in-line engine.

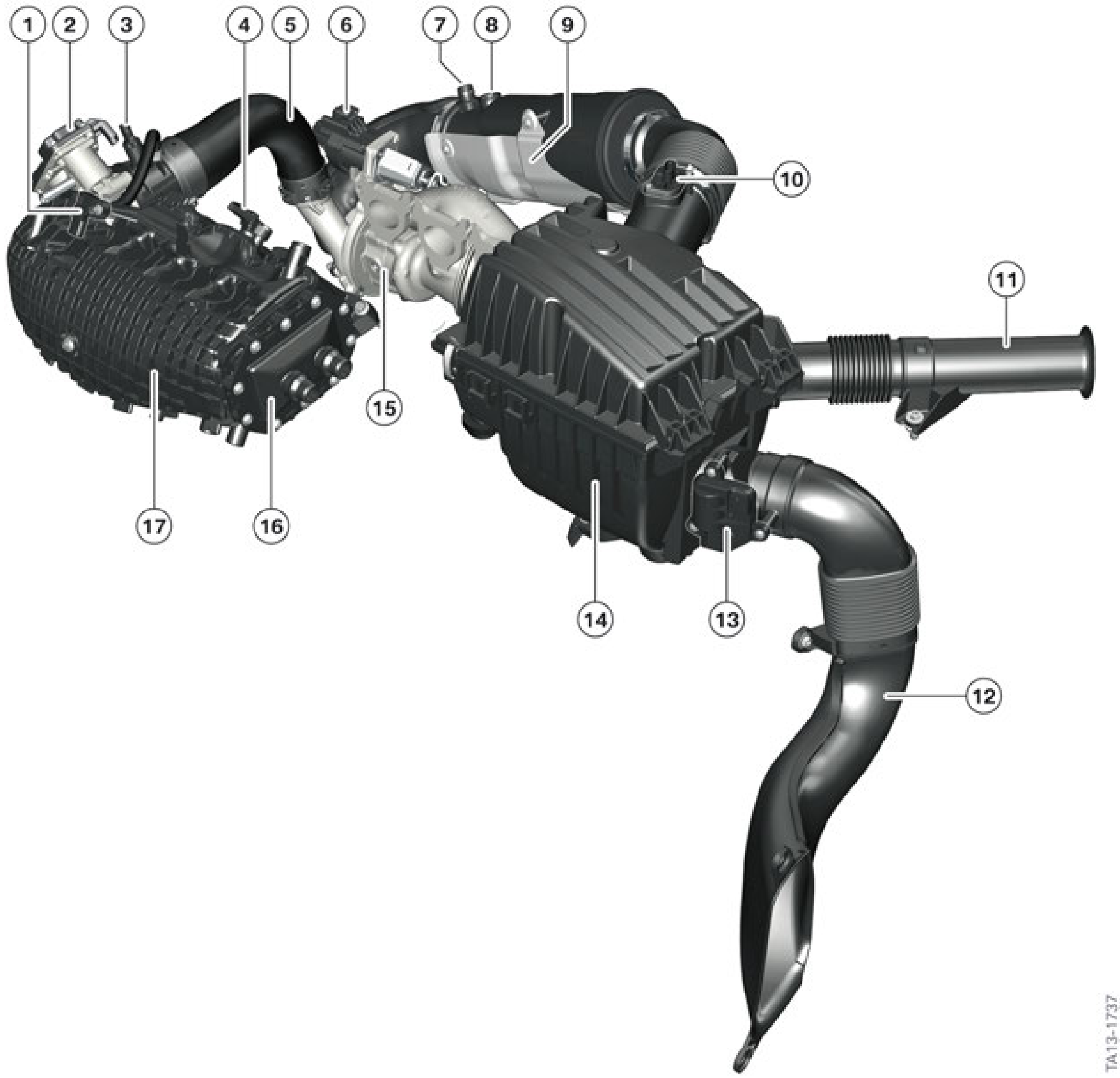
Overview of firing interval

Engine	Number of cylinders	Firing order	Firing interval
3-cylinder gasoline engine (B38)	3	1–2–3	240°

1.8. Intake air and exhaust emission systems

1.8.1. Intake air system

The intake air system in the I12 is a completely new development. The most striking feature is the twin-pipe unfiltered-air intake. It is divided into a performance path and an acoustic path. A water-cooled throttle valve is also used for the first time. A heat exchanger/intercooler in the intake manifold is responsible for cooling the charge air.



I12 Intake air system

Index	Explanation
1	Charge pressure sensor
2	Water-cooled throttle valve
3	Charge-air temperature sensor
4	Intake manifold pressure sensor
5	Charge air pipe
6	Actuator (for electronically controlled wastegate valve)
7	Tank ventilation connection
8	Connection for blow-by pipe (with engine ventilation heating)

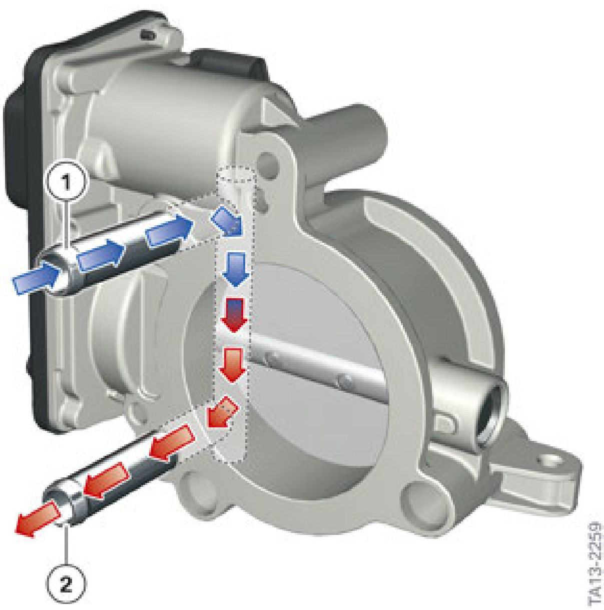
Index	Explanation
9	Heat shield
10	Hot film air mass meter
11	Unfiltered-air pipe (acoustic path)
12	Unfiltered-air pipe (performance path)
13	Unfiltered-air flap (with unfiltered-air flap controller)
14	Intake silencer
15	Exhaust turbocharger
16	Indirect charge air cooler (intercooler)
17	Intake manifold

The air inlet of the performance path (12) is located behind the left wheel arch cover at the rear axle. At the end of the unfiltered-air pipe is an unfiltered-air flap (13), which is also the intake for the intake silencer (14). Via an integrated unfiltered-air flap controller the DME can control the unfiltered-air flap (13) with help of a pulse-width modulated signal and thus close the performance path (12). This happens between an engine speed of 3000 and 4500 rpm. If the performance path is closed in this engine speed range, the intake is carried out via the acoustic path (11). This measure prevents an annoying, higher frequency noise.

⚠

If annoying noises occur during the operation of the combustion engine, the function of the unfiltered-air flap must be checked.

In order to protect the electronics of the throttle valve (2) against thermal damage, it is water-cooled. This is necessary in the I12 as the throttle valve is located upstream of the indirect charge air intercooler (16). Due to the high operating temperature the boost pressure sensor (1) was mounted at the intake air system. It is connected to the throttle valve via a hose. The water-cooled throttle valve is installed in the low-temperature cooling circuit and is located in a parallel path to the high-voltage starter motor generator.

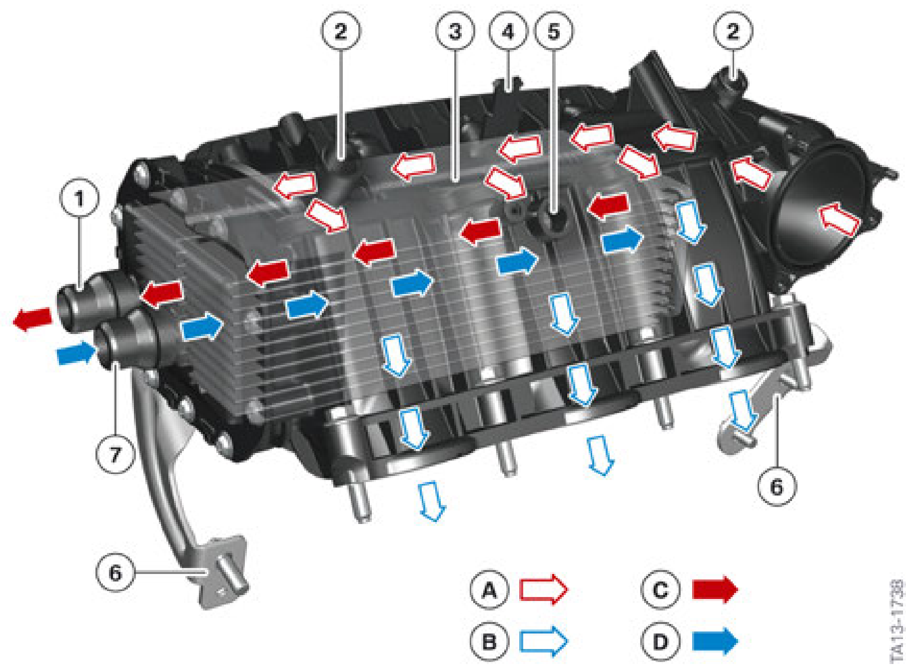


I12 Water-cooled throttle valve

Index	Explanation
1	Coolant feed line
2	Coolant return line

The charge air cooling was adapted to the installation location of the engine in the I12. The charge air cooler is not located at the front in the cooling module, but directly in the intake air system. It is indirect charge air cooling. The heat from the charged air is not emitted directly to the surrounding area via an air to air heat exchanger, but to the coolant. The coolant absorbs the heat energy and releases it again in the cooling module. With this system, the distance of the charge air line can be very short, whereby minimal losses of pressure occur and excellent load charge performance is achieved.

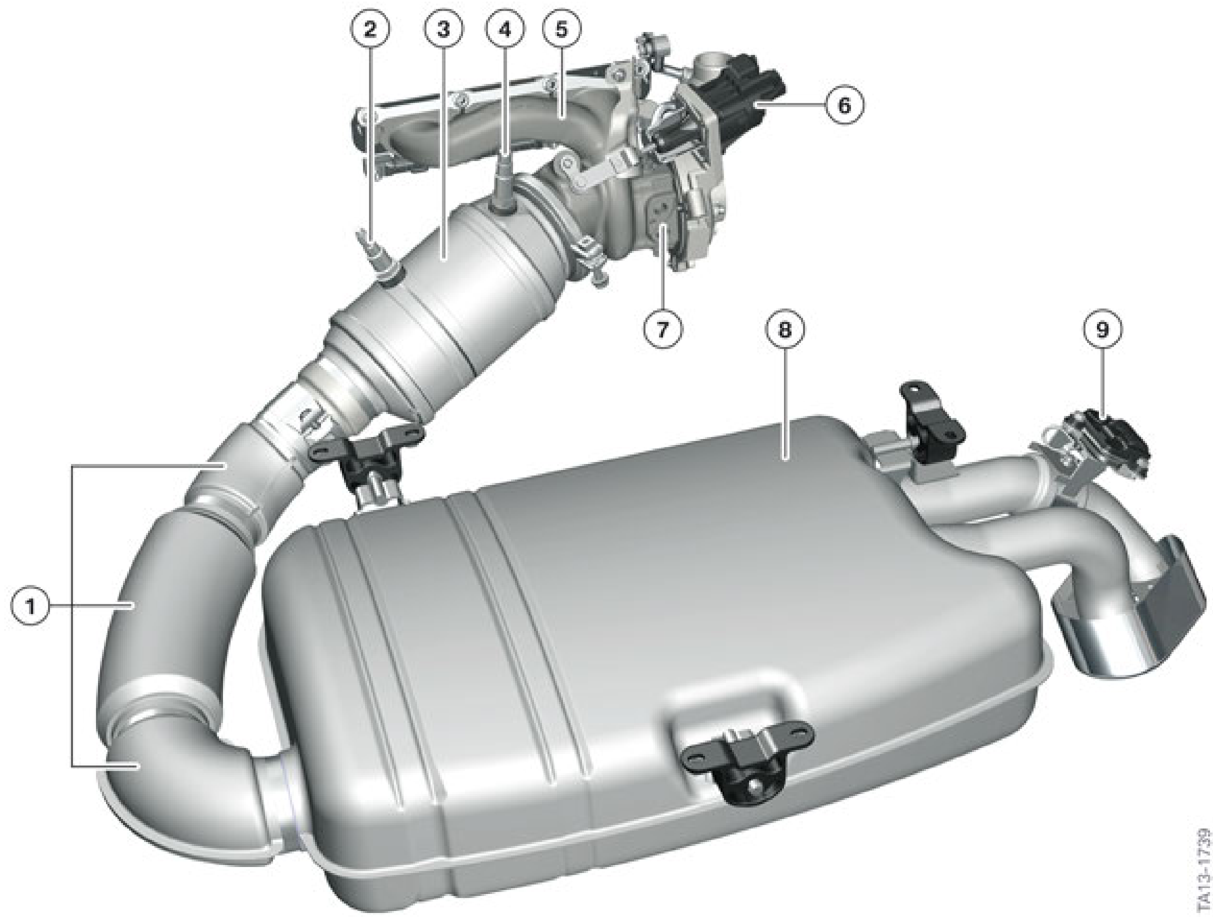
The plastic intake air system is located at the intake side of the combustion engine. The tank vent valve and the intake-manifold pressure sensor are located on the intake air system.



I12 Intake air system with indirect charge air cooler

Index	Explanation
A	Heated charge air
B	Cooled charge air
C	Heated coolant
D	Cold coolant
1	Coolant return connection
2	Connections for tank ventilation lines
3	Air-coolant heat exchanger
4	Holder for tank vent valve
5	Connection for intake-manifold pressure sensor
6	Holder
7	Coolant supply connection

1.8.2. Exhaust emission system



I12 Exhaust system

Index	Explanation
1	Insulation elements
2	Post oxygen sensor
3	Catalytic converter
4	Pre oxygen sensor
5	Exhaust manifold
6	Actuator (for electronically controlled wastegate valve)
7	Coolant connections
8	Rear silencer
9	Exhaust flap (with exhaust flap actuator)

Due to the high exhaust-gas temperatures, the exhaust manifold is made from steel and is cooled using coolant via the bearing seat. The exhaust manifold is also the turbine housing of the turbocharger. The turbocharger in the I12 has a conventional design (no variable turbine geometry, no twin-scroll). The charging pressure (boost) is controlled via an electronically controlled wastegate.

The B38 Top engine has a catalytic converter with two ceramic monoliths. The catalytic converter is arranged close to the engine behind the turbine of the turbocharger. This short exhaust pipe ensures the operating temperature of the catalytic converter is reached quickly. The engine satisfies the strict requirements ULEV 2 exhaust emission standards. The familiar Bosch oxygen sensors are used:

- Pre oxygen sensor: LSU ADV
- Post oxygen sensor: LSF 4.2

The control sensor is located ahead of the catalytic converter, as close as possible to the turbine outlet. The monitoring sensor is positioned between the first and second ceramic monoliths.

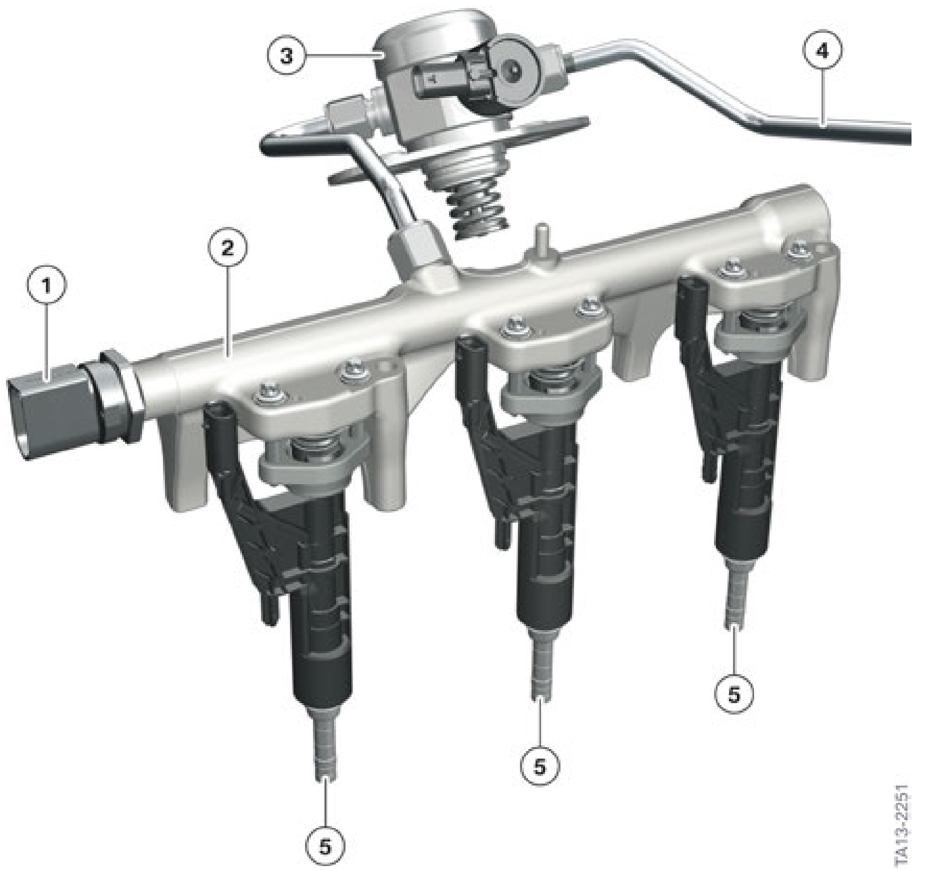
In order to protect the body from excessive heat, insulation elements are attached in the corresponding areas at the exhaust system.

There is an exhaust flap in one of the two exhaust tailpipes which are not visible from the outside. This exhaust flap is controlled by the DME and is closed in idle position, at low load and in coasting/overrun mode. As a result, the noise level of the combustion engine is reduced. At high load the exhaust flap is opened, whereby the exhaust gas back-pressure is reduced and the engine performance is increased. The exhaust flap can be replaced separately from the rear silencer.

1.9. Fuel system

1.9.1. Fuel preparation

The following overview shows the fuel preparation of the B38 Top engine in the I12. The high pressure pump powered by the exhaust camshaft supplies the fuel rail with the directly mounted fuel injectors with fuel. The high pressure lines between the fuel rail and fuel injectors could therefore be deleted. The fuel enters the cylinder combustion chamber directly via the electrically activated fuel injectors at up to 200 bar. The activation of the fuel injectors and evaluation of the rail pressure sensor are done by the DME. Overall, this results in a more compact design of the fuel preparation system with fewer connection points.



I12 Fuel preparation

Index	Explanation
1	Rail pressure sensor
2	Fuel rail
3	High pressure pump
4	Fuel delivery line
5	Fuel injectors

⚠

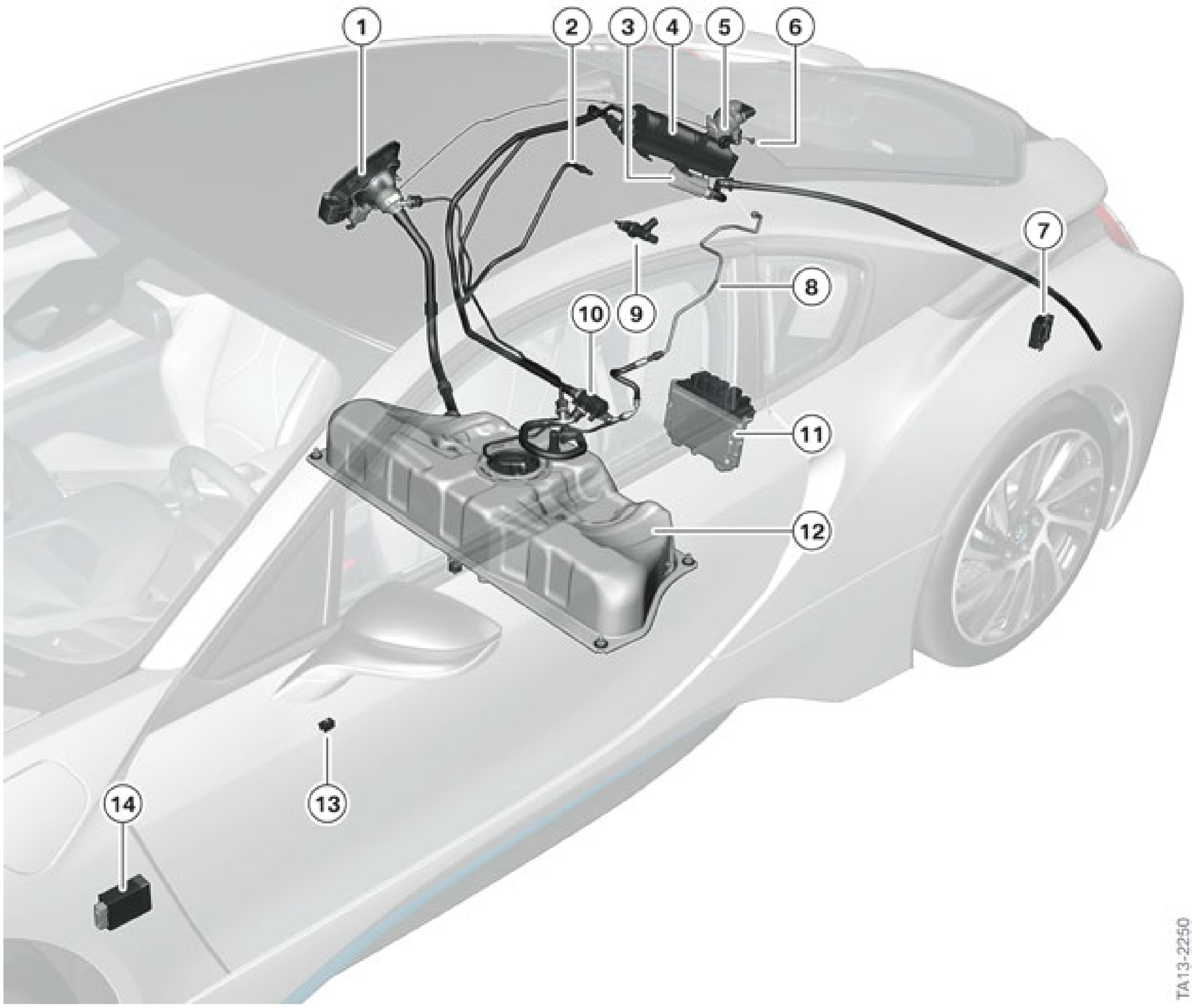
Work on the fuel system is only permitted after the combustion engine has cooled down. The coolant temperature must not exceed 40 °C / 104 °F. This must be observed at all times, otherwise there is a risk of fuel being sprayed due to residual pressure in the fuel system.

When working on the fuel system, it is essential to adhere to conditions of absolute cleanliness and to observe the work sequences described in the repair instructions. Even the slightest contamination and damage to the screw connections of the fuel lines can cause leaks.

1.9.2. Fuel supply

The I12 is equipped with a pressurized fuel tank made from stainless steel to supply the combustion engine. As a result during purely electric driving it is guaranteed that the gasoline fumes remain in the pressurized fuel tank. Only with the operation of the combustion engine is fresh air drawn in by the carbon canister for purging and the gasoline fumes are directed to the combustion chamber via the differentiated air intake air system. The fuel tank has a usable volume of 42 liters / 11.1 gallons.

Installation locations of the components



I12 Components of the fuel supply system, US version

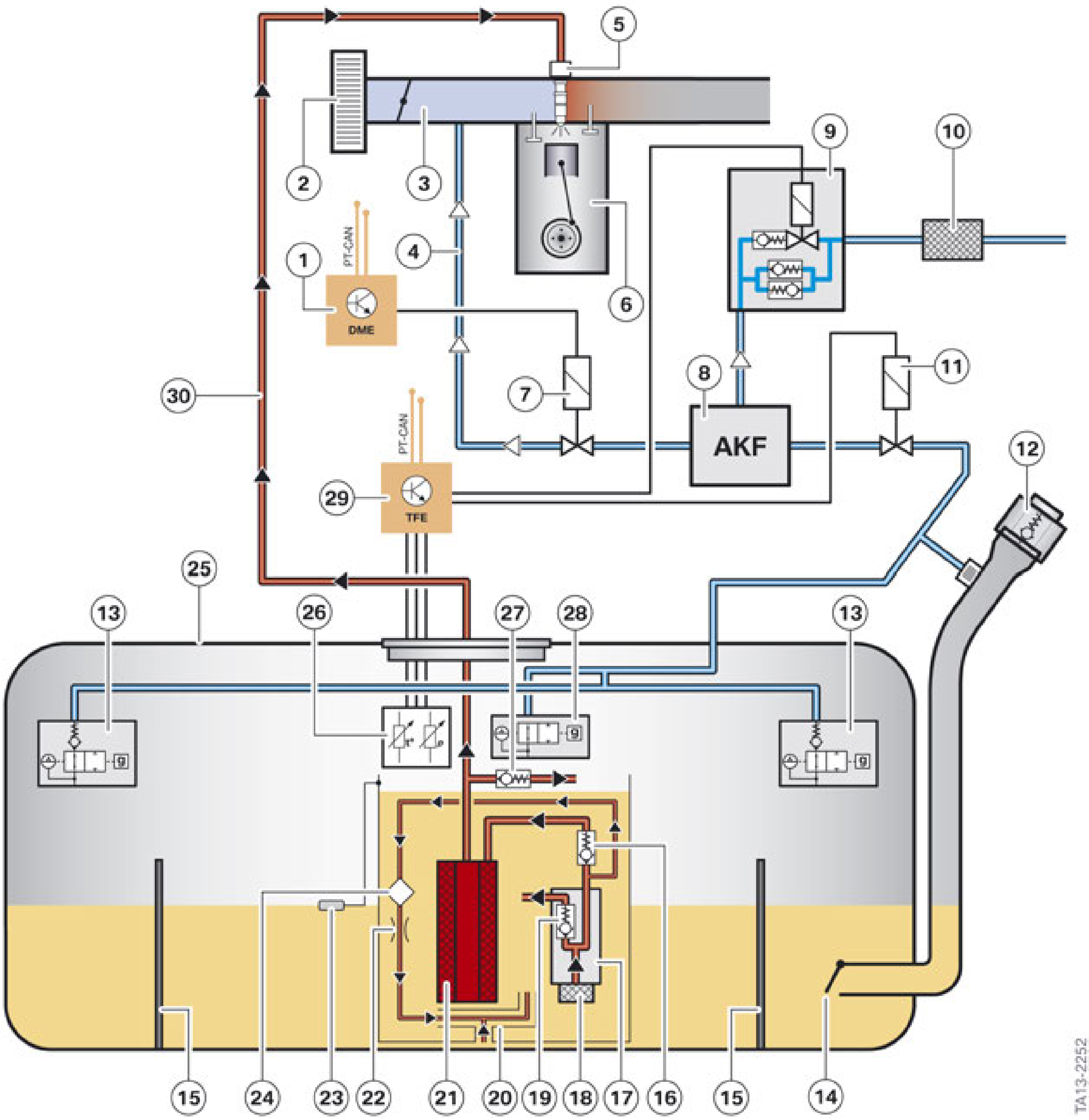
Index	Explanation
1	Fuel filler flap
2	Purge air line
3	Dust filter
4	Carbon canister

Index	Explanation
5	Fuel tank isolation valve
6	Cable for emergency release of the fuel filler flap
7	Fuel pump control
8	Fuel delivery line
9	Tank vent valve
10	Fuel tank non-return valve
11	Digital Engine Electronics (DME)
12	Pressurized fuel tank
13	Switch for unlocking the fuel filler flap
14	Hybrid pressure refuelling electronic control unit (TFE)

A passive tank leak diagnosis is also used which is described at the end of the chapter.

B38 Top Engine
1. Introduction

System overview



I12 Fuel supply

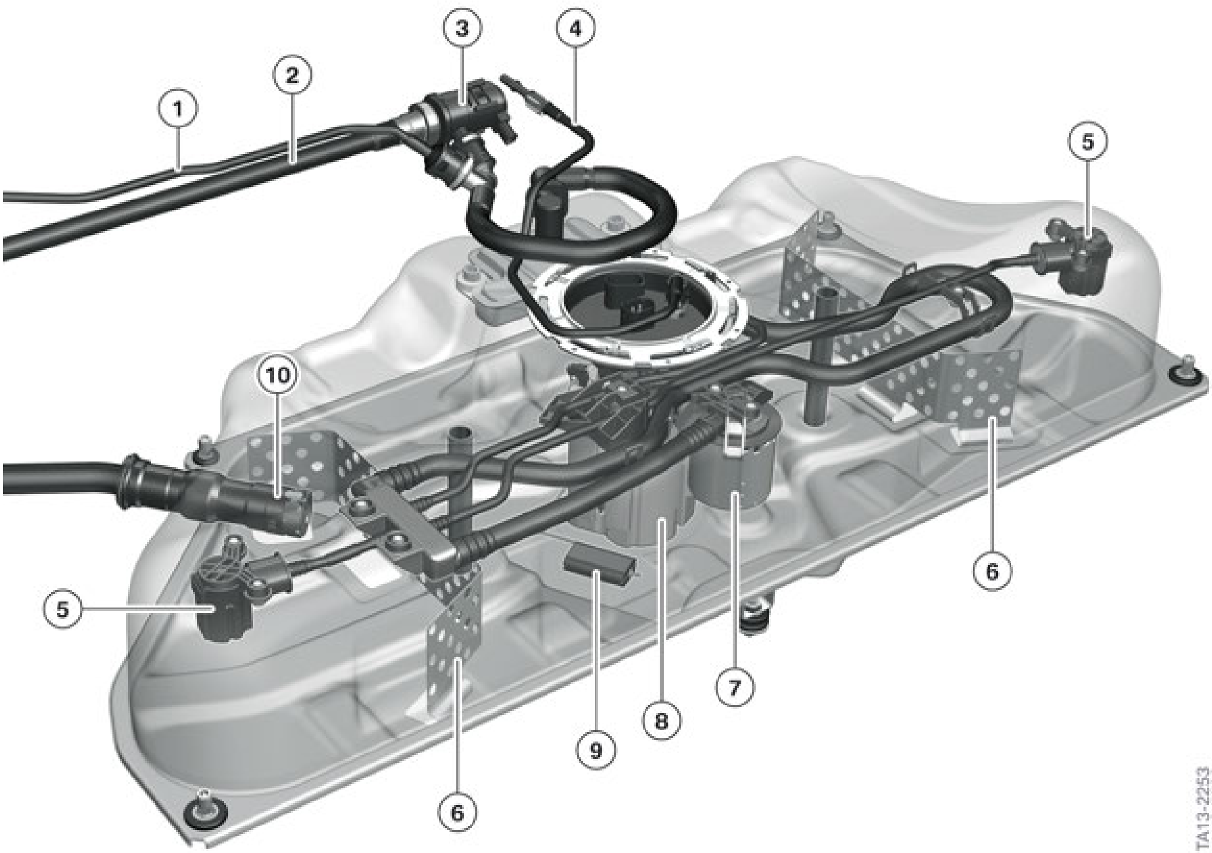
Index	Explanation
1	Digital Engine Electronics (DME)
2	Air filter element
3	Intake manifold
4	Purge air line
5	Fuel injectors

B38 Top Engine
1. Introduction

Index	Explanation
6	Combustion engine
7	Tank vent valve
8	Carbon canister
9	Fuel tank isolation valve
10	Dust filter
11	Fuel tank non-return valve
12	Fuel filler cap with pressure relief valve
13	Service vent valve
14	Non-return valve
15	Baffle plate
16	Non-return valve
17	Electric fuel pump
18	Suction strainer
19	Pressure-limiting valve
20	Suction jet pump
21	Fuel filter
22	Throttle
23	Lever sensor for fuel level
24	Filter
25	Pressurized fuel tank made from stainless steel
26	Pressure/Temperature sensor
27	Non-return valve
28	Refuelling ventilation valve
29	Hybrid pressure refuelling electronic control unit (TFE)
30	Fuel delivery line

The components in the inside of the pressurized fuel tank are technically not new. The electric fuel pump is activated via the fuel pump control module. It receives a request from the DME via a pulse-width modulated signal to control the electric fuel pump. The fuel pressure in the feed line is about 5 bar and is regulated at this level via a pressure-limiting valve directly after the electric fuel pump.

Fuel tank

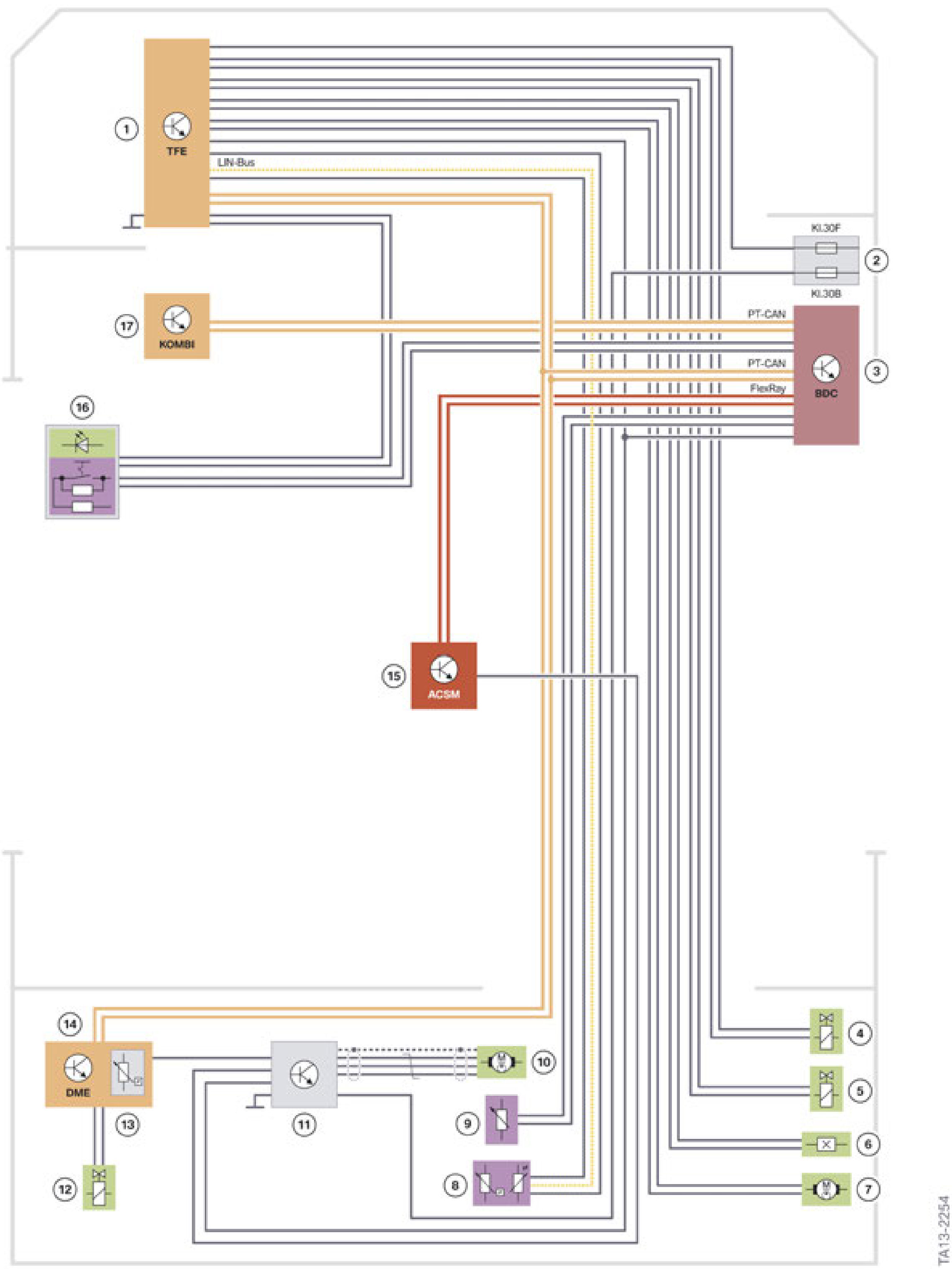


I12 Pressurized fuel tank

Index	Explanation
1	Fuel filler neck breather pipe
2	Tank ventilation line
3	Fuel tank non-return valve
4	Fuel delivery line
5	Service vent valve
6	Baffle plate
7	Refuelling ventilation valve
8	Delivery unit
9	Lever sensor for fuel level
10	Non-return valve

The fuel tank is screwed directly to the body.

System wiring diagram



I12 System wiring diagram for the fuel supply

Index	Explanation
1	Hybrid pressure refuelling electronic control unit (TFE)
2	Power distribution box in the passenger compartment
3	Body Domain Controller (BDC)
4	Fuel tank non-return valve
5	Fuel tank isolation valve
6	Sensor for the position of the fuel filler flap
7	Actuator drive for locking the fuel filler flap
8	Pressure/Temperature sensor (in the fuel tank)
9	Lever sensor for fuel level
10	Electric fuel pump
11	Fuel pump control
12	Tank vent valve
13	Ambient pressure sensor
14	Digital Engine Electronics (DME)
15	Advanced Crash Safety Module (ACSM)
16	Button with lighting for refuelling
17	Instrument cluster (KOMBI)

The relay for the electric fuel pump was replaced with a corresponding control unit which assumes the control of the electric fuel pump. In the event of a crash this control unit immediately switches off the electric fuel pump. The control unit receives the information via a separate line from the ACSM. In addition, in this case the fuel tank non-return valve is supplied with current and closed by the hybrid pressure refuelling electronic control unit. This way possible gasoline fumes are prevented from escaping into the ambient air. The fault code entry set prevents subsequent refuelling of the vehicle and all other functions of the fuel supply system (OBD, tank leak diagnosis).

Refuelling

The pressurized fuel tank must be released for refuelling. This is ensured by the fact that the refuelling request is indicated to the electronics by a button in the driver's door.

I12 Refuelling button

Index	Explanation
1	Refuelling button

The hybrid pressure refuelling electronic control unit (TFE) monitors the current operating condition via a pressure/temperature sensor in the fuel tank and then controls the pressure reduction by opening a fuel tank isolation valve. The cleaned gasoline fumes are released into the environment by the carbon canister. The actuator drive for locking the fuel filler flap is activated and the fuel filler flap with fuel filler cap can be opened manually.

Before repair work on the fuel supply is started, the refuelling procedure must be started so that the pressure in the fuel tank can be released. Leave the fuel filler cap open during repair work in order to avoid pressure building up again.

At the same time, the driver receives the status of the tank readiness displayed in the instrument cluster and in the central information display (CID). If the fuel filler flap is not opened within 10 minutes after the fuel filler cap has been released, it is automatically locked again. The position of the fuel filler flap is identified using a hall effect sensor.

After the refuelling procedure and the fuel filler cap is closed the fuel filler flap is locked again via the hybrid pressure refuelling electronic control unit and the fuel tank isolation valve closed.

Filling the fuel tank while the high-voltage battery is charging is not permitted! When the charging cable is connected, ensure sufficient safety distance to highly flammable materials. Otherwise, there is a risk of personal injury or material damage in the event of improper connection or disconnection of the charging cable.

Tank leak diagnosis

The tank leak diagnosis, which is only used in US market vehicles, is a passive diagnosis. In conventional vehicles, a defined excess pressure was applied to the fuel tank using a high pressure pump. This no longer takes place in the I12. A high pressure pump is no longer used.

After the journey is ended (terminal 15 OFF) a test of the tank leak diagnosis is initiated by the hybrid pressure refuelling electronic control unit (TFE) control unit. This is carried out over a period of about 6 hours. In this period the temperature and the pressure in the stainless steel tank is measured. As the pressure changes depending on the temperature, it is possible for the control unit to identify a loss of pressure in the fuel tank. A prerequisite is therefore that the temperature changes over the test period. If this does not happen no results can be concluded.

The ambient air pressure is also included in the calculation. A sensor in the DME calculates this and provides the information to the hybrid pressure refuelling electronic control unit via the PT-CAN.

If during the test phase the vehicle is started no result can be evaluated. After each journey is ended the tank leak diagnosis starts anew.

Following a comparison of the measured pressure readings with the saved characteristic curve in the control unit, information is transmitted to the DME via the PT-CAN in the case of a deviation from the hybrid pressure refuelling electronic control unit. A corresponding entry is set in the control unit. This happens when the ignition is switched on in the vehicle.

1.10. High-temperature cooling circuit

In the I12 two separate cooling circuits are used. A high-temperature cooling circuit and a low-temperature cooling circuit. This is necessary as the different temperature levels required cannot be combined in one circuit. The two cooling circuits guarantee that the thermal operating safety of the respective components is achieved in every situation.

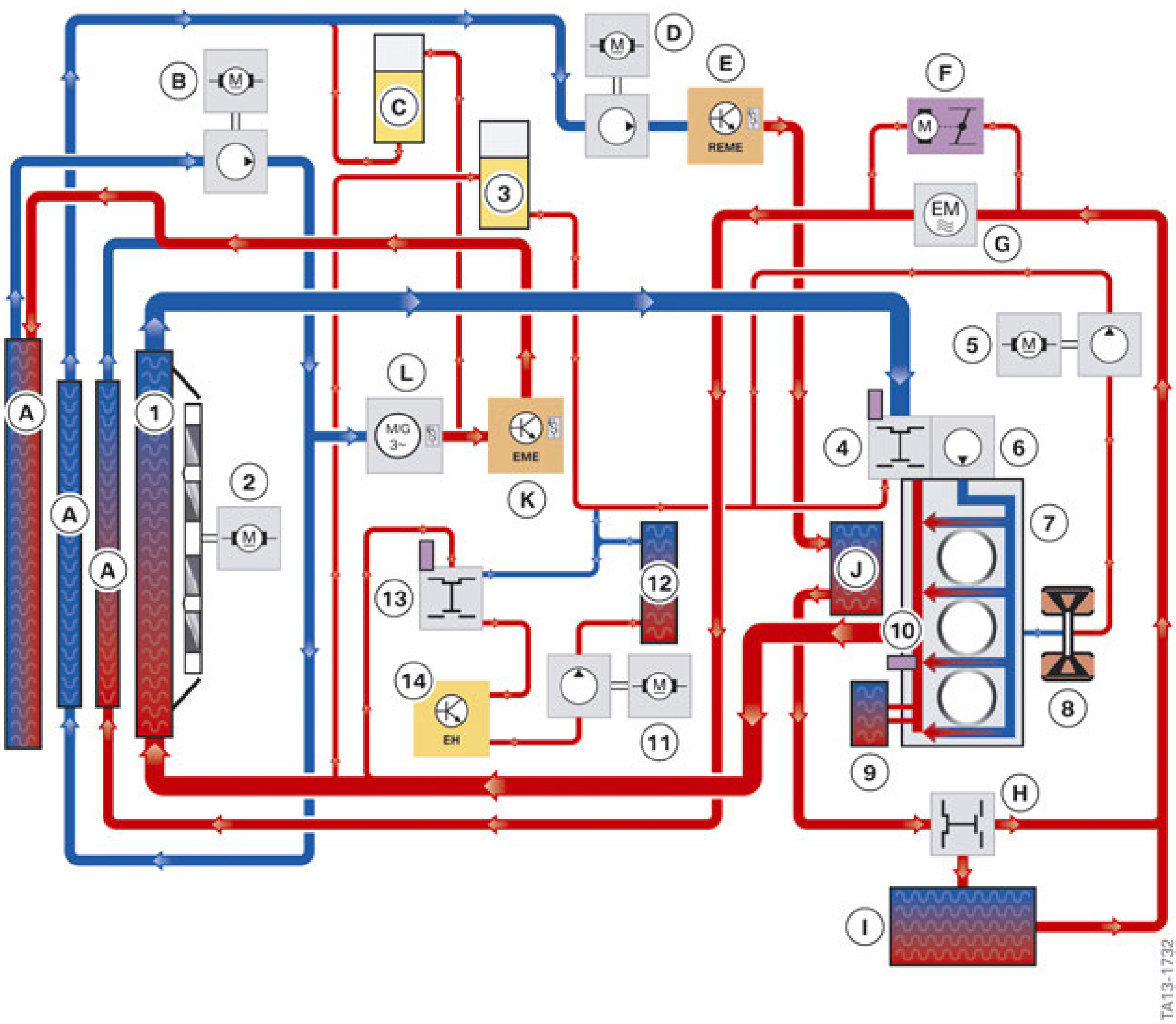
Due to the high efficiency of the electrical machines and power electronics, considerably less heat is emitted than with the combustion engine. For this reason the components to be cooled are incorporated (according to their heat dissipation and their cooling requirement) into corresponding cooling circuits. The components which have high heat dissipation are combined in the high-temperature cooling circuit (e.g. combustion engine, exhaust turbocharger). The components which have low heat dissipation and a high cooling requirement are combined in the low-temperature cooling circuit (e.g. electrical machine, integrated charge air cooler, throttle valve).

