Technical training.
Product information.

I12 Powertrain

BMW Service

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BMW Group University
Technical Training
ST1408 7/1/2014

General information

Symbols used

The following symbol/schematic diagram is used in this document to facilitate better comprehension or to highlight 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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I12 Powertrain
Contents

I12 Powertrain
Contents

I12 Powertrain
1. Introduction

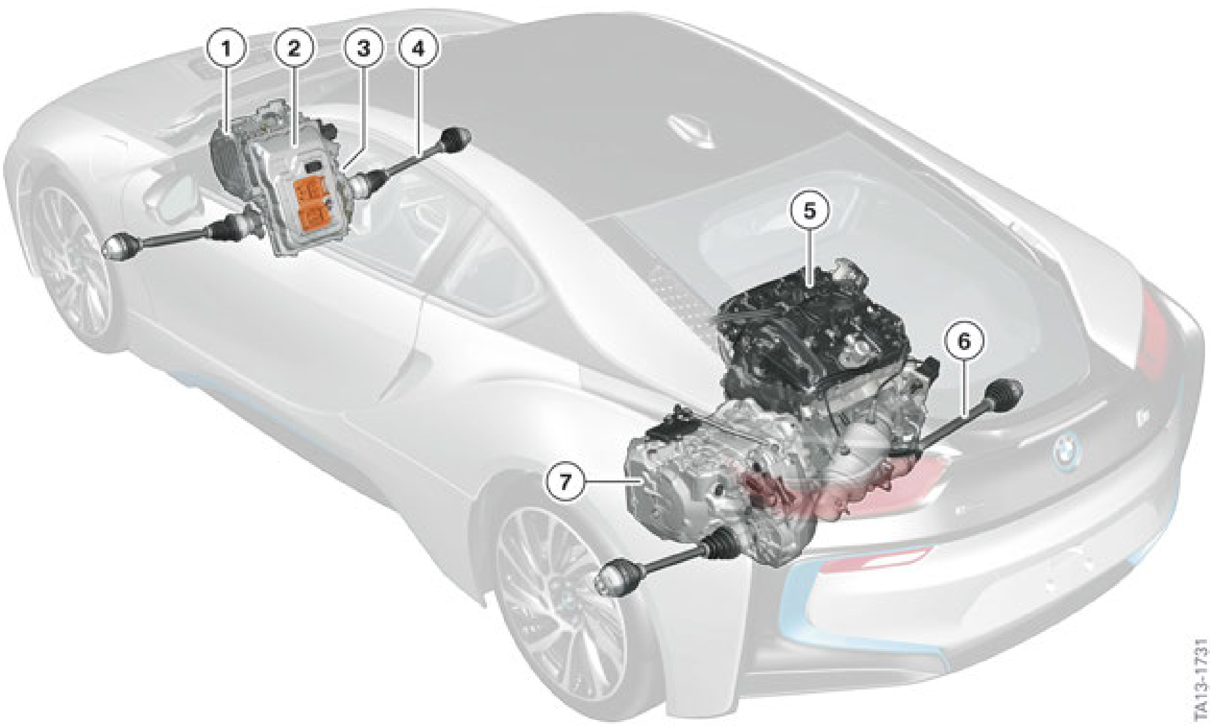
1.1. Overview

A newly developed drivetrain is used with the BMW i8 – development code I12. This innovative drive concept combines two high-performance drives in one vehicle. A high-performance 3-cylinder gasoline engine with 6-speed automatic transmission provides the drive at the rear axle. An electrical machine in combination with a 2-speed manual gearbox provides the drive at the front axle. Due to the intelligent interaction of the drives the I12 has the vehicle performance of a sports car with the efficiency of a compact car.

Designation	Unit	I12
Overall power	[kW / HP]	274 / 368
Overall torque	[Nm / lb-ft]	619 / 457
Acceleration 0-60 mph	[s]	4.2
Maximum speed	[km/h / mph]	250 / 155
Vehicle curb weight	[kg / lbs]	1567 / 3455
c_w		0.26
Fuel consumption	[l/100 km]	2.1
Electrical range	[km / miles]	up to 37 km / 23 miles

I12 Powertrain
1. Introduction

This axle hybrid configuration (which is being used for the first time at BMW) creates an individually controllable all-wheel drive system that was developed without additional components. The coordination of the front and rear drive torque enables an efficient drivetrain, which can be individually adapted to every driving situation.



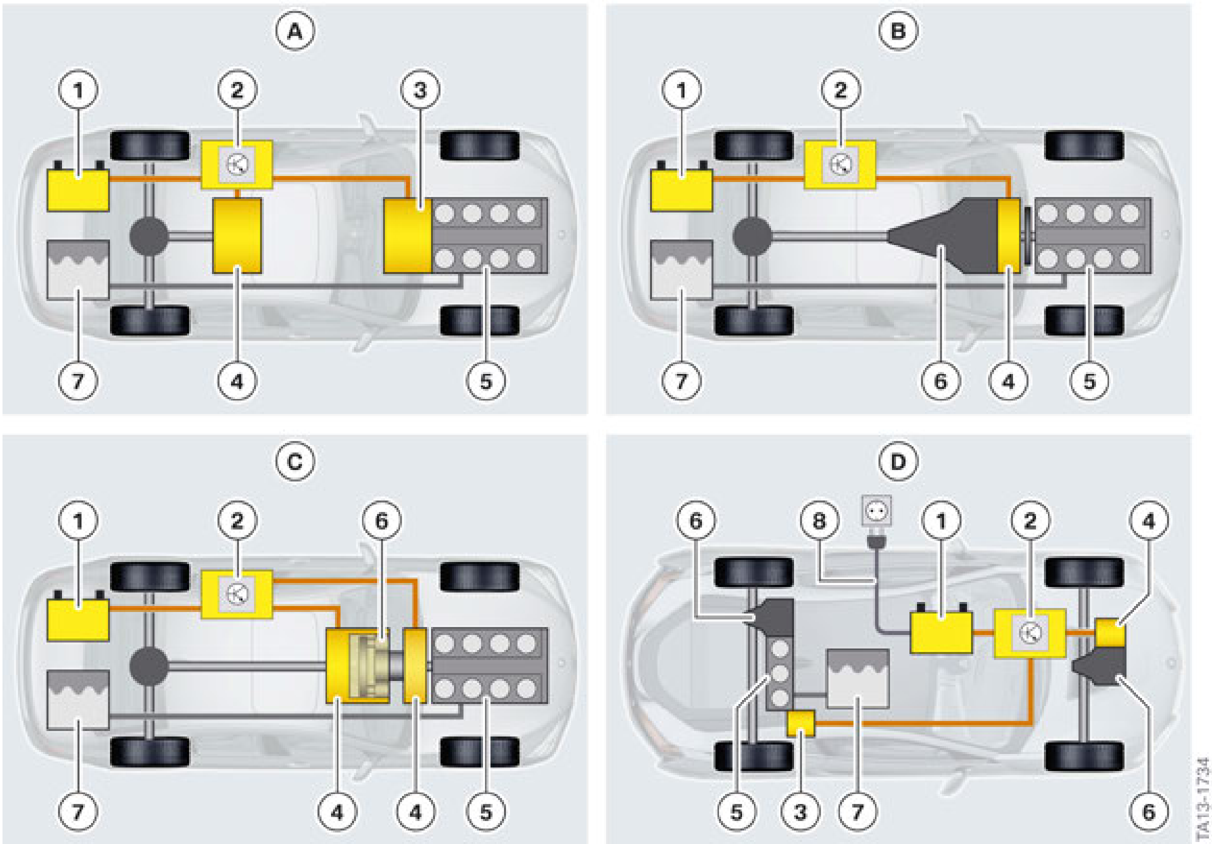
I12 Drive

Index	Explanation
1	Electrical machine
2	Electrical machine electronics (EME)
3	2-speed manual gearbox
4	Output shaft, right front axle
5	Combustion engine
6	Output shaft, right rear axle
7	Automatic transmission

The axle hybrid represents a further development of the existing BMW hybrid systems.