Similar to the cooling systems of current BMW vehicles with combustion engines, the control in the I12 is also done depending on the cooling requirement. This control is integrated in the high-temperature cooling circuit in the DME.

Only the high-temperature cooling circuit is described in this training module. As some of the components in this training module (such as the indirect charge air cooler) are in the low-temperature cooling circuit, a brief description is provided at the end of this chapter for better understanding. More precise information on the low-temperature cooling circuit can be found in the "I12 High-voltage Components" training manual.

1.10.1. System overview

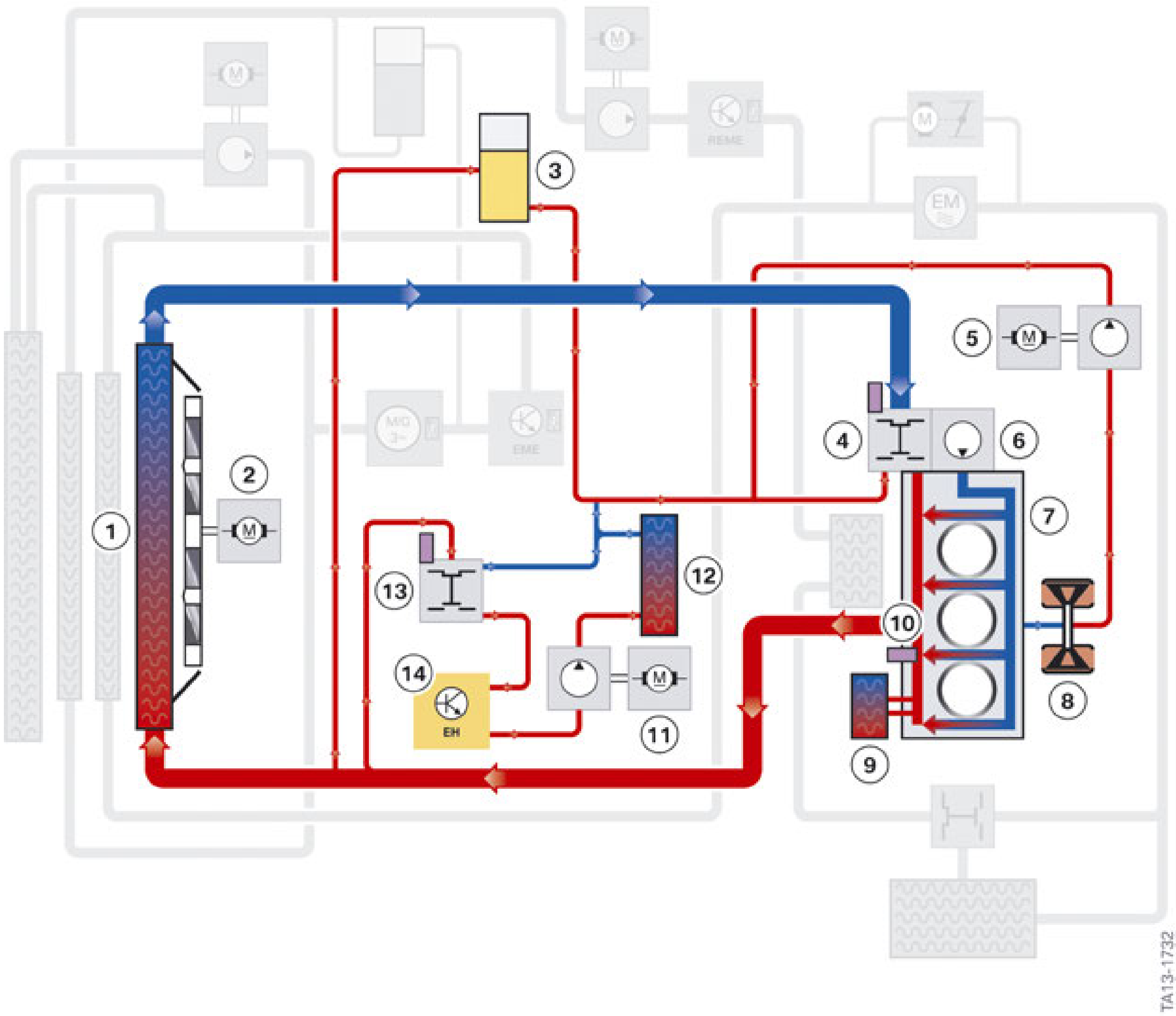
All circuits are depicted in color for better representation. The blue color indicates a lower temperature. The red color represents a high coolant temperature. The coolant flow is indicate by the arrows.



I12 System overview of the two cooling circuits

Index	Explanation
A	Radiator (for low-temperature cooling circuit)
B	Electric coolant pump, front
C	Expansion tank (for the low-temperature cooling circuit)
D	Electric coolant pump, rear
E	Range Extender Electrical Machine Electronics (REME)
F	Water-cooled throttle valve
G	High-voltage starter motor generator

Index	Explanation
H	Bypass valve for transmission oil cooler
I	Transmission oil cooler
J	Indirect charge air cooler
K	Electrical machine electronics (EME)
L	Electrical machine
1	Radiator (for high-temperature cooling circuit)
2	Electric fan
3	Expansion tank (for the high-temperature cooling circuit)
4	Map thermostat
5	Auxiliary coolant pump for the exhaust turbocharger
6	Mechanical coolant pump
7	Combustion engine
8	Exhaust turbocharger
9	Engine oil cooler
10	Coolant temperature sensor
11	Coolant pump for electric heating
12	Heat exchanger
13	Changeover valve
14	Electric heating



I12 System overview for high-temperature cooling circuit

Index	Explanation
1	Radiator
2	Electric fan
3	High temperature coolant expansion tank
4	Map thermostat
5	Auxiliary coolant pump for the exhaust turbocharger
6	Mechanical coolant pump
7	Combustion engine
8	Exhaust turbocharger
9	Engine oil cooler
10	Coolant temperature sensor

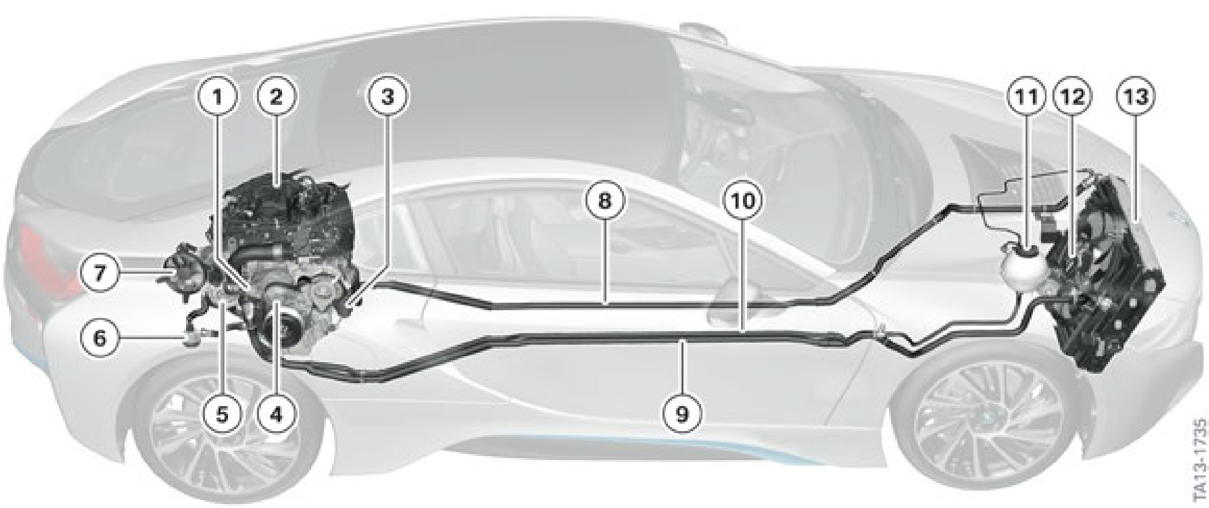
Index	Explanation
11	Coolant pump for electric heating
12	Heat exchanger
13	Changeover valve
14	Electric heating

The high-temperature cooling circuit assumes the task of dissipating heat from the combustion engine and ensuring the thermal operating safety of the respective components. Similar to conventional vehicles, it is also divided into a small and large cooling circuit.

In order to be able to optimally use the excess heat of the combustion engine, the cooling circuit for heating the passenger compartment is integrated in the high-temperature cooling circuit. If the coolant has not reached a sufficiently high temperature for heating the passenger compartment, a changeover valve redirects the heater circuit from the high-temperature cooling circuit. The coolant is then heated by the electric heater and fed to the heat exchanger by a separate electric coolant pump. This may be the case, for example for purely electric driving. As the electric heating is a high-voltage component, the precise functions and further information can be found in the "I12 High-voltage Components" training manual.

The mechanical coolant pump is on the front of the combustion engine (belt drive side). The map thermostat was flange-mounted at its housing. The bearing of the drive shaft in the mechanical coolant pump was reinforced. This is necessary because the combustion engine is started via the high-voltage starter motor generator in the belt drive and greater forces occur in the belt drive. An additional electric coolant pump assumes the cooling of the turbocharger. The engine oil-coolant heat exchanger together with the oil filter housing is secured directly at the crankcase of the combustion engine.

1.10.2. Components



I12 High-temperature cooling circuit - Installation locations

B38 Top Engine
1. Introduction

Index	Explanation
1	Thermostat housing
2	Combustion engine
3	Oil filter housing
4	Mechanical coolant pump
5	Turbocharger
6	Engine compartment fan
7	Auxiliary coolant pump for the turbocharger
8	Coolant return line
9	Coolant feed line (from the cooling module)
10	Coolant feed line (from the coolant expansion tank)
11	High temperature coolant expansion tank
12	Electric fan
13	Radiator

The cooling module in the front of the vehicle consists of a large radiator, three low-temperature radiators, an air conditioning condenser with receiver drier and an electric fan. The coolant in the high-temperature cooling circuit only flows through the large radiator and dissipates the heat energy to the surrounding area.

There are two versions of the electric fan attached at the inside of the tilted cooling module. In the US variant the electric fan delivers up to 850 W. The DME is responsible for the activation of the cooling fan.

The coolant expansion tank is located under the front engine compartment lid on the right. It can hold a volume of 2.3 liters and is equipped with an electrical level sensor.

In order to reduce the drag and the consumption of the vehicle, the I12 is equipped as standard with an active air-flap control. Depending on the cooling requirement, the air flaps only close or open the lower cooling air inlet in the front bumper. The DME activates an actuator via a LIN bus which opens the air flaps in up to three positions. The cooling air flowing in at the bottom is fed for the most part to the front brakes after the cooling module by cooling air ducts. The upper cooling air inlet is always done via the upper radiator grille. In the variant for hot countries the inlet opening of the radiator grille is bigger. A large amount of the cooling air drawn in at the top flows out again after the cooling module through the front engine compartment lid.

Requirements for opening the air flaps:

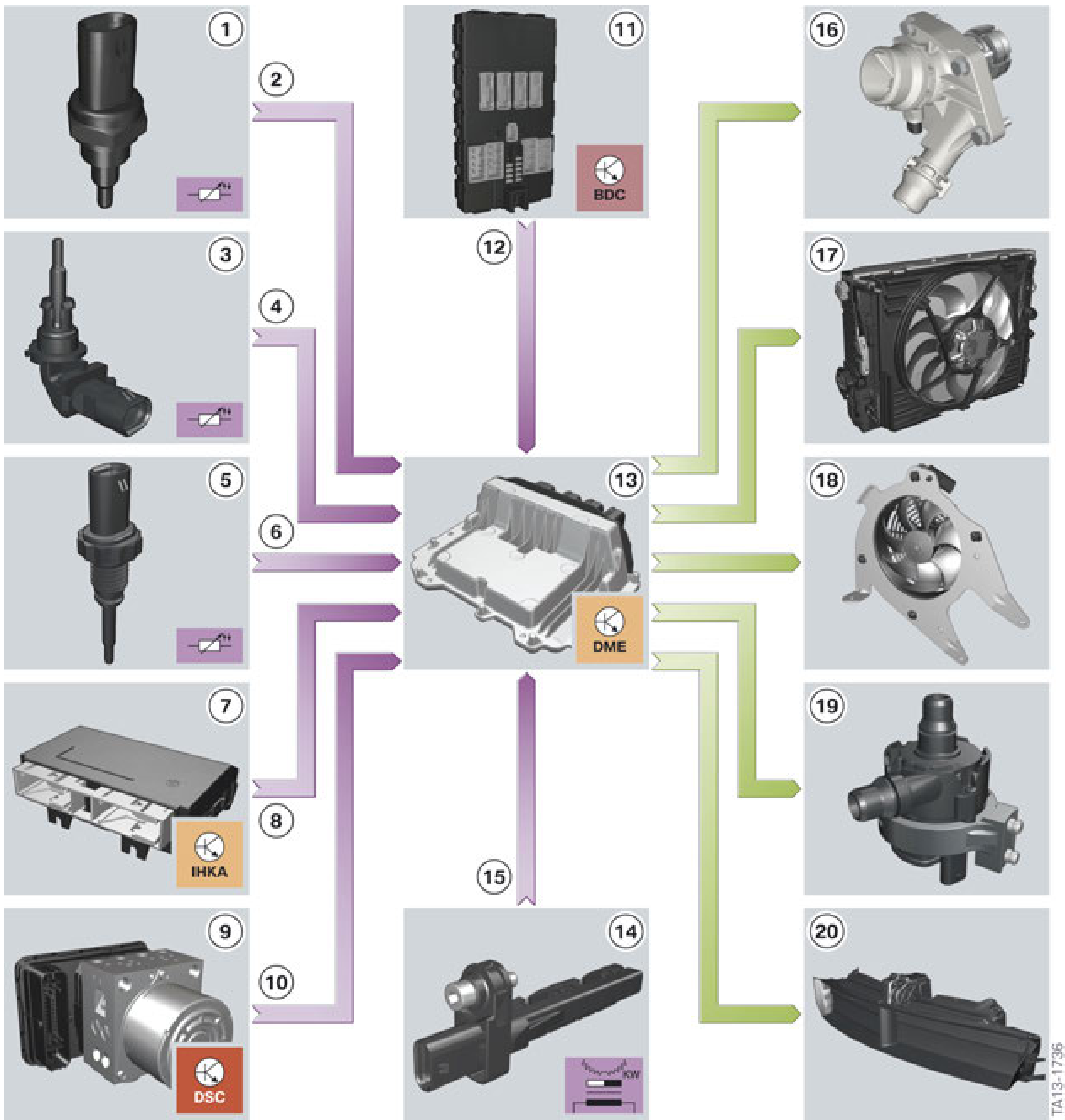
- Cooling requirement of drive components
- Cooling requirement of heating and air-conditioning system
- Afterrun requirement of electric fan
- DSC requirement due to brake cooling

B38 Top Engine
1. Introduction

The electrical auxiliary coolant pump for the turbocharger has a power rating of 20 W and is always switched off when the combustion engine is running. The DME activates the electrical auxiliary coolant pump after the combustion engine is shut down in order to keep the bearing seat of the turbocharger cool.

An additional electric fan is used in the I12, located in the rear engine compartment (on the right side). This engine compartment fan ensures recirculation of the excess heat in the engine compartment and thus serves for cooling the combustion engine. To be able to fulfill this task, the engine compartment fan runs together with the combustion engine. The DME uses the rpm speed signal of the combustion engine.

It is also possible that the engine compartment fan continues to run when the engine (which is at operating temperature) is off and/or the electric drive is used. The engine compartment fan is located behind the wheel arch on the right and is not visible from the outside and is mounted with an aluminum bracket between the rear axle module and the wheel arch. In order to calculate the temperature in the engine compartment, a separate temperature sensor is used. This is located close to the oil filler neck and in addition to the calculation of the engine compartment temperature is also used for the diagnosis of the engine compartment fan.



Input/Output of high-temperature cooling circuit

Index	Explanation
1	Coolant temperature sensor
2	Coolant temperature
3	Engine compartment temperature sensor
4	Engine compartment temperature
5	Intake air temperature sensor
6	Intake air temperature

Index	Explanation
7	Integrated automatic heating / air conditioning (IHKA)
8	Cooling requirement (for air conditioning condenser)
9	Dynamic Stability Control (DSC)
10	Cooling requirement (for brakes)
11	Body Domain Controller (BDC)
12	Signal, terminal status
13	Digital Engine Electronics (DME)
14	Crankshaft sensor
15	Engine speed
16	Map thermostat
17	Electric fan
18	Engine compartment fan
19	Auxiliary coolant pump for the exhaust turbocharger
20	Active air-flap control

1.10.3. Service information

The familiar mixture of 50:50 split of water and antifreeze and corrosion inhibitors in BMW vehicles is used as a coolant.

Due to the complexity and size of the cooling system the vacuum filling device must always be used when filling the two cooling circuits. Only this way is it guaranteed that the cooling system is adequately bled.

⚠

A depressurized filling of the high-temperature cooling circuit by simple pouring into the coolant expansion tank is not permitted as the circuit cannot be adequately bled. The special tool for vacuum filling in accordance with the repair instructions must always be used.

The system must be bled after the replacement of components in the cooling circuit.

For the bleeding of the high-temperature cooling circuit proceed in the same way as the procedure for conventional vehicles. However, unlike in the low-temperature cooling circuit, the bleeding procedure does not end automatically, but must be independently completed by a Service employee.

1. Evacuate and fill cooling system using vacuum filling device. Remove the vacuum filling device after the filling procedure is completed.
2. When the expansion tank is open, open the bleeder screw for 20 seconds.
3. Close the bleeder screw and expansion tank again.
4. Terminal 15 ON, set IHKA controls to 28 °C / 82 °F at blower speed 1 and "Air conditioning OFF".
5. Press the accelerator pedal for about 20 seconds at full load (engine OFF).

6 Start combustion engine in selector lever position "P" with Automatic Hold brake engaged.

7 Increase engine speed using accelerator pedal 4 times for about 5 to 10 seconds to roughly 3500 rpm, with a 10 second interval between the respective engine speed increases. Repeat procedure every 2 minutes for about 16 to 18 minutes.

8 Increase engine speed using accelerator pedal 4 times for about 5 to 10 seconds to roughly 5500 rpm, with a 10 second interval between the respective engine speed increases.

9 After 20 minutes carry out a test drive in selector lever position "S" and with heating turned on fully.

10 The ventilation is completed as soon as hot air flows continuously from the air outlets.

11 Adapt coolant in the cooled down state to MAX filling level.

⚠

The bleeding procedure must be cancelled immediately in the case of a yellow warning light due to excess temperature. In this case start again with point 1.

The engine compartment temperature sensor is not used directly for controlling the engine compartment fan, but is required for its diagnosis, among other things. If there is a fault with the engine compartment temperature sensor or the engine compartment fan, the output torque of the combustion engine is reduced by the DME.

⚠

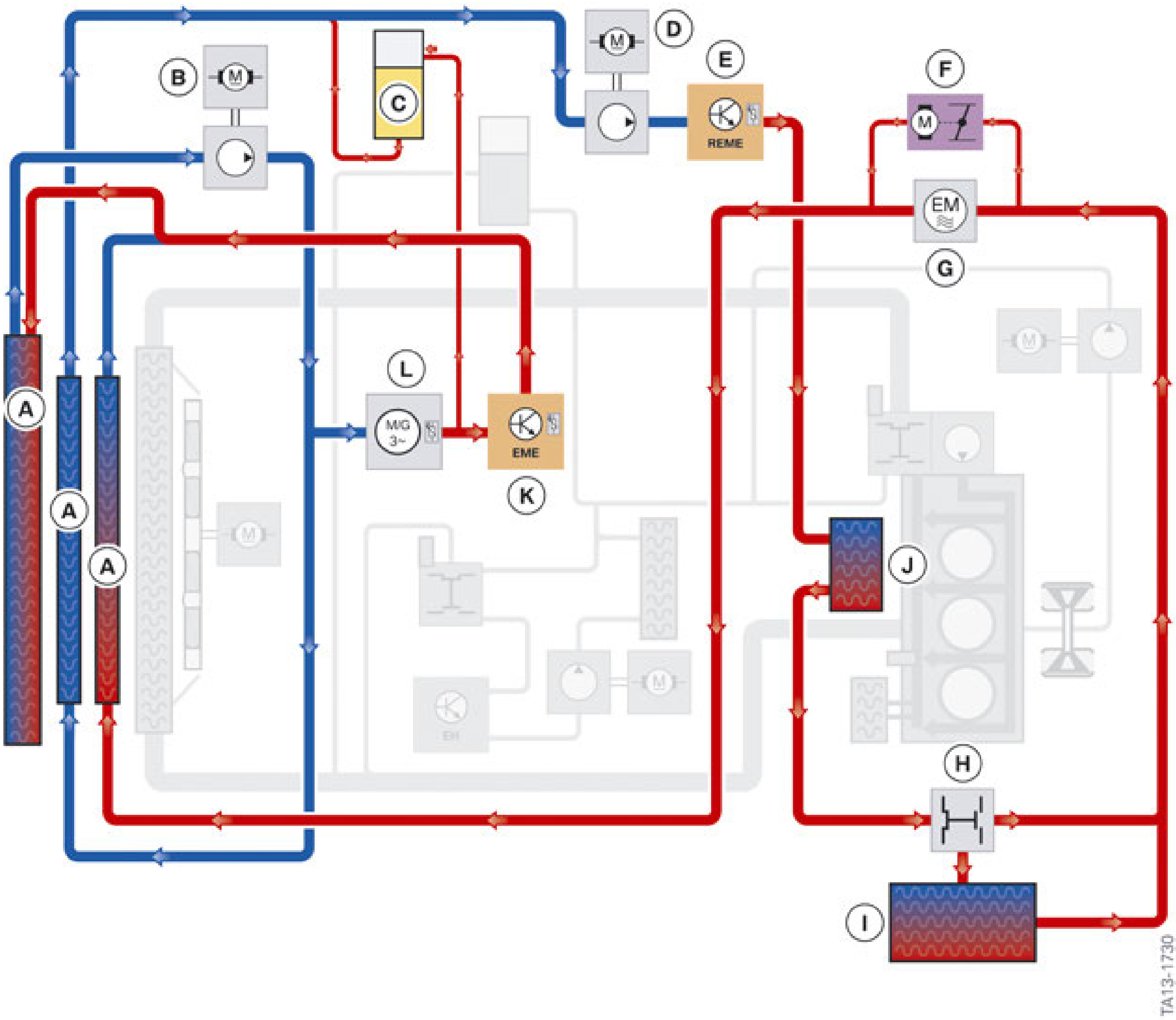
When terminal 15 is switched on the coolant pump and electric fan can be switched on automatically. A reason for this may be a cooling requirement in the low-temperature cooling circuit. Therefore always ensure terminal 15 is switched off when working with an open engine compartment lid or at the cooling module.

⚠

The coolant pump and the electric fan can be switched on automatically when charging the high-voltage battery. A reason for this may be a cooling requirement in the low-temperature cooling circuit or in the refrigerant circuit. The high-voltage battery cannot be charged when working with the engine compartment lid open or at the cooling module.

1.11. Low-temperature cooling circuit

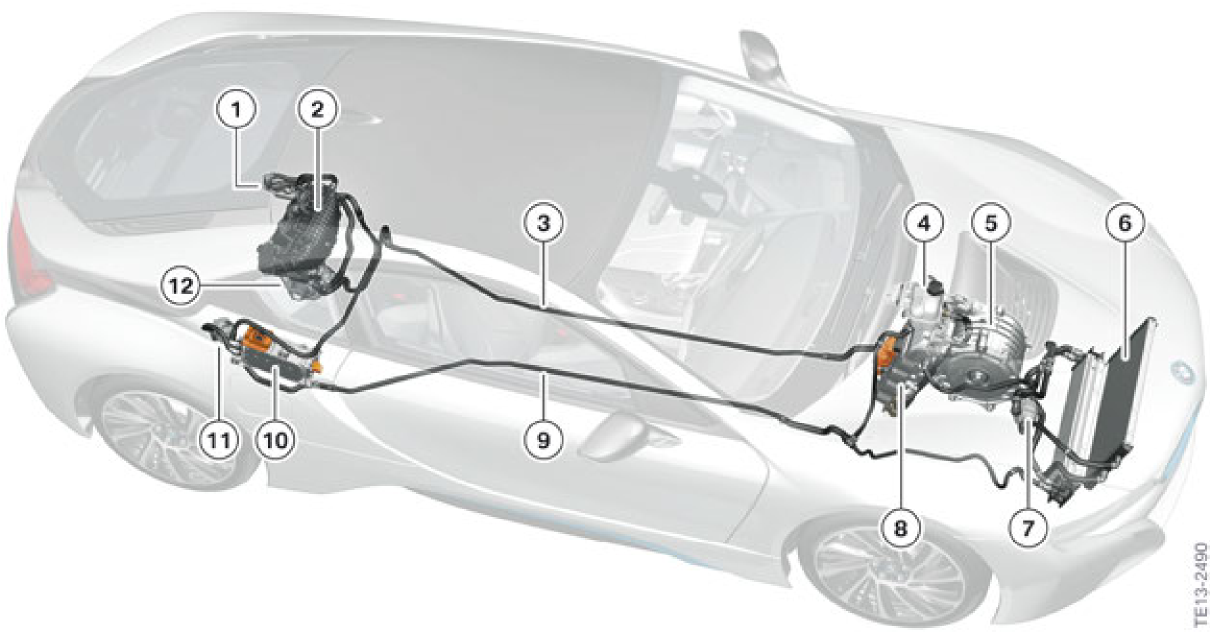
The low-temperature cooling circuit assumes the cooling of the high-voltage components (except the high-voltage battery unit) and the auxiliary units of the combustion engine. The cooling of the integrated charge air cooler is particularly important so that the combustion engine reaches its full power. Two independent electric coolant pumps (both 80 W) ensure the distribution of the coolant. They can be controlled depending on requirements, thus guaranteeing intelligent adaptation to the respective operating situation. Three radiators are used in the low-temperature cooling circuit.



I12 System overview of low-temperature cooling circuit

Index	Explanation
A	Radiator
B	Electric coolant pump, front
C	Coolant expansion tank (Low temperature)
D	Electric coolant pump, rear
E	Range Extender Electrical Machine Electronics (REME)
F	Water-cooled throttle valve
G	High-voltage starter motor generator
H	Bypass valve for transmission oil cooler

Index	Explanation
I	Transmission oil cooler
J	Indirect charge air cooler
K	Electrical machine electronics (EME)
L	Electrical machine



I12 Low-temperature cooling circuit - Installation locations

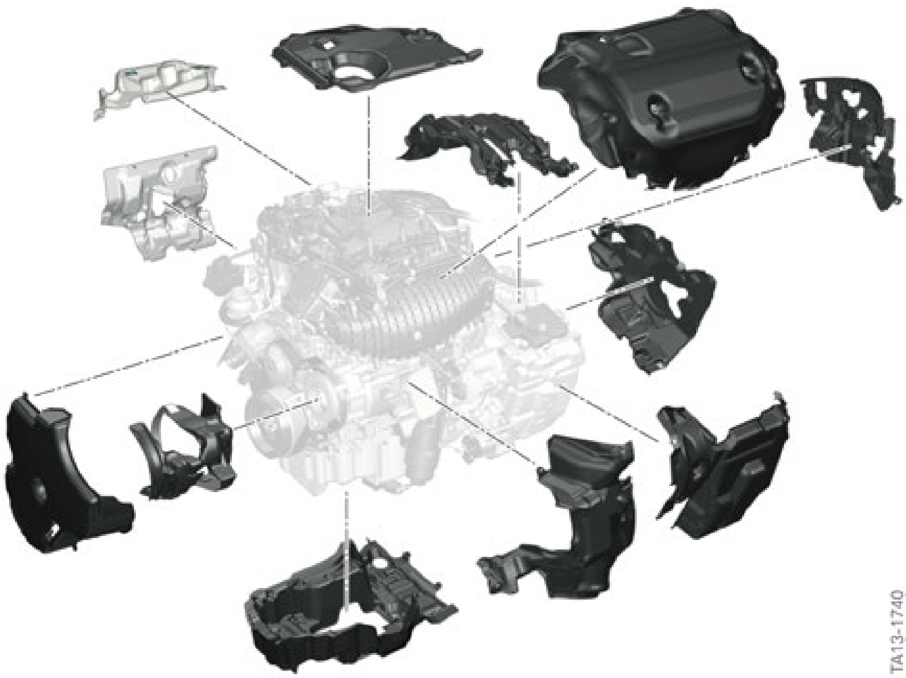
Index	Explanation
1	Transmission oil cooler
2	Indirect charge air cooler
3	Coolant return line
4	Coolant expansion tank (Low temperature)
5	Electrical machine
6	Radiator
7	Electric coolant pump, front
8	Electrical machine electronics (EME)
9	Coolant feed line
10	Range Extender Electrical Machine Electronics (REME)
11	Electric coolant pump, rear
12	High-voltage starter motor generator

More information regarding the low-temperature cooling circuit can be found in the "I12 High-voltage Components" training manual.

B38 Top Engine

1. Introduction

1.12. Acoustic covers



I12 Installation locations of the acoustic covers

The B38 Top engine in the I12 is completely enclosed by acoustic covers. They reduce engine and transmission noises. The acoustic covers are manufactured from lightweight foam and have non-woven fleece on both sides. Their form is adapted to the respective installation location. They also have aluminum covering in specific locations subject to high temperatures.

As a result of the use of acoustic covers directly at the drivetrain, other acoustic measures at the body were able to be deleted so that the overall vehicle weight could be reduced.

1.13. Notes for Service

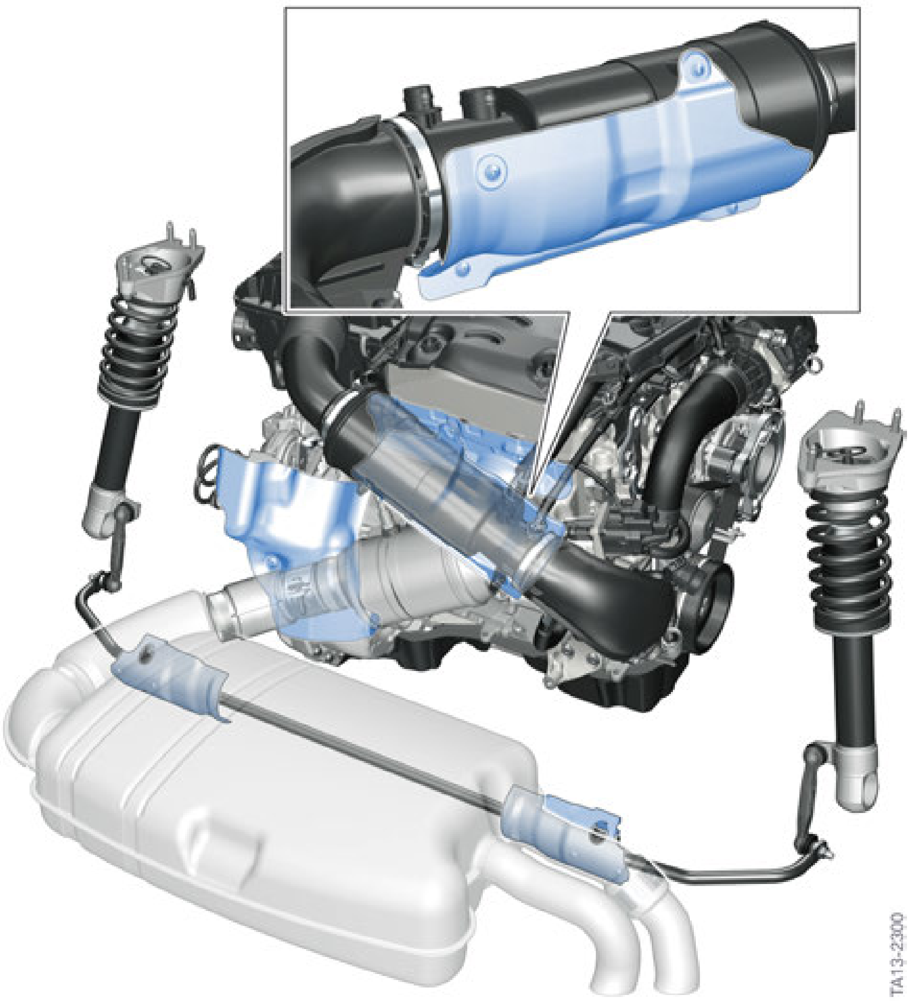
For all work at the drive unit the instructions in the current repair instructions must be followed!

⚠

Work on the high-voltage components can only be carried out by Service employees with the relevant certification ST1408 I12 Complete Vehicle training course completed.

Heat shields are installed for thermal operating safety in the engine compartment to protect the vehicle and engine components. They reflect the heat to insulate the components underneath.

1. Introduction



I12 Installation location of heat shields

Use extreme caution when handling heat shields and acoustic covers. Pay attention to the following:

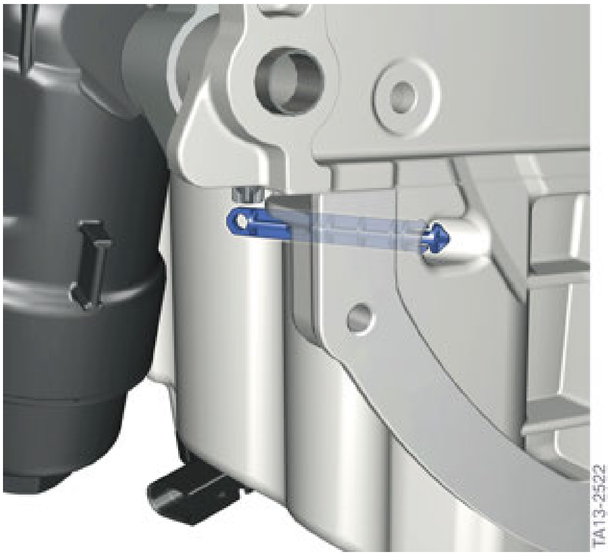
- Proper installation according to the repair instructions.
- Heat shields and acoustic covers must be checked for damage before installation.
- Any oil, grease or fuel residue must be removed before installation of the heat shields and acoustic covers.

⚠

The repair instructions must be followed precisely when handling heat shields and acoustic covers. Incorrect handling, particularly during installation, can cause serious damage to components or the vehicle.

The TDC setting (top dead center) of the combustion engine can be retained by using an alignment pin at the oil sump. The seal plug near the oil filter housing must be removed beforehand.

B38 Top Engine
1. Introduction

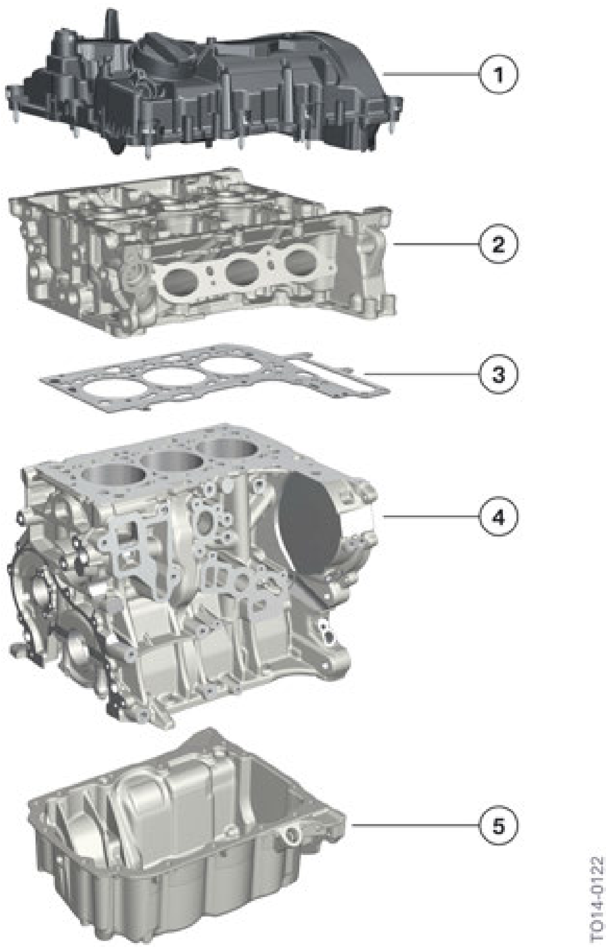


I12 Seal plug dowel hole top dead center

For most repair on work the engine, it must be removed from the underside of the vehicle.

2. Engine Mechanics

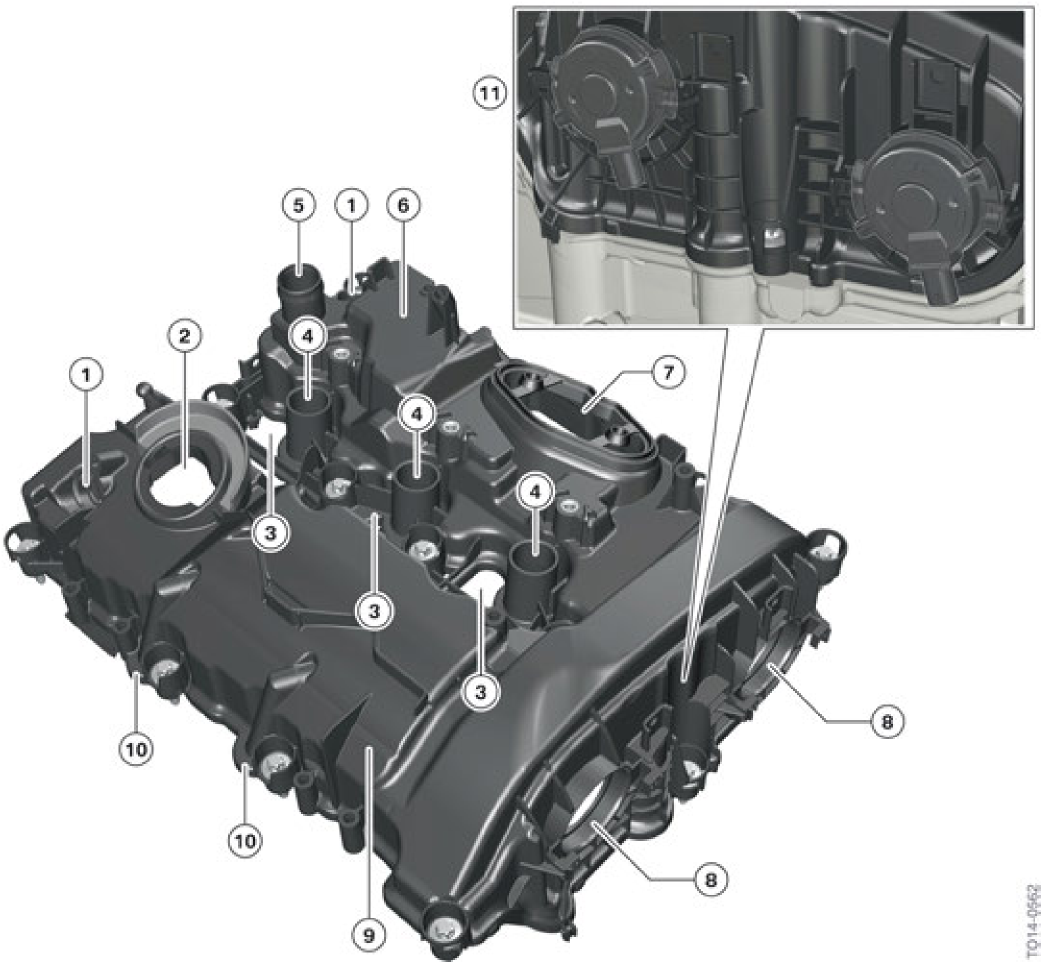
2.1. Engine housing



Engine housing of B38 engine

Index	Explanation
1	Cylinder head cover
2	Cylinder head
3	Cylinder head gasket
4	Crankcase
5	Oil sump

2.1.1. Cylinder head cover



Cylinder head cover B38 engine

Index	Explanation
1	Mountings of camshaft sensors
2	Oil filler neck
3	Recesses for injectors
4	Mountings for ignition coils
5	Blow-by channel, turbocharged operation
6	Oil separator, turbocharged operation
7	Mounting for high pressure pump
8	Mountings of VANOS solenoid valve actuators
9	Oil separator, naturally aspirated engine operation
10	Blow-by channel, naturally aspirated engine operation
11	Bayonet fitting with retaining clips

The B38 engine also has recesses for mounting the VANOS solenoid valve actuators in the cylinder head cover. The VANOS solenoid valve actuators are not screwed on, and instead are fastened using a bayonet fitting and retaining clips.

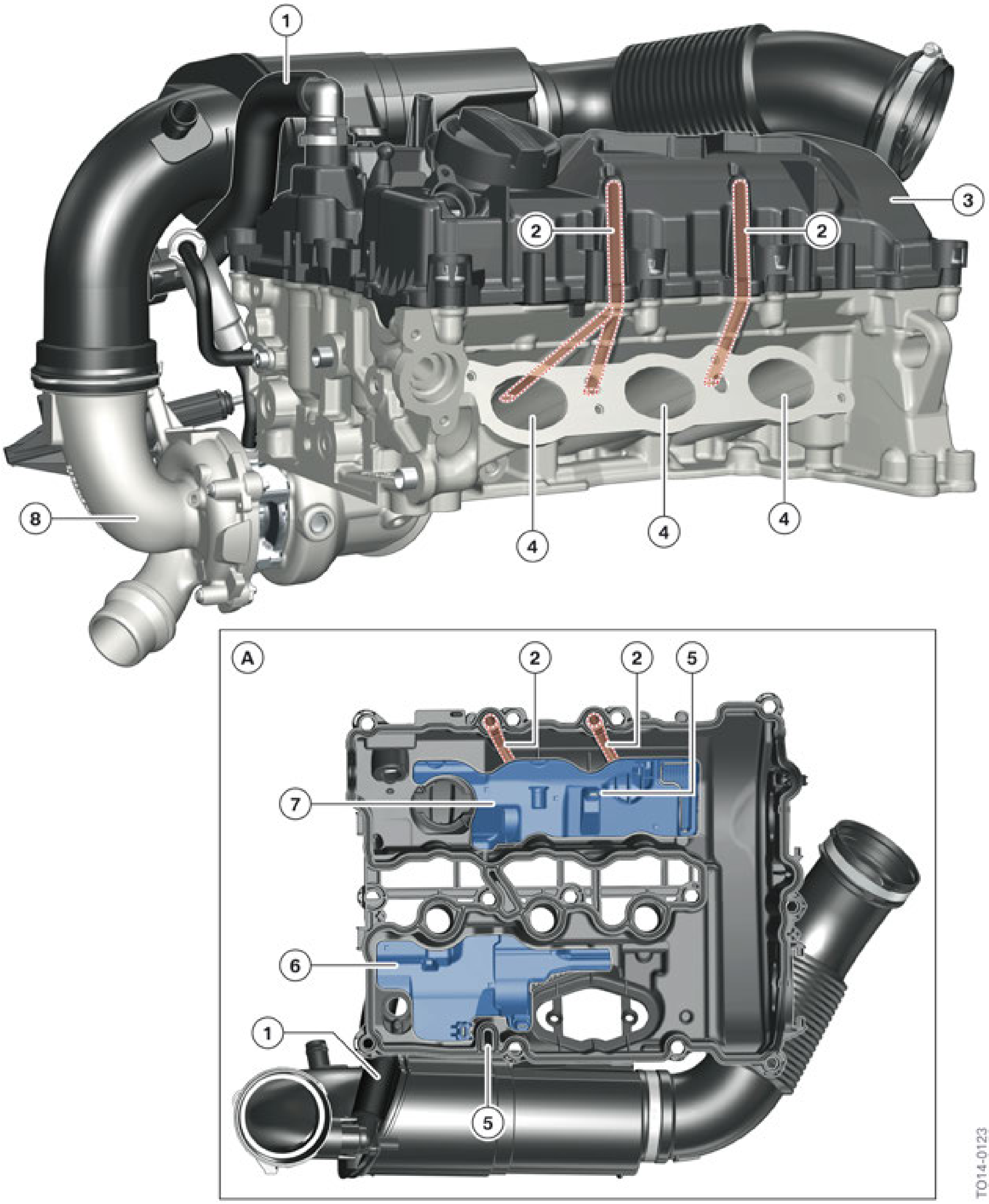
Tasks of crankcase ventilation:

- Regulation of the internal engine pressure.
- Cleaning the blow-by gases to remove engine oil.
- Recirculation of the cleaned blow-by gases in the intake area.