I12 Powertrain

1. Introduction



Overview of hybrid systems

Index	Explanation
A	Serial hybrid
B	Parallel hybrid
C	Power-split hybrid
D	Axle hybrid
1	High-voltage battery
2	Power electronics
3	Range Extender Electrical Machine or high-voltage starter motor generator
4	Electrical machine
5	Combustion engine
6	Transmission
7	Fuel tank
8	Charging socket

The serial hybrid drive (A) is used in the I01 with range extender, the parallel hybrid (B) in the F04 and the power-split hybrid (C) in the E72.

I12 Powertrain
1. Introduction

Unlike with the other hybrid systems, with the axle hybrid (D) the respective axles of the vehicles are driven independently of each other. The only connection between the two axles is the road. It is therefore possible to drive the vehicle with the use of both drive systems at the same time or individually depending on the situation. With sufficient capacity of the high-voltage battery, greater distances can be covered, emission-free and quietly using the electric drivetrain. The design of the combustion engine also enables a larger range and a sporty driving style with low fuel consumption (particularly in combination with the electric drive). The installation of two electrical machines allows for a high degree of flexibility in the design of the operating strategy. This type of hybrid system is designed for coping with future challenges in the urban environment.

1.2. Mid-engine

For the first time since 1978 a mid-engine configuration is used again in a BMW. In the BMW M1 (E26) a 204 kW / 273 hp 6-cylinder gasoline engine (M88/1) was used. Only a low volume of these engines were produced.

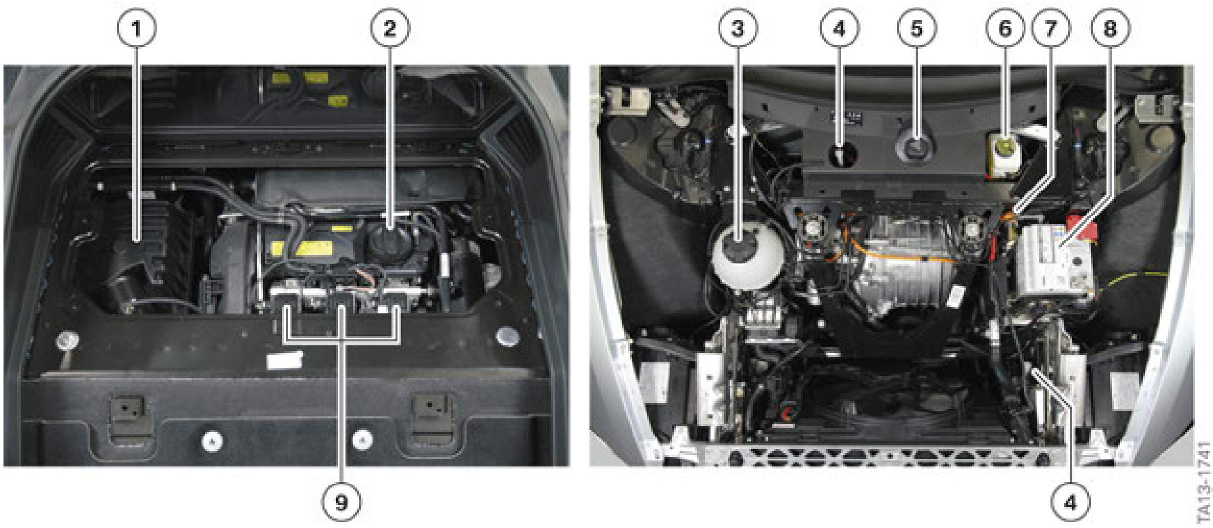
The designation mid-engine describes the installation position of the combustion engine. The combustion engine always sits between the axles of a vehicle. The combustion engine with a manual gearbox in front of the (driven) rear axle and behind the passenger compartment is characteristic of the mid-engine design. This is also the case in the I12. A transverse mounted 3-cylinder gasoline engine with a power rating of 170 kW / 231 hp (mounted in front of the rear axle) also drives the rear axle.

The advantages of the mid-engine design are:

- **Higher cornering speeds are possible**
  The mid-engine allows approximately the same weight distribution to the front and rear axle, as well as a mass concentration near the vehicle's center of gravity. This results in a neutral driveability, which enables high cornering speeds.
- **More spontaneous steering while cornering**
  The mass concentration near the vehicle's center of gravity brings about a low inertia torque around the vertical vehicle axis. The vehicle is thus more agile and maneuverable.
- **Enhanced passive safety**
  The larger space in the front and rear area allows a better design of the crumple zones and the pedestrian protection.
- **Increased design possibilities of the front section**
  Aerodynamic advantages can be made easier as a result of the greater freedom in design.

I12 Powertrain
1. Introduction

Unlike in standard design vehicles, the B38 Top engine in the I12 is accessed via the (tailgate) rear engine compartment lid. After the cover is removed, the combustion engine is accessible from above. It is possible, for example, to top off the engine oil, replace the spark plugs or the air filter element from this location. The oil filter element for the engine oil is accessible from below. All other service-relevant interfaces can be reached as usual via the front engine compartment lid.



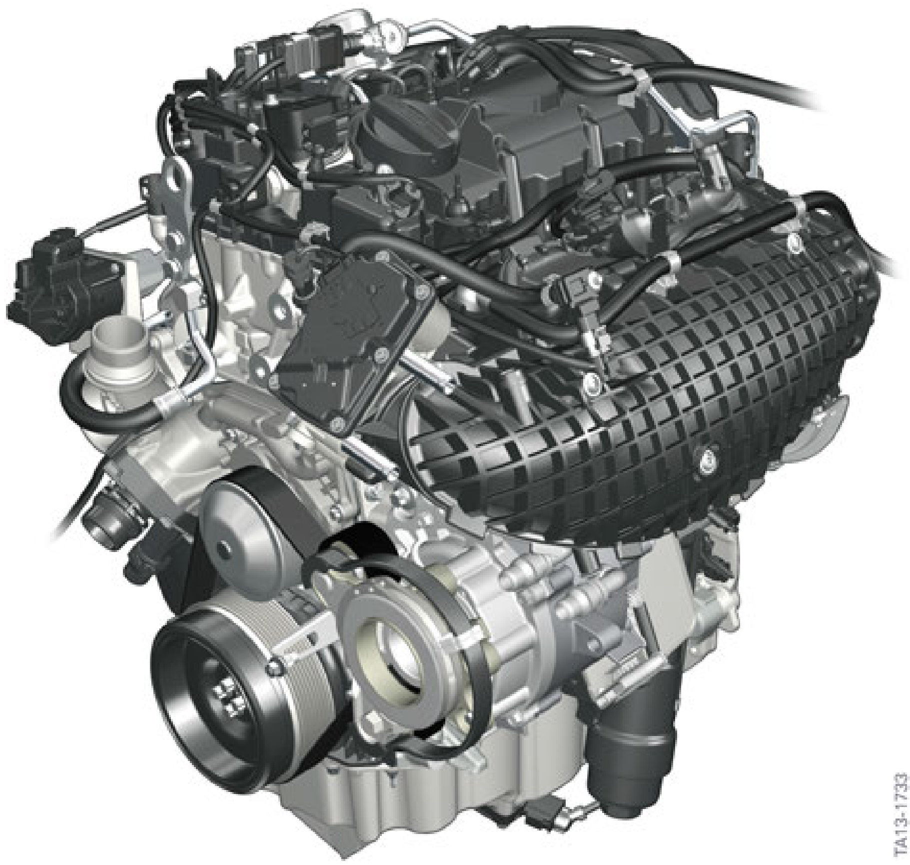
I12 General view under the front and rear the engine compartment lids

Index	Explanation
1	Intake silencer (with air filter element)
2	Oil filler neck
3	Expansion tank for the high-temperature cooling circuit
4	Connections for A/C service station
5	Expansion tank for the low-temperature cooling circuit
6	Brake fluid expansion tank
7	High-voltage safety connector (Service Disconnect)
8	12 V battery
9	Single-spark ignition coils

I12 Powertrain

2. B38 Top Engine

The B38K15T0 engine is used the first time in the I12. This 170 kW / 231 hp 3-cylinder gasoline engine is based on the previous B38 engines in other BMW Group vehicles. It is installed in the I12 as a transverse mounted mid-engine. Only the differences and special features are mentioned in this reference manual. The engine block is described in the "B38/B48 Engine" training reference manual.



B38 Top engine

I12 Powertrain

2. B38 Top Engine

2.1. 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.

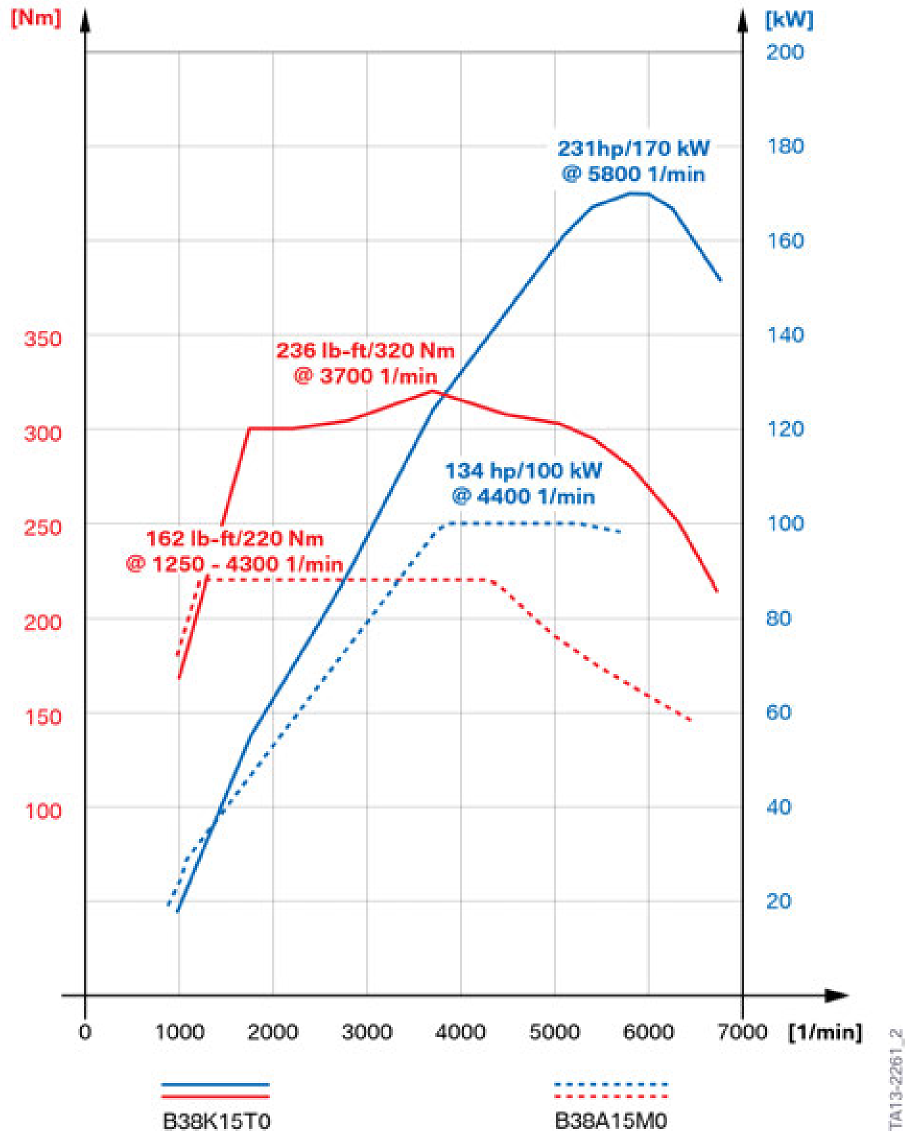
Position	Meaning	Index	Explanation
1	Engine developer	M, N, B P S W	BMW Group BMW M Sport BMW M GmbH Bought-in engines
2	Engine type	1 2 3 4 5 6 7 8	4-cylinder in-line engine (e.g. N18) 4-cylinder in-line engine (e.g. N20) 3-cylinder in-line engine (e.g. B38) 4-cylinder in-line engine (e.g. N43) 6-cylinder 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

2. B38 Top Engine

2.2. 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 (231) 5800
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

2. B38 Top Engine



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

2.3. Changes

The following list provides an overview of the changes to the previous B38 engines.

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.