When the engine is in operation, gases (referred to as "blow-by gases") from the combustion chamber pass through the cylinder walls and enter the crankcase. These blow-by gases contain unburnt fuel and all elements of the exhaust gas. In the crankcase they are mixed with engine oil which is available there in the form of oil mist.

The volume of the blow-by gases is dependent on the engine speed and the load. Without crankcase ventilation excess pressure would arise in the crankcase. This excess pressure would be present in all cavities connected to the crankcase (e.g. oil return duct, chain shaft, etc.) and lead to oil leakage at the seals.

The crankcase ventilation prevents this. It routes the extensively engine oil-free blow-by gases to the clean air pipe and the separated droplets of oil flow back to the oil sump via an oil return pipe.
In addition, the crankcase ventilation, in combination with a pressure control valve, ensures a low vacuum in the crankcase.



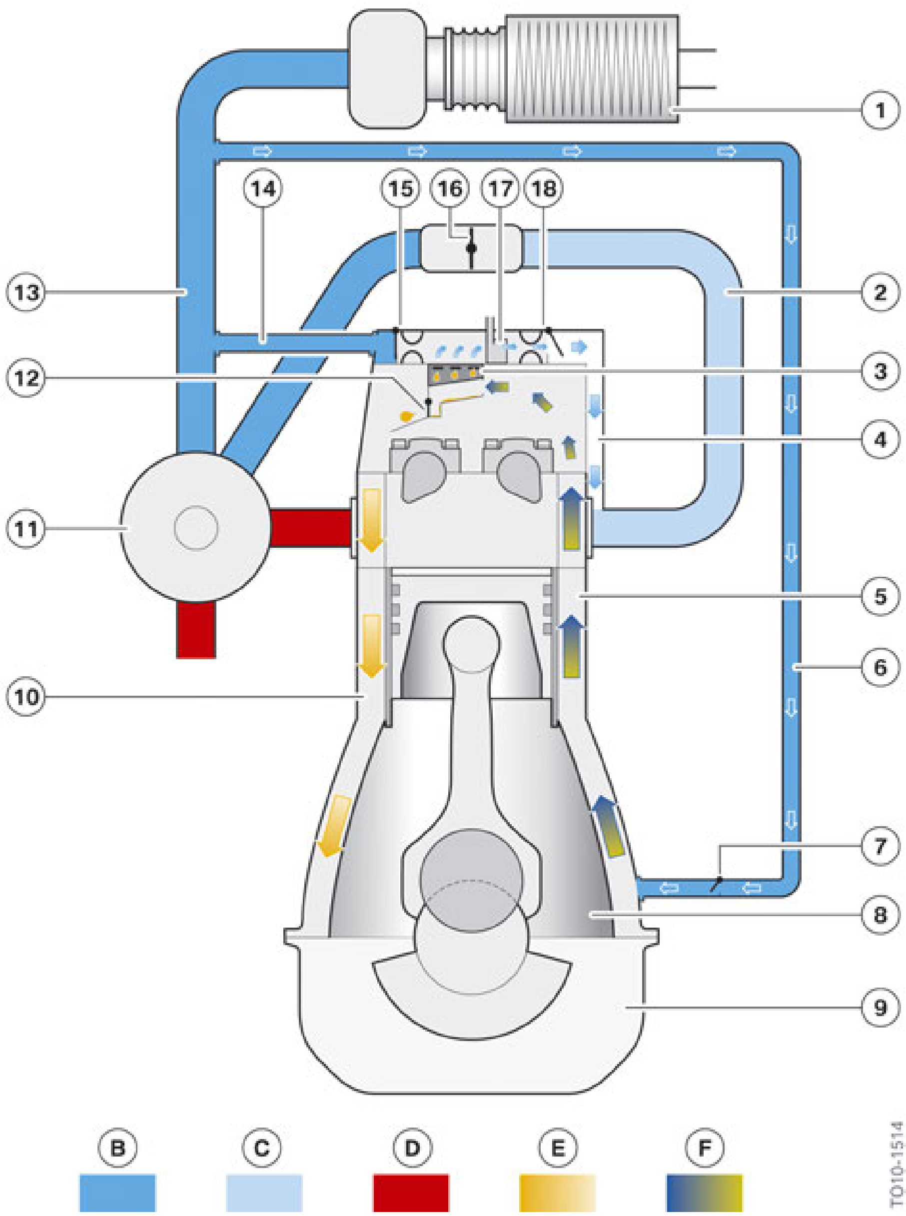
Crankcase ventilation, B38 engine

Index	Explanation
A	Cylinder head cover, view from below
1	Blow-by channel into clean air pipe (turbocharged operation)
2	Blow-by channel upstream of the intake valves (naturally aspirated engine operation)
3	Cylinder head cover
4	Intake ports
5	Oil return
6	Oil separator (turbocharged operation)
7	Oil separator (naturally aspirated engine operation)
8	Exhaust turbocharger

The crankcase ventilation in B38 engine has a two-stage design. This means that, depending on the load condition, the blow-by gases are routed via different channels.

Naturally aspirated engine operation

During naturally-aspirated engine operation, the blow-by gases upstream of the intake valves are routed to the intake port.



Crankcase ventilation, naturally aspirated operation of B38 engine

Index	Explanation
B	Ambient pressure
C	Vacuum
D	Exhaust gas
E	Oil
F	Blow-by gas
1	Air filter
2	Intake manifold

Index	Explanation
3	Separator
4	Blow-by channel upstream of the intake valves
5	Blow-by channel upstream of crankcase
6	Purge air line
7	Non-return valve
8	Crank chamber
9	Oil sump
10	Oil return
11	Exhaust turbocharger
12	Non-return valve, oil return
13	Clean air pipe
14	Hose to clean air pipe
15	Non-return valve with restrictor
16	Throttle valve
17	Pressure control valve
18	Non-return valve with restrictor

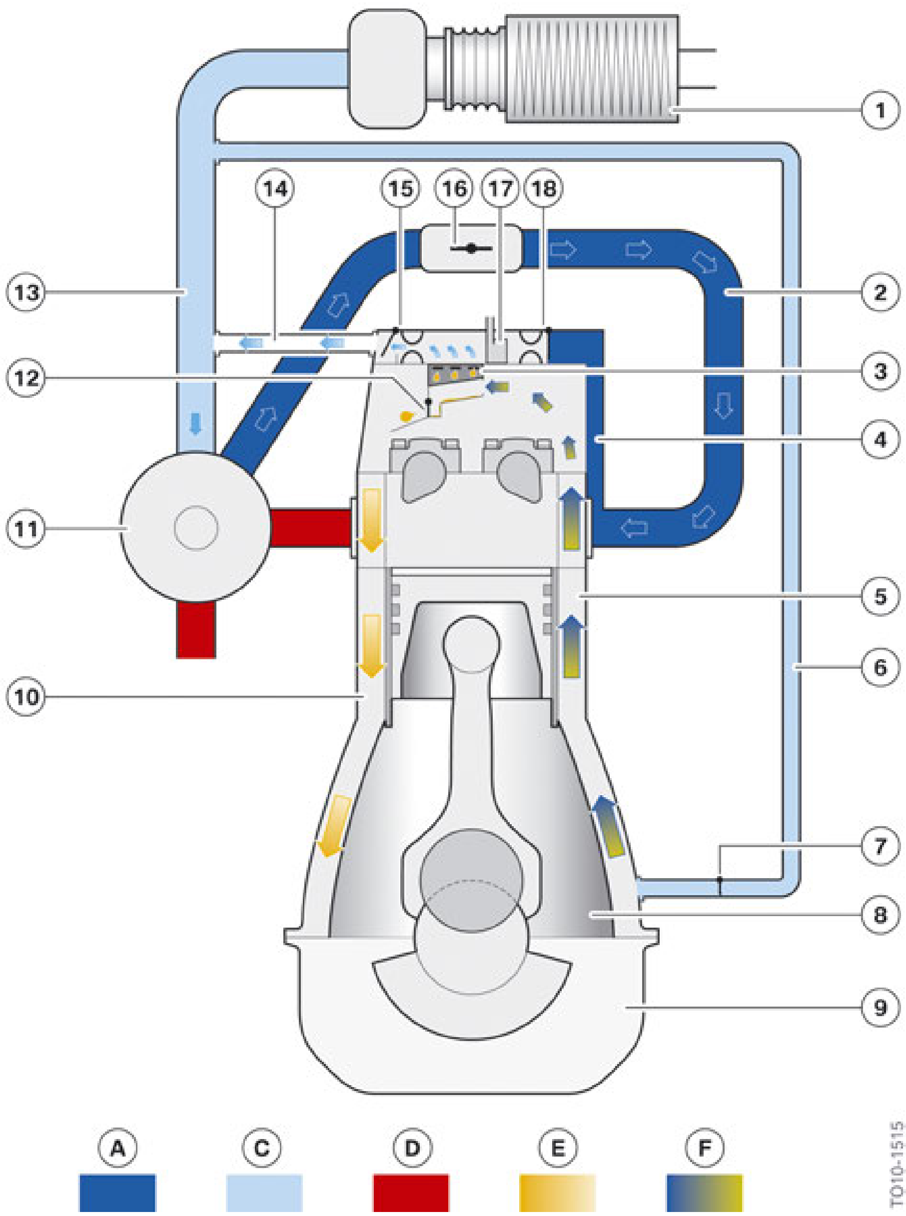
The fine oil mist is separated from the blow-by gases with the assistance of a separator and the oil droplets formed are routed back to the oil sump via the oil return.

The throttle valve is closed during naturally-aspirated engine operation. This produces a vacuum in the intake system. which draws in the blow-by gases via blow-by channels cast into the cylinder head directly upstream of the intake valves. In systems controlled by Valvetronic, the throttle valve is also lightly shut in these operating conditions to guarantee the engine ventilation function.

A purge air line, which is connected to the clean air pipe ahead of the exhaust turbocharger and to the crankcase, routes fresh air via a non-return valve directly into the crank chamber. The bigger the vacuum in the crankcase, the bigger the air mass introduced into the crankcase. This purging prevents the pressure control valve from icing up.

Charged operation

As a significant overpressure prevails in the intake pipe during turbocharged operation, the blow-by gases cannot be introduced upstream of the intake valves in the intake port. The blow-by gases are therefore introduced into the clean air pipe in this operating condition.



Crankcase ventilation with turbocharged operation of B38 engine

Index	Explanation
A	Charging pressure
C	Vacuum
D	Exhaust gas
E	Oil
F	Oil and blow-by fuel-air mixture
1	Air filter
2	Intake manifold

Index	Explanation
3	Separator
4	Blow-by channel upstream of the intake valves
5	Blow-by channel upstream of crankcase
6	Purge air line
7	Non-return valve
8	Crank chamber
9	Oil sump
10	Oil return
11	Exhaust turbocharger
12	Non-return valve, oil return
13	Clean air pipe
14	Hose to clean air pipe
15	Non-return valve with restrictor
16	Throttle valve
17	Pressure control valve
18	Non-return valve with restrictor

The fine oil mist is separated from the blow-by gases with the assistance of a separator and the oil droplets formed are routed back to the oil sump via the oil return.

The cylinder head cover is connected to the clean air pipe by a hose. During turbocharged operation, a vacuum is produced in the clean air pipe. This vacuum draws the blow-by gases into the clean air pipe via the hose.

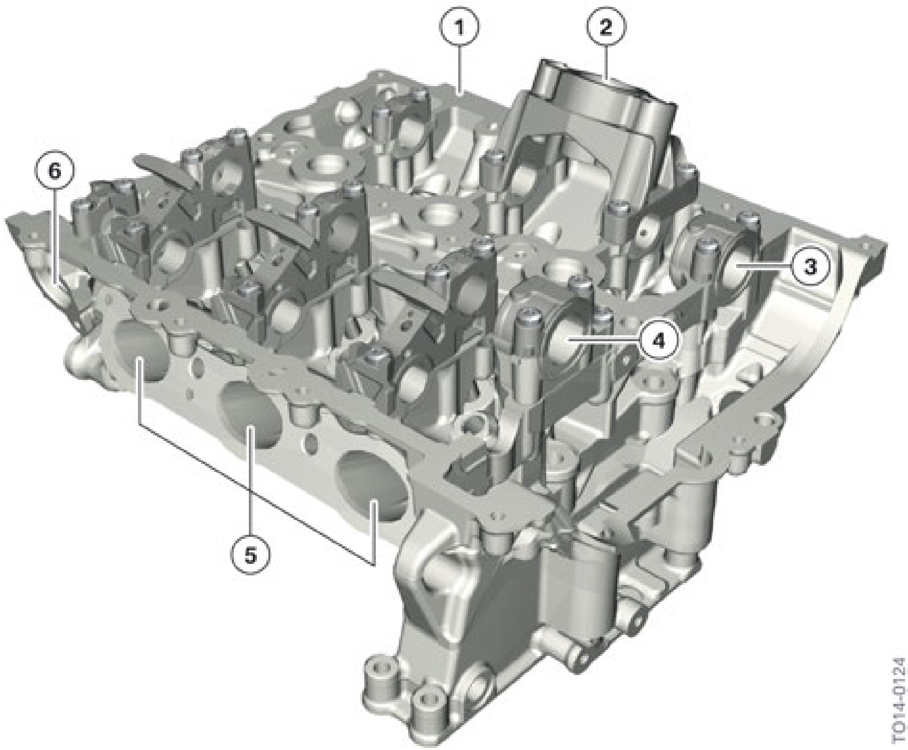
⚠

Always ensure absolute cleanliness when filling the engine with engine oil. Clean the oil filler neck before you screw on the sealing cap. Engine oil residue at the sealing cap may lead to misdiagnosis at the crankcase ventilation.

2.1.2. Cylinder head

Technical features:

- Material: AlSi7MgCU0.5
- Coolant cooling according to the cross-flow principle
- Four valves per cylinder
- Mounting of the valve gear
- Mounting of the Valvetronic and the Valvetronic servomotor
- Mounting of the high pressure pump.



Cylinder head of B38 engine

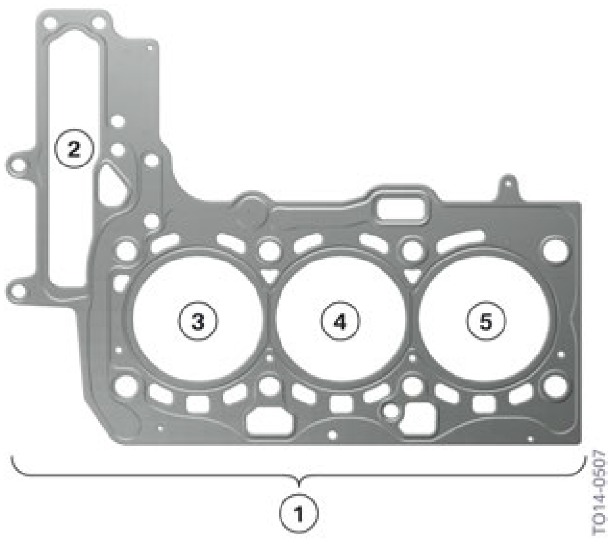
Index	Explanation
1	Cylinder head
2	Mounting, high pressure pump
3	Axial bearing, exhaust camshaft
4	Axial bearing, intake camshaft
5	Intake ports
6	Mounting, Valvetronic servomotor

Cooling concept of cylinder head

The B38 engine has a cylinder head with cross-flow cooling. In the case of cross-flow cooling, the coolant flows from the hot exhaust side to the cooler intake side. This has the advantage of providing uniform heat distribution in the overall cylinder head. Loss of pressure in the cooling circuit is also prevented.

Cylinder head gasket

In order to satisfy the high demands of the B38 engine, a triple-layer spring steel gasket is used as the cylinder head gasket.



Cylinder head gasket in B38 engine

Index	Explanation
1	Spring steel gasket
2	Sealing area of the chain shaft
3	Sealing area, combustion chamber, cylinder 3
4	Sealing area, combustion chamber, cylinder 2
5	Sealing area, combustion chamber, cylinder 1

⚠

The cylinder head gasket must be replaced after removal of the cylinder head.

2.1.3. Crankcase

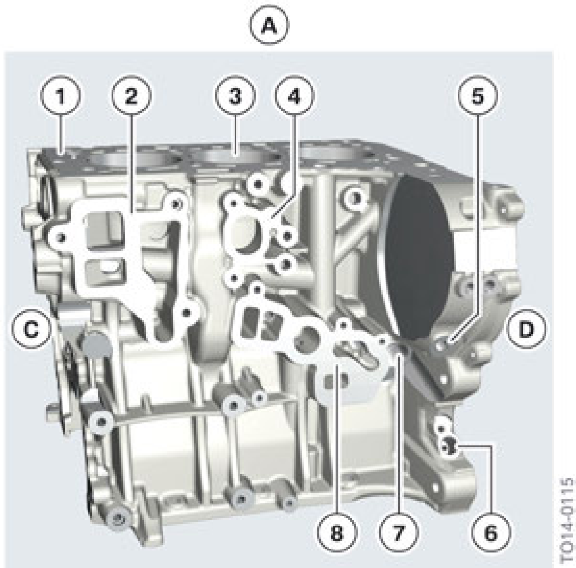
Overview

	Unit	B38A15M0
Displacement	[cm³]	1498
Hole	[mm]	82
Stroke	[mm]	94.6
Single cylinder volumes	[cm³]	499.6
Compression ratio		11 : 1
Distance between cylinders	[mm]	91

The crankcase is a completely new design which takes the different requirements of the B38 designs into account.

B38 Top Engine
2. Engine Mechanics

Overview



Side view of crankcase, B38 engine

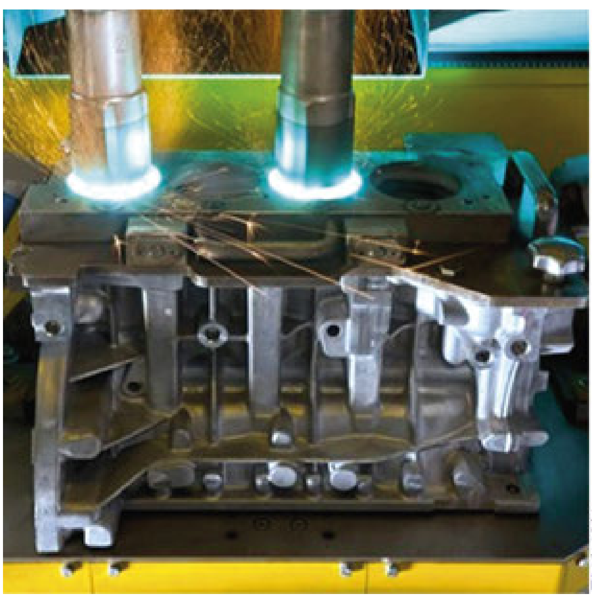
Index	Explanation
A	Crankcase of B38 engine
C	Belt drive side
D	Flywheel side
1	Closed Deck
2	Sealing surface, coolant pump (transverse installation)
3	Cylinder barrels (LDS = electric arc wire sprayed)
4	Coolant outlet
5	Bore hole for oil pressure sensor
6	Bore hole for vacuum duct
7	Bore hole, solenoid valve
8	Sealing surface, oil filter module

As the previous graphic clearly shows, the various components occupy the same positions on the crankcase.

Characteristics of crankcase:

- Heat-treated all aluminium crankcase made from AlSiMgCu 0.5.
- Electric arc wire-sprayed cylinder barrels.
- Weight-optimized main bearing cap of crankshaft with embossing teeth.
- Closed-deck design.
- Deep Skirt.
- Oil ducts for the use of a map-controlled oil pump.
- Support of counterbalance shaft(s) in cored tunnel.

Electric arc wire spraying (LDS)



Electric arc wire spraying method, B38 engine

The cylinder barrels of the B38 engine are coated by means of an electric arc wire spraying process. In this procedure a conductive metal wire is heated until it melts. The melt is then sprayed onto the cylinder barrels at high pressure. This layer of ferrous material is roughly 0.3 mm thick, extremely wear-resistant and facilitates an efficient transfer of heat from the combustion chambers to the crankcase, and from there to the coolant ducts.

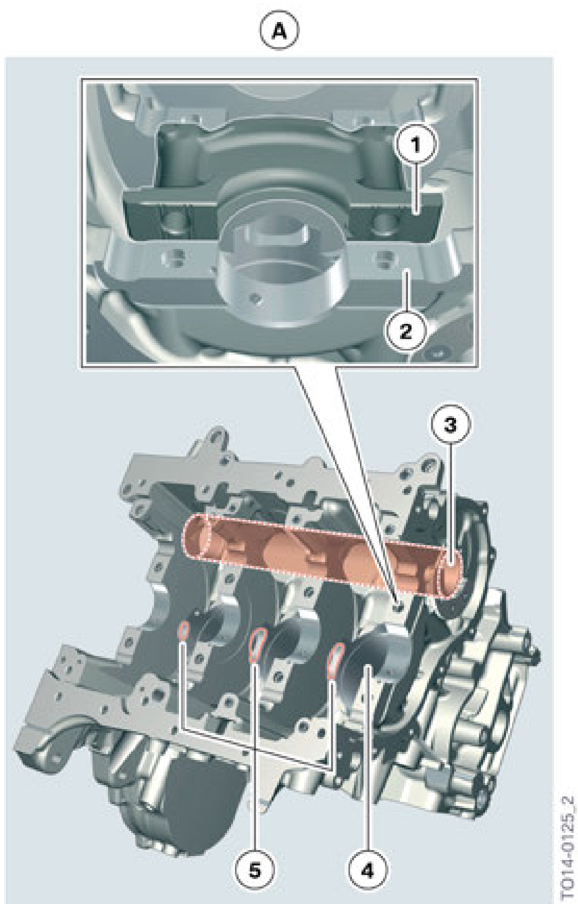
Advantages:

- Lower weight.
- High wear resistance.
- Good heat dissipation to the crankcase.
- Lower internal engine friction thanks to excellent sliding properties.

⚠

Due to the thin material application during the electric arc wire-spraying procedure, subsequent processing of the cylinder barrels is not possible.

Bearing, counterbalance shaft



Crankcase from below, B38 engine

Index	Explanation
A	Crankcase of B38 engine
1	Embossed main bearing cap
2	Main bearing seat
3	Position of counterbalance shaft 1
4	Cylinder barrel (coated by electric arc wire spraying)
5	Ventilation holes

Due to the odd number of cylinders, different types of forces occur at the crankcase. In the 3-cylinder engine, these forces are reduced by just one rotating counterbalance shaft. For more information, refer to the chapter Counterbalance shafts.

Closed Deck

With the closed-deck design, the coolant ducts around the cylinder are closed from above and provided with coolant bore holes.

Deep Skirt

With the "deep skirt" concept, the side walls extend far downwards. This lends the crankcase a high degree of stability and considerable flexibility in terms of the piston stroke length.

Embossed crankshaft bearing cap

The weight of the main bearing cap of the crankshaft has been further optimized for the new B38 engine. The new main bearing caps are common parts for the B38 engine. When the impression connection is made the main bearing cap is designed with a profile. When the main bearing bolts are tightened for the first time, this profile pushes into the surface of the bearing block on the crankcase side.

⚠

Exchange of the main bearing cap, or positioning in another bearing position on the crankshaft, is not permitted and will lead to engine damage.

Ventilation holes

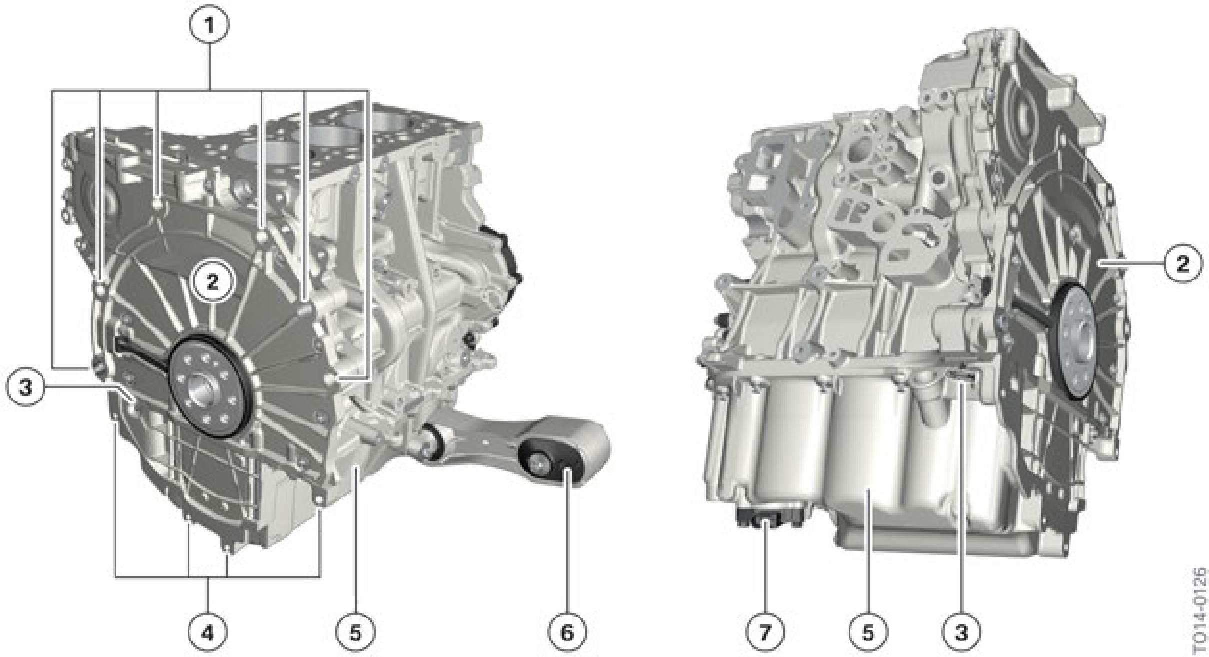
The combustion chambers are connected via ventilation bore holes at the bottom end of the cylinder barrels. The air flows, which arise as a result of the upward and downward movement of the pistons, can thus escape easier via the ventilation bore holes. This reduces the blow-by gas volume, as the air flows do not reach the oil sump area. In addition, as the displacement of air volume has been simplified by using the ventilation bore holes, the piston can move up and down more easily. This reduces the internal friction of the engine and ensures the engine operates more efficiently.

2.1.4. Oil sump

The oil sump is manufactured from die-cast aluminium.

Tasks:

- Collecting vessel for engine oil
- Collection area for returning engine oil
- Reinforcing component in the engine-transmission combination
- Fixture for the oil-level sensor and oil drain plug
- Connection of the anti-roll bar link for transverse mounting.

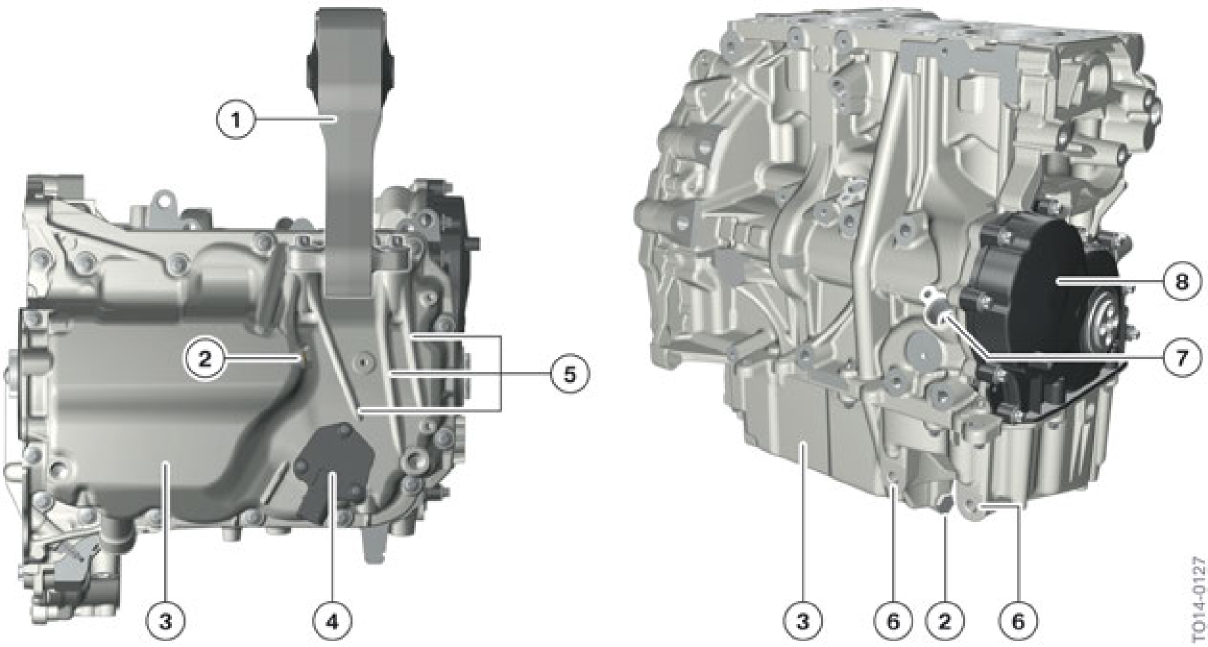


Side view of B38 engine

Index	Explanation
1	Attachment points, crankcase at transmission
2	Timing case cover
3	Seal plug for bore hole of the holding fixture
4	Attachment points, oil sump at transmission
5	Oil sump
6	Anti-roll bar link
7	Oil level sensor

The engine can be disconnected via a bore hole in the oil sump for adjusting the timing.
When installing the oil sump with the transmission removed, make sure that the transmission contact surface of the oil sump and the timing case cover are in one plane. Always use the corresponding special tool. If a gap arises between the two areas when tightening the mounting bolts of the transmission, it causes damage to the oil sump.

2. Engine Mechanics



Oil sump of B38 engine

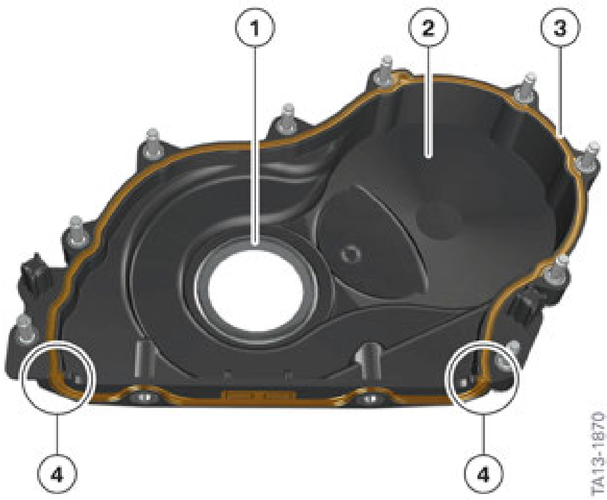
Index	Explanation
1	Anti-roll bar link
2	Oil drain plug
3	Oil sump
4	Oil level sensor
5	Reinforcing ribs
6	Connection of anti-roll bar link at oil sump
7	Oil return to oil sump
8	Crankcase end cover (belt side)

Because the engine is mounted transversely, an anti-roll bar link is used. The forces that occur with this arrangement are transmitted via reinforcing ribs to the housing of the oil sump.

The engine oil flows from the oil circuit back to the oil sump via the return line of the exhaust turbocharger.

The B38 engine does not have an oil dipstick. The oil level is monitored electronically at all times with the assistance of the oil-level sensor and can be requested via the on-board computer.

Sealing B38 engine



Crankcase end cover of B38 engine

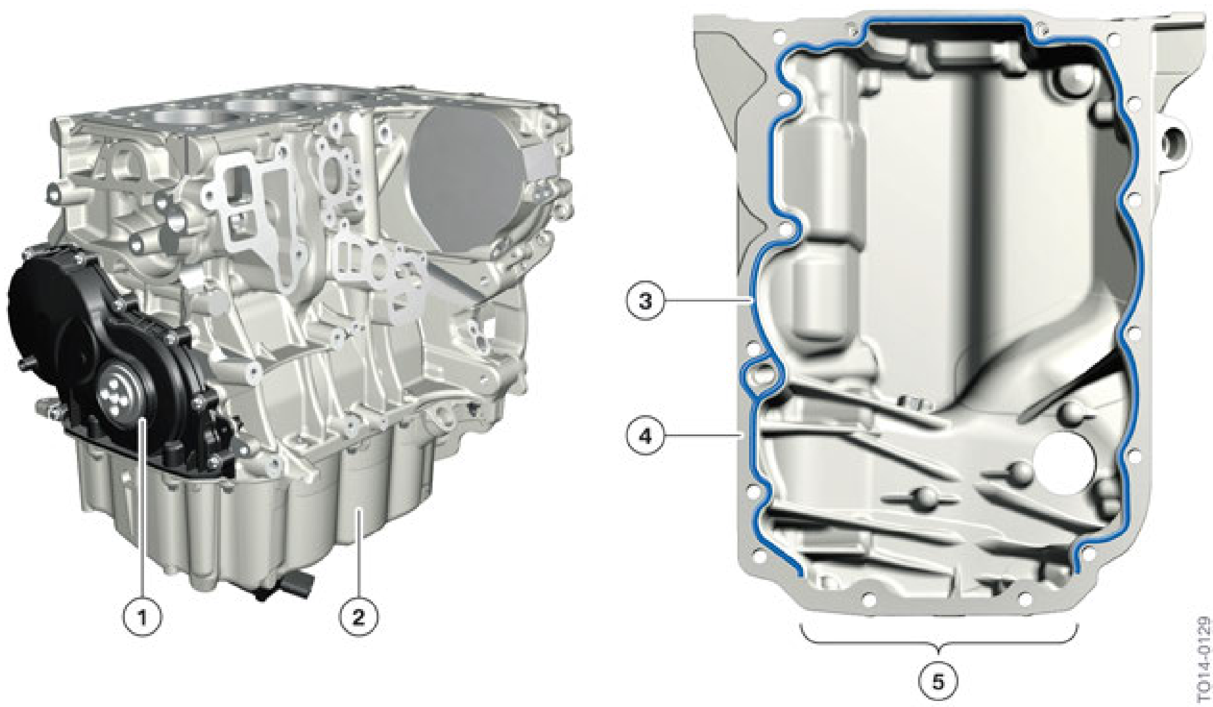
Index	Explanation
1	Radial shaft seal
2	Crankcase end cover
3	Elastomer seal
4	"Triangular area" crankcase end cover, crankcase and oil sump

With the B38 engine the belt side is sealed using a crankcase end cover with integrated elastomer seal.

The radial shaft seal is integrated in the crankcase end cover and cannot be replaced separately. The sealing area of the "triangular area" between the crankcase end cover, crankcase and oil sump must be very carefully considered in relation to leaks. This is why the procedure prescribed in the repair instructions for the installation of the crankcase end cover must be observed.

⚠

In order to prevent leaks at the engine, the crankcase end cover must be replaced each time it is removed.



Engine oil sump seal for B38 engine

Index	Explanation
1	Radial shaft seal
2	Oil sump
3	Silicone bead
4	Sealing surface, oil sump
5	Sealing surface area of the crankcase end cover without bevel

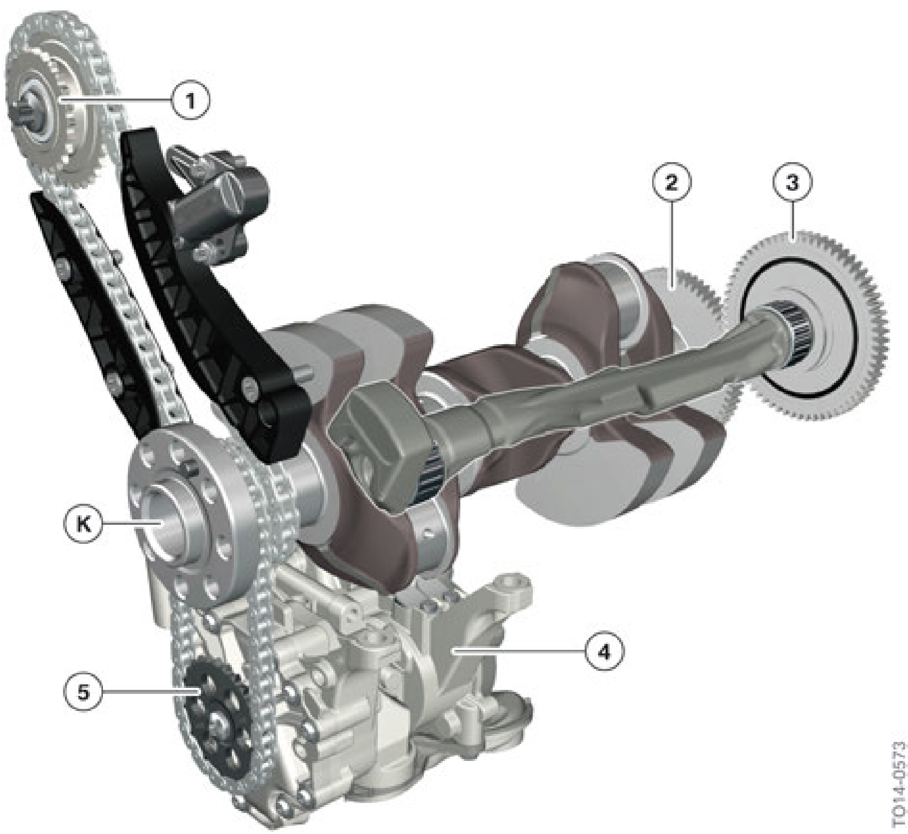
In the sealing area of the crankcase end cover there is no bevel on the inside of the oil sump. This area is not sealed using the sealing compound silicone Loctite 5970, but via an elastomer seal integrated in the crankcase end cover.

If the oil sump is disassembled and the crankcase end cover remains at the crankcase, sealing of the sealing surface area at the crankcase end cover is no longer guaranteed. In this case the silicone bead must be applied around the entire sealing surface area of the oil sump. Refer to the repair instructions for the exact procedure.

2.2. Crankshaft drive

2.2.1. Crankshaft

Overview of crankshaft of B38 engine



Crankshaft of B38 engine

Index	Explanation
K	Flywheel side, crankshaft
1	Camshaft sprocket, intermediate shaft
2	Crankshaft gear
3	Gear, counterbalance shaft
4	Oil and vacuum pump
5	Oil pump sprocket

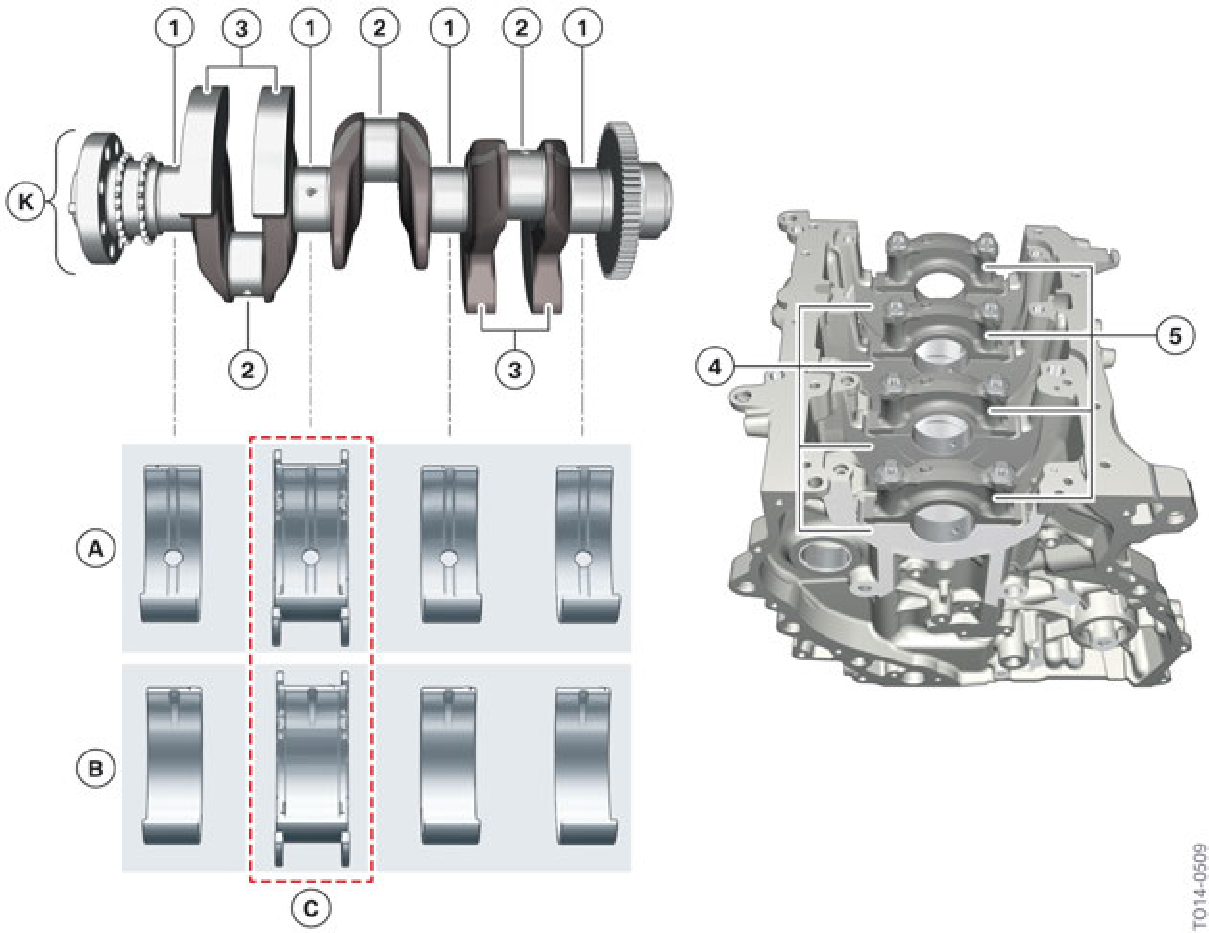
The timing chain of the B38 engine is located on the flywheel side. In contrast, the counterbalance shaft is driven via gears on the opposite belt side.

B38 Top Engine
2. Engine Mechanics

Technical data, crankshaft

Characteristics	Unit	B38K15T0 engine
Material		C38+N2
Manufacture		Forged
Diameter of the main bearing journal	[mm]	45
Width of the main bearing journal	[mm]	25
Diameter of the connecting rod bearing journal	[mm]	45
Width of connecting rod bearing journal	[mm]	24
Stroke of the connecting rod bearing journal	[mm]	94.6
Throw angle	[°]	240
Number of counterweights		4
Number of main bearing positions		4
Position of the thrust bearing		Bearing 3

Crankshaft bearing in B38 engine



Overview of bearing shells at the B38 engine

Index	Explanation
A	Bearing shell in main bearing seat
B	Bearing shells in main bearing cap
C	Axial guide bearing
K	Flywheel side
1	Crankshafts, main bearing
2	Connecting rod bearing journal
3	Counterweights
4	Main bearing seat
5	Main bearing cap

The crankshaft is mounted using different bearing shells. The bearing shells in the low-load zone of the bearing seat have oil holes and a peripheral groove for fresh oil supply. The highly stressed bearing shells in the area of the main bearing cap have no oil holes or grooves.