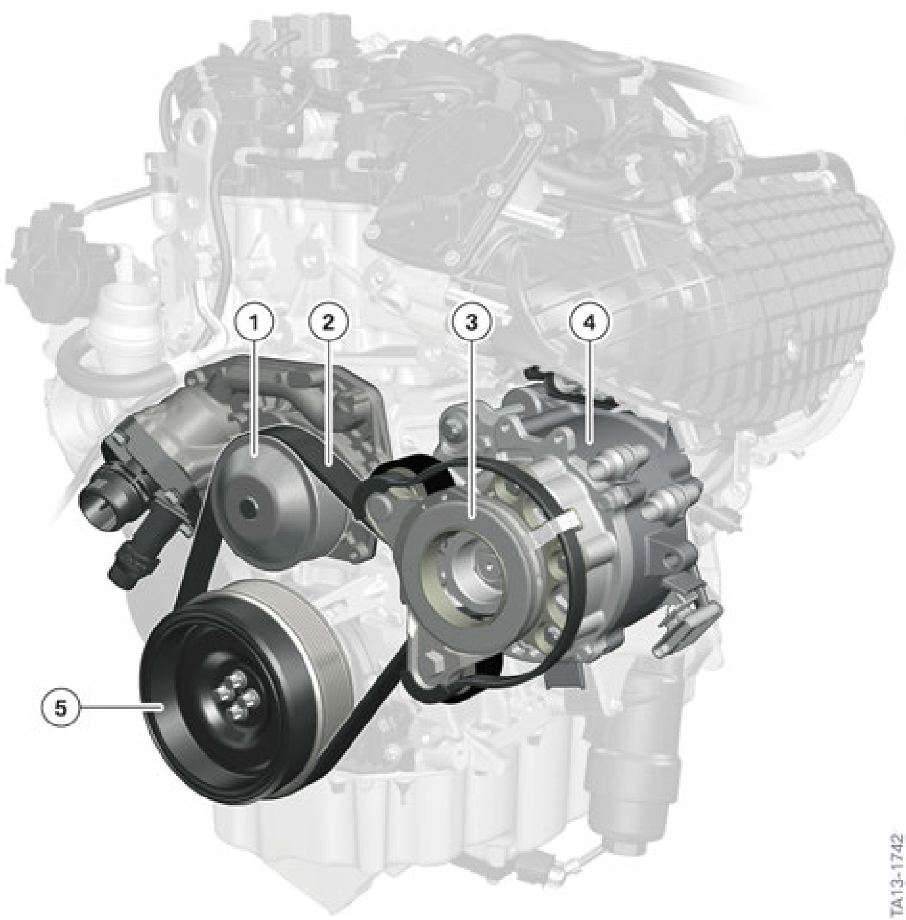
2.4. Belt drive

The belt drive of the B38 Top engine is different to that of the B38 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.

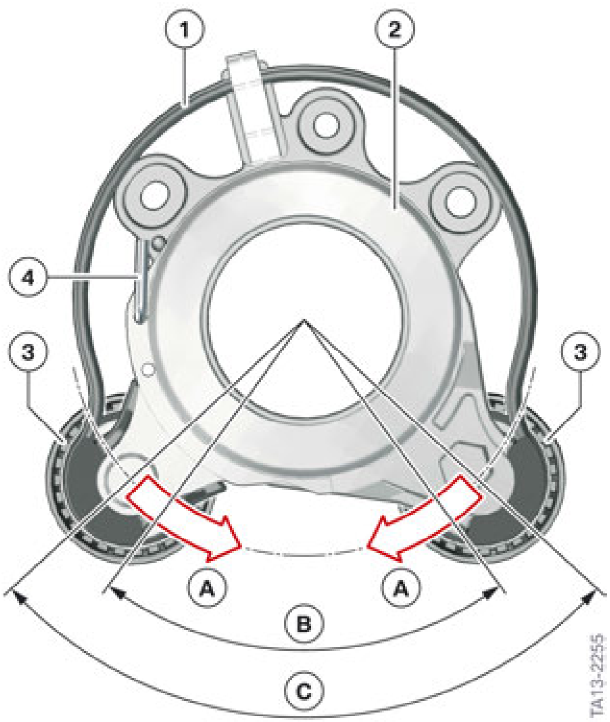
High-voltage components are marked with the following warning stickers:

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.

2.4.1. 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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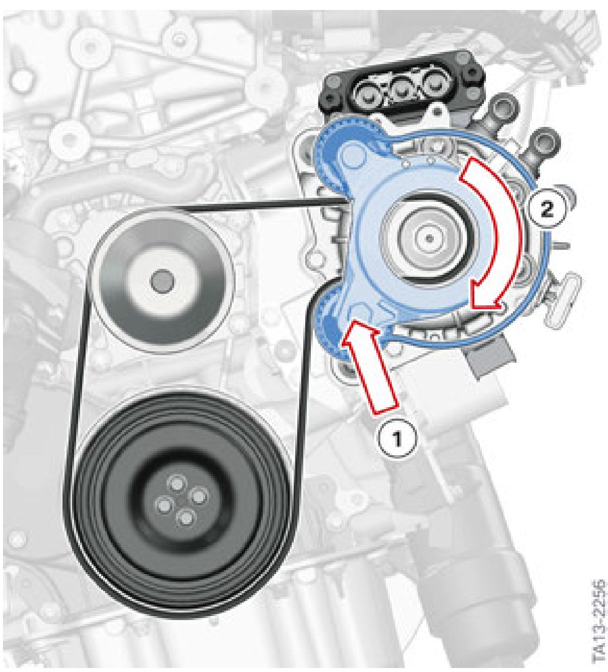
After the pendulum belt tensioner is secured at the housing and the drive belt has been properly installed, the assembly bolt must be removed. Using the open-end wrench relax the pendulum belt tensioner in an counter-clockwise direction until the assembly bolt can be removed.

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.

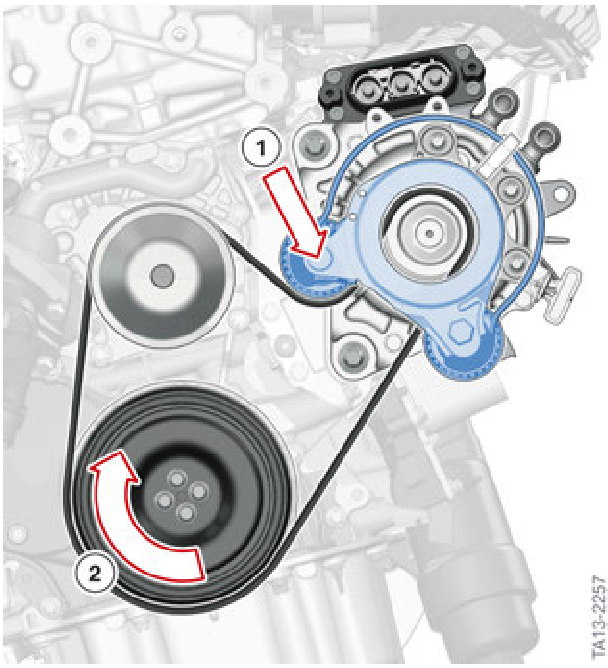


I12 Belt drive in starting mode of the high-voltage starter motor generator

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.

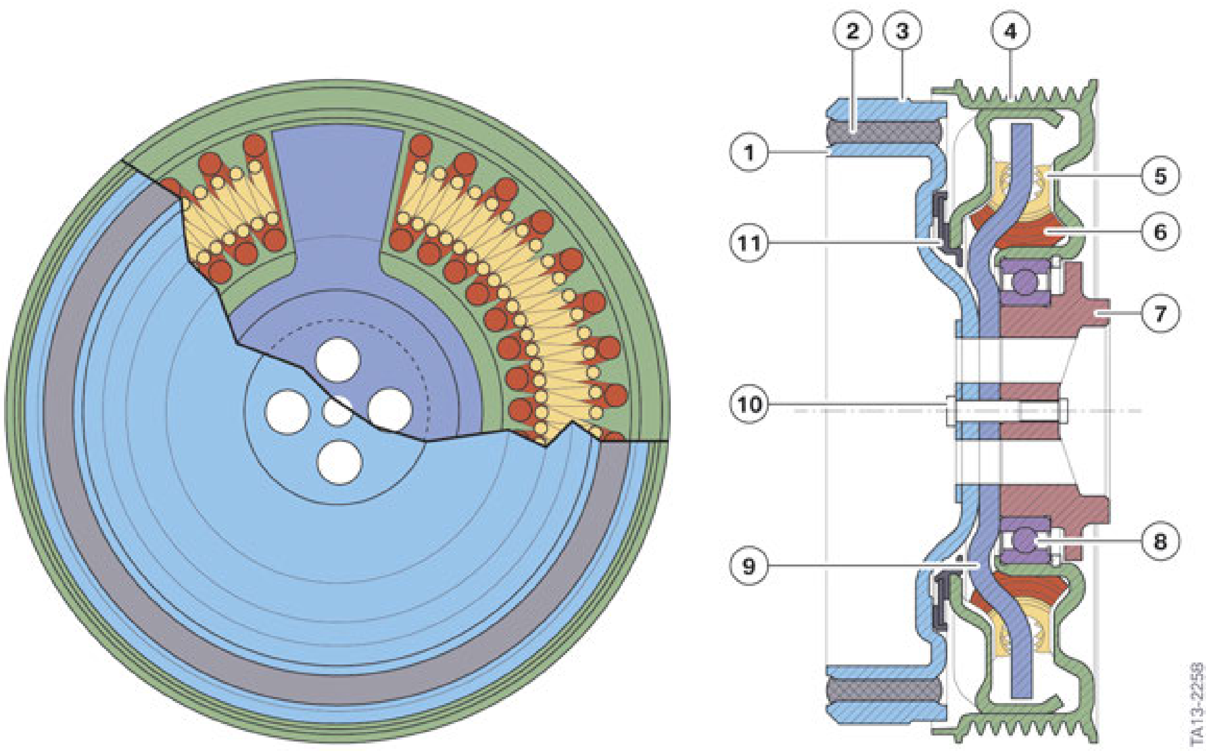


I12 Belt drive in charge mode of the high-voltage starter motor generator

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

2.4.2. 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.

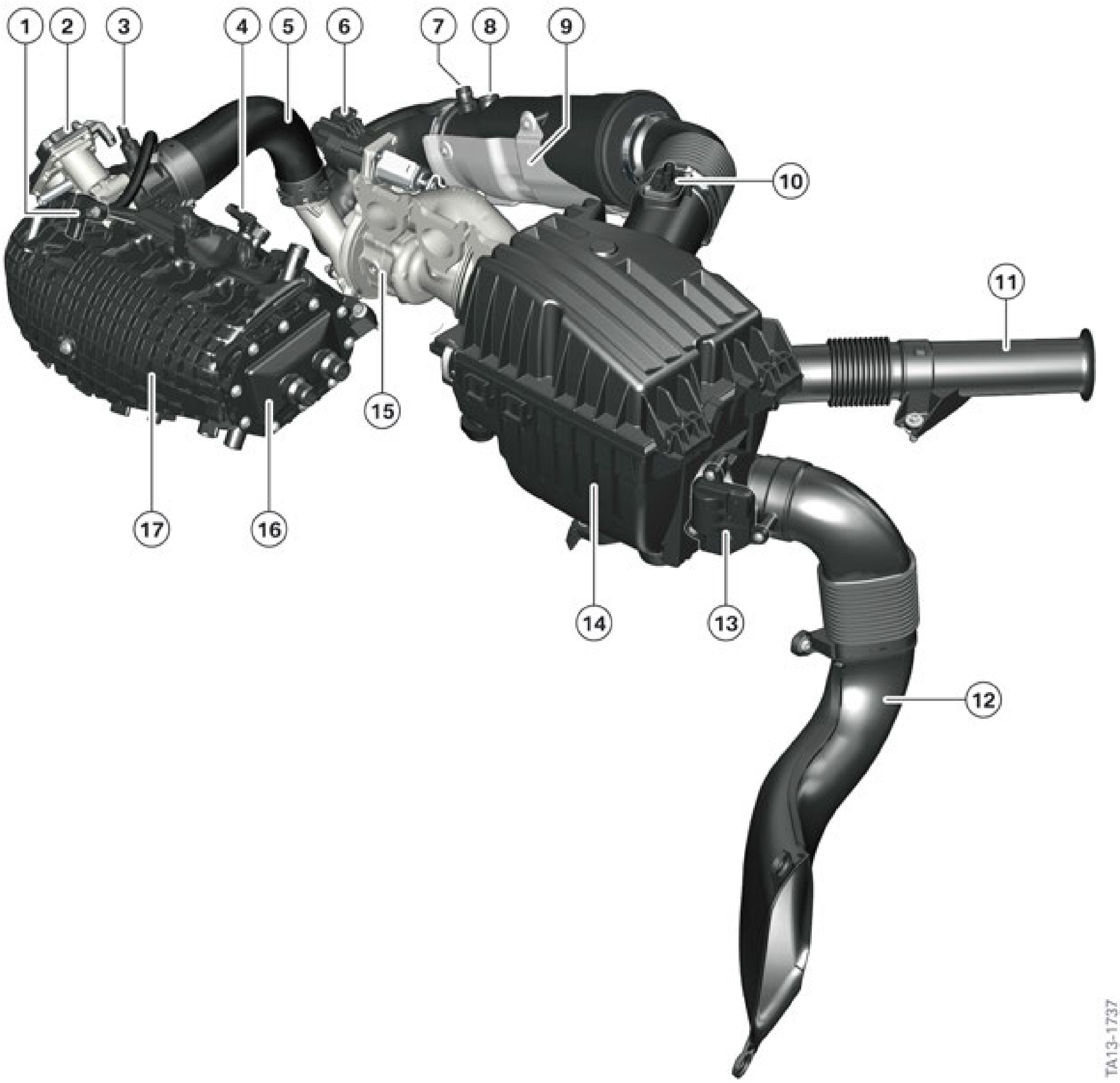
In the event of emerging grease, the vibration damper with disconnected belt pulley must be replaced.

2. B38 Top Engine

2.5. Intake air and exhaust emission systems

2.5.1. 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)
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.