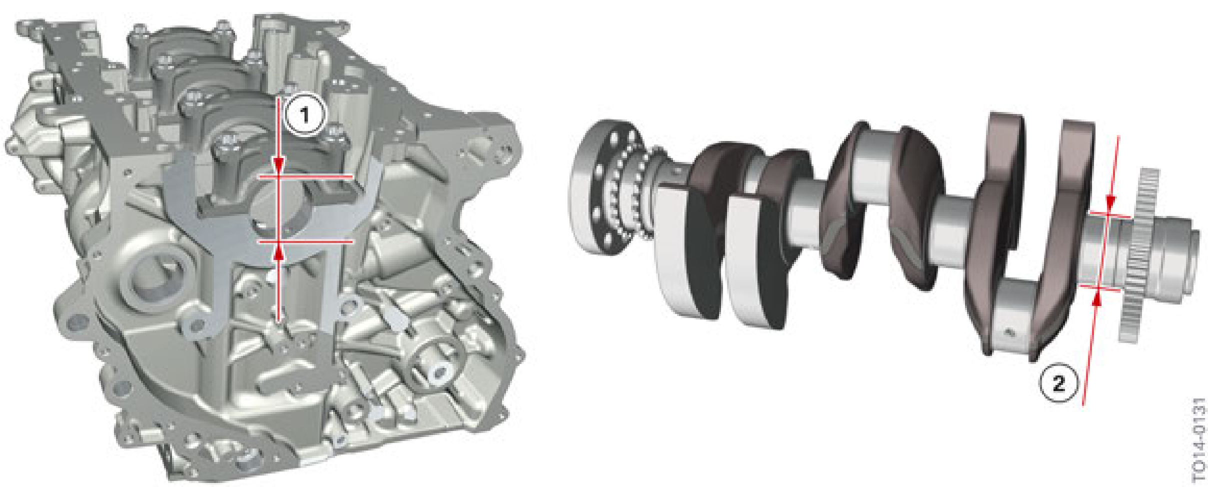
Due to the very low tolerances, special attention must be paid to cleanliness when handling bearing shells.

The axial guide bearing is located in the center bearing area of the crankshaft. This bearing holds the crankshaft in the axial direction and must absorb forces in the longitudinal direction which, for example, can arise during the operation the clutch.

Before the completion of the engine, check the side clearance in accordance with the repair instructions. Excessive side clearance may cause electrical faults or damage to the components.

Identifying the bearing shells

So that the crankshaft can carry out its main task effectively, incorporation of the lifting movement and conversion to a rotational movement, it must be positioned correctly. The dimension to be adjusted can also be called a fit and is generated using crankshaft bearing shells with varying degrees of thickness.



Crankshaft bearing in B38 engine

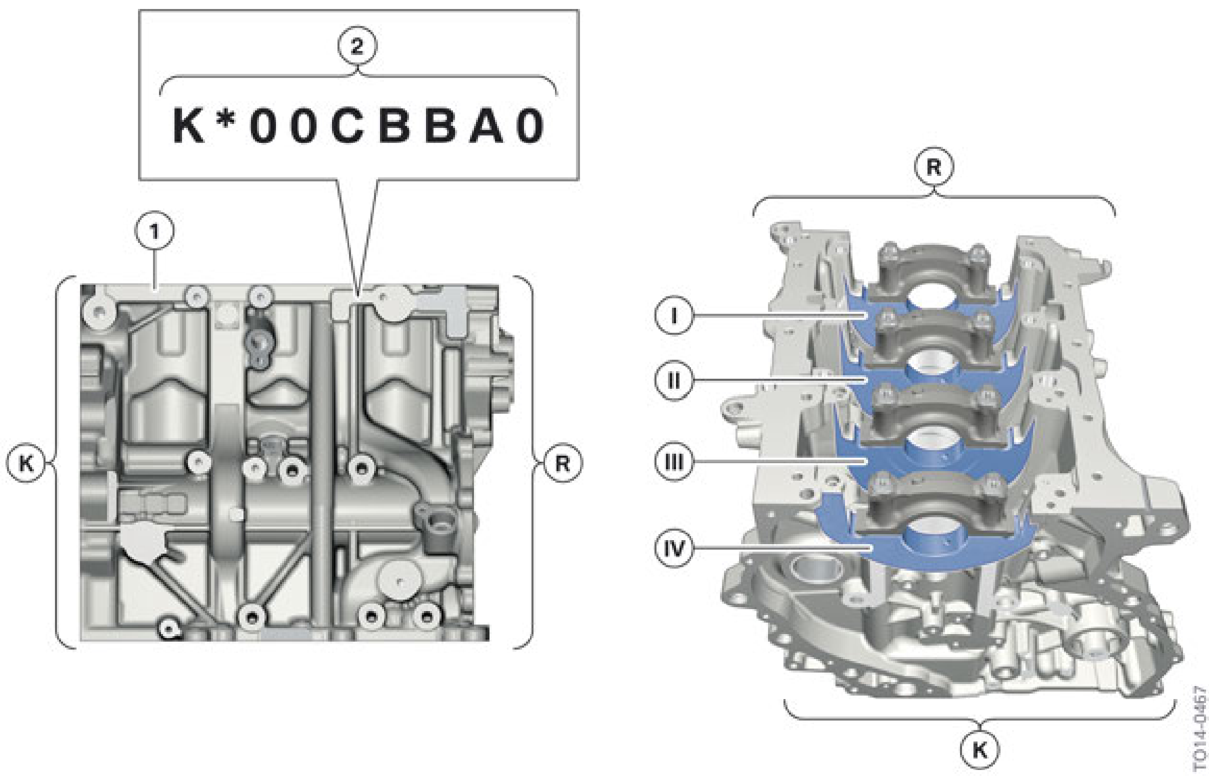
Index	Explanation
1	Hole
2	Shaft

A distinction is made between three types of fit in the design:

- Clearance fit
- Transition fit
- Interference fit

The fit is viewed as an accurate relationship between the bore hole and the shaft. The crankcase represents the bore hole and the crankshaft represents the shaft. This is why the numbers for the classification of the bearing shells are located on the crankcase and the crankshaft. In the case of a dimension being adjusted, this is a so-called clearance fit. A clearance fit is characterized by the fact that in each case the minimum dimension of the bore hole is greater than the maximum dimension of the shaft. This creates the necessary play between the shaft and the bore hole, which is needed for the bearing of the crankshaft.

Bearing shell classification on the bearing seat



Bearing shell classification on the bearing seat, B38 engine

Index	Explanation
I	Bearing seat 1
II	Bearing seat 2
III	Bearing seat 3
IV	Bearing seat 4
K	Flywheel side
R	Belt side
1	Crankcase
2	Stamped letters

The stamped letters on the crankcase are used to determine the bearing shell sizes of the bearing seat.

The following letters are used for the classification:

- A = highest possible play (thinnest bearing shell)
- B = medium play (medium bearing shell)
- C = lowest possible play (thickest bearing shell)

The letter K stands for the flywheel side of the crankcase. It also specifies the counting order for the assignment.

If there is a K before the stamped letters, then the first letter of the code refers to the bearing shell of bearing seat 4, which is located on the flywheel side. The subsequent letters, read from left to right, refer to the bearing seat 3, 2 and 1. The positions marked with "0" are placeholders for larger engines and are simply omitted.

Using the previous graphic for reference, the following combination is obtained:

Assignment:

- Flywheel side = K
- Bearing seat 4 = C
- Bearing seat 3 = B
- Bearing seat 2 = B
- Bearing seat 1 = A

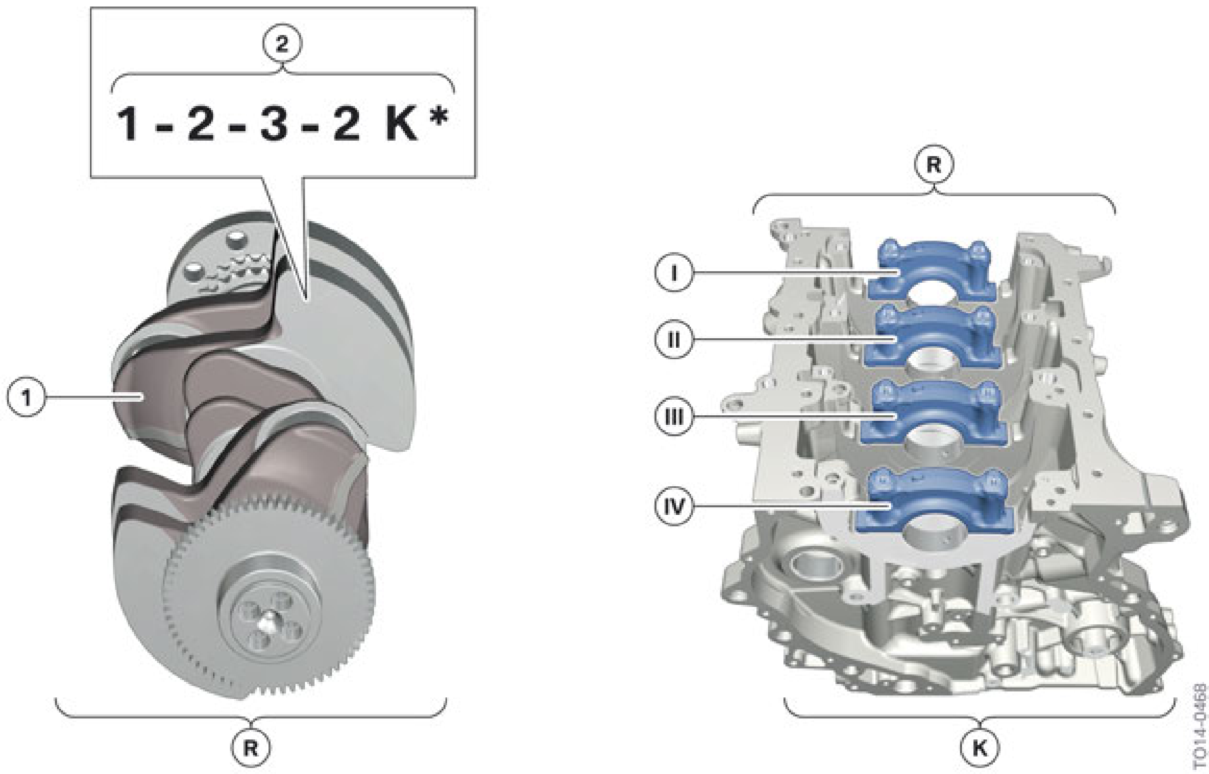
If the stamped letters are not preceded by "K", then the first letter of the code refers to the bearing shell of bearing seat 1, which is located opposite the flywheel side on the belt side. The subsequent letters, read from left to right, refer to bearing seat 2, 3 and 4.

When assigning the letters without "K", the following combination is obtained:

Assignment:

- Bearing seat 1 = C
- Bearing seat 2 = B
- Bearing seat 3 = B
- Bearing seat 4 = A

Bearing shell classification on main bearing cap



Bearing shell classification on main bearing cap, B38 engine

Index	Explanation
I	Main bearing cap 1
II	Main bearing cap 2
III	Main bearing cap 3
IV	Main bearing cap 4
K	Flywheel side
R	Belt side
1	Crankshaft
2	Stamped digits

The stamped digit on the crankshaft determines the bearing shell sizes of the main bearing cap.

The following numbers are used for the classification:

- 1 = highest possible play (thinnest bearing shell)
- 2 = medium play (medium bearing shell)
- 3 = lowest possible play (thickest bearing shell)

In the case of the crankshaft, the letter K also defines the assignment of the bearing position. The digit next to the K is to be assigned to the main bearing cap 4 which is on the flywheel side. The subsequent digits, read from left to right, refer to the main bearing cap 3, 2 and 1.

Using the previous graphic for reference, the following combination is obtained:

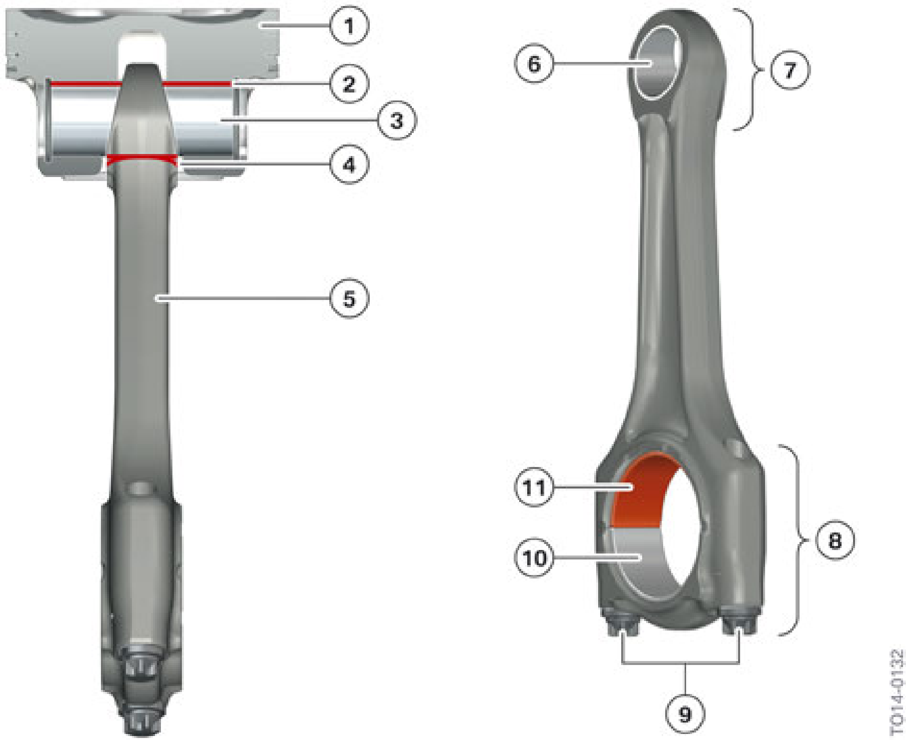
Assignment:

- Main bearing cap 1 = 1
- Main bearing cap 2 = 2
- Main bearing cap 3 = 3
- Main bearing cap 4 = 2
- Flywheel side = K

Deciphering the combination of letters and digits

The letter and digit combination of the main bearing shells can be decrypted using a table in the repair instructions. The correct bearing shell sizes are determined with help of the color codes.

2.2.2. Connecting rod



Connecting rod of B38 engine

Index	Explanation
1	Piston
2	Force-transmitting surface
3	Wrist pin
4	Connecting rod bearing bushing with shaped bore hole
5	Connecting rod
6	Connecting rod bushing
7	Small connecting rod eye (trapezoidal shape)
8	Large connecting rod eye (cracked)
9	Connecting rod bolts of the connecting rod bearing cap
10	Connecting rod bearing shell of the connecting rod bearing cap
11	Connecting rod bearing shell of the connecting rod (IROX-coated)

The familiar drop-forged cracked connecting rods are used.

⚠

If a connecting rod bearing cap is mounted the wrong way round or on another connecting rod, the fracture structure of both parts is destroyed and the connecting rod bearing cap is not centered. In this event the entire connecting rod set must be replaced with new parts. In Service please observe the specified jointing torques and angle of rotation specifications in the repair instructions.

Weight classification

To guarantee smooth engine running, the connecting rods are divided into weight classes. The large and small connecting rod eyes are weighed separately and divided into various classes according to their weight.

⚠

In Service only connecting rods of the same weight class can be used. This is why only a full set of connecting rods is available in the event of a replacement. This set comprises the corresponding number of connecting rods of a weight classification.

Irox-coating

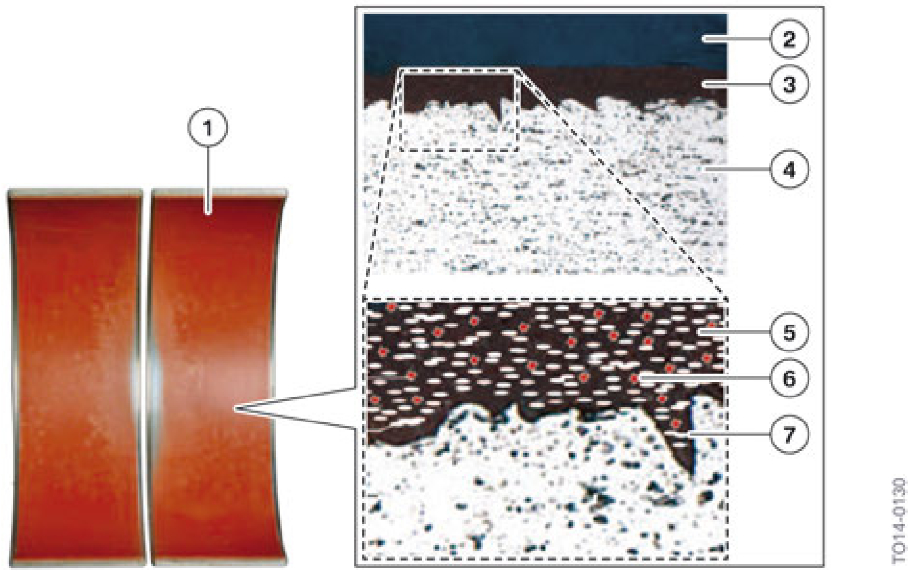
In order to comply with the increasingly stringent exhaust emission regulations, most combustion engines nowadays are equipped with the automatic start-stop function. This has led to a huge increase in starting cycles.

To ensure the engine runs smoothly, it is important that sufficient lubricating oil is supplied to the bearing positions of the crankshaft. If the oil supply can be ensured, solid body contact will not occur between the connecting rod bearing journal and connecting rod bearing shell due to the thin lubricating film.

If the engine is now stopped, it will not be possible for the mechanically-driven oil pump to maintain the oil supply. The oil film between the bearing positions flows off. Solid body contact occurs between the connecting rod bearing journal and connecting rod bearing shell. Once the engine is restarted, it takes a certain amount of time for the lubricating film to fully re-establish itself. The connecting rod bearing shell may be subject to wear in this short period. The Irox-coating reduces this wear to a minimum.

The IROX-coated bearing shells are only located on the connecting rod side as here the load acts mainly on the bearing shells. The bearing shell caps are equipped with a bearing shell without IROX coating.

The IROX ball bearings are red due to their special coating.



Detailed magnification of the Irox-coating of the B38 engine

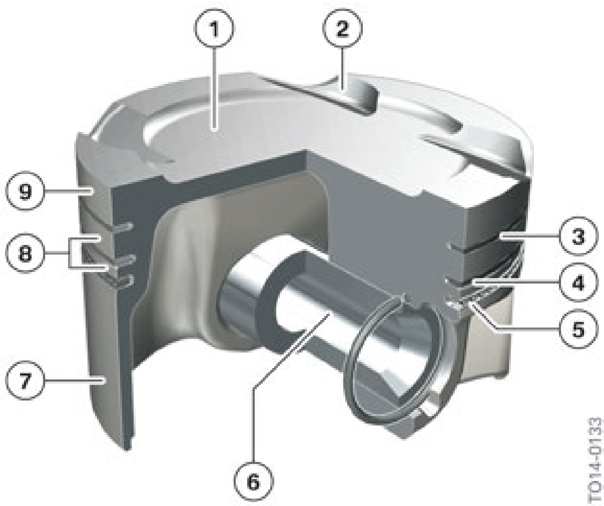
Index	Explanation
1	Irox-coated bearing shell
2	Oil film
3	Irox-coating
4	Bearing shell
5	Binding resin
6	Hard particle
7	Solid lubricant

The Irox-coating is applied to a conventional bearing shell. It consists of a binding resin matrix made of polyamide-imide with embedded hard particles and solid lubricants. The polyamide-imide ensures, in combination with the hard particles, that the bearing shell surface is so hard that material loss is no longer possible. The solid lubricants reduce surface friction and replace the oil film which briefly no longer exists between the bearing shell and the connecting rod bearing journal during the starting phase.

Bearing shell classification of connecting rod bearing

The connecting rod bearing shells are available in one standard size. It is therefore not necessary to follow a procedure similar to that used with the main bearing shells of the crankshaft.

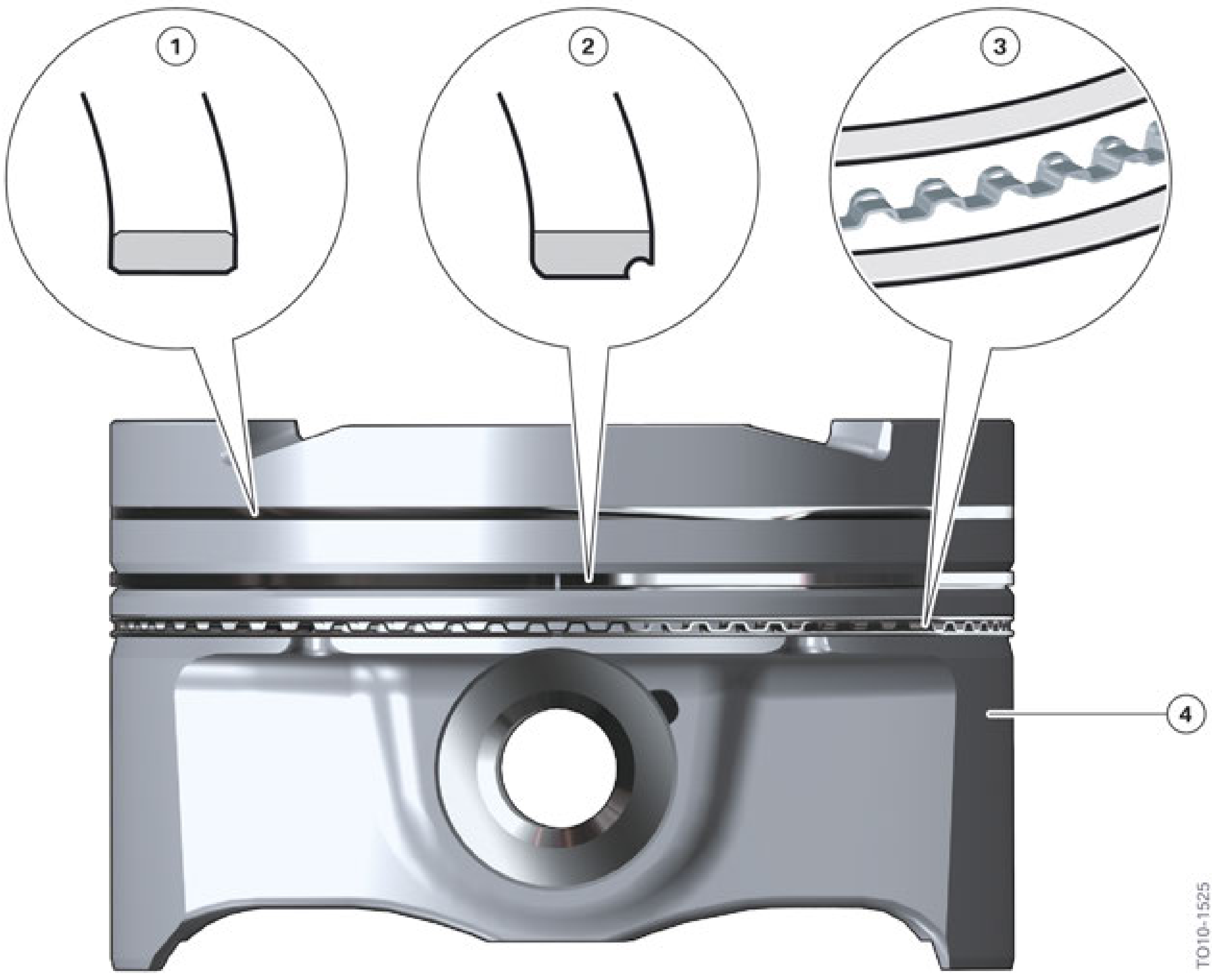
2.2.3. Piston



Piston of B38 engine

Index	Explanation
1	Piston crown
2	Valve relief
3	1st piston ring
4	2nd piston ring
5	3rd piston ring
6	Wrist pin
7	Piston skirt
8	Ring bar
9	Fire land

Piston rings



Piston rings of B38 engine

Index	Explanation
1	Plain compression ring
2	Stepped compression ring
3	Oil scraper ring
4	Piston

To perform their functions, it is necessary for the piston rings to touch the cylinder wall and the edge of the piston groove. Contact with the cylinder wall is effected by the radially acting spring force of the ring. The oil scraper ring is supported by an additional ring.

The piston rings rotate in the grooves while the engine is running and thereby alter the position of the gap. This stems from the lateral force which acts on the piston rings during change of contact.
This process removes deposits from the ring grooves. It also prevents the piston ring gap from cutting into the cylinder barrel.

The B38 engine has two compression rings and one oil scraper ring.

The plain rectangular compression ring sits in the first piston ring groove and is used as a plain compression ring.

The taper faced piston ring is also a compression ring. A sharp wiper edge develops through the lug for controlling the oil supply. The undercut of the lug implies that the oil scraped from the running edge is diverted and an oil blockage does not form there, which would otherwise reduce the scraping effect.

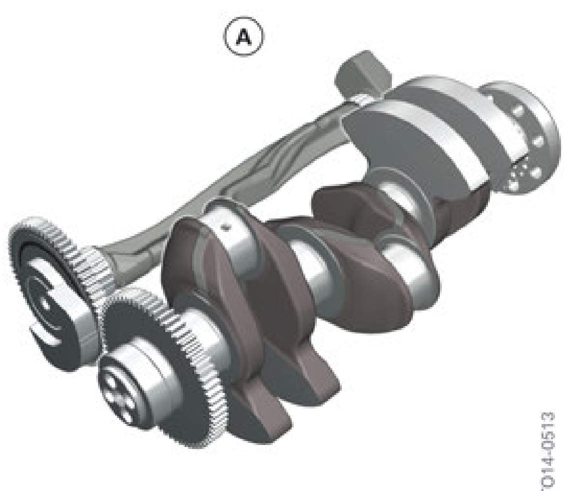
The oil scraper ring is a steel band ring with spring. The two lands and in particular the chamfer create a high surface contact pressure, which promotes the oil-scraping effect.

⚠

The plain rectangular compression ring and the taper faced piston ring have a Top mark. When installing the two piston rings the Top mark must be facing in the direction of the piston crown.

2.2.4. Counterbalance shafts

Due to the operating principle of the piston engine, undesired oscillations occur at the engine housing when driving, which can be transmitted to the vehicle interior. To counteract this negative effect counterbalance shafts in are installed. Their role is to cancel out free inertia forces and therefore increase ride comfort. In addition to the inertia forces, so-called 'free moments of inertia' also exist, which can also adversely effect ride comfort. Varying degrees of free inertia forces and free moments of inertia occur.

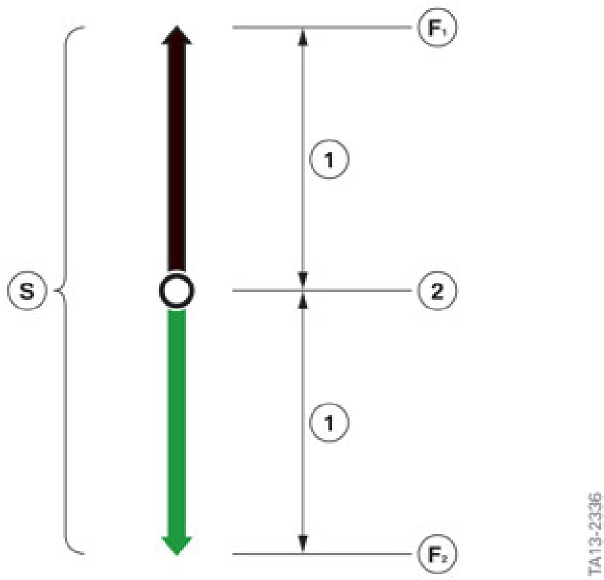


Counterbalance shaft system of the B38 engine

Index	Explanation
A	Counterbalance shaft for the reduction of free inertia torques in the B38 engine

The mass balance is used to offset structural imbalances. The task of the mass balance is to improve the running and noise characteristics of the engine, by neutralizing the free inertia forces and torques. For this reason a brief description of the special features of forces and torques is provided below.

Forces



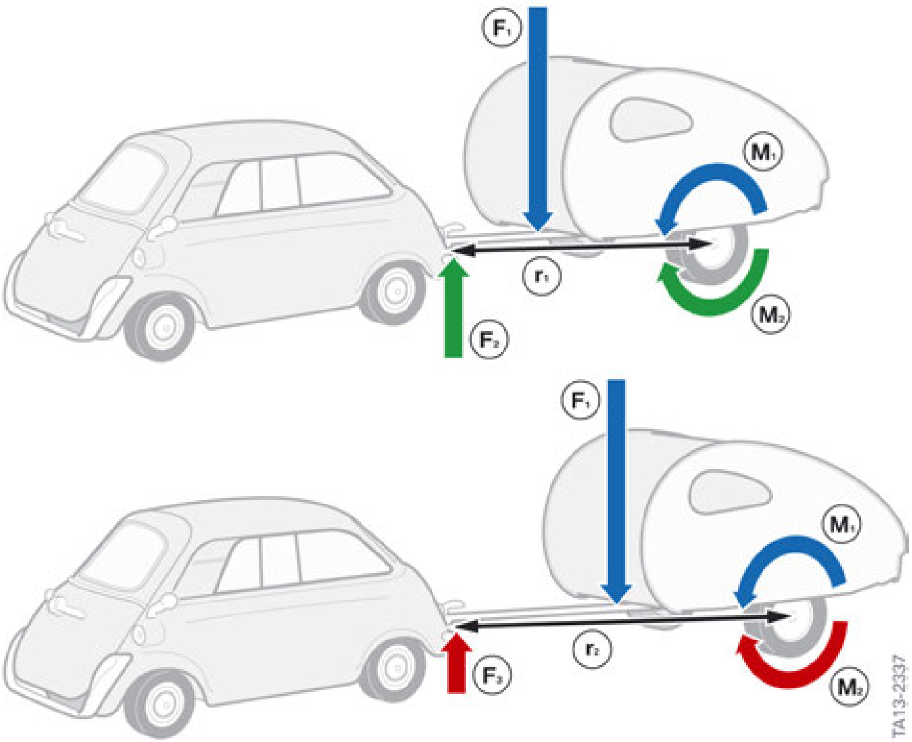
Static force

Index	Explanation
F_1	First force with upwards operating direction
F_2	Second force with downwards operating direction
S	Static
1	Intensity of force
2	Point of action

Forces are invisible and can only be noticed by their effects. They consist of a point of action and an operating direction. Their state can be dynamic or static. The forces are shown as an arrow (vector). The arrowhead provides information on the operating direction of the force. At the other end of the arrow (vector), opposite the arrowhead, is the point of action. The intensity of the force is determined by the arrow length (vector length). The physical unit of force is [N] and the symbol is [F].

The previous graphic shows two forces acting in exactly opposite directions with the same intensity. The system is balanced (static) as both forces cancel each other. When observed from the outside, a reaction cannot be determined.

Torques



Static torque

Index	Explanation
F_1	Contact force [F]
F_2	Large counterforce [F]
F_3	Small counterforce [F]
M_1	Contact torque [M]
M_2	Counter-torque [M]
r_1	Small lever arm [r]
r_2	Large lever arm [r]

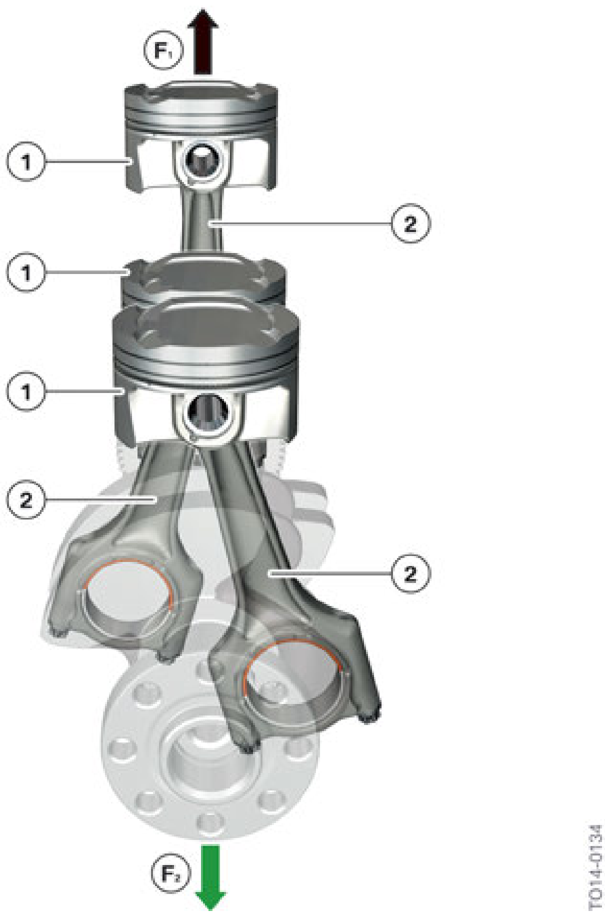
Torques occur if a force is transmitted at its point of action via a lever arm. The physical unit of torque is [Nm] and its symbol is [M]. The lever arm and the force acting at the point of action are decisive for the size of the torque. The following mathematical context emerges:

- $M = F \cdot r$

The previous graphic shows two torques which cancel each other out. If the contact force is increased, without increasing the counterforce to the same degree, the two torques are no longer at equilibrium. The pendant would fall to the floor. To re-establish the static equilibrium of the system, either the counterforce has to be increased or the lever arm extended at which the counterforce acts.

Oscillating and rotating forces

The upwards and downwards movement of the pistons, as well as the connecting rods, is called an oscillating force and the rotational movement of the crankshaft is called a rotating force. These two different forces also cause the undesired oscillations when the engine is running.



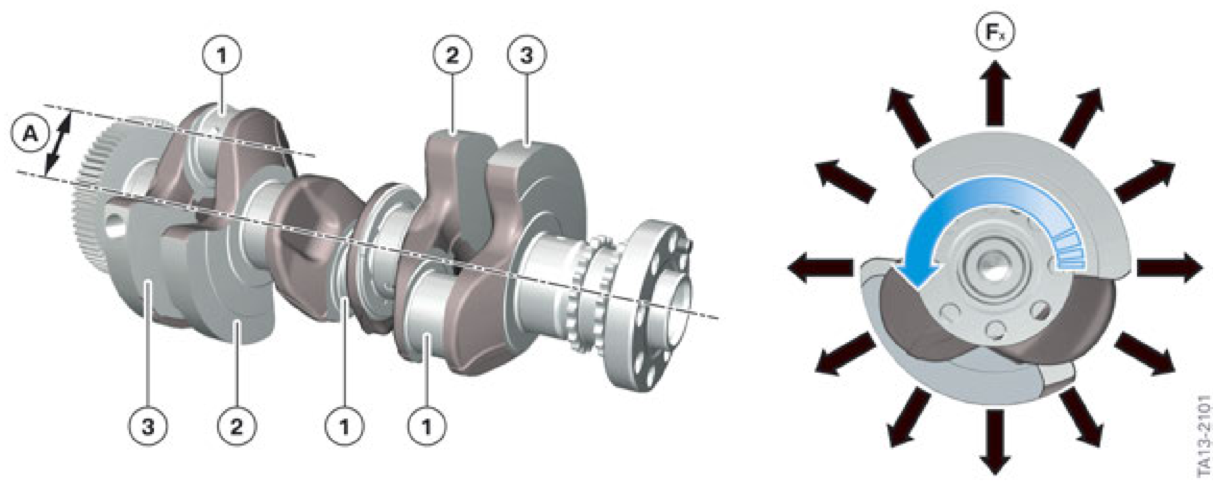
Oscillating forces in the B38 engine

Index	Explanation
F_1	Force directed upwards
F_2	Force directed downwards
1	Piston
2	Connecting rod

Oscillating forces occur in the piston engine when the direction changes at bottom and top dead center. Due to the inertia of the piston and the connecting rod, the force is directed either upwards or downwards. The following therefore applies: the lower the mass of the piston and the connecting rod, the lower the corresponding oscillating forces will be.

2. Engine Mechanics

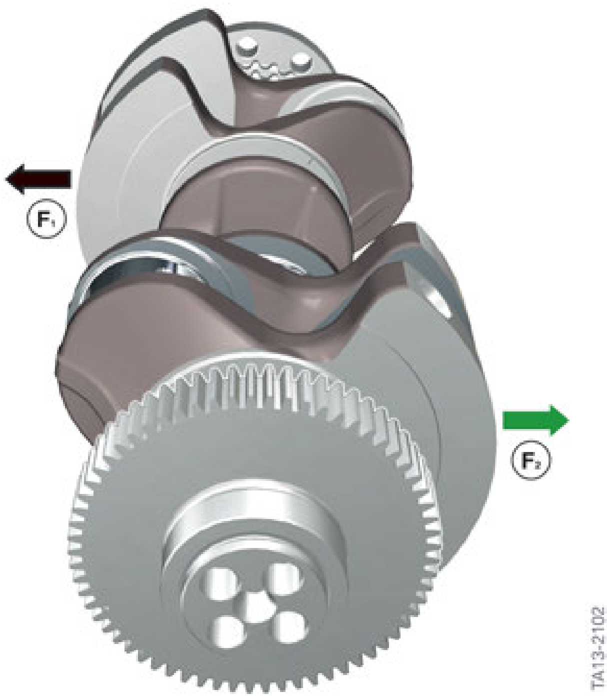
In order to reduce the fuel consumption according to the EfficientDynamics strategy, the power output per liter is increased. Through the use of exhaust turbochargers more power is obtained from the same displacement. This means the pistons and the connecting rod are exposed to higher ignition pressures and must have a more solid design. The masses of the components subsequently increase, and thus the oscillating forces.



Rotating forces in the B38 engine

Index	Explanation
A	Piston stroke (offset of connecting rod bearing journal)
F_x	Rotating forces
1	Connecting rod bearing journal
2 + 3	Counterweights

To produce a rotating movement of the crankshaft from the stroke of the piston, the connecting rod bearing journals that support the large connecting rod eye are not located on the axis of rotation of the crankshaft. An imbalance when turning the crankshaft occurs by the offset of the connecting rod bearing journals. The arising imbalance is counteracted by the use of counterweights.



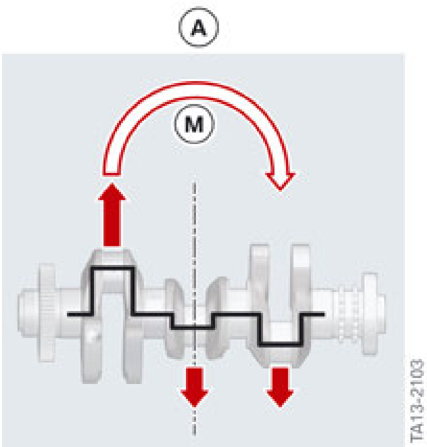
Counterweights of crankshaft of B38 engine

Index	Explanation
F_1	Force of the crankshaft weight directed to the left
F_2	Force of the crankshaft weight directed to the right

The rotating inertia forces can be completely neutralized with help of the counterweights at the crankshaft. Some of the weight at the crankshaft is also used to reduce the oscillating inertia forces (change of direction of the piston and connecting rod). If the entire oscillating inertia forces are reduced by counterweights at the crankshaft, the forces or torques in the top and bottom dead center of the pistons are neutralized. However, this would also mean that in the piston intermediate position (piston between top dead center and bottom dead center) the inertia forces of the counterweights work in a lateral direction. The result would be vibrations which are transmitted via the crankshaft bearing to the crankcase and finally to the entire vehicle.

This conflict can be resolved through the use of counterbalance shafts, as well as clever weight classification of the counterweights at the crankshaft.

Oscillating torques



Oscillating torques

Index	Explanation
A	3-cylinder engine
M	Torque

This example shows why the design plays a role in which forces or torques occur during engine operation.

With the 3-cylinder engine, a free moment of inertia occurs at the crankshaft due to the positions of the connecting rod bearing journals when the engine is running. This torque is absorbed via the crankshaft bearing and transmitted at the crankcase. Unpleasant vibrations are caused at the vehicle.

Order

The inertia forces are divided into "orders". The more frequently an inertia force occurs during each crankshaft revolution (360°), the greater its order of magnitude will be.

The free inertial forces and torques categorized as follows:

- Inertia forces, 1st order
- Inertia forces, 2nd order
- Inertia torques, 1st order
- Inertia torques, 2nd order

The following table provides an overview of the arising forces and torques depending on the design and number of cylinders:

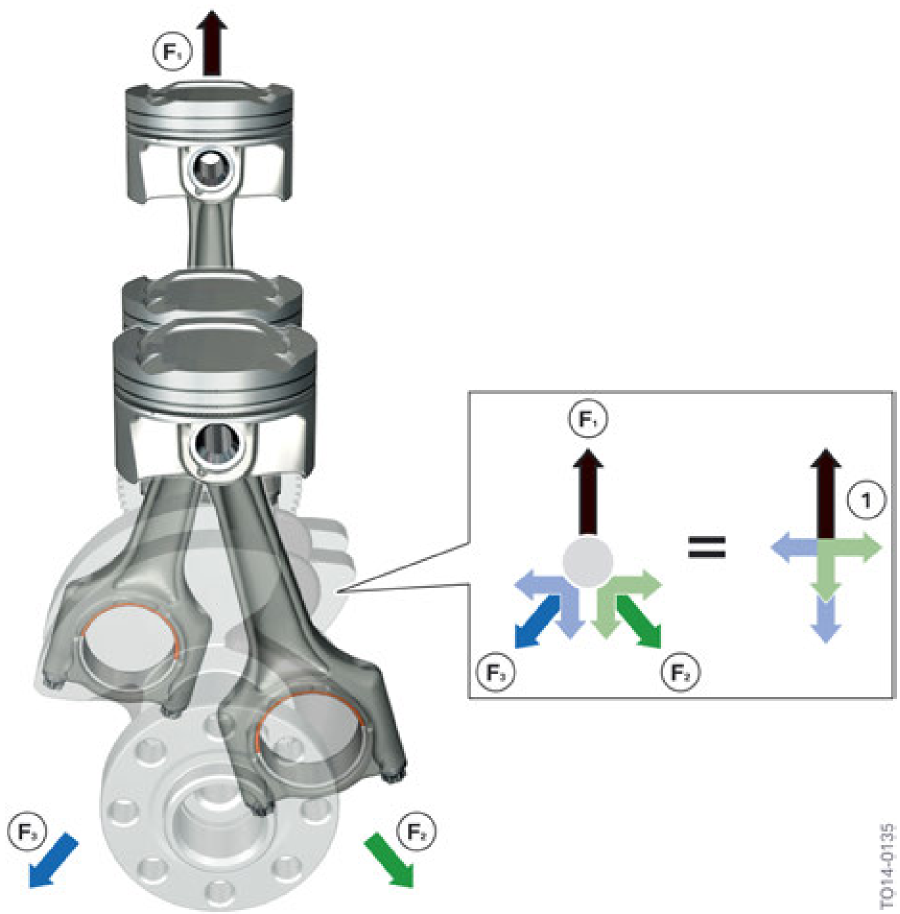
	Inertia forces, 1st order	**Inertia forces, 2nd order**	**Inertia torques, 1st order**	**Inertia torques, 2nd order**
3-cylinder in-line engine	—	—	X	X
6-cylinder in-line engine	—	—	—	—

The table provides information on which forces and torques occur and their order of magnitude. Free inertial forces and moments of inertia of the first order are the most noticeable. Free inertia forces and moments of inertia of the second order are perceived is much less troublesome. The greater the order of magnitude is therefore, the more it can be disregarded for the purposes of mass balancing.

The table shows that the best engine design in terms of smooth running is the 6-cylinder in-line engine. All forces cancel each other out. Therefore, with this engine design no additional measures for neutralizing the rotating or oscillating masses have to be implemented.

2.2.5. Counterbalance shafts of B38 engine

As the table shows, no free inertia forces occur in the 3-cylinder in-line engine. The following graphic demonstrates the reason for this

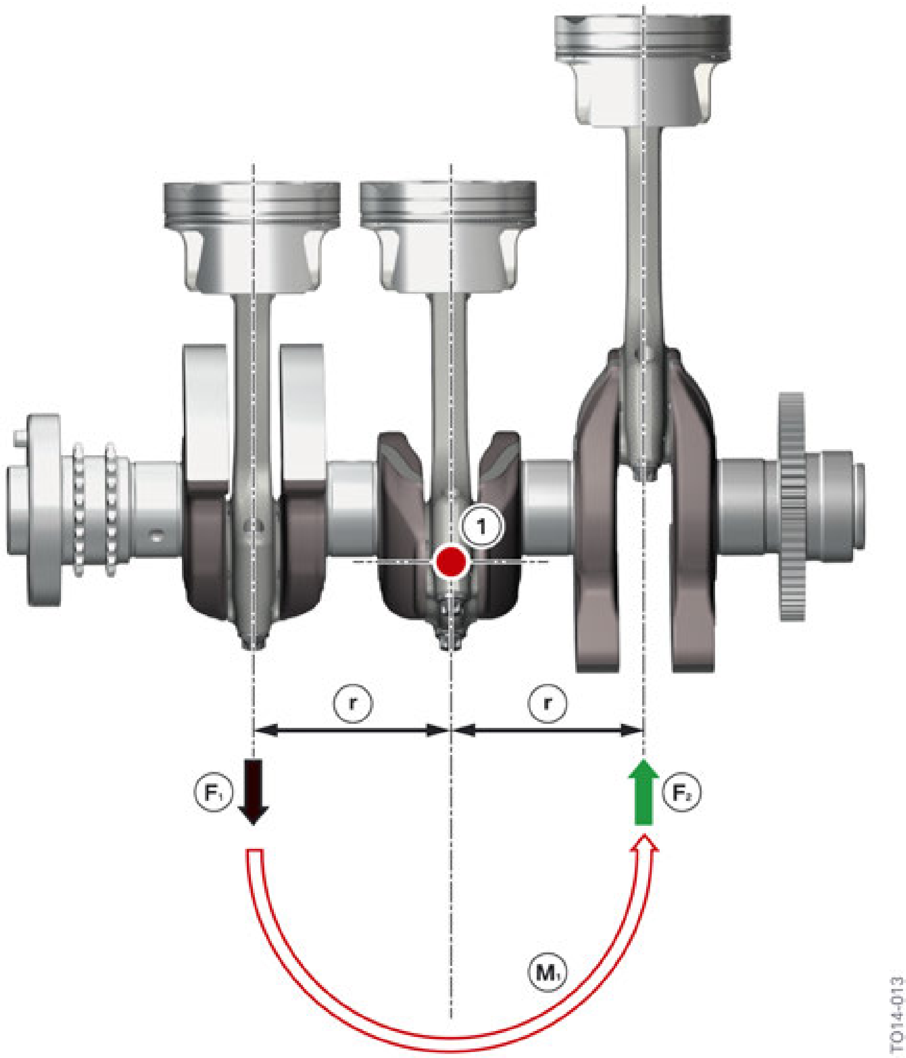


Inertia forces in B38 engine

Index	Explanation
F_1	Oscillating and rotating inertia force with operating direction 0° crank angle
F_2	Oscillating and rotating inertia force with operating direction 120° crank angle
F_3	Oscillating and rotating inertia force with operating direction 240° crank angle
1	Inertia forces in equilibrium (static)

Due to the uniform arrangement of the connecting rod bearing journals at a distance of 120° crankshaft angle, all forces occurring in the various operating directions at the crankshaft cancel each other out. The crankshaft is thus in equilibrium (static) when examined from the front.

If the crankshaft is examined from the side, the following schematic diagram of various forces arises:

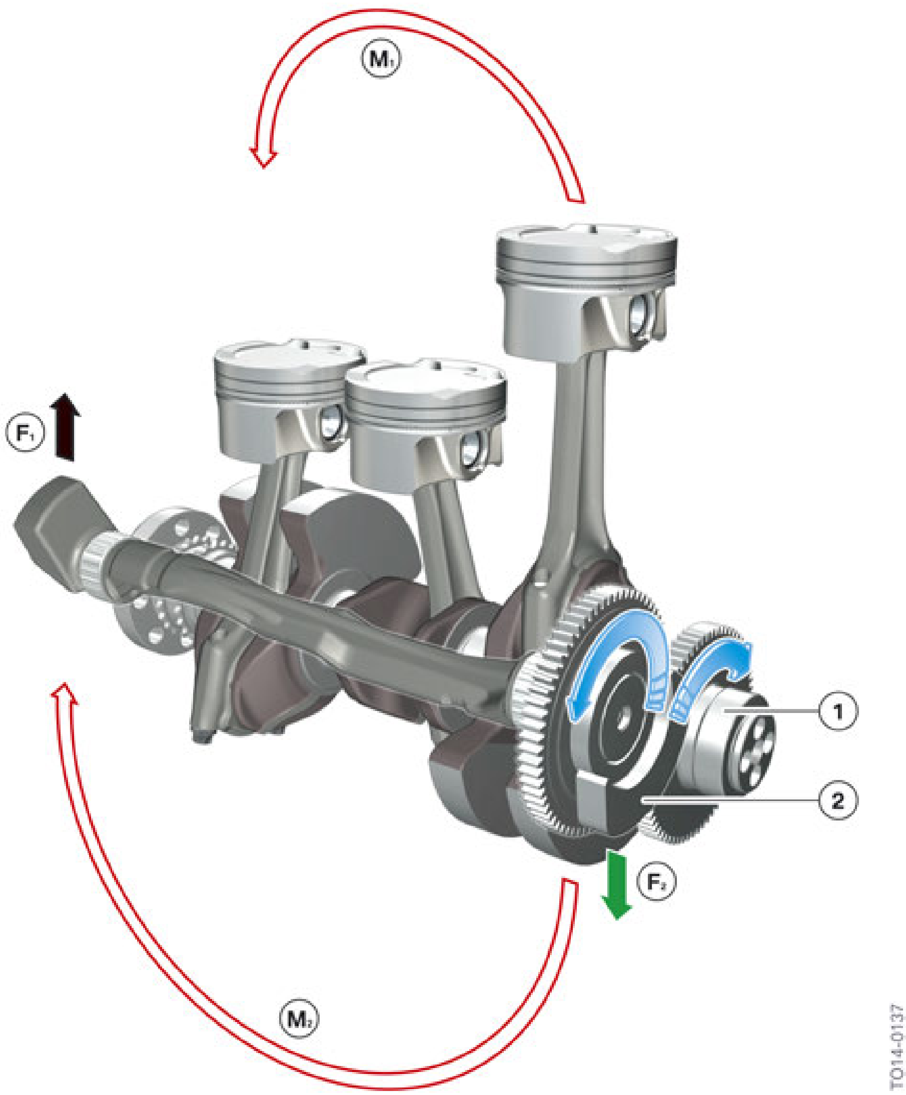


Side view, free inertia torques in B38 engine

Index	Explanation
F_1	Force directed downwards
F_2	Force directed upwards
M_1	Torque
r	Lever length
1	Torque-neutral point

Due to the positions of the connecting rod bearing journals in the B38 engine, free moments of inertia of the 1st and 2nd order occur.

As the effects of the free moments of inertia of the 1st order are more intensive than the 2nd order, in the B38 engine the priority is to neutralize the free inertia torques of the 1st order.

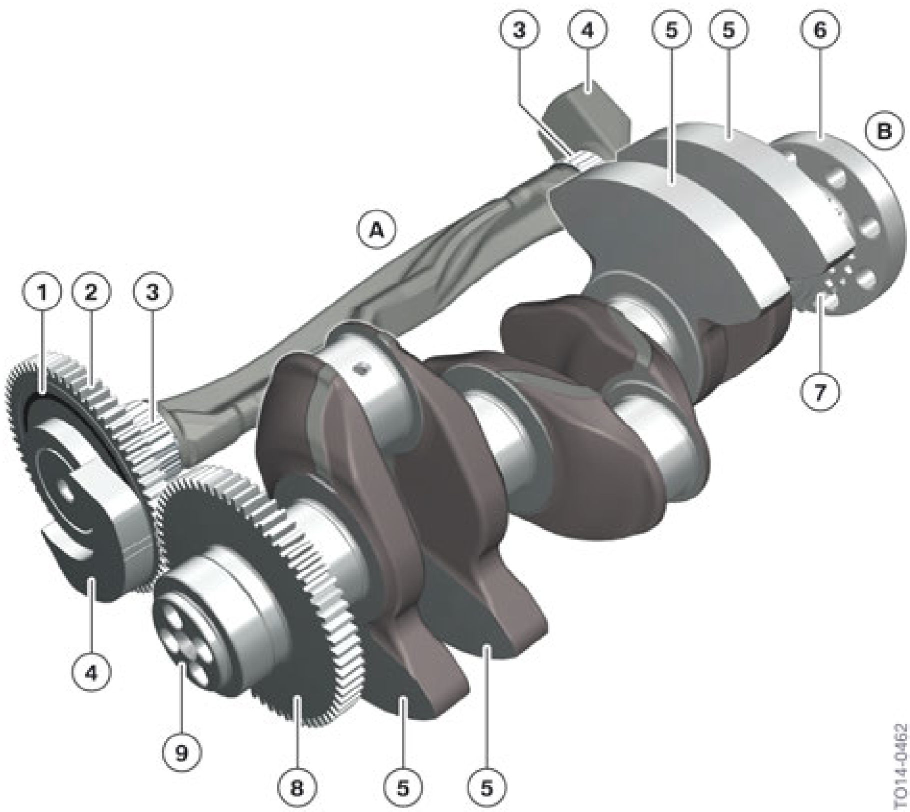


Side view of operating principle of counterbalance shaft in B38 engine

Index	Explanation
1	Crankshaft
2	Counterbalance shaft
F_1	Force of counterbalance shaft directed upwards
F_2	Force of counterbalance shaft directed downwards
M_1	Torque at the crankshaft
M_2	Counter-torque at the counterbalance shaft

2. Engine Mechanics

A counterbalance shaft, which rotates at engine speed, is used. The two weights of the counterbalance shaft are located at the outer sides of the counterbalance shaft in order to generate a high counter-torque with the least possible weight. The radial support is provided by two needle bearings. Lubrication is provided by the oil spray from the crankcase.



Overview of counterbalance shaft, B38 engine

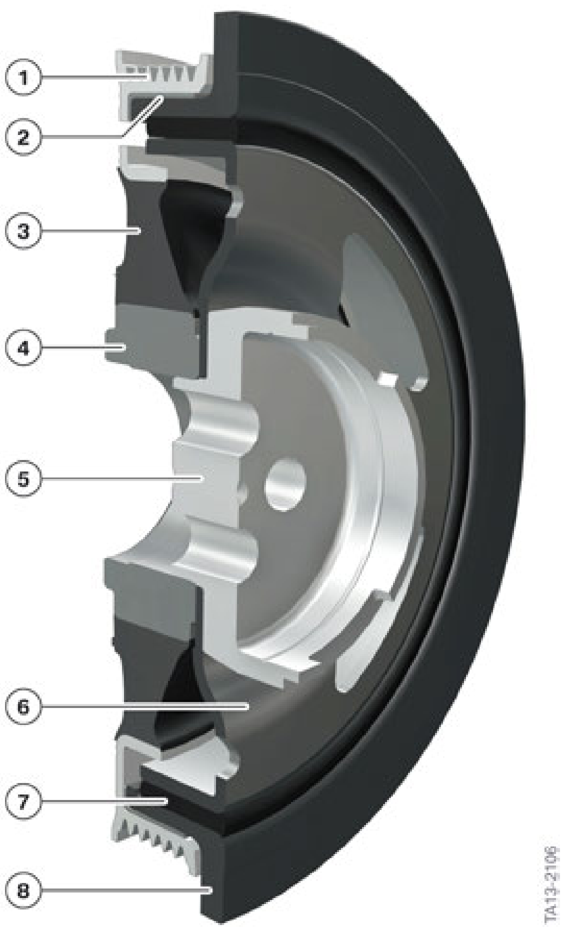
Index	Explanation
A	Counterbalance shaft
B	Crankshaft
1	Vulcanization
2	Straight tooth gearing
3	Needle bearing
4	Counterbalance shaft weights
5	Crankshaft weights
6	Output flange on transmission side
7	Output pinion, timing chain/drive chain, oil pump
8	Output drive gear, crankshaft
9	Crankshaft flange on belt side

The running noise produced, due to the tooth backlash which is required for the straight tooth gearing, is attenuated by the vulcanized gear of the counterbalance shaft.

2.2.6. Torsional vibration damper

A torsional vibration damper is used on the belt drive of B38 engine. The torsional vibration damper assumes the following tasks:

- Reduction of the torsional oscillations of the crankshaft.
- Reduction of the rotational deformity of the ancillary components.



Variant of a torsional vibration damper, B38 engine

Index	Explanation
1	Belt pulley
2	Plain bearing
3	Belt pulley rubber isolation element
4	Uncoupled belt pulley hub
5	Pressure hub
6	Vibration damper hub
7	Vibration damper rubber part
8	Flywheel

Vibration damper

The vibration damper comprises a hub, a rubber element, which acts as a spring, and a flywheel, which serves as weight. The rotary oscillations of the crankshaft are reduced by the combined action of the spring and mass element. This reduces the load of the crankshaft and the noises emitted by the engine.

Uncoupled belt pulley

The uncoupled belt pulley is important for smooth low-wear drive of auxiliary components.
The belt pulley is uncoupled from the hub by the rubber isolation element. The rubber isolation element permits greater rotation, and reduces the remaining rotational imbalance and thereby the load on the drive belt. The belt pulley is supported by the plain bearing.

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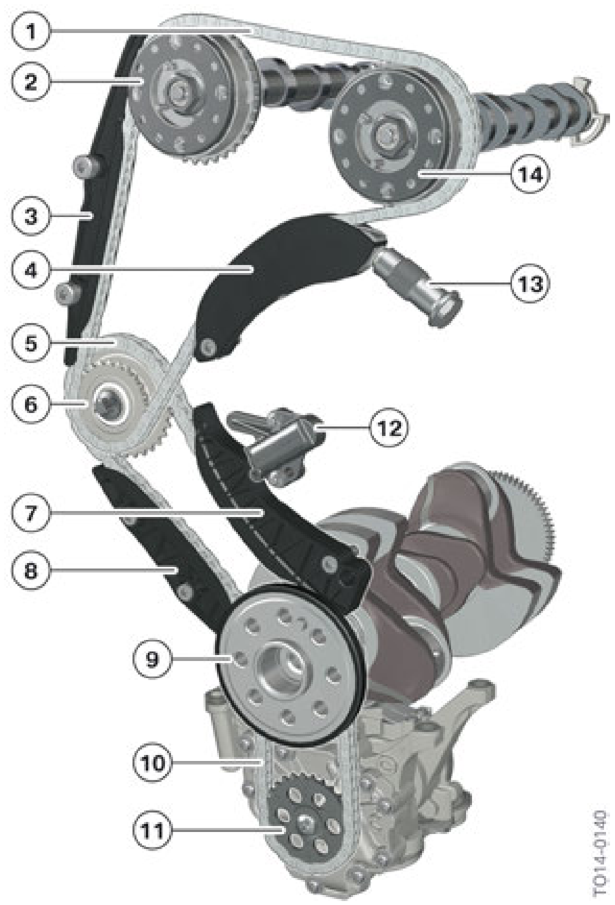
To avoid damage to the torsional vibration damper, the engine must not be operated without drive belts.

2.2.7. Chain drive

Features:

- Chain drive at the side of the engine emitting the forces.
- Two-part chain drive for drive of camshafts.
- Simple sleeve-type chains.
- Electric motor of the combined oil-vacuum pump via a separate chain.
- Plastic tensioning rails and guide rails.
- Hydraulic chain tensioner with spring preload.



Chain drive, B38 engine

Index	Explanation
1	Upper timing chain
2	VANOS with intake camshaft sprocket
3	Upper guide rail
4	Top tensioning rail
5	Lower timing chain
6	Camshaft sprocket, intermediate shaft
7	Bottom tensioning rail
8	Lower guide rail
9	Crankshaft
10	Chain oil-vacuum pump
11	Oil-vacuum pump camshaft sprocket
12	Lower chain tensioner
13	Upper chain tensioner
14	VANOS with exhaust camshaft sprocket

The chain drive is on the transmission side. The inertia of the transmission at this engine end significantly reduces the rotary oscillations and also therefore the loads acting on the chain drive.

The B38 engine is equipped with a two-part chain drive. With this arrangement, the bottom timing chain drives the camshaft sprocket of the intermediate shaft. The drive torque is simply diverted to the top timing chain via the intermediate shaft.

Sufficient lubrication of the bottom timing chain is ensured by the oil mist in the crankcase and the engine oil that drips off.

In the B38 engine, the combined oil-vacuum pump is also driven by the crankshaft via a separate drive chain.

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The screw connection of the oil and vacuum pump camshaft sprocket has a left-hand thread.

Lubrication of top chain drive

Lubrication of top chain drive, B38 engine

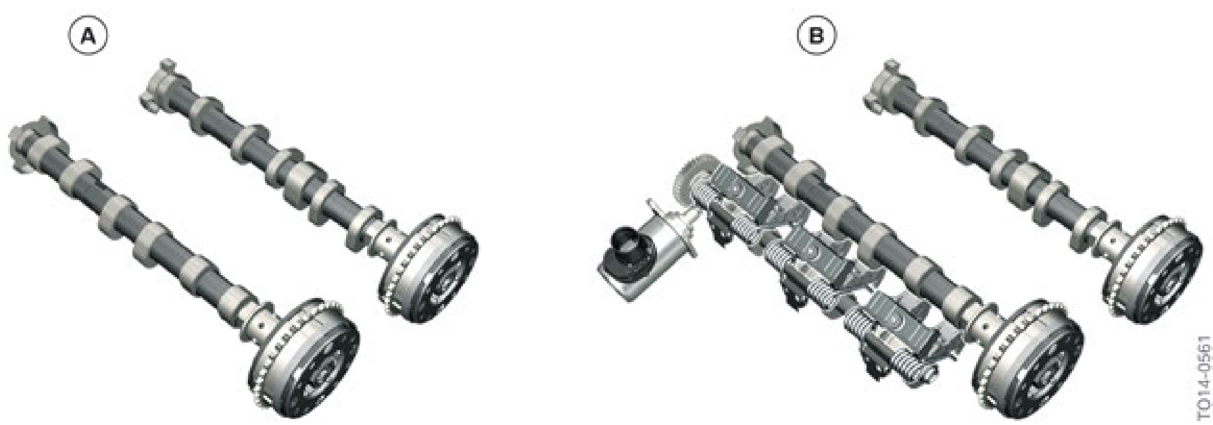
Index	Explanation
1	Upper guide rail
2	Top tensioning rail
3	Upper timing chain
4	Top chain tensioner with oil spray nozzle
5	Spray pattern

The timing chain is always tensioned on the unloaded side. This is performed by a tensioning rail on which a chain tensioner acts. The upper timing chain is lubricated by an oil spray nozzle in the top chain tensioner. There is an opening in the tensioning rail to ensure that oil reaches the top timing chain.

2.3. Valve gear

2.3.1. Variants

Two different technologies are used in the area of the valve gear.



Valve gear, B38 engine.

Index	Explanation
A	VANOS
B	Valvetronic

The following table provides an overview of the technology used in the different engines:

Engine	VANOS	Valvetronic
B38K15T0	YES	YES

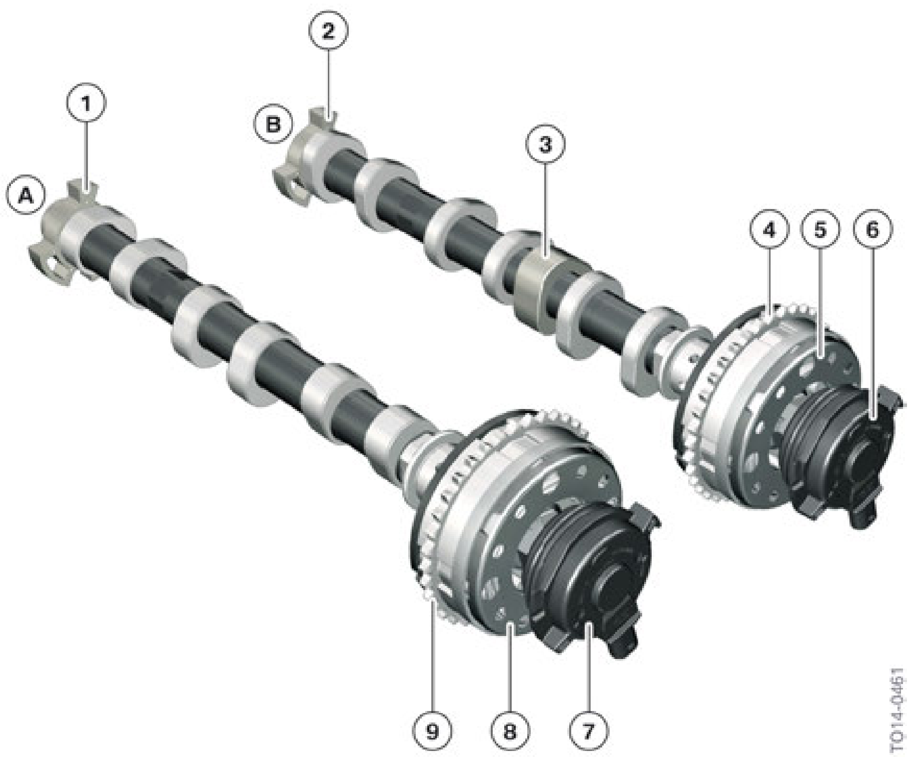
2.3.2. VANOS

The valve overlap times have a significant impact on the characteristics of a gasoline engine.

An engine with smaller valve overlap therefore tends to have a high maximum torque at low engine speeds but the maximum power which can be achieved at high engine speeds is low. The maximum power achieved with a large valve overlap on the other hand is higher, but this is at the expense of the torque at low engine speeds.

The VANOS provides a solution. It makes a high torque possible in the low and medium engine speed range and a high maximum power in the higher engine speed ranges. A further benefit of the VANOS is the option of internal EGR. This reduces the emission of harmful nitrogen oxides NOx, particularly in the partial load range. The following is also achieved:

- Faster heating up of catalytic converter
- Lower pollutant emissions during cold start
- Reduction in consumption.



Double VANOS, B38 engine

Index	Explanation
A	Intake camshaft
B	Exhaust camshaft
1	Increment wheel, intake camshaft
2	Increment wheel, exhaust camshaft
3	Triple cam for high pressure pump drive system
4	Exhaust camshaft sprocket
5	VANOS unit, exhaust side

Index	Explanation
6	VANOS solenoid valve actuator, exhaust
7	VANOS solenoid valve actuator, intake
8	VANOS unit, intake side
9	Intake camshaft sprocket

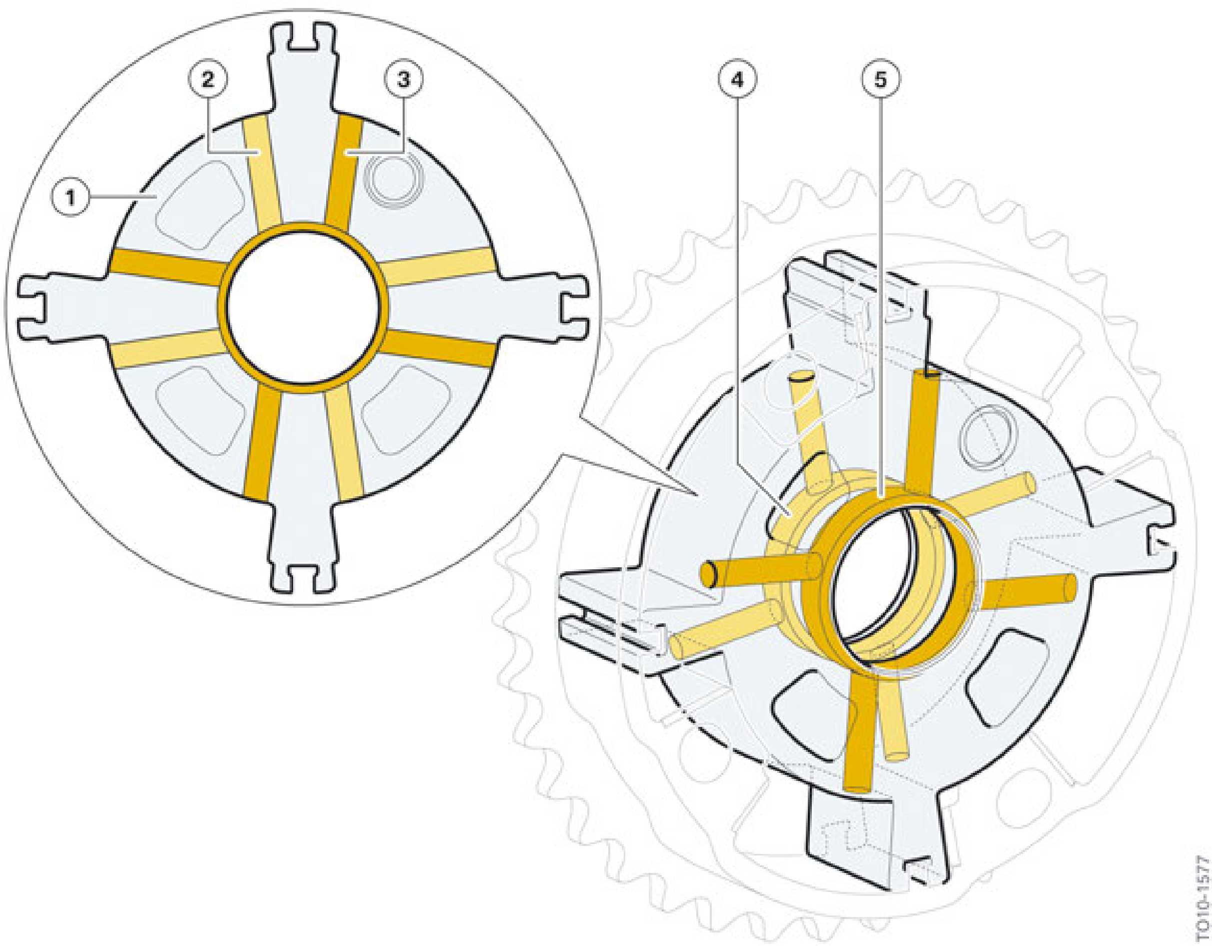
Reason for using VANOS and Valvetronic

The advantages of a Valvetronic are lower charge cycle losses and therefore potential for reducing fuel consumption by adopting an appropriate driving style. However, in contrast to throttle valve-controlled systems, Valvetronic cannot reduce charge-cycle losses in the full load range.

VANOS unit

The oil ducts in the cylinder head are reduced and the adjustment speed is increased by using a VANOS solenoid valve unit and a mechanical VANOS central valve, which is located inside the VANOS unit.

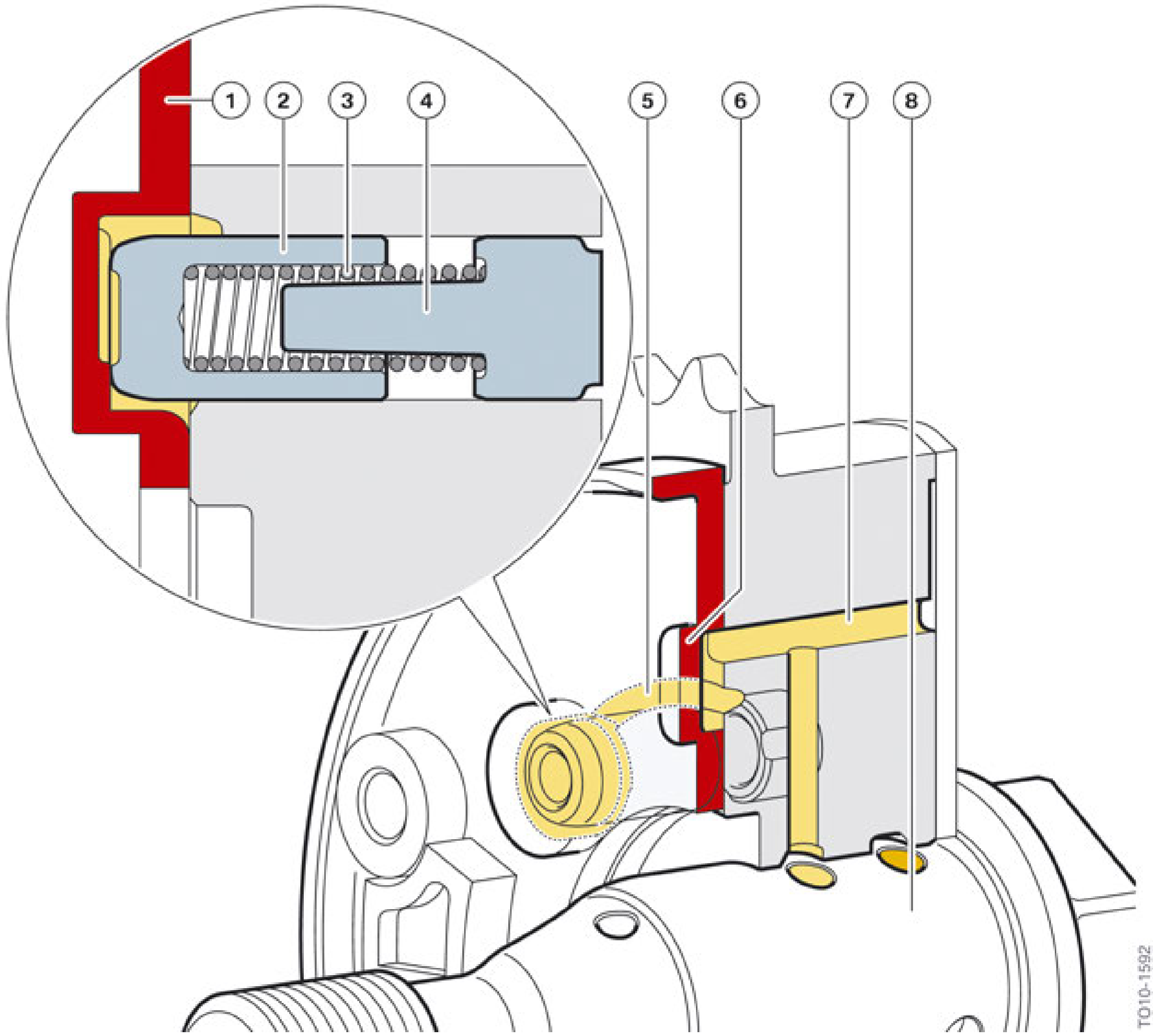
The following graphic shows the oil ducts in the VANOS unit:



VANOS unit, intake camshaft, B38 engine

Index	Explanation
1	Rotor
2	Oil duct for timing advance
3	Oil duct for timing retardation
4	Oil duct for timing advance
5	Oil duct for timing retardation

The intake camshaft can be “advanced” with the ducts shaded light yellow; the VANOS unit can be “retarded” with the ducts shaded dark yellow.

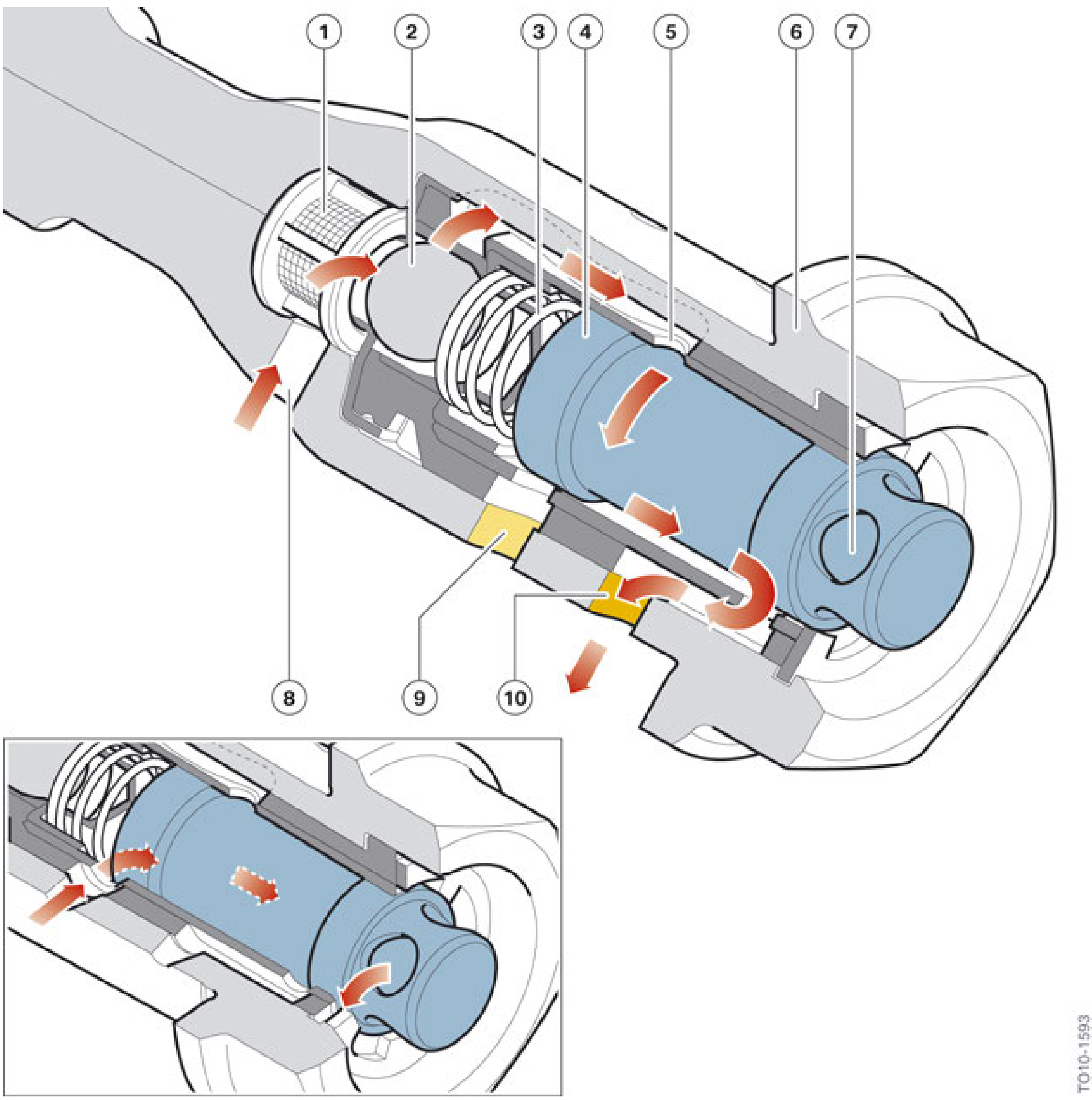


Locking pin, B38 engine

Index	Explanation
1	Locking cover
2	Locking pin
3	Locking spring
4	Cartridge
5	Oil duct
6	Locking cover
7	Oil duct
8	VANOS central valve

The locking pin ensures that the VANOS unit adopts a clear, locked position in the depressurized state. The locking spring ensures the unit is locked by continuously pushing the locking pin into the locked position when the actuator is de-energized. The VANOS unit is blocked in this condition. The timing can be adjusted in this way. This is important when the engine is started to ensure exact timing. The oil pressure which is present for timing advance simultaneously unlocks the locking pin via oil ducts in the VANOS unit. If the camshaft is to be “advanced”, the locking pin is then forced by the applied oil pressure against the locking spring towards the cartridge and the locking cover is released for VANOS adjustment.

The following graphic shows the oil flow rate in the VANOS central valve which is used to control the camshaft adjustment:



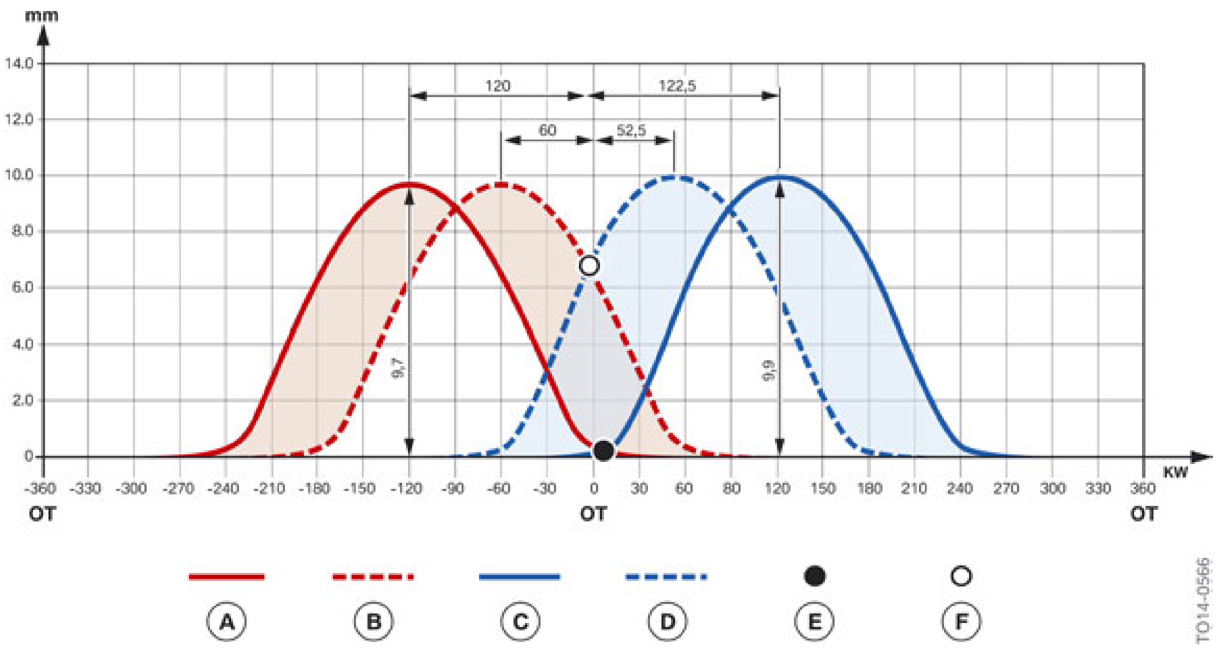
VANOS central valve, intake camshaft, B38 engine

Index	Explanation
1	Filter
2	Ball
3	Spring
4	Piston
5	Sleeve
6	Housing
7	Opening in plunger
8	Oil supply from main oil duct
9	Bore to oil duct in VANOS (timing advance)
10	Bore to oil duct in VANOS (timing retardation)

The VANOS unit is secured to the camshaft by the VANOS central valve. The oil flow into the VANOS unit is simultaneously controlled by this VANOS central valve. The system is actuated by a solenoid actuator with its own piston that pushes on and displaces the piston of the VANOS central valve. The oil flow is controlled by means of the plunger.

The previous graphic shows the de-energized VANOS central valve. The locking pin blocks the VANOS unit.

Timing diagram



Variable valve overlap, B38 engine

Index	Explanation
1	valve travel
2	Spread, exhaust camshaft
3	Spread, intake camshaft
4	Degree crankshaft
A	VANOS solenoid valve, exhaust, de-energized
B	VANOS solenoid valve, exhaust, duty cycle 100%
C	VANOS solenoid valve, inlet, de-energized
D	VANOS solenoid valve, inlet, duty cycle 100%
E	Smallest valve overlap in idle
F	Maximum valve overlap in partial load

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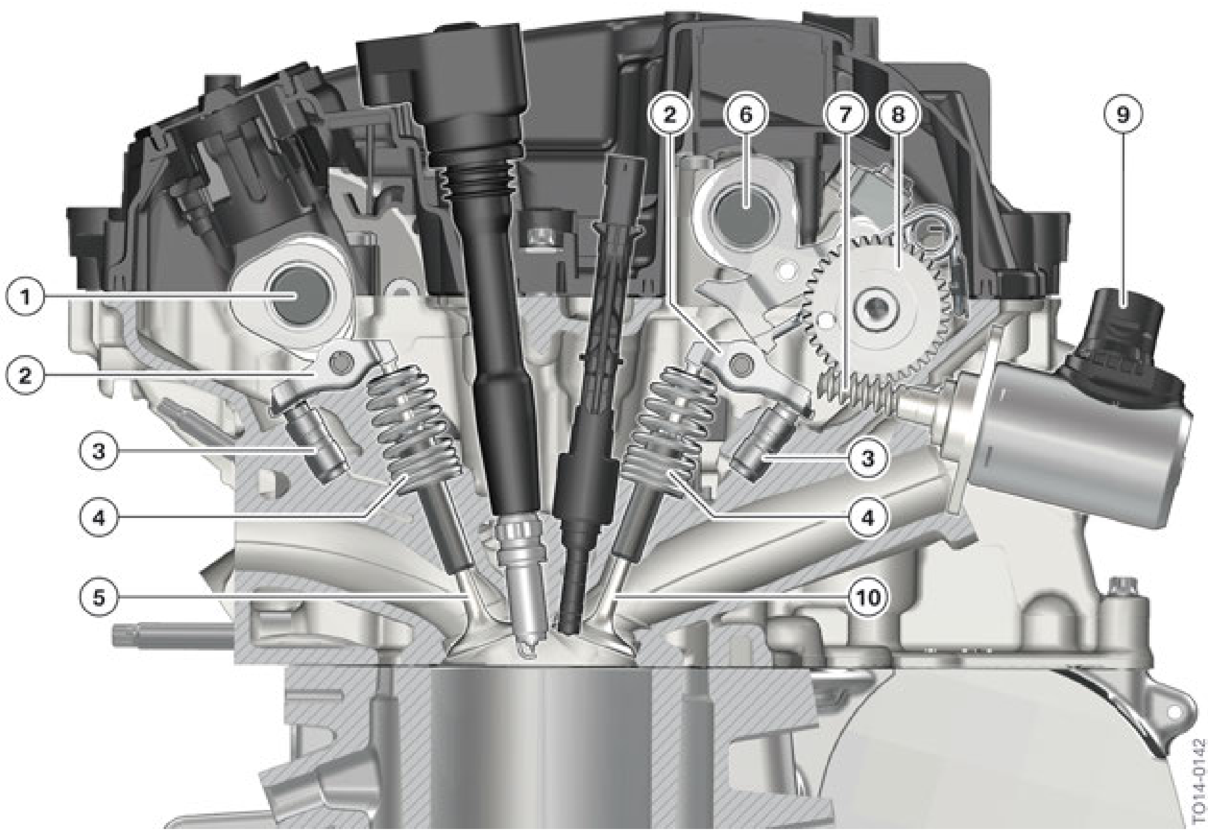
The following is to be expected if the VANOS unit drops out:

- Emergency operation
- Fault code entry in the Digital Engine Electronics (DME)

2.3.3. Valvetronic

The Valvetronic has been further developed for use in the new B38 engine. The fourth-generation Valvetronic is used in both engine variants. A distinguishing feature is the Valvetronic servomotor which is visible from the outside.