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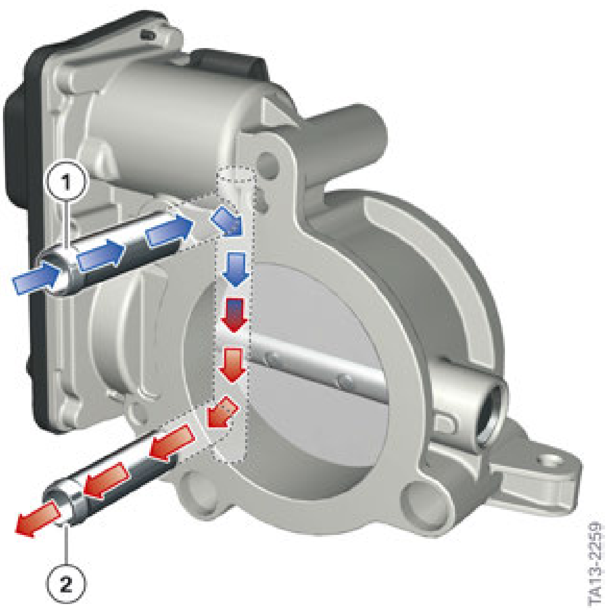
If annoying noises occur during the operation of the combustion engine, the function of the unfiltered-air flap must be checked.

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.

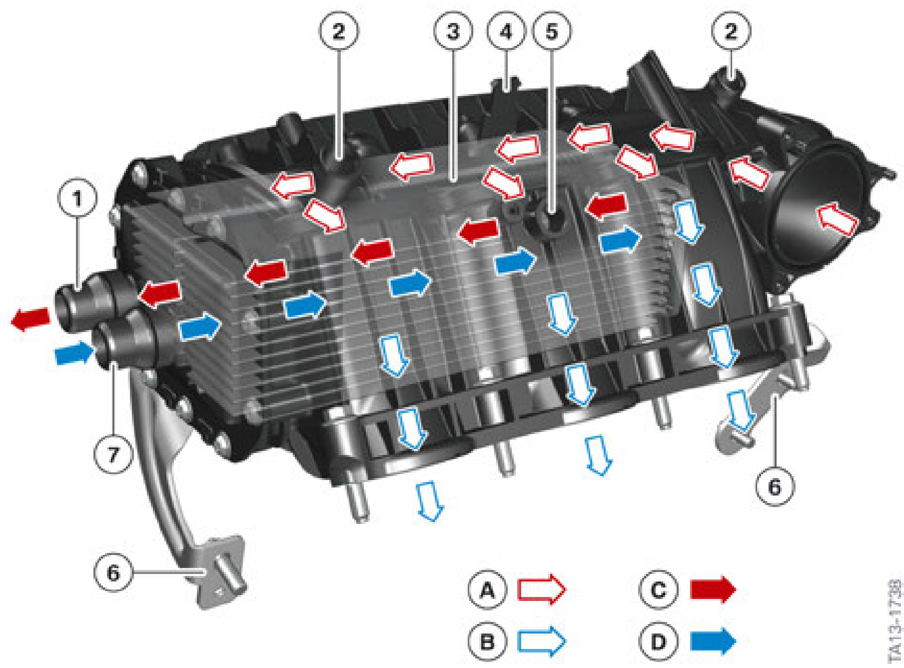


I12 Water-cooled throttle valve

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.

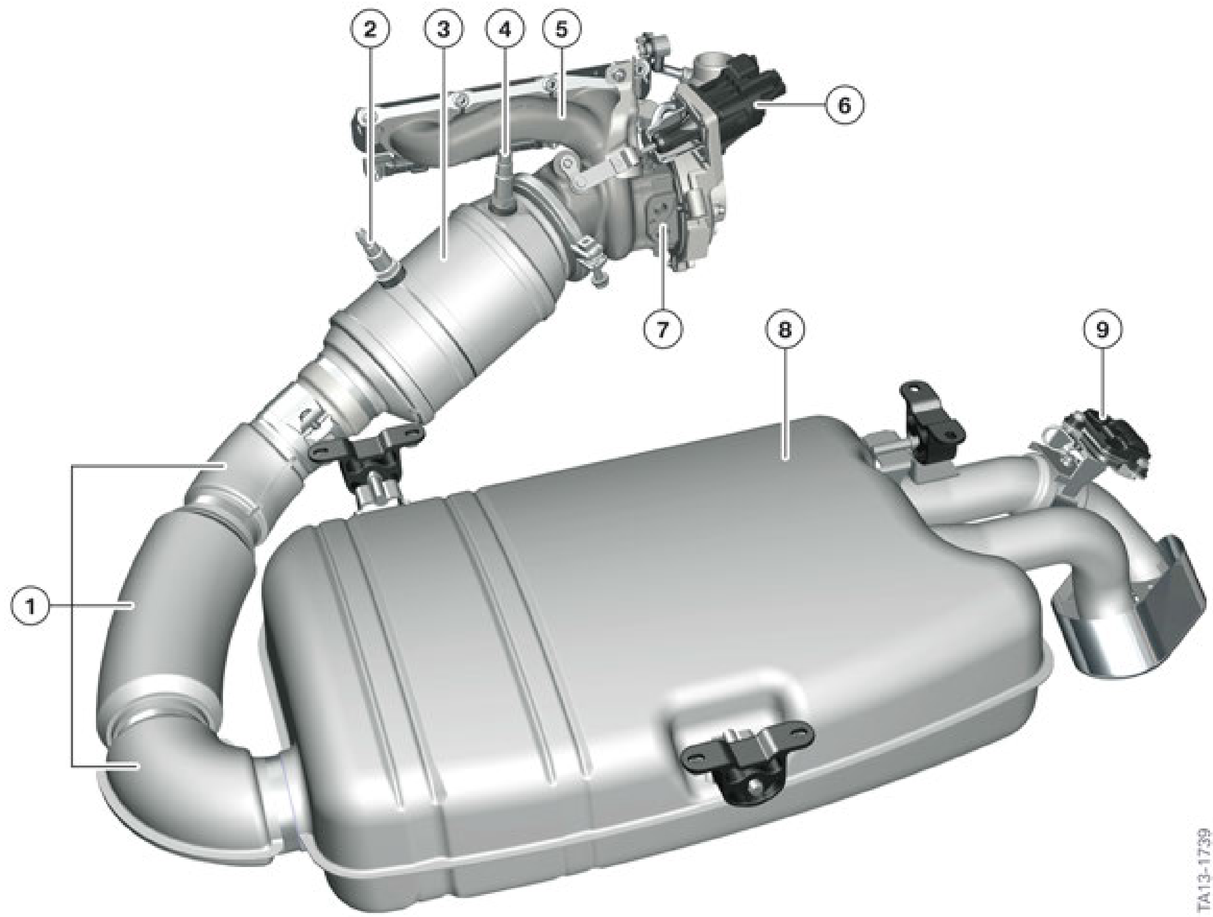
The plastic intake air system is located at the intake side of the combustion engine. The tank vent valve and the intake-manifold pressure sensor are located on the intake air system.



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

2.5.2. 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 (unlike in the previous B38 engine) 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.