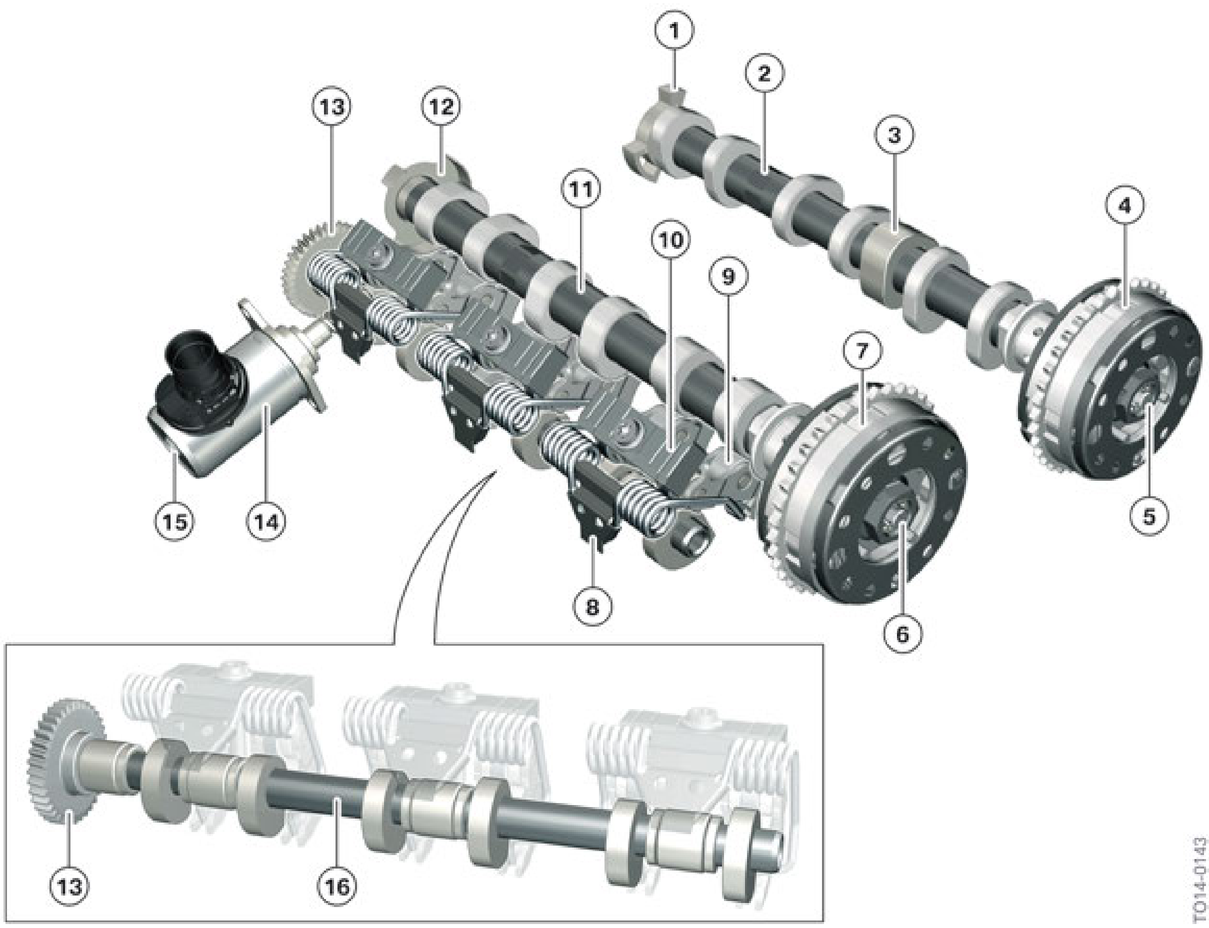


Valvetronic 4th generation, B38 engine

Index	Explanation
1	Exhaust camshaft
2	Roller cam follower
3	Hydraulic valve clearance compensation element
4	Valve spring
5	Exhaust valve
6	Intake camshaft
7	Worm gear
8	Eccentric shaft
9	Electrical connection, Valvetronic servomotor
10	Intake valve

The Valvetronic comprises a fully-variable valve lift control and a double VANOS. It operates according to the principle of throttle-free load control. With this system, a throttle valve is only used to stabilize the engine operation at critical operating points and to ensure a slight vacuum for the engine ventilation. A very small vacuum can be produced in the intake pipe by slightly tilting the throttle valve, which allows treated blow-by gases to be introduced into the intake port during naturally-aspirated engine operation.

The following graphic provides an overview of the design of the Valvetronic:



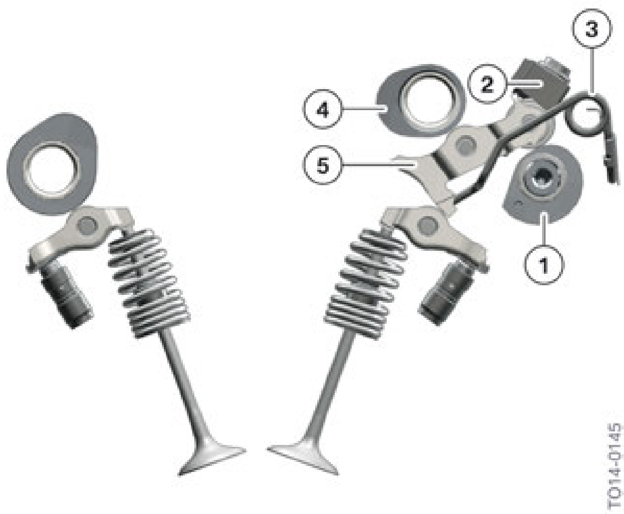
Valvetronic, B38 engine

Index	Explanation
1	Increment wheel, exhaust camshaft
2	Exhaust camshaft
3	Triple cam for high pressure pump drive system
4	VANOS unit with exhaust camshaft sprocket
5	VANOS central valve, exhaust side
6	VANOS central valve, intake side
7	VANOS unit with intake camshaft sprocket

Index	Explanation
8	Return spring with insert plate
9	Intermediate lever
10	Gate
11	Intake camshaft
12	Increment wheel, intake camshaft
13	Drive pinion, eccentric shaft
14	Valvetronic servomotor
15	Hexagon socket
16	Eccentric shaft

The following components of the Valvetronic are for use in the B38 engine:

- Assembled eccentric shaft
- Smaller worm gear ratio of 37:1
- Thinner lighter sliding blocks with only one screw connection
- Return spring inserted and not screwed
- Oil spray nozzle for lubrication of worm gear omitted
- Smaller more powerful Valvetronic servomotor

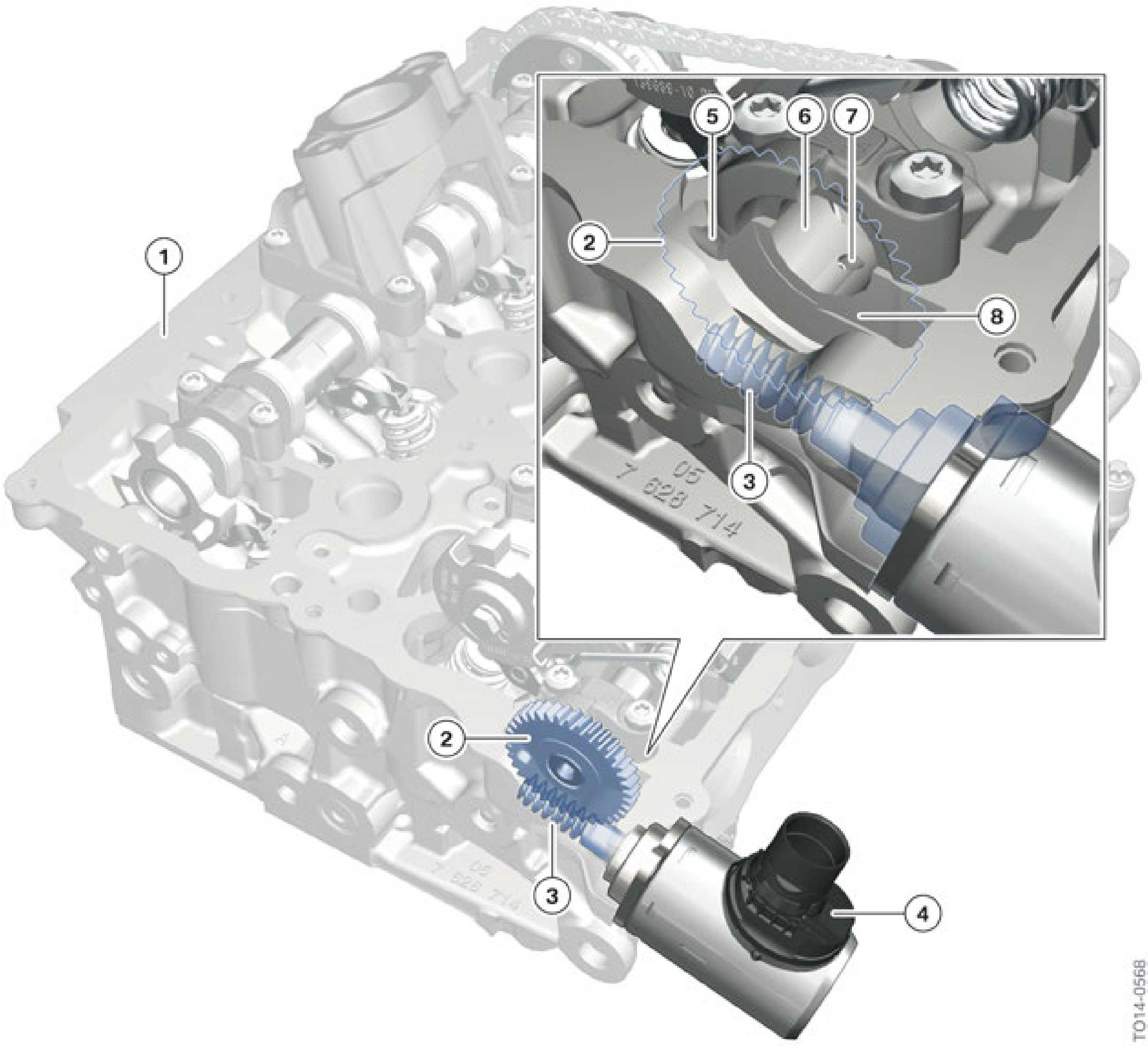


Valvetronic with B38 engine

Index	Explanation
1	Eccentric shaft
2	Gate
3	Return spring
4	Camshaft
5	Intermediate lever

By reworking the Valvetronic, it has, most importantly, been possible to significantly reduce the installation space. A considerable height advantage has been gained by swapping the intake camshaft and the eccentric shaft. The new position of the intermediate lever and gate simplifies the application of force in the cylinder head. The gate is therefore only attached to the bearing support with one screw and is positioned via two precise contact surfaces in the cylinder head. The return spring for the intermediate lever between the cylinder head and bearing position is self-supporting and does not require its own attachment point. The eccentric shaft is, as is already the case with the camshaft, an "assembled" design.

Lubricating oil supply to the Valvetronic worm gear



Lubricating oil supply to the Valvetronic worm gear, B38 engine

Index	Explanation
1	Cylinder head
2	Drive pinion of the eccentric shaft
3	Worm gear of Valvetronic servomotor
4	Valvetronic servomotor
5	Outlet bore hole
6	First bearing position of eccentric shaft
7	Inlet bore hole
8	Oil chamber

Due to the fast adjustment speeds of the eccentric shaft of less than 300 milliseconds from minimum to maximum stroke and the wide adjustment range from 0.2 millimeters (minimum) to 9.9 millimeters (maximum) valve lift with a small transmission ratio, sufficient lubrication between the worm gear of the Valvetronic servomotor and drive pinion of the eccentric shaft must be ensured. The lubricating oil reaches the oil chamber via an inlet bore hole at the first bearing position of the eccentric shaft. Here, the oil volume rises to the lower edge of the outlet bore hole. The excess oil flows back to the oil circuit via the outlet bore hole. The gearing of the worm gear is now supported in the oil bath and is therefore lubricated at all times.

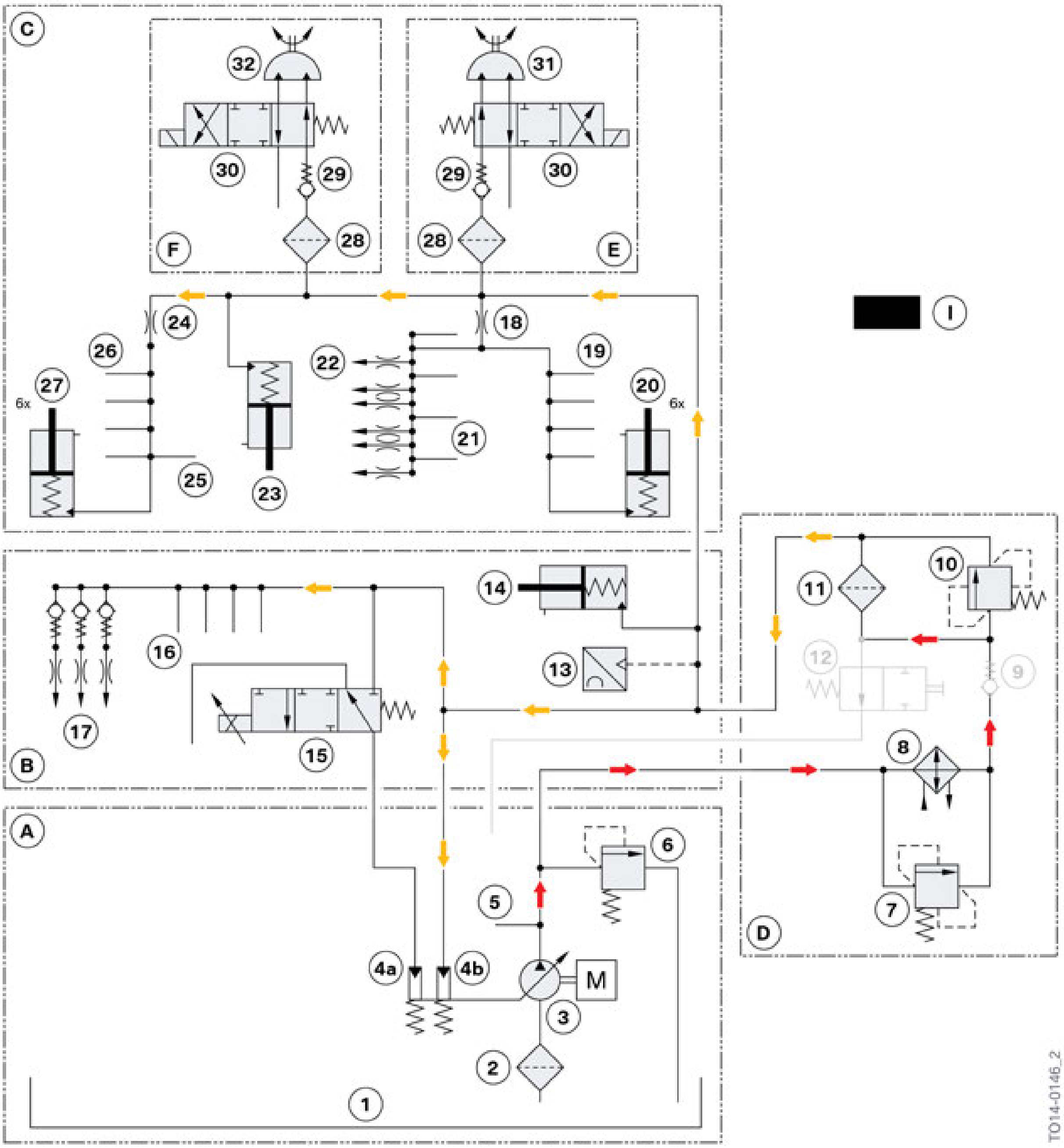
Information on disassembly and installation work

As numerous changes have been made, a new special tool is used to remove the return springs.

The hexagon socket on the Valvetronic servomotor is for manual adjustment of the worm gear. This is necessary if the Valvetronic servomotor needs to be removed, for example. To avoid damage to the worm gear, it must be greased prior to start-up using a special lubricant (Longtime PD part number: 83 19 2 160 340). The Valvetronic in the Digital Engine Electronics can be taught-in using the teach-in routine in ISTA. During this process, the limit positions of the system are determined once again and stored in the Digital Engine Electronics. The precise procedure for removing the Valvetronic is described in the current repair instructions.

3. Oil Supply

3.1. Oil circuit



Hydraulic circuit diagram, B38 engine

Index	Explanation
A	Oil pump
B	Crankcase
C	Cylinder head
D	Oil filter module

B38 Top Engine
3. Oil Supply

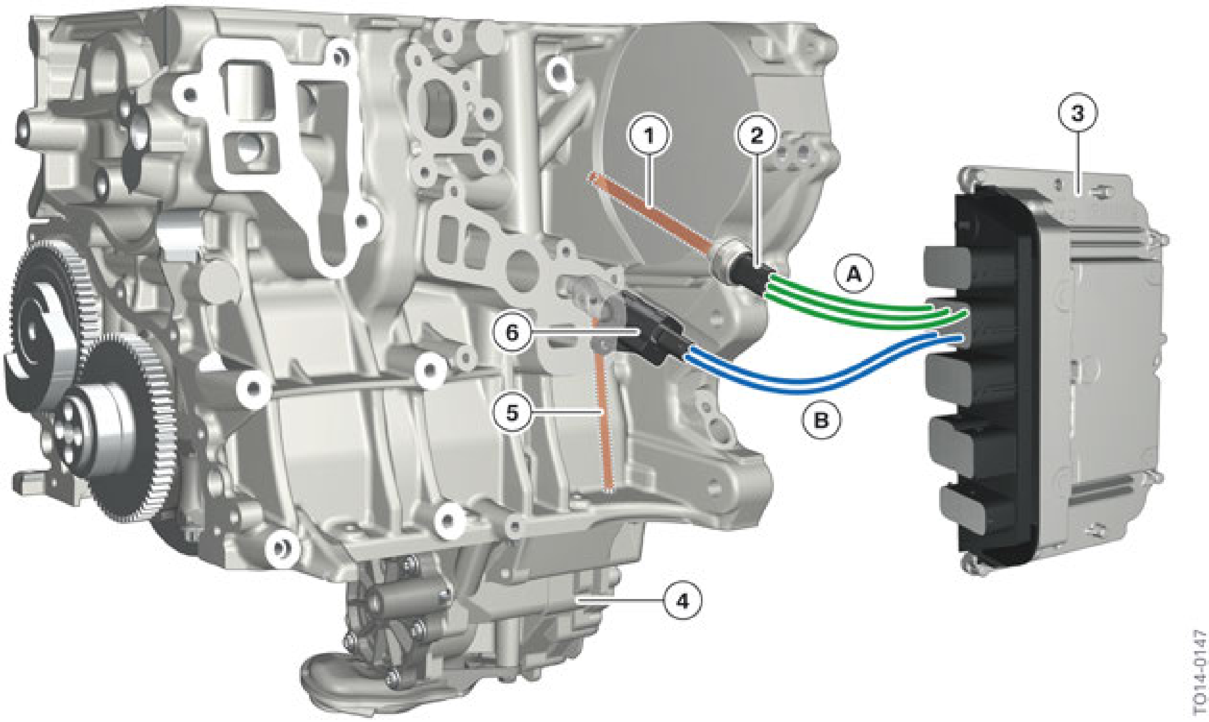
Index	Explanation
E	VANOS unit, intake camshaft
F	VANOS unit, exhaust camshaft
I	3-cylinder engine
1	Oil sump
2	Intake pipe with filter
3	Oil and vacuum pump
4 a	Map-controlled control chamber (normal operation)
4 b	Second-level control chamber (emergency operation)
5	Oil supply of vacuum pump
6	Pressure limiting valve (built-in to pump)
7	Oil-to-water heat exchanger, bypass valve
8	Engine oil-to-coolant heat exchanger
9	Not for US
10	Filter bypass valve
11	Oil filter
12	Not for US
13	Oil pressure sensor
14	Chain tensioner, bottom
15	Map-controlled valve
16	Lubricating oil supply to crankshaft bearing shells of bearing seat
17	Oil spray nozzles for piston cooling
18	Throttle
19	Lubrication points on intake camshaft
20	Hydraulic valve clearance compensation
21	Lubricating points, eccentric shaft
22	Oil spray nozzles, intermediate lever
23	Chain tensioner, top
24	Throttle
25	Lubrication point, high-pressure pump
26	Lubricating point, exhaust camshaft
27	Hydraulic valve clearance compensation
28	Oil strainer, solenoid valve

Index	Explanation
29	Non-return valve
30	Solenoid valve
31	VANOS swivel rotor (intake camshaft)
32	VANOS swivel rotor (exhaust camshaft)

With force-fed circulation lubrication the oil is drawn out of the oil sump by the oil pump through an intake pipe and forwarded into the circuit. The oil passes through the engine oil cooler with an integrated full-flow oil filter and from there into the main oil duct, which runs in the engine block parallel to the crankshaft. Branch ducts lead to the crankshaft main bearings. There are bore holes between the main bearings of the crankshaft and the connecting rod bearing journal which admit the oil to the lubricating points of the connecting rod bearing.

Some of the oil is diverted from the main oil duct and directed to the cylinder head to the relevant lubricating points and adjustment units. When the engine oil flows through the consumers, it either returns to the oil sump via the return ducts or it drips back freely.

3.2. Map control



System overview of map-controlled oil supply of B38 engine

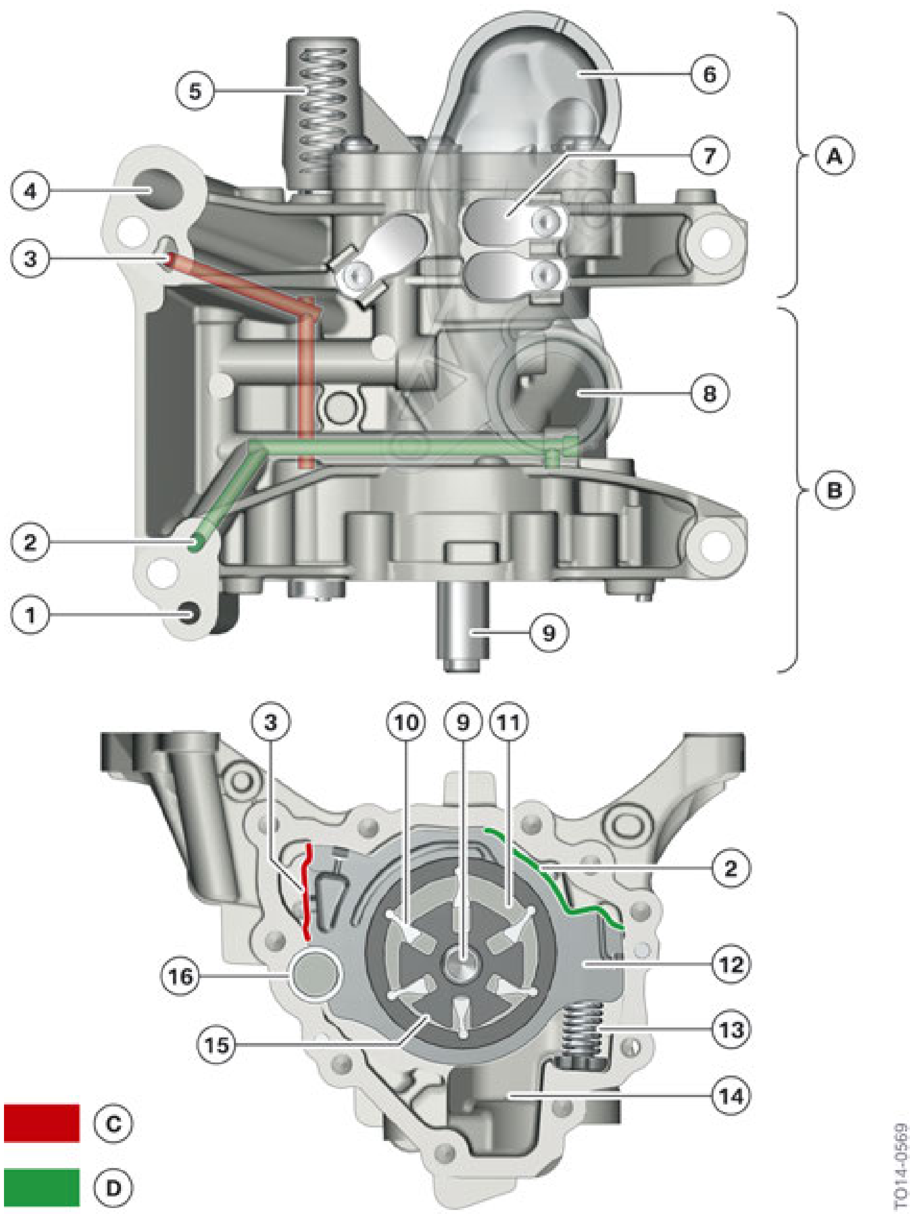
Index	Explanation
A	Oil pressure sensor signal
B	Activation of map-controlled control valve
1	Main oil duct to the oil pressure sensor
2	Oil pressure sensor
3	Digital Engine Electronics
4	Oil pump
5	Oil duct to map-controlled control chamber of oil pump
6	Map control valve

The B38 engine is equipped with the familiar map-controlled oil pump which is already used. The actual oil pressure is recorded via an oil pressure sensor and forwarded to the Digital Engine Electronics. The Digital Engine Electronics performs a target/actual comparison based on the stored characteristic maps. The map-controlled control valve is activated by means of a pulse-width modulated signal until the nominal pressure stored in the characteristic map has been reached. During this process, the delivery rate of the oil pump varies according to the oil pressure in the oil duct to the map-controlled control chamber.

3.3. Oil pump

The oil pump plays a central role in modern combustion engines. Due to the high power and enormous torque which is present even at low engine speeds, it is necessary to ensure a reliable oil supply. This is necessary on account of the high component temperatures and heavily loaded bearings. To achieve low fuel consumption, the delivery rate of the oil pump must be adapted to the requirements.

The oil pump is driven by the crankshaft via a chain.



Design of oil pump, B38 engine

Index	Explanation
A	Vacuum pump
B	Oil pump
C	Second-level control area (emergency operation)
D	Map-controlled control area (normal operation)
1	Vacuum duct to vacuum pump
2	Oil duct to map-controlled control chamber
3	Oil duct to second-level control chamber
4	Oil pressure channel, pump output
5	Pressure-limiting valve
6	Intake pipe with filter
7	Discharge valves, vacuum pump
8	Oil intake port
9	Pump shaft
10	Rotor with pendulum
11	Suction side
12	Adjusting ring
13	Adjusting ring spring (2x)
14	Pump input
15	Major thrust face
16	Bearing tube (center of rotation)

A vacuum pump is integrated into the oil pump housing.

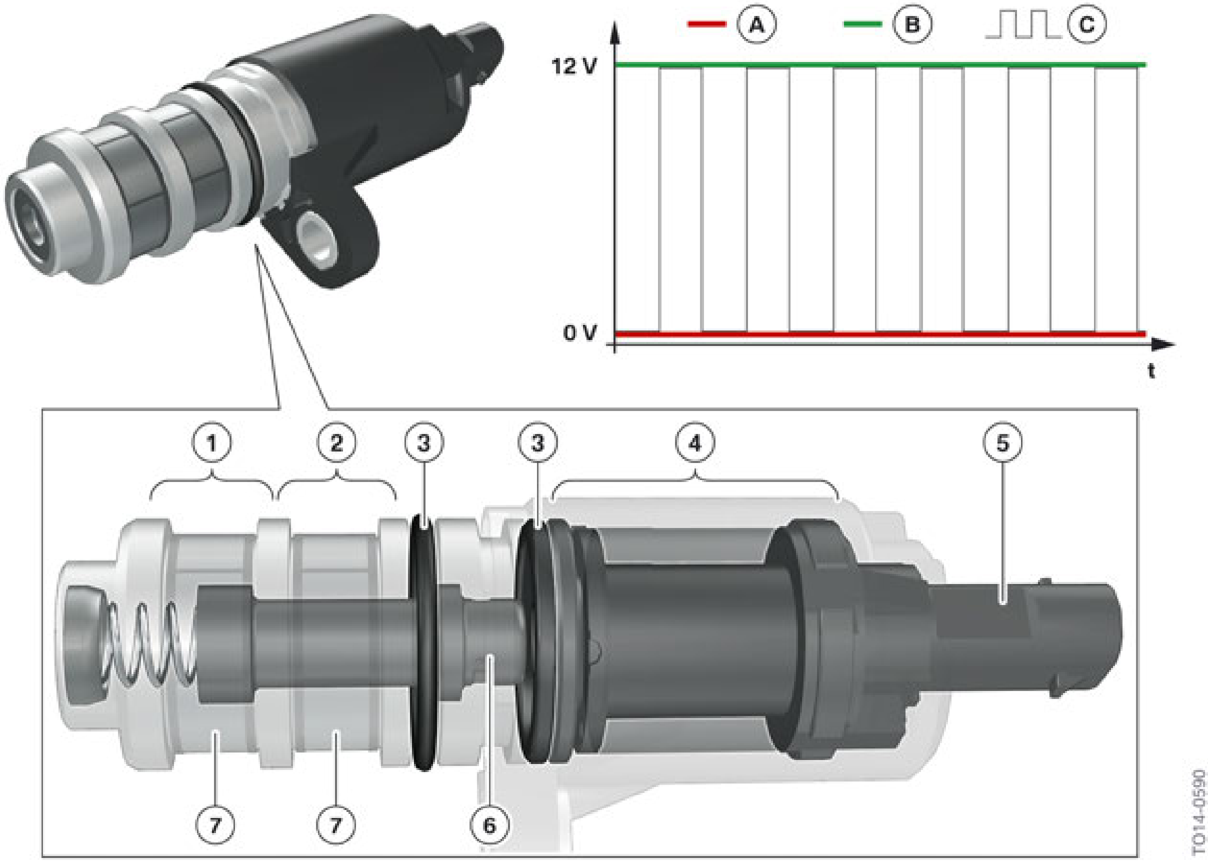
A rotor with pendulum rotates as shown in the graphic on the pump shaft. A crescent-shaped cavity arises through the eccentric position. During this process, the oil is drawn into the expanding chamber (intake side) and is delivered via the contracting chamber (pressure side).

When the engine is in operation, oil pressure is admitted to the map-controlled control surface and the second-level control surface of the oil pump. Depending on the oil pressure, the adjusting ring is pushed via the center of rotation at the bearing tube to varying degrees of force against the adjusting ring springs. The change in eccentric position of the adjusting ring changes the size of the chamber, and therefore also the intake and pressure power of the oil pump.

To prevent overloading of the oil pump, a filter is installed upstream of the pump inlet. The maximum oil pressure of the oil circuit at the pump outlet is restricted by a pressure limiting valve. The opening pressure of the pressure limiting valve is 11.4 +/– 1.4 bar.

3.3.1. Map control valve

The map-controlled control valve is a proportional valve which can control the oil pressure steplessly.



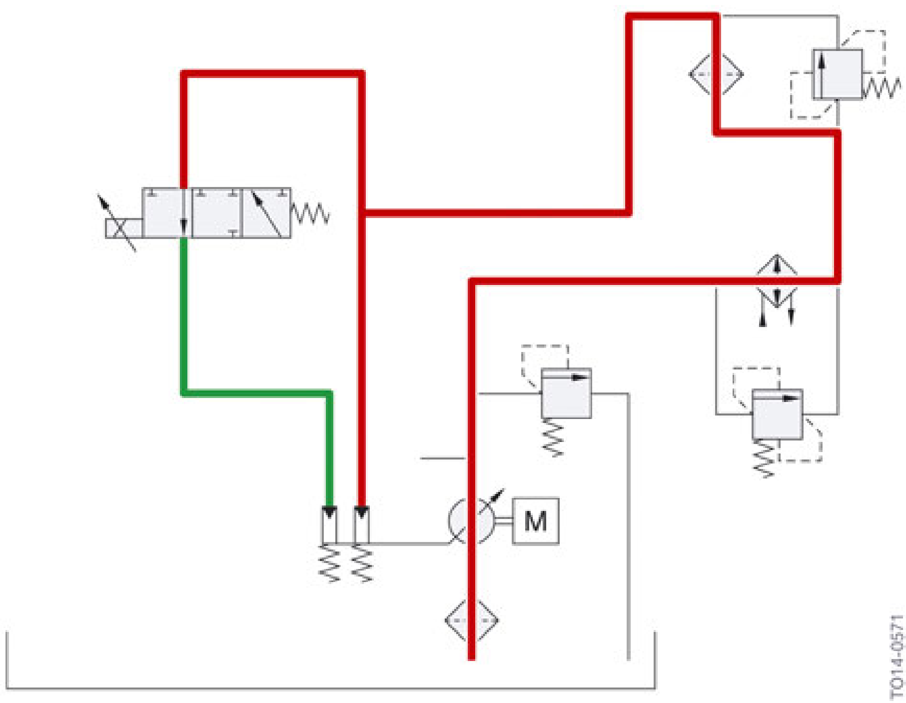
Map-controlled control valve, B38 engine

Index	Explanation
A	Voltage curve, maximum delivery rate
B	Voltage curve, minimum delivery rate
C	Voltage curve, 50% delivery rate
1	Oil duct from the oil filter
2	Oil duct to oil pump
3	Sealing ring
4	Solenoid coil
5	Electrical connection
6	Valve spool
7	Filter

The oil pressure sensor is connected to the main oil duct and delivers the actual oil pressure at the Digital Engine Electronics. The Digital Engine Electronics calculates the required nominal oil pressure based on the engine speed and fuel injection rate. A pulse-width modulated signal is sent to the map-controlled control valve based on the determined setpoint deviation. Depending on the pulse-width modulated signal, the width of the valve spool opening in the map-controlled control valve varies. Depending on the available opening cross-section, more or less engine oil can flow from the oil duct of the oil filter into the oil duct and to the oil pump. This oil flow changes the position of the adjusting ring in the oil pump, and therefore the delivery rate of the pump.

3.3.2. Normal operation

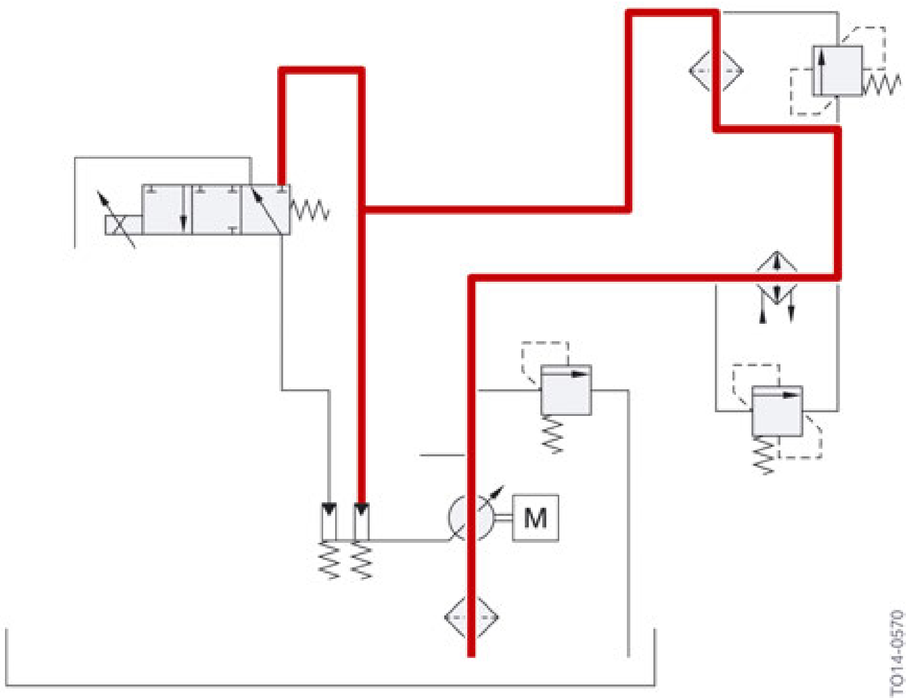
The oil pump has two separate control loops in order to guarantee normal operation (map-controlled control operation) and emergency operation (second-level control operation).



Oil circuit during normal operation, B38 engine

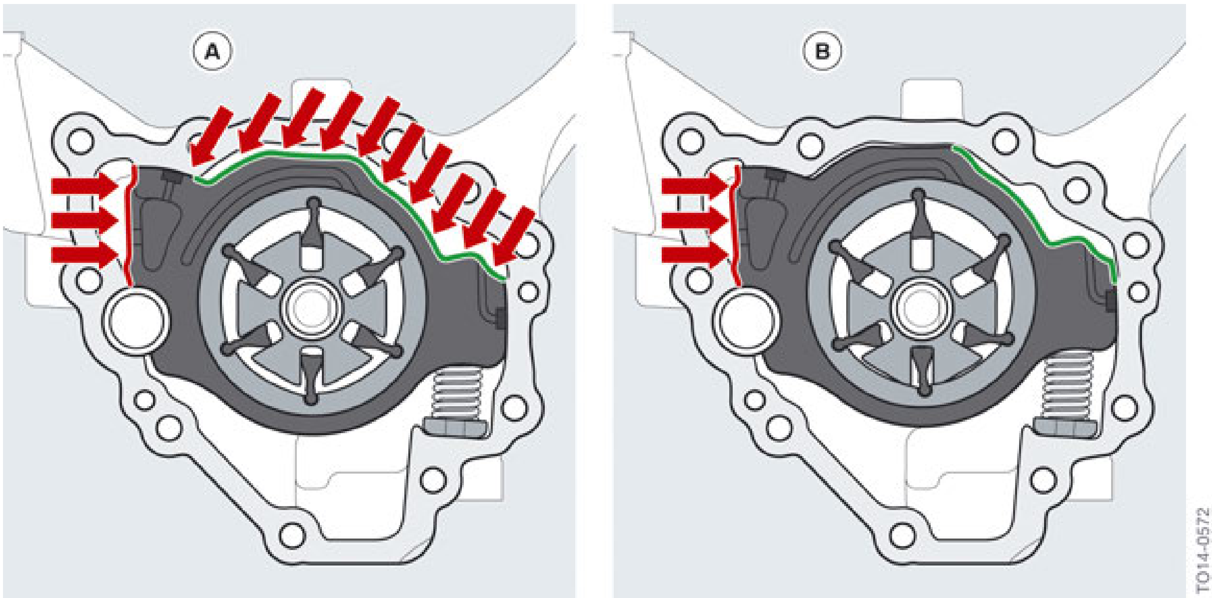
This control loop operates with an external map-controlled valve. The map-controlled control valve controls the oil pressure in the map-controlled control chamber via a software in the Digital Engine Electronics. If the oil pressure in the map-controlled control chamber increases, the adjusting ring further compresses the adjusting ring spring and the pump eccentricity is reduced. This results in a lower volumetric flow.

3.3.3. Emergency operation



Oil circuit during emergency operation, B38 engine

During emergency operation, the system operates without the map control by the Digital Engine Electronics. The map-controlled control valve is de-energized in this operating condition and is therefore closed. The purpose of the emergency operation is to maintain the oil pressure in the oil pump at a consistently high level. The oil pressure is guided directly from the main oil duct to the second-level control chamber. This leads to an adjustment of the adjusting ring against the adjusting ring spring and thus a reduction of the volumetric flow. As it contains no actuators, intervention in this control system is not possible and it also cannot be switched off.



Operating principle of oil pump control system, B38 engine

Index	Explanation
A	Normal operation
B	Emergency operation

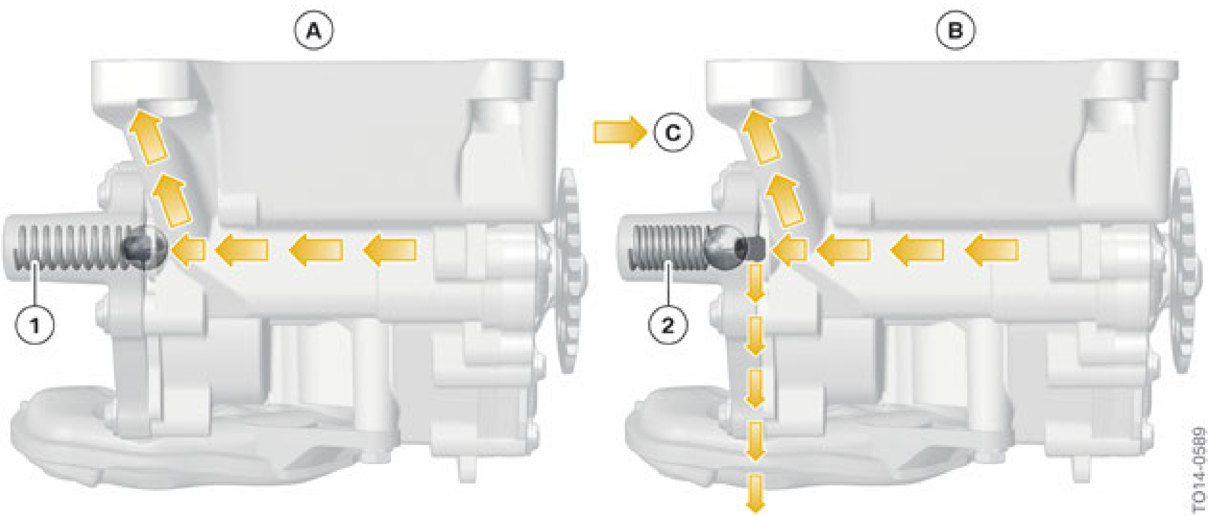
3.4. Suction pipe

The oil pump draws oil from the oil sump through the intake pipe. The suction pipe is positioned so that the suction opening is below the oil level under all operating conditions. The intake pipe incorporates an oil strainer, which prevents coarse dirt particles from getting into the oil pump.

Intake pipe in B38 engine

The intake pipe is a separate component which is bolted on to the oil pump.

3.5. Pressure-limiting valve

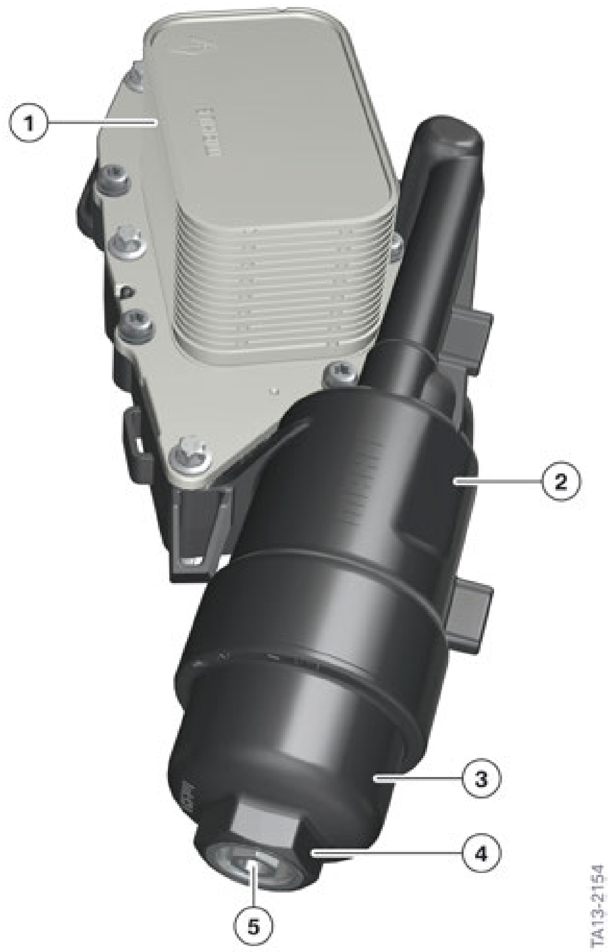


Pressure limiting valve in oil circuit in B38 engine

Index	Explanation
A	Oil pressure < 11.4 +/– 1.4 bar
B	Oil pressure > 11.4 +/– 1.4 bar
C	Engine oil volumetric flow
1	Pressure limiting valve closed
2	Pressure limiting valve open

The pressure limiting valve is responsible for protecting the oil pump and the oil circuit against overloading. This valve opens at an oil pressure of > 10 bar and directs the excess engine oil back to the oil sump. This valve is used if necessary when starting the engine at cold ambient temperatures (values < 0 °C), as the viscosity of the engine oil is very high here.

3.6. Oil filter module



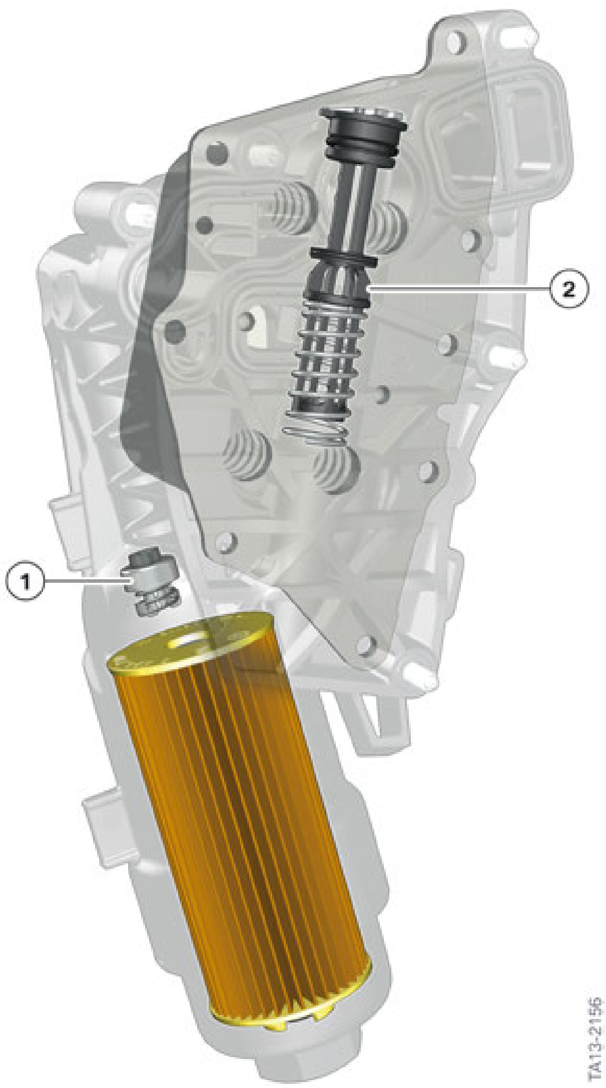
Oil filter module

Index	Explanation
1	Engine oil-to-coolant heat exchanger
2	Oil filter housing
3	Oil filter cover
4	Hexagon head for opening the oil filter cover
5	Hexagon head for opening the oil drain plug

Due to the construction space, the oil filter housing is suspended in the transverse mounting. The inspection is carried out from the bottom of the vehicle. Using an oil drain plug the Service Technician can drain the engine oil from the oil filter module before opening the oil filter cover.