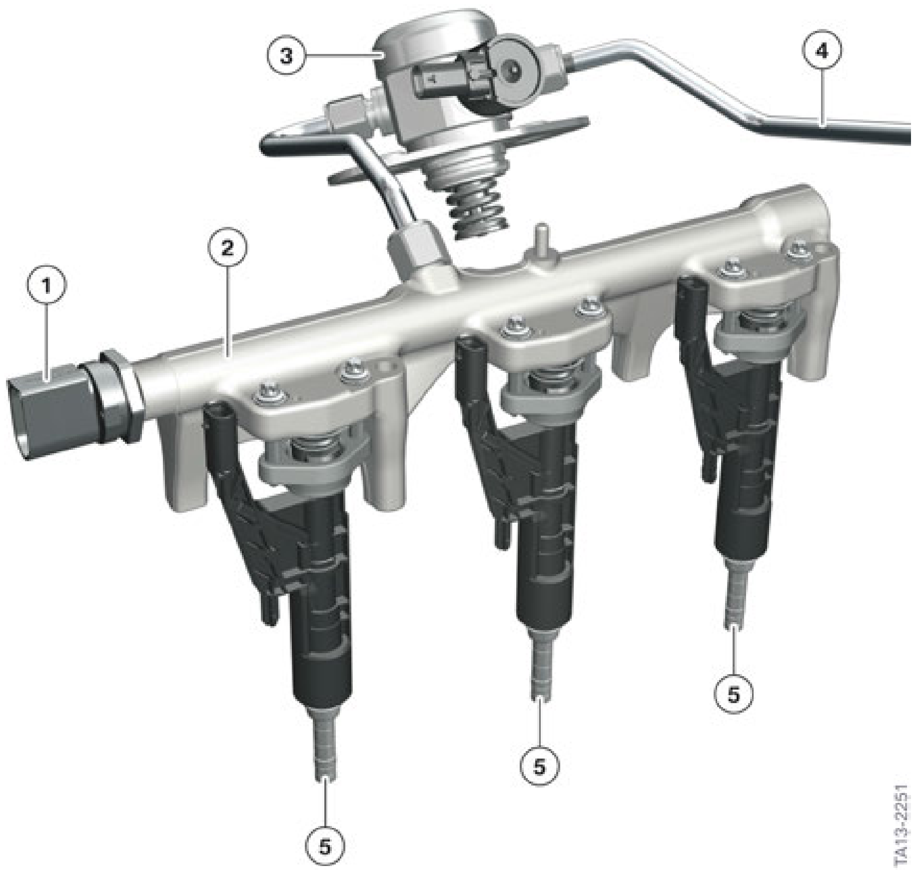
In order to protect the body from excessive heat, insulation elements are attached in the corresponding areas at the exhaust system.

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.

2.6. Fuel system

2.6.1. 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

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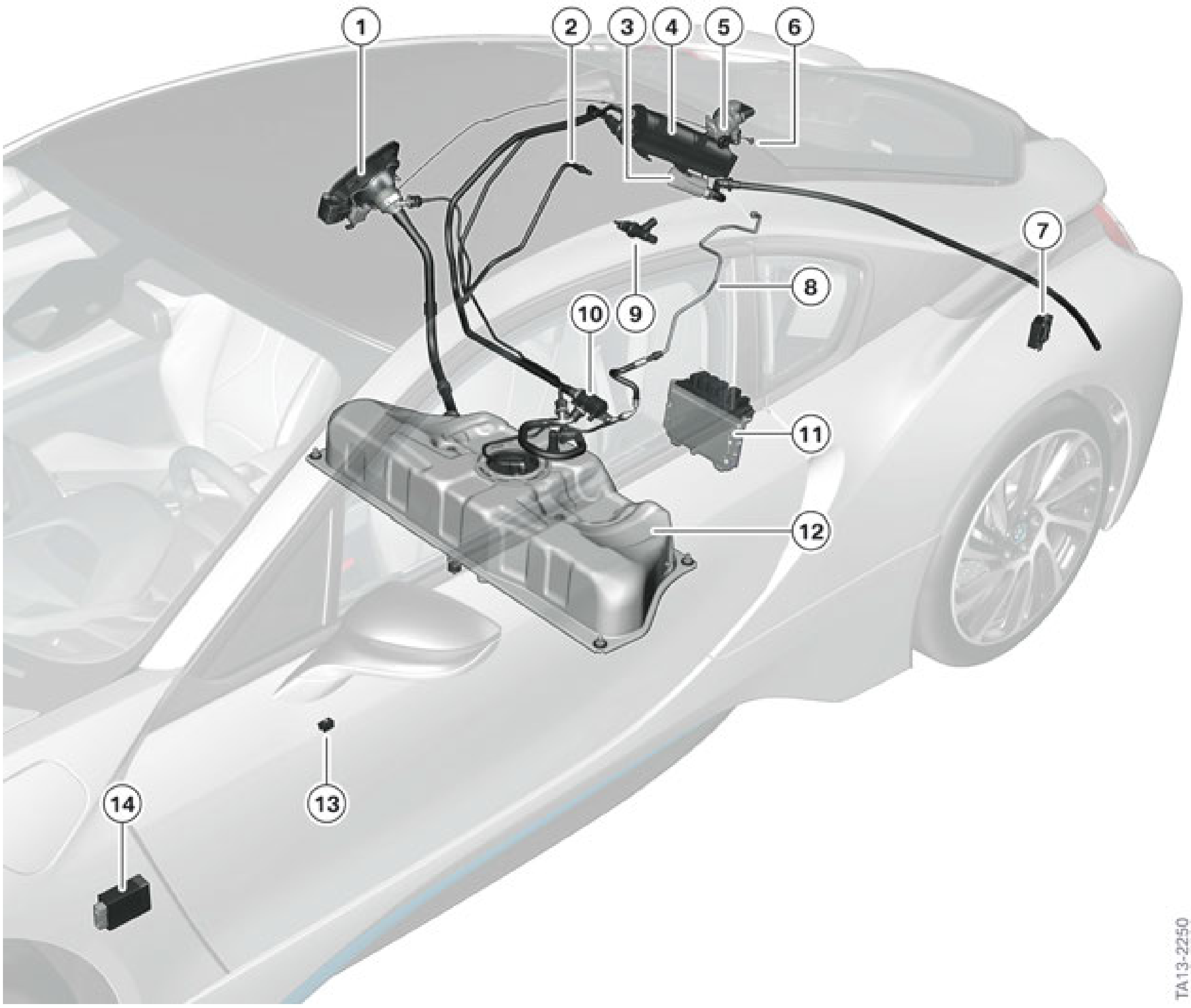
Work on the fuel system is only permitted after the combustion engine has cooled down. The coolant temperature must not exceed 40 °C / 104 °F. This must be observed at all times, otherwise there is a risk of fuel being sprayed due to residual pressure in the fuel system.

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.