⚠

In Service, the specified torques for the oil drain plug and the oil filter cover must be observed. The two O-rings must be replaced each time the oil filter cover and the oil drain plug are opened. Both O-rings are included in the oil filter service kit.



Valves of the oil filter module

Index	Explanation
1	Filter bypass valve
2	Heat exchanger bypass valve

A non-return valve is not required thanks to the suspended mounting. The filter cannot run empty after the engine is stopped due to its position.

3.6.1. Filter bypass valve

When a filter is blocked, the filter bypass valve ensures that engine oil reaches the lubrication points of the engine. It opens when the differential pressure upstream and downstream of the oil filter is 2.5 bar ± 0.3 bar.

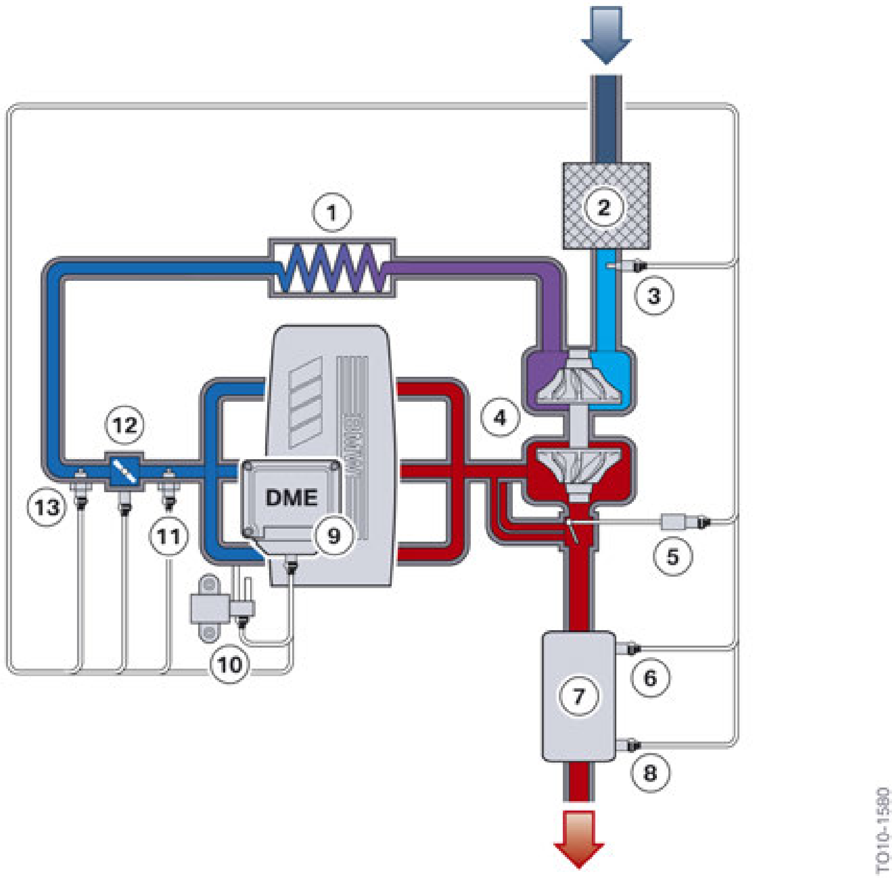
3.6.2. Heat exchanger bypass valve

The heat exchanger bypass valve has the same function as the filter bypass valve. If, on account of a blocked oil-to-water heat exchanger, the oil pressure rises, the heat exchanger bypass valve opens at an oil pressure of 2.5 bar ± 0.3 bar and the lubricating oil can flow uncooled to the lubrication points.

⚠

To ensure the engine runs perfectly, only engine oils approved for BMW can be used.

4. Intake Air and Exhaust System



System overview of intake air and exhaust emission system in the B38 engine

Index	Explanation
1	Charge air cooler
2	Intake silencer
3	Hot film air mass meter
4	Exhaust turbocharger
5	Actuator of electrically adjustable wastegate valve
6	Broadband oxygen sensor upstream of catalytic converter (control sensor)
7	Catalytic converter
8	Voltage-jump sensor downstream of catalytic converter (monitoring sensor)
9	Digital Engine Electronics (MEVD 17.2.3)
10	Tank vent valve
11	Intake manifold pressure sensor
12	Throttle valve
13	Charge-air temperature and charge-air pressure sensor

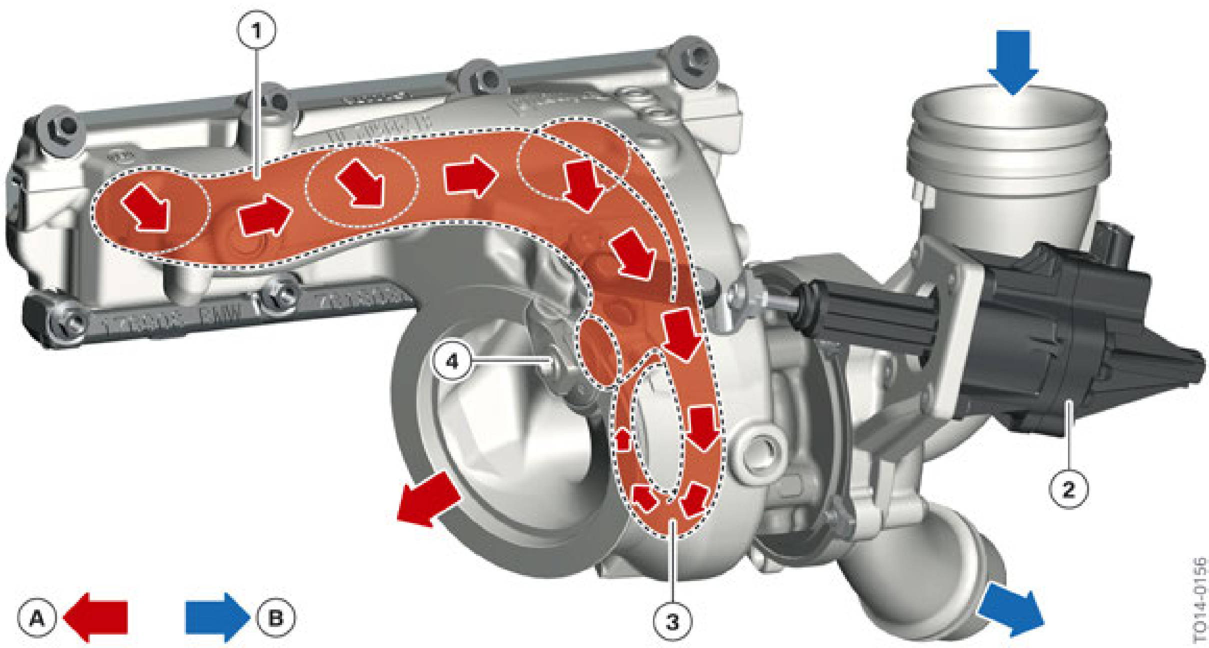
B38 Top Engine

4. Intake Air and Exhaust System

4.1. Exhaust emission system

4.1.1. Exhaust turbocharger

Exhaust turbocharger in the B38 engine



Exhaust turbocharger in the B38 engine

Index	Explanation
A	Turbine side
B	Compressor side
1	Exhaust duct
2	Actuator of electrically adjustable wastegate valve
3	Mono-scroll
4	Wastegate valve

Due to the number of cylinders, a twin-scroll exhaust turbocharger cannot be used with the 3-cylinder engine.

The exhaust manifold and exhaust turbocharger housing have been designed as one common cast part and cannot be replaced individually.

The charging pressure is adjusted via an electrical actuator.

4.1.2. Blow-off valve

A blow-off valve is not used in current models. Pressure peaks, caused by sudden load shedding due to the inertia of the turbine of the exhaust turbocharger, can be avoided by careful tuning of the Digital Engine Electronics software. With foresighted charging pressure control, pressure peaks can be predicted and reduced by quick adjustment of the electrically-adjustable wastegate valve. Assisted by a delayed load control of the Valvetronic (in the minimum lift direction) or the throttle valve (in the closed direction), the remaining charge air which is produced can be routed to the exhaust emission system via the engine. This form of control thus prevents the exhaust turbocharger shaft from being exposed to excessive torsional stress due to high pressure peaks.

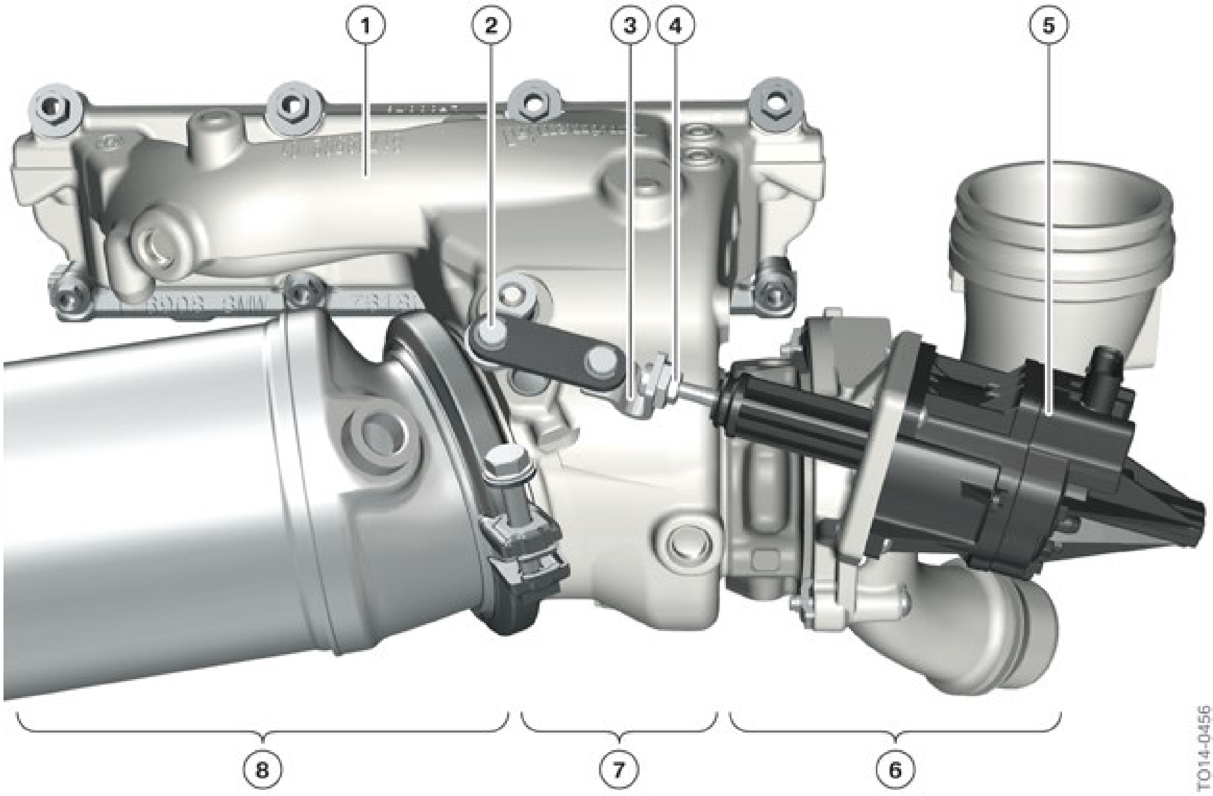
4.1.3. Charging pressure control

The charging pressure in the B38 engine is controlled via an electrically adjustable wastegate valve.

Electric adjustment

In contrast to a vacuum-controlled charging pressure control, the following components are not required:

- Vacuum unit
- Vacuum lines
- Electro-pneumatic pressure converter
- Vacuum reservoir



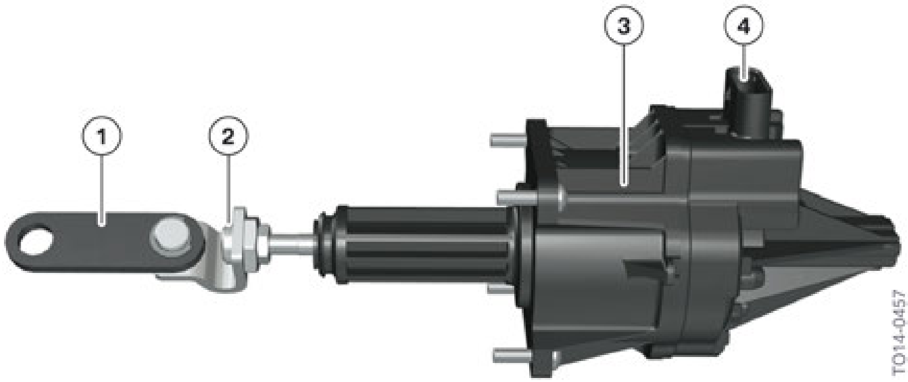
Overview of electrically adjustable wastegate valve, B38 engine

Index	Explanation
1	Exhaust manifold
2	Wastegate valve
3	Adjusting linkage
4	Lock nut
5	Actuator of electrically adjustable wastegate valve
6	Exhaust turbocharger, compressor side
7	Exhaust turbocharger, turbine side
8	Catalytic converter

Advantages of electrical activation

- Faster control speed
- More precise control
- Simpler diagnosis
- Fewer components
- Larger opening angle of wastegate valve

Operating principle



Actuator of electrically adjustable wastegate valve

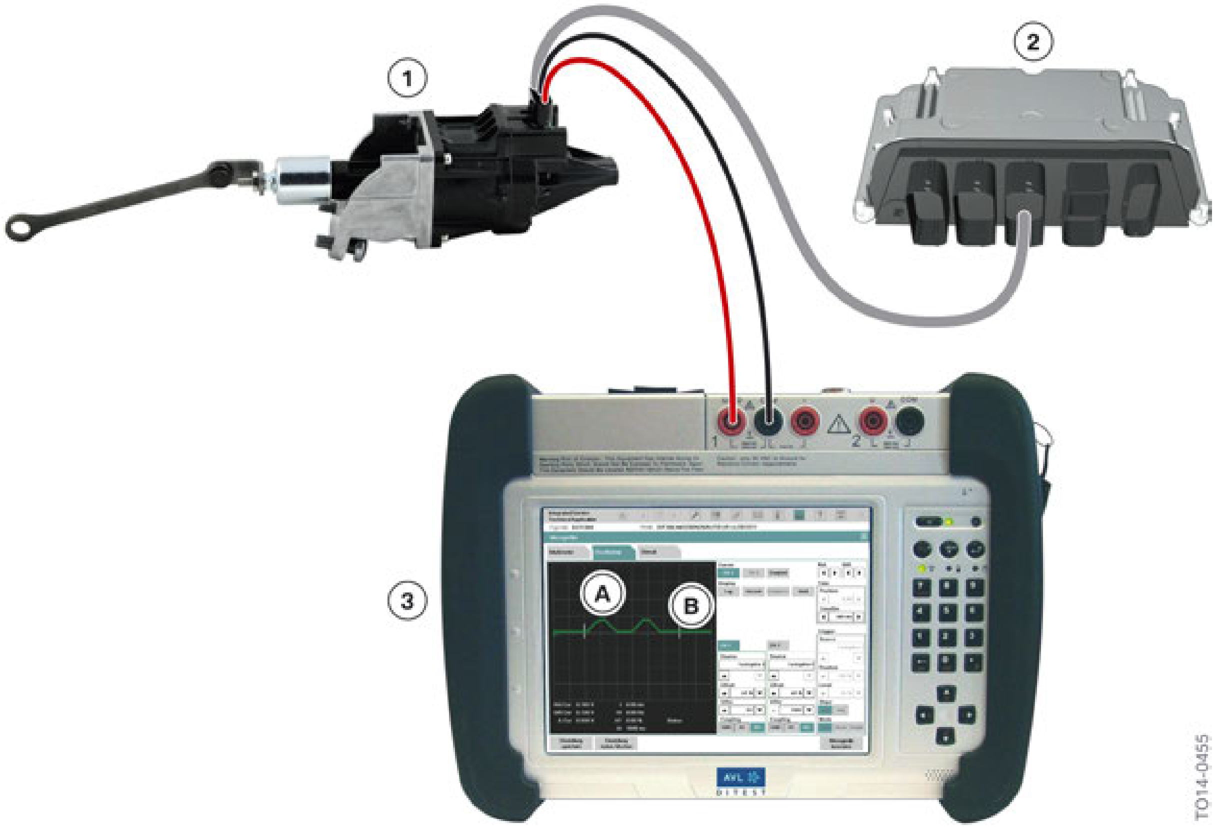
Index	Explanation
1	Stroke linkage
2	Adjustment linkage
3	Actuator
4	Electrical connection

A direct current motor and a sensor are located in the actuator of the electrically adjustable wastegate valve, resulting in a total of five electrical connections. The wastegate valve is opened or closed by a lifting movement of the linkage.

The actuator of the electrically adjustable wastegate valve can be replaced separately in Service. Each time the adjusting linkage is activated, the system must be re-adjusted with the assistance of the BMW diagnosis system ISTA. This measure is not required when replacing the entire exhaust turbocharger as the linkage is supplied preset.

⚠

If the actuator is replaced individually, a teach-in routine must be performed using the BMW diagnosis system ISTA.



Sensor signal to electrically adjustable wastegate valve

Index	Explanation
A	Wastegate valve closed
B	Wastegate valve opened
1	Actuator of electrically adjustable wastegate valve
2	Digital Engine Electronics

The sensor is used to determine the position of the wastegate valve. The wastegate valve can move to any required position between maximum open and maximum closed. When the sensor signal or actuator drops out, the wastegate valve adopts the open position to allow charging pressure to build up. This ensures the journey continues with reduced engine performance.

⚠

As the position sensor is a linear Hall sensor, a resistance measurement for testing the sensor is not permitted.

4.1.4. Exhaust system

Engine	One exhaust tailpipe
B38	YES

The B38 engine already satisfies the exhaust gas emission regulations of the ULEV 2 exhaust emission standards when introduced on the market.

Measures for reduction of exhaust gas emissions

- Precise and fast charging pressure control
- Catalytic converter heating during cold start
- Positioning of catalytic converter near engine
- New LSF Xfour voltage-jump sensor by Bosch

Catalytic converter heating

When starting the combustion engine from cold, the wastegate valve is opened as wide as possible and the ignition point is adjusted to retard. The retarded ignition point delays the combustion process which in turn supports the heat input for heating of the catalytic converter. As the turbine housing is short, it has been possible to position the catalytic converter very close to the wastegate valve. As the exhaust gas flows into the catalytic converter at the perfect angle and because of its position close to the engine, the catalytic converter reaches its operating temperature very quickly. If the wastegate valve is opened when cold, pulsation of the exhaust gas may cause vibrations in the wastegate valve, which are perceived as noise. This is not due to a defective component, and is normal running noise. This noise becomes less audible as the temperature of the component increases.

Positioning

The position of the catalytic converter near the engine of the B38 engine ensures lower exhaust temperatures upstream of the catalytic converter, and therefore slows down the ageing process of the catalytic converter considerably.

Control sensor

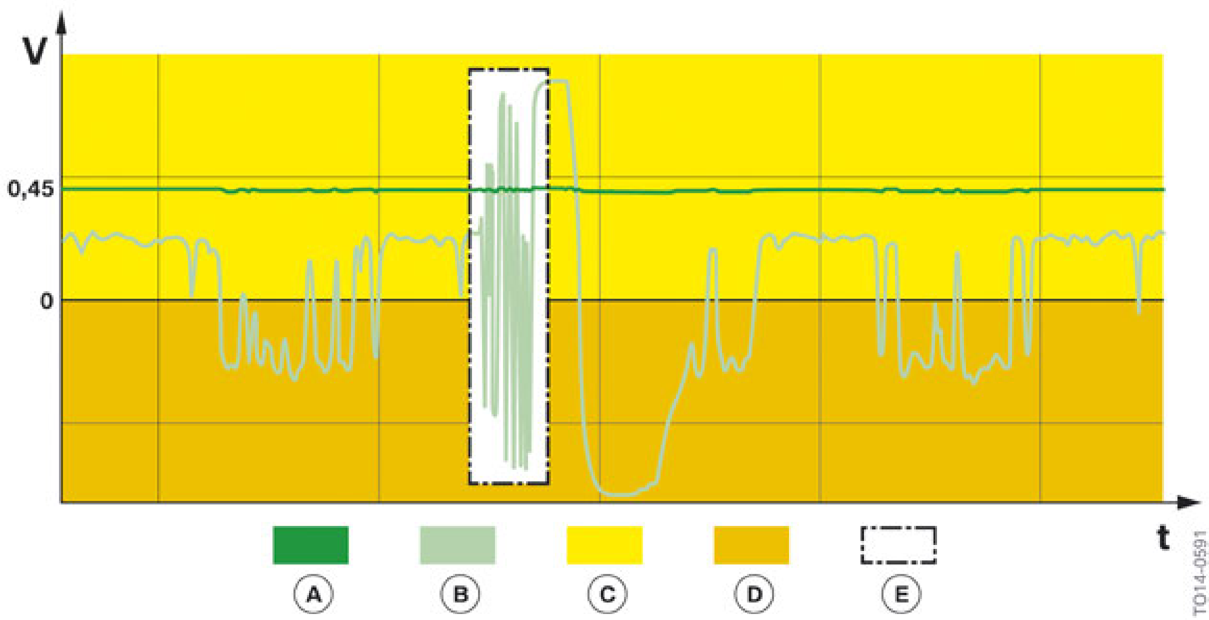
With a stoichiometric air/fuel ratio ($\lambda=1$), the proportion of oxygen in the exhaust gas is ideal for conversion of the pollutants in the 3-way catalytic converter. By measuring the oxygen content in the exhaust gas, the oxygen sensor of the Digital Engine Electronics delivers important information for mixture preparation.

A broadband oxygen sensor with the designation LSU ADV has been specially developed for engines with exhaust turbochargers and is used as the control sensor. One of the major characteristics of broadband oxygen sensors is their extensive measuring range. The measuring range of the LSU ADV is from a lambda of $\lambda=0.65$ to λ=air.

The broadband oxygen sensor LSU ADV is a combination of a measuring cell and pump cell. There is a small diffusion gap between these two cells which serves as a measuring chamber and is connected to the exhaust gas duct. The measuring cell operates according to the principle of a voltage-jump sensor and measures the residual oxygen content in the exhaust gas. If the fuel-air mixture is too lean ($\lambda > 1$), the control electronics applies voltage to the pump cell so that oxygen ions are pumped out of the diffusion gap. If the mixture is too rich (λ < 1), oxygen ions are pumped into the diffusion gap by activating the pump cell accordingly. The pump flow required to control the pump cell is directly proportional to the oxygen concentration and therefore serves as the control variable for the air ratio.

The control strategy has been devised so that the oxygen concentration in the area of the diffusion gap corresponds to an air ratio of λ = 1. As this control method is extremely fast and incredibly accurate, the voltage value of the measuring cell always remains at a constant level (450 mV).

The following graphic shows the two voltage curves of the measuring cell and the pump cell when the engine is in operation:



Voltage signal, LSU ADV broadband oxygen sensor

Index	Explanation
A	Signal voltage, measuring probe
B	Control voltage, pump sensor
C	Positive control voltage
D	Negative control voltage
E	Press on accelerator
t	Time
V	V

In the positive range of the control voltage (U > 0 V), there is excess oxygen in the area of the diffusion gap (λ > 1). The engine is running slightly too lean. The pump cell pumps oxygen out of the diffusion gap in order to maintain the level of 450 mV in the measuring cell constant.

In the negative range of the control voltage (U < 0 V), there is insufficient oxygen in the area of the diffusion gap (λ < 1). The engine is running slightly too rich. The pump cell pumps oxygen into the diffusion gap in order also to maintain the level of 450 mV in the measuring cell constant.

An integrated heating element ensures that the broadband oxygen sensor quickly reaches its operating temperature.

Connections, broadband oxygen sensor

- Positive terminal of pump cell
- Negative terminal of pump cell and measuring cell
- Heating minus
- Heating plus
- Positive terminal of measuring cell

Monitoring sensor

A new voltage-jump sensor with the designation LSF Xfour is used as the monitoring sensor. The new oxygen sensor has the following benefits:

- Sturdier design
- Small installation space
- Higher measuring accuracy
- Faster control readiness

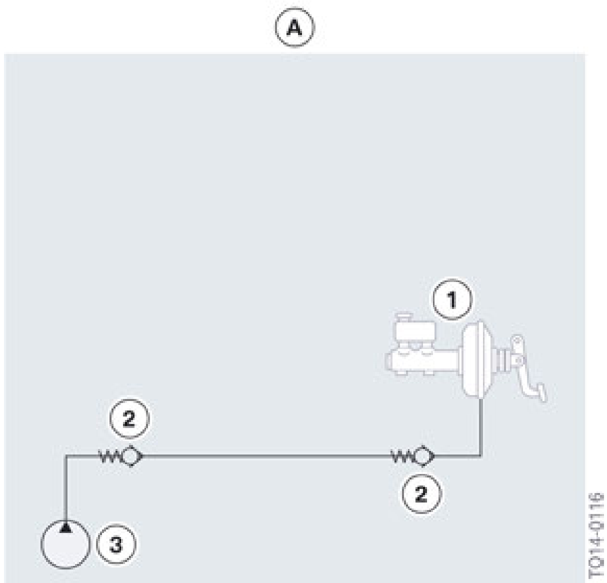
The oxygen sensor is suitable for engine start-stop operation. In this case, the sensor must be heated throughout the entire stop phase. The voltage required during the heating phase is 7.5 volts and the heating current is around 1 ampere.

Engine operation	Air ratio	Sensor voltage
Rich operating phase	λ=0.98	0.9 V
Lean operating phase	λ=1.02	0.1 V

B38 Top Engine
5. Vacuum Supply

The main purpose of the vacuum system is to generate the vacuum for the brake servo.

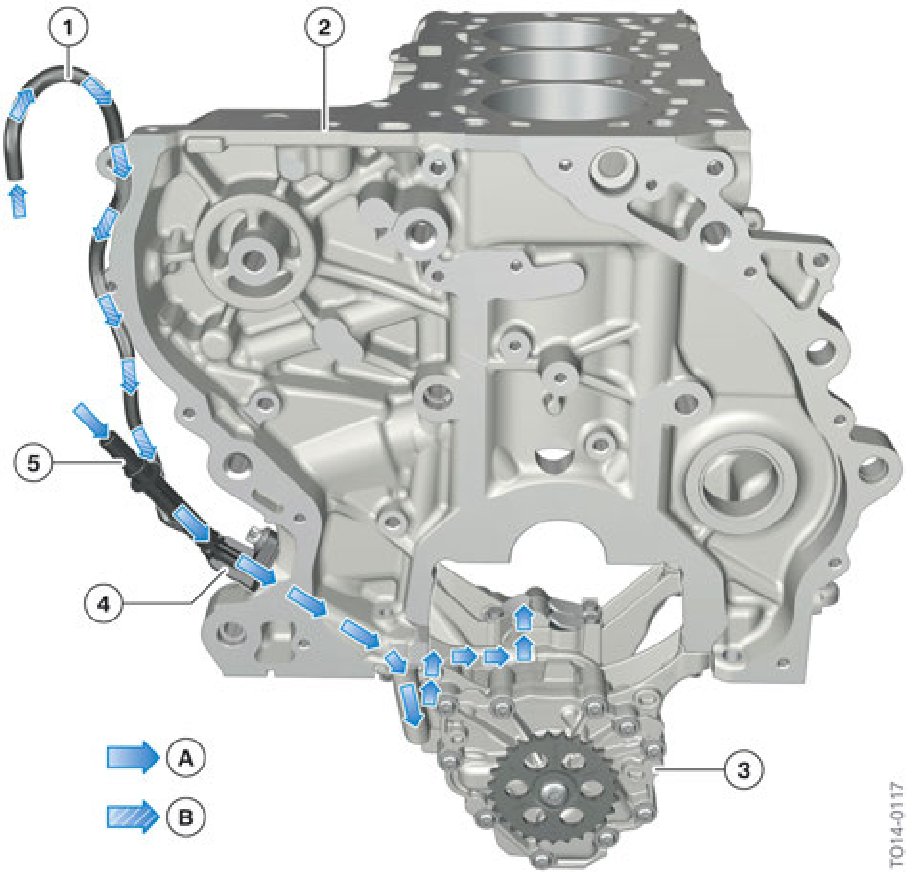
5.1. System overview



Schematic representation of vacuum supply

Index	Explanation
A	B38 engine
1	Brake servo
2	Non-return valve
3	Vacuum pump

5.2. Vacuum pump

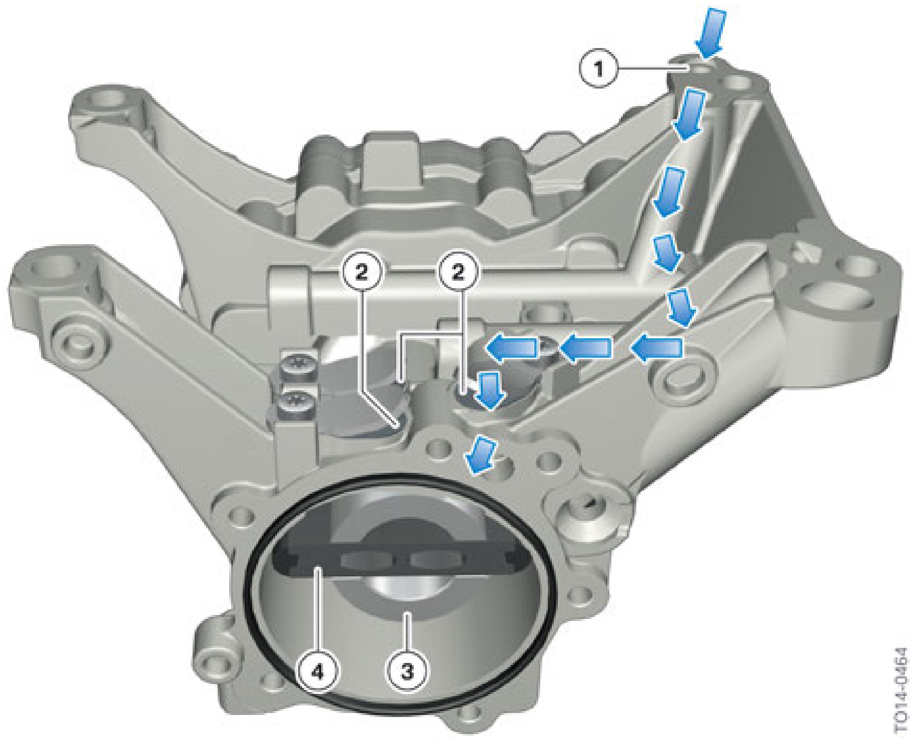


Installation location of vacuum pump, B38 engine

Index	Explanation
A	Vacuum, secondary volume
B	Vacuum, main volume
1	Vacuum line for auxiliary consumer
2	Crankcase
3	Oil pump
4	Non-return valve
5	Vacuum line for main consumer (brake servo)

The low pressure pump and oil pump are installed together in one housing.

The vacuum duct leads to the vacuum pump, passing through the transmission end of the crankcase. There is a plastic connection at the output of the crankcase to which the various consumers are connected. There is a non-return valve inside the plastic connection.



Vacuum pump in the B38 engine

Index	Explanation
1	Vacuum duct
2	Exhaust valves
3	Steel rotor
4	Plastic vane

There is a steel rotor with a plastic vane on the inside of the vacuum pump. It is driven together with the oil pump by the crankshaft via a chain.

The evacuating output of the vacuum pump is 500 mbar vacuum (absolute) in less than six seconds.

As the running surfaces of the vacuum pump are coated with oil, the volume of air drawn in cannot be released into the atmosphere. The air volume delivered by the vacuum pump is transferred to the crankcase via discharge valves. From here, it reaches the air intake system via the crankcase ventilation.

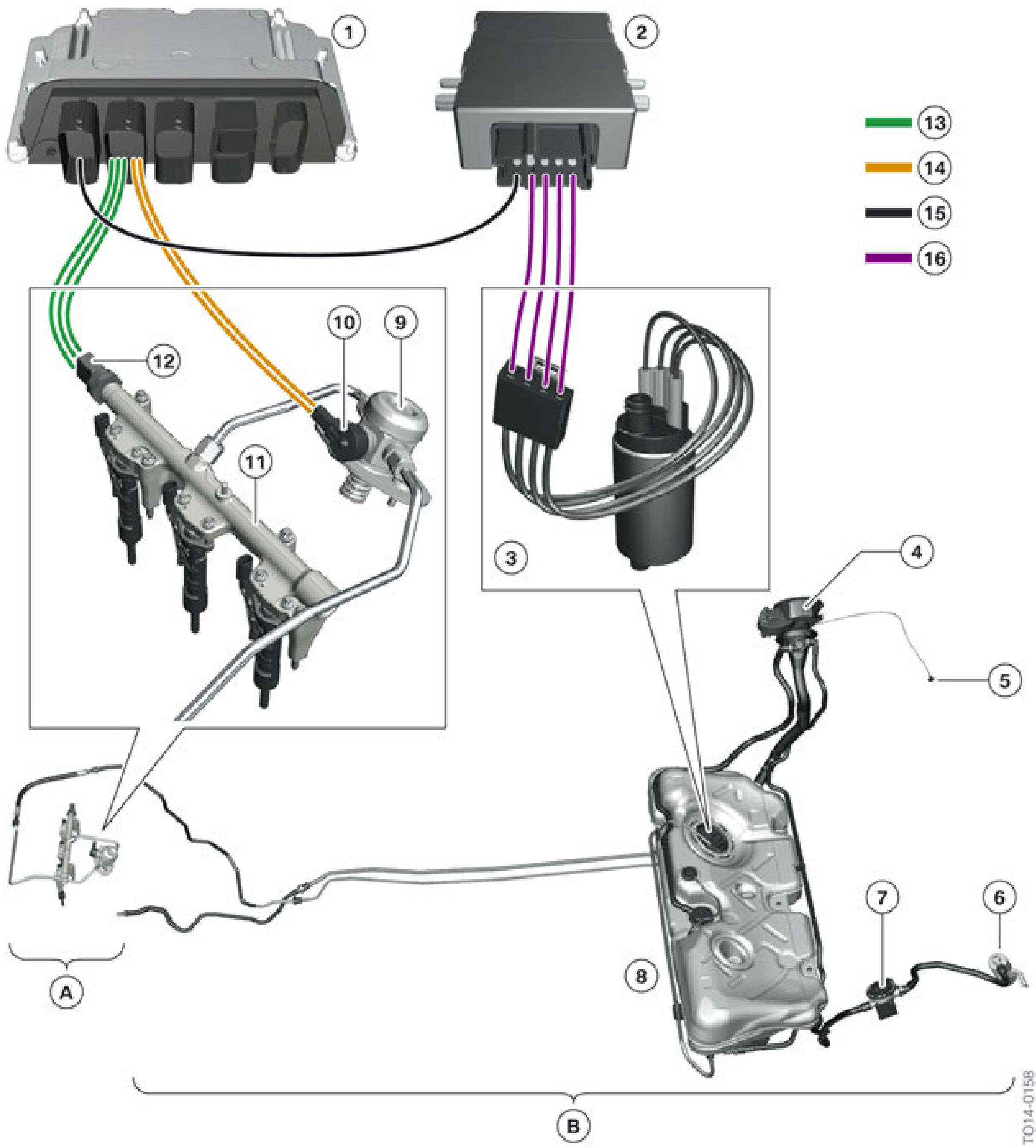
⚠

Leaks in the vacuum system lead to a reduced brake power assistance.

6. Fuel System

The fuel system is made up of the fuel supply and fuel preparation systems. The fuel supply includes the fuel tank with all mounted parts and the fuel lines up to the engine compartment.

The fuel filter lines in the engine compartment and all the fuel system parts on the engine belong to the fuel preparation system.



Fuel system, B38 engine in the F56

Index	Explanation
A	Fuel preparation
B	Fuel supply
1	Digital Engine Electronics
2	Fuel pump control module
3	Electric fuel pump
4	Fuel filler neck
5	Emergency release
6	Dust filter
7	Fuel tank leak diagnosis system
8	Fuel tank
9	High-pressure pump
10	Quantity control valve
11	Rail (high-pressure accumulator)
12	High-pressure sensor
13	Sensor line, rail pressure sensor
14	Actuating wire, quantity control valve
15	Pulse-Width Modulated data line
16	Actuating wire, electric fuel pump (three-phase line U, V, W)

6.1. Fuel pump control module

The new engine has a fuel pump control module. The fuel pump control module is not shown in the control unit overview. The fuel pump control module is responsible for processing information about the necessary fuel pressure from the Digital Engine Electronics and for activating the electric fuel pump according to these requirements via a three-phase brushless DC motor.

6.2. Electric fuel pump

The electric fuel pump is activated as required. The requirements are calculated by the Digital Engine Electronics. The request regarding the extent of the fuel low pressure is sent to the fuel pump control module with the assistance of a pulse-width modulated signal (PWM signal). The fuel pump control module processes the pulse-width modulated signal and with help of an inverter generates a three-phase DC voltage U, V, W to activate the three-phase motor of the electric fuel pump according to requirements.

If the PWM data line is disconnected, the electric fuel pump is activated with the maximum system performance. If a PWM data line is interrupted, this only leads to a fault code entry. The customer is not informed about this status, by the illumination of a warning and indicator light, for example.
The electric fuel pump is designed for continuous full load operation and is also not damaged if the PWM data line is interrupted for a longer period.

There is no fuel pressure sensor in the low-pressure range of the fuel system. The low pressure is calculated in the Digital Engine Electronics based on a mathematical model. The power consumption of the electric fuel pump also provides information on the low pressure fuel system. If the power consumption is high, this means that a high fuel low pressure exists and if the power consumption is low, this means that a lower fuel low pressure prevails.

The following table provides information on the technical data of the electric fuel pump

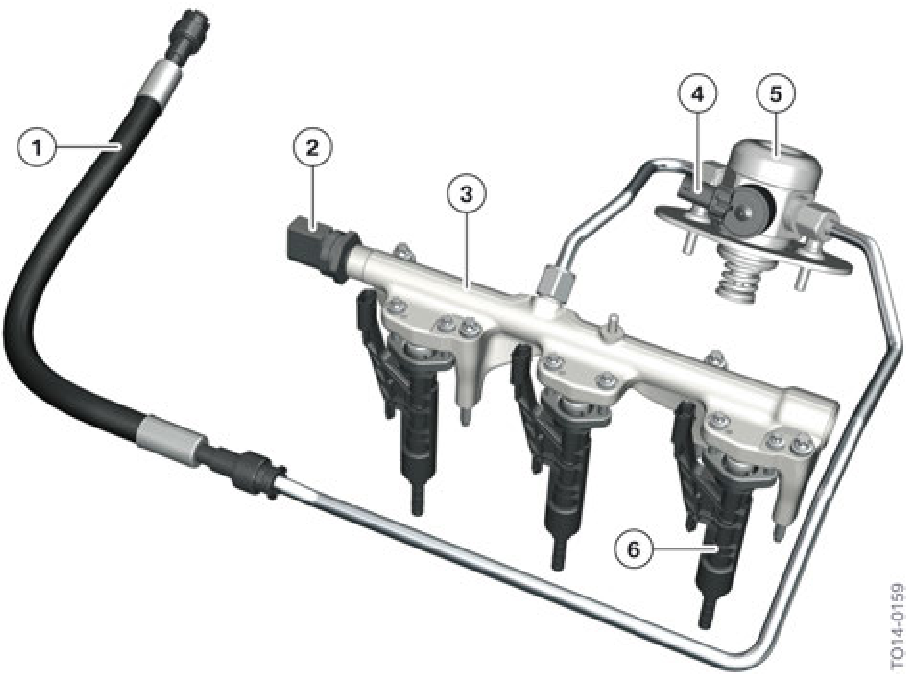
	Technical data
Engine speed range	2600 – 6000 rpm
Pressure area	2.0 - 6.5 bar
Supply voltage	12 V
Delivery rate at 3200 rpm and 3.5 bar	> 80 liters/60 minutes
Delivery rate at 4250 rpm and 6.3 bar	> 105 liters/60 minutes
Delivery rate at 5600 rpm and 5.3 bar	> 190 liters/60 minutes

⚠

The electric fuel pump becomes impermissibly hot with excessive dry running > 1 minute.
There is a risk of a component fault!

6.3. Fuel preparation

The fuel preparation has been modified to meet the requirements of emission legislation.
A new direct rail which has been developed to which the injectors are now bolted to.



Overview of fuel preparation

Index	Explanation
1	Fuel delivery line
2	Rail pressure sensor
3	Direct rail
4	Quantity control valve
5	High-pressure pump
6	Solenoid valve injector

A single-piston reciprocating pump with integrated quantity control valve is used.

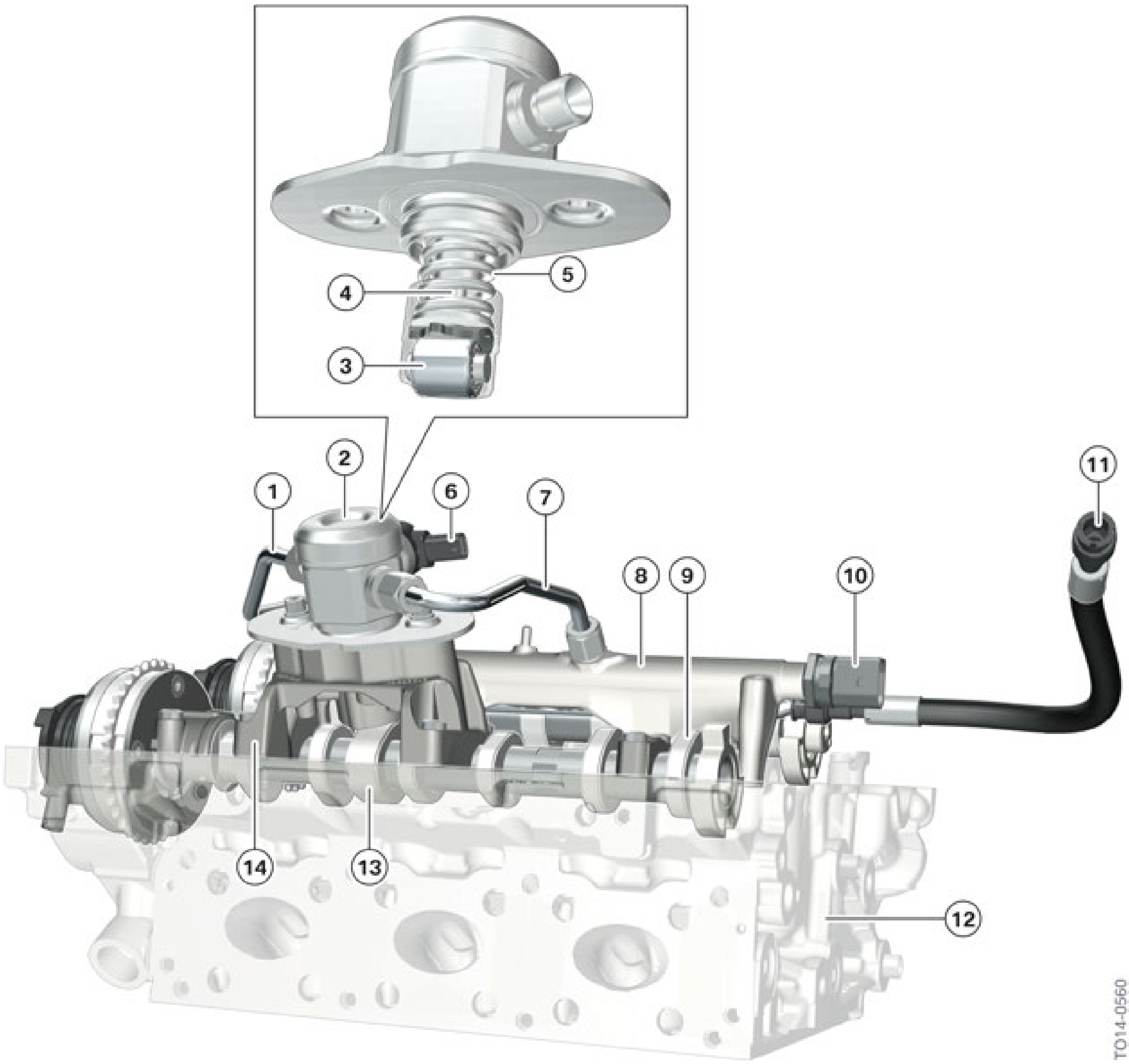
The direct rail represents a departure from the familiar systems used up till now. With this system, the high pressure lines have been omitted and the injectors are attached to the rail directly.

Directly connecting the solenoid valve injectors to the rail has the following advantages:

- Less volume needs to be available for high-pressure injection.
- Fewer interfaces and therefore less problematic with respect to leaks.
- Short cycle times during production due to compact design.

Strict cleanliness must be observed when carrying out any work on the fuel system!

6.3.1. Fuel high-pressure pump



Overview of fuel high-pressure pump

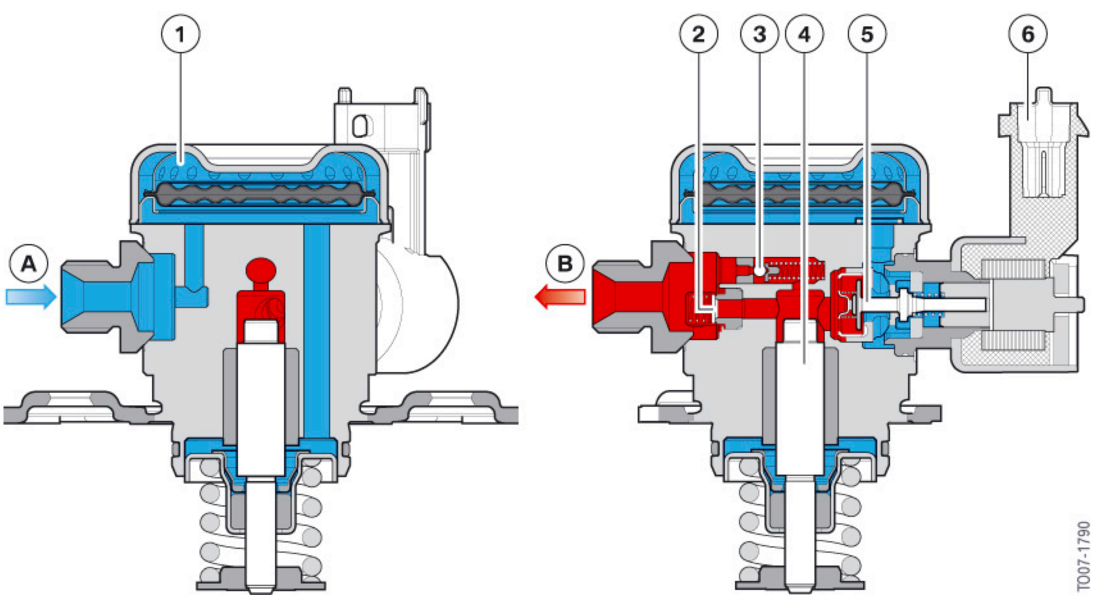
Index	Explanation
1	Fuel feed line to high pressure pump
2	High-pressure pump
3	Roller tappet
4	Pump piston
5	Spring
6	Quantity control valve
7	High pressure line to rail

Index	Explanation
8	Rail
9	Exhaust camshaft
10	Rail pressure sensor
11	Snap fastener, fuel feed line
12	Cylinder head
13	Actuating cam, high pressure pump
14	Bearing bracket, high pressure pump

A single-piston high pressure pump by Bosch is used. The high pressure pump is driven by a triple cam which is attached to the exhaust camshaft. The low pressure fuel is supplied to the high pressure pump via the fuel feed from the electric fuel pump.

⚠

Due to the high fuel pressures, the fuel lines must never be detached when the engine is in operation. When removing the high pressure pump, follow the specifications in the current repair instructions. Excessive tilting of the pump can damage the pump piston!



Bosch high-pressure pump

Index	Explanation
A	Low-pressure connection
B	High-pressure connection
1	Balancing chamber
2	High-pressure non-return valve

Index	Explanation
3	Pressure-limiting valve
4	Pump piston
5	Quantity control valve
6	Electrical connection of quantity control valve

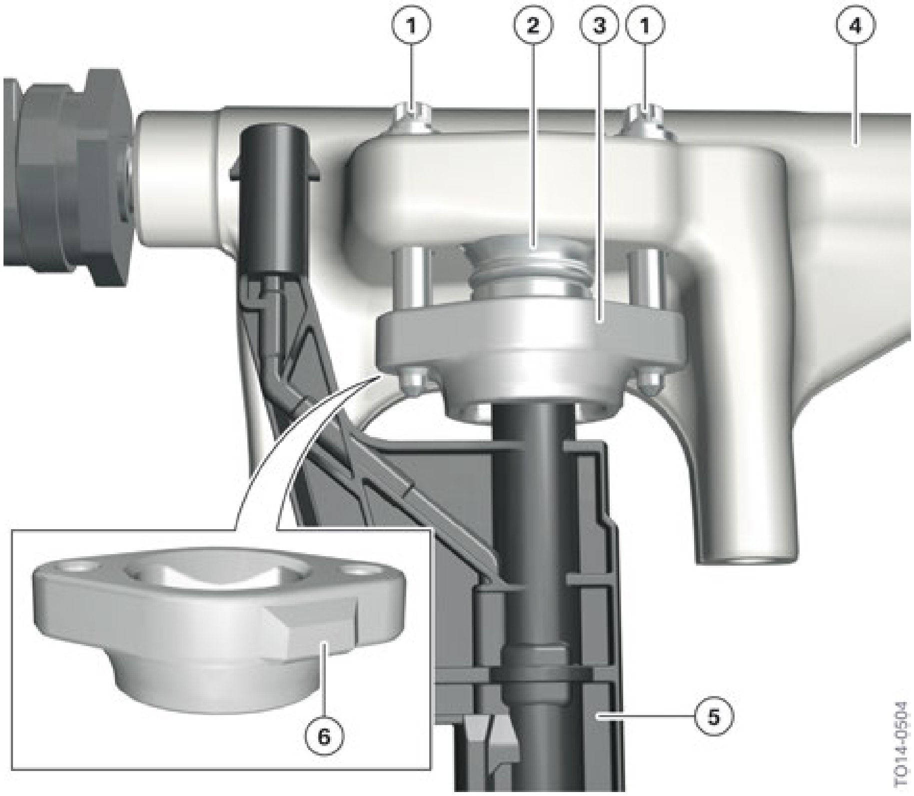
The quantity control valve at the high pressure pump adjusts the fuel pressure in the rail.
The maximum pressure in the rail is 200 bar. The high pressure pump contains a pressure limiting valve which opens at a pressure of 245 bar. The quantity control valve is activated via a pulse-width-modulated signal and assumes the open position in the de-energized state. This means the pump piston of the high pressure pump cannot compress the fuel.

It follows that the high pressure pump cannot build up pressure in the high-pressure fuel system when the quantity control valve is removed. In this situation, the maximum fuel low pressure (6.5 bar) would be present in the rail during an engine start. The system would be in emergency operation. To ensure the engine remains capable of running in this state, the opening period of the solenoid valve injectors has been extended and the idle speed increased. Although the vehicle remains drivable, the maximum engine performance is not available.

⚠

The quantity control valve is not resistant to continuous current. A permanent current supply with 12 V direct current voltage would render the component defective.

6.3.2. Direct rail



Mounting the injectors

Index	Explanation
1	Mounting bolts
2	Plastic sleeve
3	Holding clamp with bayonet fitting
4	Rail
5	Solenoid valve injector
6	Casting lug

The solenoid valve injectors are fastened to the holding clamp with a bayonet fitting. There is a plastic sleeve between the holding clamp and direct rail. This is not designed to collect escaping fuel. Its only purpose is to carry out a helium pressure test during assembly at the factory in order to check the tightness. After the initial assembly, this plastic sleeve is of no relevance to the engine operation. When the solenoid valve injectors are replaced, the plastic sleeves are no longer required and do not need to be reinserted.

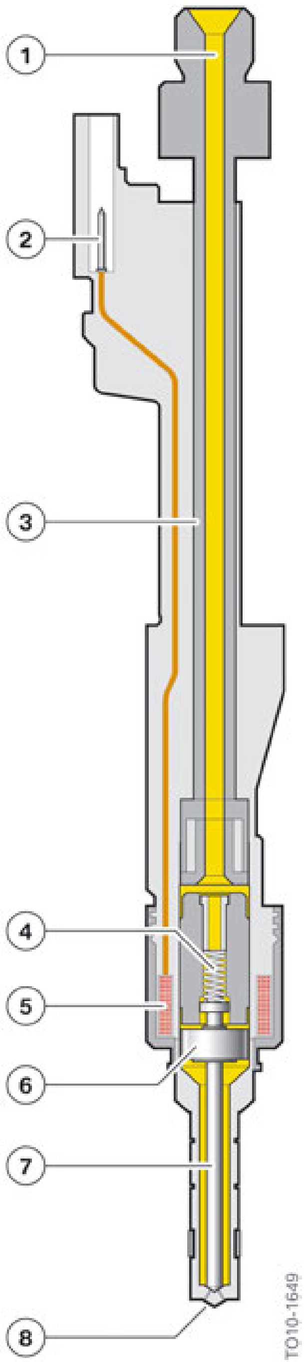
When manufacturing the holding clamp, casting lugs are produced when the component is detached from the tool. Due to the low installation tolerances, when installing the solenoid valve injectors it must be ensured that these casting lugs point in the direction of the exhaust manifold. If they are pointing in the wrong direction (towards the intake pipe), this can lead to mechanical contact between the holding clamp and cylinder head cover.

The mounting bolts of the holding clamp must be replaced each time they are released.

⚠

The shank of the solenoid valve injectors is sensitive to high tensile forces and rotational angles. When removing and installing the solenoid valve injectors, the procedure in the current repair instructions must be followed! If the solenoid valve injectors are damaged, fuel may be discharged.

6.3.3. Solenoid valve injector



Solenoid valve injector HDEV 5.2

Index	Explanation
1	Fuel line connection
2	Electrical connection
3	Stem
4	Compression spring
5	Solenoid coil
6	Armature
7	Nozzle needle
8	6-hole nozzle

The new B38 engine is equipped with the Bosch HDEV 5.2 solenoid valve injector. The designation of the injectors is a combination of the following:

- HDEV = high-pressure fuel injection valve
- 5 = generation designation
- 1 = maximum fuel injection pressure of 150 bar
- 2 = maximum fuel injection pressure of 200 bar

If current is supplied to the solenoid coil, a magnetic field is produced which attracts the magnet armature. The magnet armature runs upwards on the nozzle needle. The linear travel of the magnet armature in the direction of the solenoid coil carries the nozzle needle along with it and the nozzle bores are released in the direction of the combustion chamber.

The repair instructions that are currently valid must be followed when removing and installing the injectors in Service. If the rotational angle at the shank of the injector is too large, this can lead to damage and therefore leaks in the fuel system.

ULEV 2 measures at the solenoid valve injector

Due to the more stringent exhaust gas emission regulations which are required to meet the ULEV 2 exhaust emission standards, technical changes had to be made to the solenoid valve injectors.

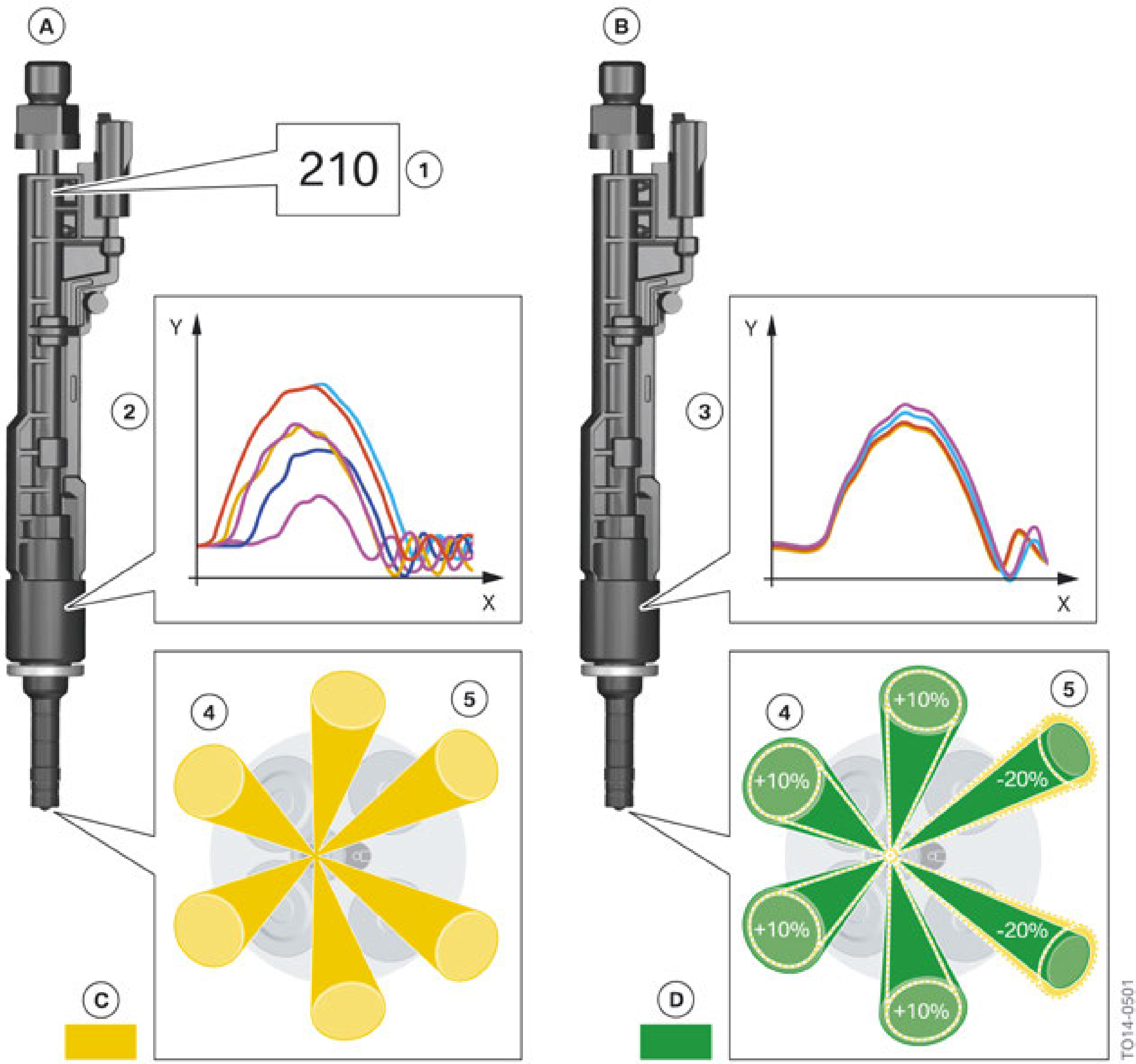
The limit value for the particle concentration (PN) is also stipulated in the ULEV 2 exhaust emission standards for gasoline engine passenger cars.

The reason for this is that in modern gasoline engines with direct injection no homogeneous fuel/ air mixture arises in comparison to engines with intake pipe fuel injection. There are therefore more particles in the exhaust gas (particulate matter).

Different diameters of laser-manufactured bore holes are used with the new high-pressure fuel injection valves, for example. The fuel quantity of the two spray jets in the exhaust direction is reduced by 20%, which increases the other spray jets by 10% respectively.

The solenoid valve injectors can only be used in a predefined position in the injector shaft of the cylinder head. This ensures correct alignment of the injection pattern in the combustion chamber.

The following graphic illustrates the differences between the ULEV and ULEV 2 version:



ULEV 2 measures, solenoid valve injector

Index	Explanation
A	Solenoid valve injector ULEV
B	Solenoid valve injector ULEV 2
C	Even nozzle bore geometry
D	Uneven nozzle bore geometry
X	Opening period
Y	Needle travel
1	Injection quantity compensation code

Index	Explanation
2	Conventional operation
3	Automatic operation
4	Spray pattern, intake valve side
5	Spray pattern, exhaust valve side

The high-pressure fuel injection valves are adapted during start-up via the injection quantity compensation code in the Digital Engine Electronics in order to compensate for possible manufacturing tolerances of the individual high-pressure fuel injection valves. To adapt all injectors in relation to one another, this only happens once during start-up (injection quantity compensation). During conventional operation, the parameters for activation of the injectors, such as current and activation duration, are the same for all injectors throughout the entire operating time and cannot be individually adapted. Another adaptation during the entire operating time is no longer possible.

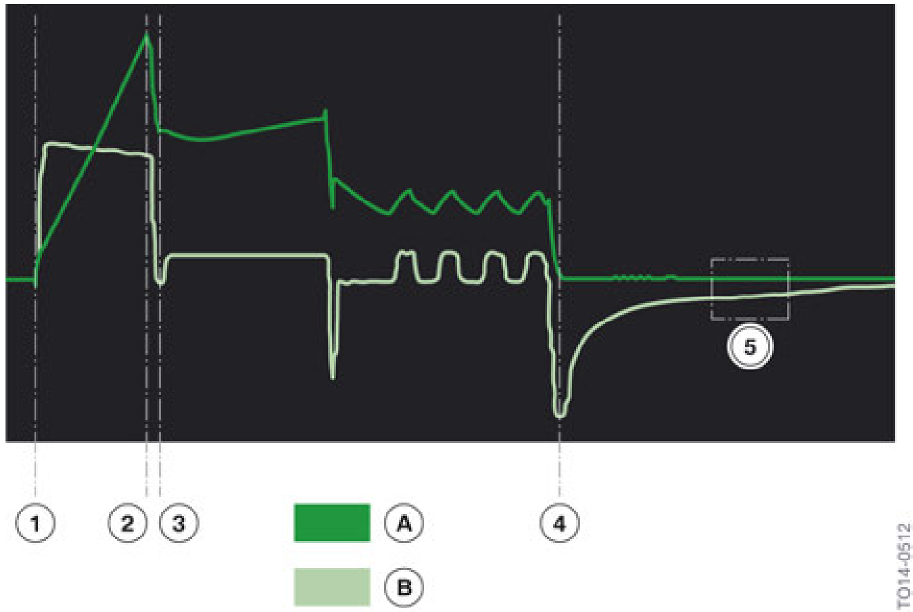
An automatic operation allows precise dosing of fuel, particularly when using extremely small injection quantities. Analysis of the voltage and current curve in injector mode allows conclusions to be drawn about the movement of the needle. The most important information in relation to the movement of the needle is the needle travel and opening period. The fuel injection rate can be determined from these two variables. It has therefore no longer necessary to manually input the fuel injector compensation code.

Controlled Valve Operating (CVO)

The Digital Engine Electronics permanently ensures automatic operation of the solenoid valve injectors throughout the entire operating time.

The basic principle of this CVO function is that the precise opening period of the high-pressure fuel injection valves is determined. The Digital Engine Electronics can determine the precise opening period based on the following parameters:

- Power consumption of the high-pressure fuel injection valve
- Voltage of the high-pressure fuel injection valve.



Current and voltage curve of the solenoid valve injector

Index	Explanation
A	Current flow
B	Voltage curve
1	Start of activation
2	Nozzle needle, opening start
3	Nozzle needle, fully open
4	End of activation
5	Nozzle needle closing

These current and voltage values change in the event of a needle movement in the high-pressure fuel injection valve, for example:

- Armature mists up/when the needle valve is withdrawn from the valve seat.
- Armature moves/needle valve moves in direction of open position.
- Armature stationary/needle valve comes to rest at the maximum open position.
- Reverse movement.
- Armature moves/needle valve moves in direction of closed position.
- Armature suffers impact and is braked hydraulically/needle valve closed.

With these values, calculated from current and voltage values of the aforementioned needle movements, the Digital Engine Electronics can determine the actual opening period of the high-pressure fuel injection valves. If the precise opening periods are known, the Digital Engine Electronics can also determine the exact fuel injection rate based on this information.

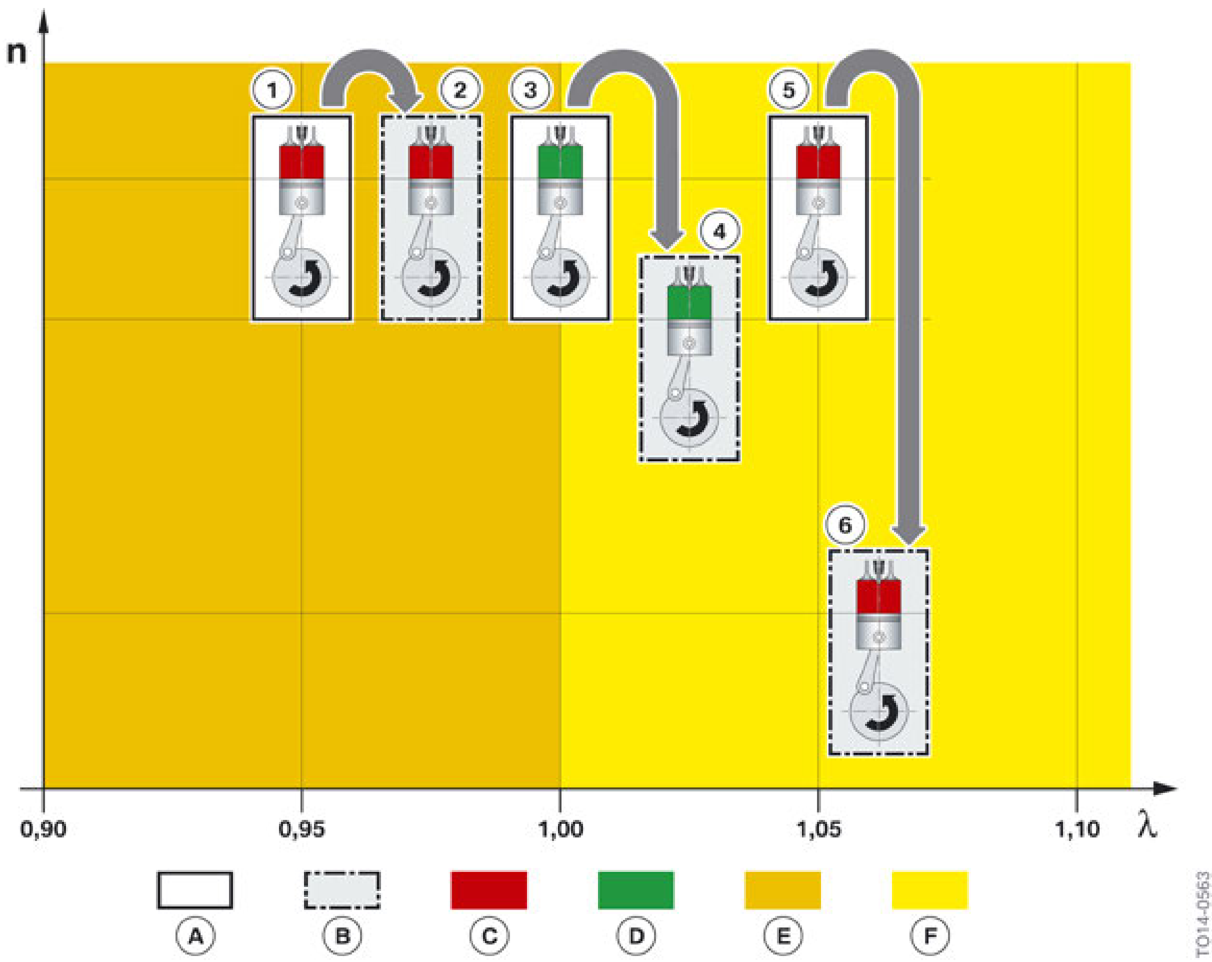
If variable fuel injection rates are now to be used, the Digital Engine Electronics can vary the fuel injection rate throughout the opening period by activating the respective high-pressure fuel injection valve individually. The Digital Engine Electronics thus has the option to adjust all high-pressure fuel injection valves to the same nominal fuel injection rate.

This measure guarantees the same nominal fuel injection rate in all cylinders, especially in the range where extremely small amounts are injected, as well as at idle speed. This measure inside the engine reduces exhaust emissions and therefore ensures compliance with the existing exhaust emission standards.

Cylinder Imbalance Monitoring (CIM)

The "Cylinder Imbalance Monitoring" function is an additional software function in the Digital Engine Electronics which monitors the correctness of the mixture preparation. The primary aim is to determine age-related operating time impairments of the fuel and intake area. Conclusions can be drawn about the air flow differences and different fuel injection rates. For example, these kind of differences are normally attributable to age-related leaks of the intake-components and pressure fluctuations in the rail.

The following graphic illustrates the operating principle of the Cylinder Imbalance Monitoring software:



Cylinder Imbalance Monitoring function

Index	Explanation
A	Cylinder in normal operation
B	Test cylinder with higher air/fuel ratio
C	Cylinder outside the tolerance
D	Cylinder inside the tolerance
E	Rich range
F	Lean range
n	Speed of crankshaft
λ	Air ratio
1	Cylinder in rich range
2	Test cylinder speed constant

Index	Explanation
3	Cylinder in ideal range
4	Test cylinder speed slightly slower
5	Cylinder in lean range
6	Speed of test cylinder significantly slower

The function is cyclically actuated by the Digital Engine Electronics. During this process, the air/fuel ratio is increased for each cylinder in succession during engine operation. At the same time as the air/fuel ratio in the test cylinder is increased, the remaining cylinders are enriched in order to maintain the overall lambda value of the exhaust gas passage within the range $\lambda=1$. This ensures perfect functionality of the 3-way catalytic converter.

If a test cylinder is operated when the air/fuel ratio is too low, a slight increase will not bring about a change in the crankshaft speed.

When the air/fuel ratio in a test cylinder is increased in the ideal range, this brings about a slight change in speed at the crankshaft.

If a test cylinder is operated when the air/fuel ratio is too high, the speed at the crankshaft drops rapidly.

The engine speed variations at the crankshaft are not evaluated directly, but rather the changes in smooth running during engine operation. Rough running of the cylinders in relation to one another is balanced out by a so-called 'cylinder balancing control'. The test cylinder in the rich range therefore brings about a minor change in rough running and the test cylinder in the lean range brings about a major change in rough running.

Mixture errors determined are stored as a fault code entry in the Digital Engine Electronics. The fault code entry provides information about which cylinder is affected and the rich or lean value determined. The driver is informed about the error via a malfunction indicator lamp.

Service note

When replacing the injector, the taught-in values of the CVO function and CIM function must be reset. This is done with the assistance of the BMW diagnosis system ISTA. Adjustment functions are available in the service functions. In order to inform the Digital Engine Electronics about the injector replacement, every ULEV 2 solenoid valve injector with the same dummy value (215) is taught in. Once the teach-in procedure has been successfully completed, the stored adaptations are reset and new adaptations are taught in via the CVO and CIM function.

⚠

When the solenoid valve injectors are replaced, they must be started up with the assistance of the BMW diagnosis system ISTA.

B38 Top Engine
7. Engine Electrical System

7.1. Digital Engine Electronics (DME)

Digital Engine Electronics MEVD 17.2.3 is used.

The control unit number is made up of the following:

- M = engine electronics
- E = electrical load control (without cable)
- V = Valvetronic control
- D = direct fuel injection
- 17 = control unit generation
- 2 = Bosch-internal project number for BMW
- 3 = control unit index

The Digital Engine Electronics is the computing and switching center. Sensors on the engine and the vehicle deliver the input signals and actuators implement the commands. The Digital Engine Electronics calculates the corresponding activation signals for the actuators from the input signals, and also the computing models and characteristic maps stored.

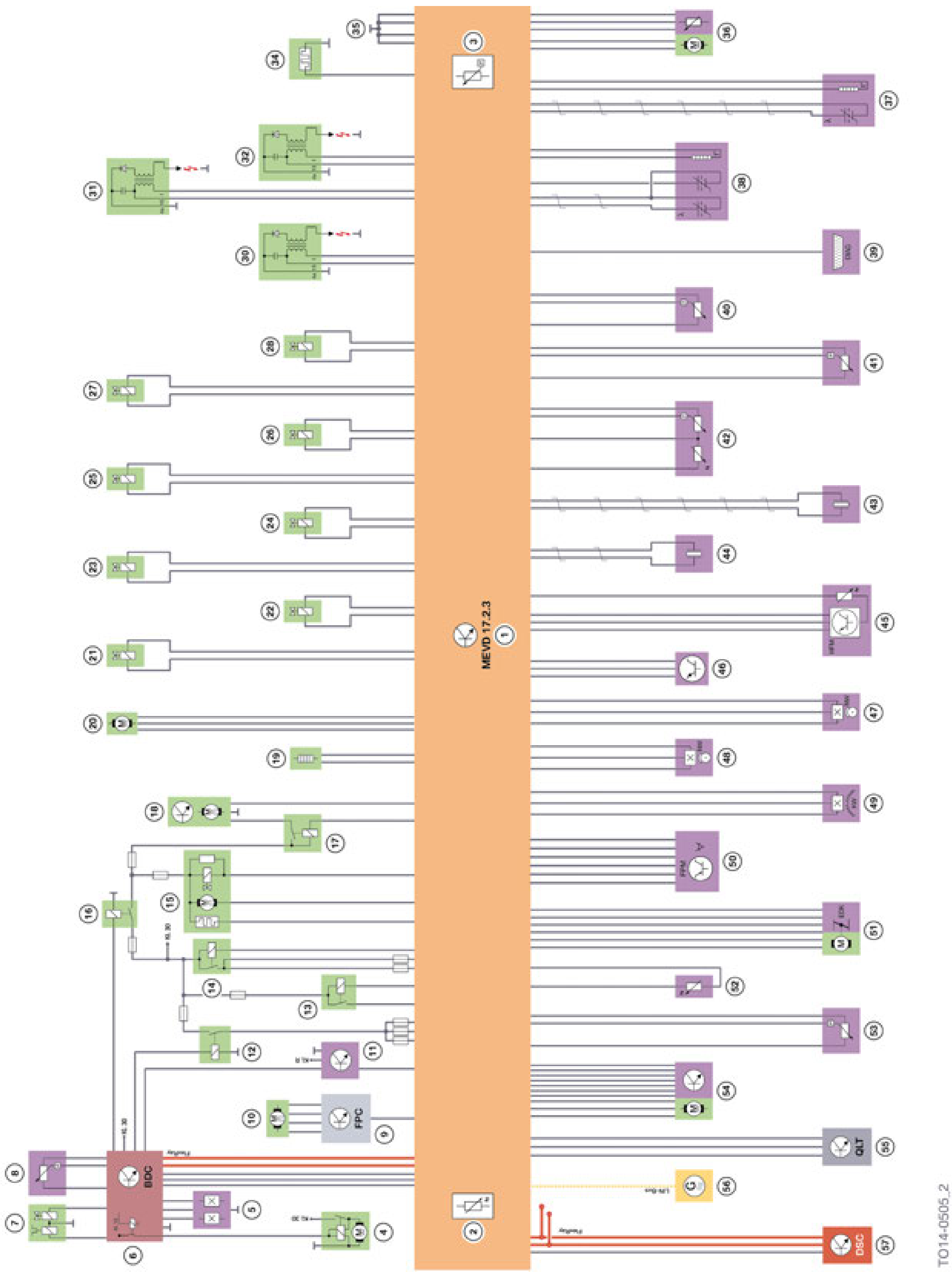
The operating voltage range of the Digital Engine Electronics is between 6 and 16 volts.

An ambient pressure sensor and a temperature sensor are integrated in the Digital Engine Electronics.

The ambient pressure sensor permits precise determination of the density of the ambient air. This information is required for various diagnostic functions. In addition, in the event of a failure of the hot film air mass meter, a precise substitute value can be calculated for the cylinder filling with the help of additional input variables.

The temperature sensor measures the temperature inside the control unit. If the temperature there rises too sharply, multiple fuel injection is reduced for example, in order to cool the output stages slightly and to keep the temperature inside the control unit in a non-critical range.

7.2. System wiring diagram, B38 engine



System wiring diagram (ULEV 2 version), B38 engine

Index	Explanation
1	Engine electronics Valvetronic direct fuel injection MEVD 17.2.3
2	Temperature sensor
3	Ambient pressure sensor
4	Starter motor
5	Brake light switch
6	Body Domain Controller
7	Air conditioning compressor
8	Refrigerant pressure sensor
9	Fuel pump control module
10	Electric fuel pump
11	Clutch switch
12	Relay, terminal 15N
13	Relay, Valvetronic
14	Relay, ignition and fuel injection
15	Diagnostic module for tank leaks
16	Relay, terminal 30B
17	Relay for electric fan
18	Electric fan
19	Map thermostat
20	Electric coolant pump (20 W)
21	Tank vent valve
22	VANOS solenoid valve, intake camshaft
23	VANOS solenoid valve, exhaust camshaft
24	Map-controlled valve, oil pump
25	Quantity control valve
26 – 28	Injectors, 3-cylinder engine
30 – 32	Ignition coils, 3-cylinder engine
34	Not for US
35	Ground connections
36	Actuator for electrically adjustable wastegate valve
37	Oxygen sensor after catalytic converter (LSF Xfour voltage-jump sensor)
38	Oxygen sensor before catalytic converter (LSU ADV broadband oxygen sensor)
39	Diagnostic socket
40	Intake-manifold pressure sensor after throttle valve

Index	Explanation
41	Rail pressure sensor
42	Charge air temperature and charging pressure sensor upstream of throttle valve
43	Knock sensor
44	Knock sensor
45	Hot film air mass meter
46	Gear sensor
47	Camshaft sensor, intake camshaft
48	Camshaft sensor, exhaust camshaft
49	Crankshaft sensor
50	Accelerator pedal module
51	Electromotive throttle actuator
52	Coolant temperature sensor
53	Oil pressure sensor
54	Valvetronic servomotor
55	Oil level sensor
56	Alternator
57	Dynamic Stability Control

7.2.1. Engine speed adjustment

A new feature in the area of the engine electronics is the engine speed adjustment which is active during the gear shift and supports the driver when shifting down using systematic throttle bursts.

The current position of the gearshift shaft inside the transmission is transferred to the Digital Engine Electronics with the assistance of a neutral sensor on the manual gearbox. Information about which gear is engaged is transferred while the gear shift operation is still in progress. The purpose of the engine speed adjustment is to adapt the engine speed to the selected gear before it is engaged. A smooth engagement is ensured by adapting the engine speed to the speed of the transmission input shaft.

⚠

The engine speed adjustment can be permanently deactivated with the assistance of the BMW diagnosis system ISTA.

7.3. Map ignition

The B38 engine is equipped with an inductive ignition system with static ignition distribution. Each cylinder has a separate ignition coil which is inserted directly into the cylinder head cover.

To achieve optimum consumption and minimum pollutant emissions and the highest possible torque, the ignition point must be perfectly adjusted.

The following factors influence the ignition point:

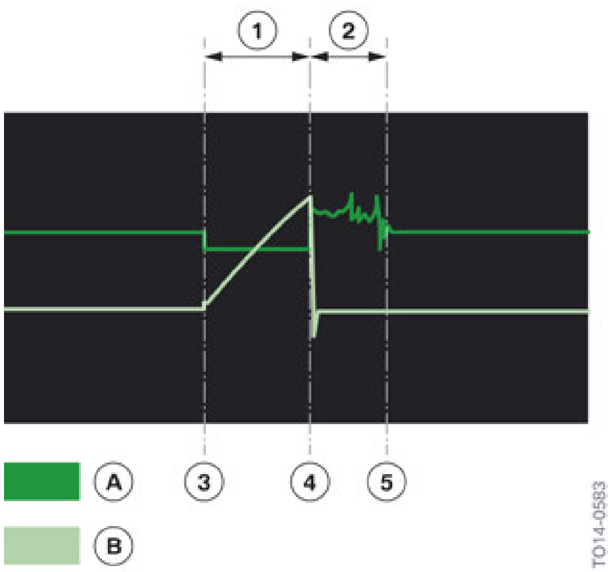
- Engine speed
- Engine torque
- Charging pressure
- Current air ratio
- Coolant temperature
- Intake air temperature
- Fuel grade
- Operating condition (engine start)

These variables are recorded by the Digital Engine Electronics via sensors, processed with the assistance of different characteristic maps and output as control signals to the ignition coils.

7.3.1. Diagnostic functions

As faults in the area of the ignition system directly affect the quality of the exhaust gas, the ignition processes are monitored by the Digital Engine Electronics. During this process, the combustion period for the ignition of each individual cylinder is evaluated as a priority. The voltage difference of the primary coil at terminal 1 and terminal 15 is determined and evaluated by carrying out a measurement within the Digital Engine Electronics. An increased voltage difference is measurable while an ignition spark is present. The period of this voltage difference is referred to as 'combustion period'.
The combustion period is not evaluated during the following operating conditions:

- During the starting operation
- Vehicle voltage < 12 volts



Current and voltage curve of ignition

Index	Explanation
A	Voltage curve
B	Current flow
1	Charging time of primary coil
2	Combustion period of ignition spark
3	Start of charging of primary coil
4	Start of ignition
5	End of ignition

Combustion period too short

The minimum thresholds for the combustion period are determined by the Digital Engine Electronics depending on the engine speed and load. When these minimum thresholds are undercut and misfiring also occurs, a fault code entry "Combustion period too short" is stored.

Combustion period outside the tolerance

The current combustion period of all individual cylinders is read in and combined to obtain a mean value. As the speed and load is the same in all cylinders, the calculated mean value is similar to the individual values read in. By comparing the individual values with the mean value obtained, the Digital Engine Electronics can draw conclusions about the combustion period. If an individual value exceeds or undercuts the minimum thresholds stored, a fault code entry "Combustion period outside the tolerance" is stored.

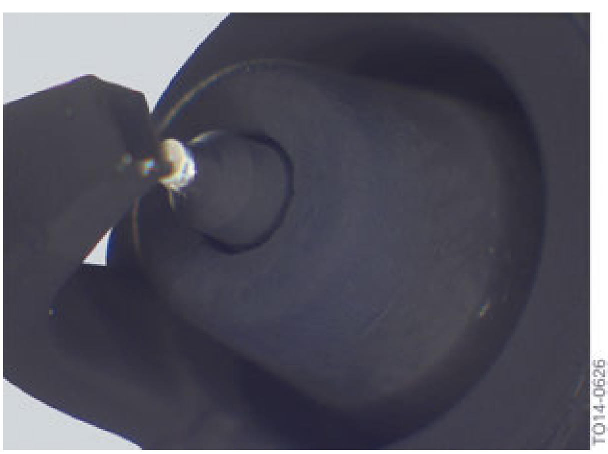
Note for Service

Fault code entries with the note "Combustion period too short" or "Combustion period outside the tolerance" are not necessarily always attributable to a defect in one or several ignition coils. Combustion period abnormalities can be identified via the diagnosis entry in the Digital Engine Electronics.

The following can cause deterioration of the combustion period:

- Contact resistances at the engine wiring harness of the ignition coil.
- Poor plug-in contact at the connector of the ignition coil.
- Coil resistance of ignition coils outside the permissible range.
- Ignition sparks inside silicone hose of the ignition coil.
- Carbon fouled spark plug(s).

The following graphic shows carbon fouling on the spark plug.



Carbon fouled spark plug

The fault code entry "Combustion period too short" is frequently caused by one or several spark plug(s) with heavy buildup. The buildup leads to deterioration of the ignition spark and therefore a very short combustion period.

7. Engine Electrical System

Carbon fouled spark plugs accompanied by a reduction in the combustion period may be caused by the following:

- Fault in the mixture preparation
  - leaks at the air intake system
  - fault at the injector
  - fault at the high pressure pump
  - deposits in the area of the intake valves.
- Fault in the engine electrical system
  - fault in the area of the coolant temperature sensor
  - fault in the area of the oxygen sensor
  - fault in the area of the hot film air mass meter.
- Large number of cold starts
  - frequent catalytic converter heating phases
  - few self-cleaning phases of the spark plugs.

With the fault code entry "Combustion period", a potential component fault at the relevant coil can be confirmed or disproved by swapping the ignition coil.

If misfiring occurs following component errors, different test modules in the workshop and diagnosis system ISTA can be processed. As the causes of faults in the ignition system are many and varied, the various test and diagnosis instructions in the test module must be followed. If a faulty component is replaced without eliminating the actual cause, this will only remedy the problem in the short term.

7.3.2. Ignition coils

Overview of ignition coils

The following graphic shows the current ignition coil used in the B38 engine:

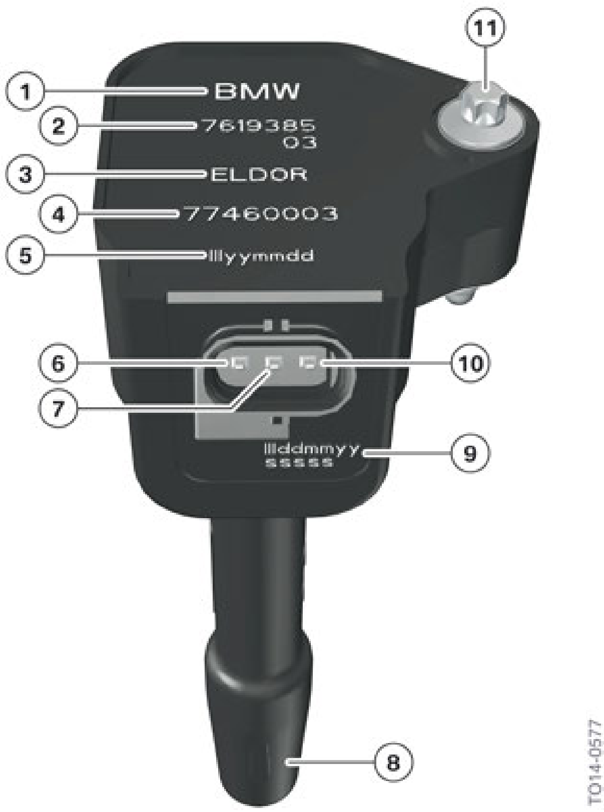
Overview of ignition coil

Index	Explanation
A	Compact ignition coil (manufacturer: Eldor)
1	Electrical plug-in contact
2	Silicone hose
3	Mounting bolt

The table below provides an overview of the engines in which the various ignition coils are used:

Engine	Compact ignition coil
B38	YES

Compact ignition coil



Ignition coil, B38 engine

Index	Explanation
1	Manufactured for BMW
2	BMW part number
3	Supplier
4	Supplier code
5	Production date
6	Terminal 15
7	Terminal 4a
8	Silicone hose
9	Serial number
10	Terminal 1
11	Mounting bolt

The primary and secondary coil required to raise the ignition voltage can be found in the area of the electrical plug-in contact. The transfer factor achieved by both coils is around 1:80.

When servicing the ignition coils, observe the following:

- A slight rotational movement when pulling out and inserting the ignition coils makes disassembly and installation easier.
- There must be no sign of contamination by oil or other fluids in the area of the electrical plug-in contact.
- The pins of the electrical plug-in contact must not be bent.
- There must be no sign of cracking on the silicone hose.
- The spring which transmits the ignition spark must be positioned at the center of the silicone hose.
- The silicone hose of the ignition coils must not come into contact with fuel or mineral oils.
- The specified torque of the mounting bolt must be observed.
- Prior to disassembly of the ignition coil, remove the plug-in contact from the engine wiring harness, as the ignition coils cannot be operated without spark plugs.

⚠

The ignition coils are not fuel-resistant. All ignition coils should therefore be removed before opening the fuel system. Fuel residues must be removed before inserting the ignition coils in the spark plug shaft.

7.3.3. Spark plugs

A change interval applies for spark plugs and they must be renewed in accordance with the manufacturer's specifications. To avoid damage and ensure perfect function of the spark plugs, the prescribed tightening torques must be observed.

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