2.6.2. 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



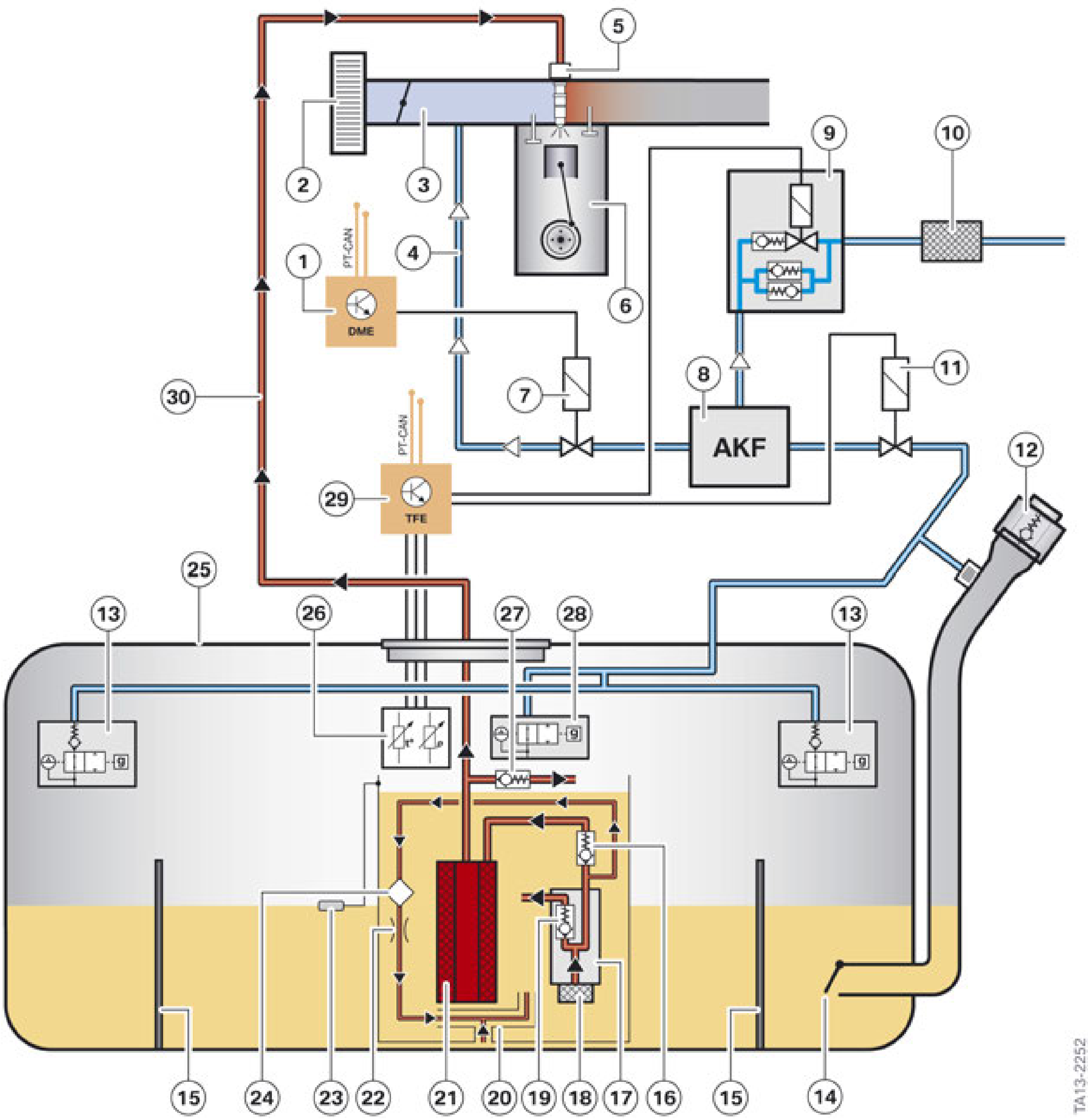
I12 Components of the fuel supply system, US version

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.

System overview



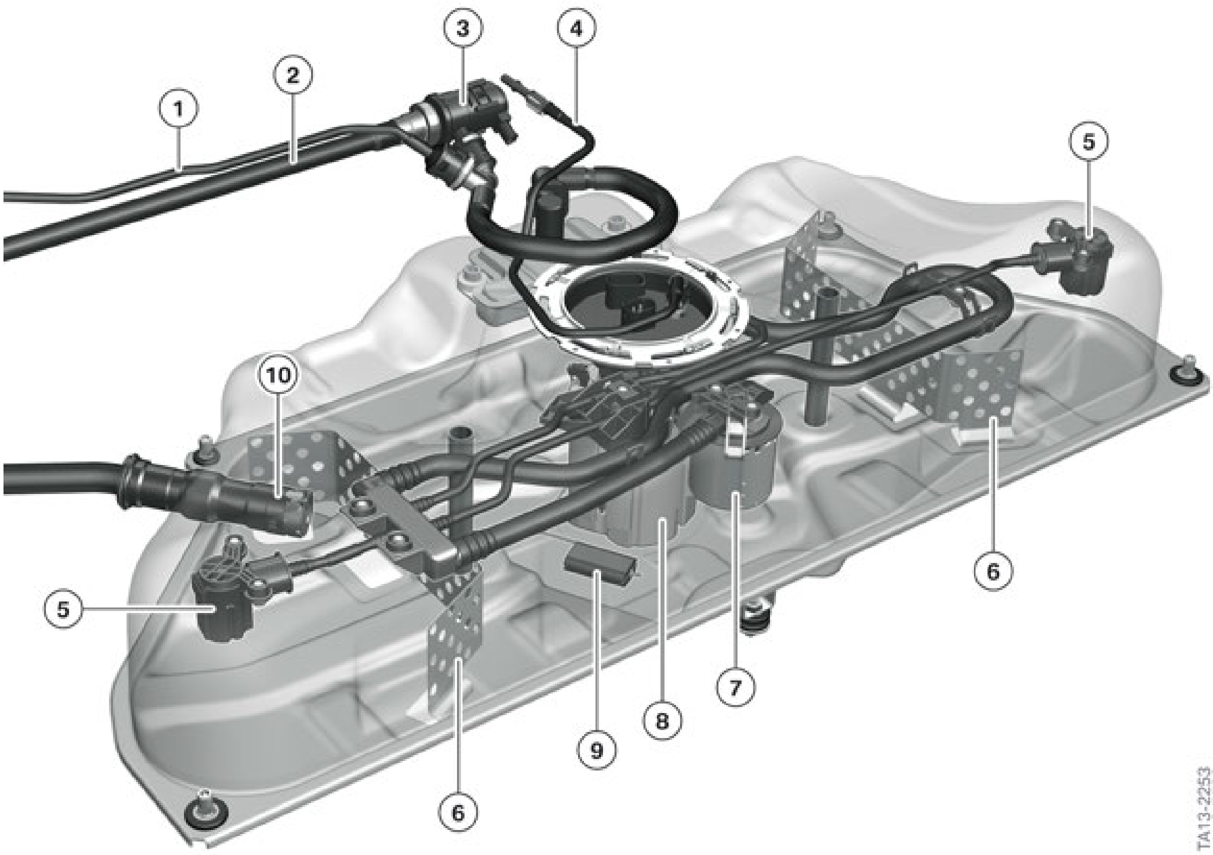
I12 Fuel supply

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

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

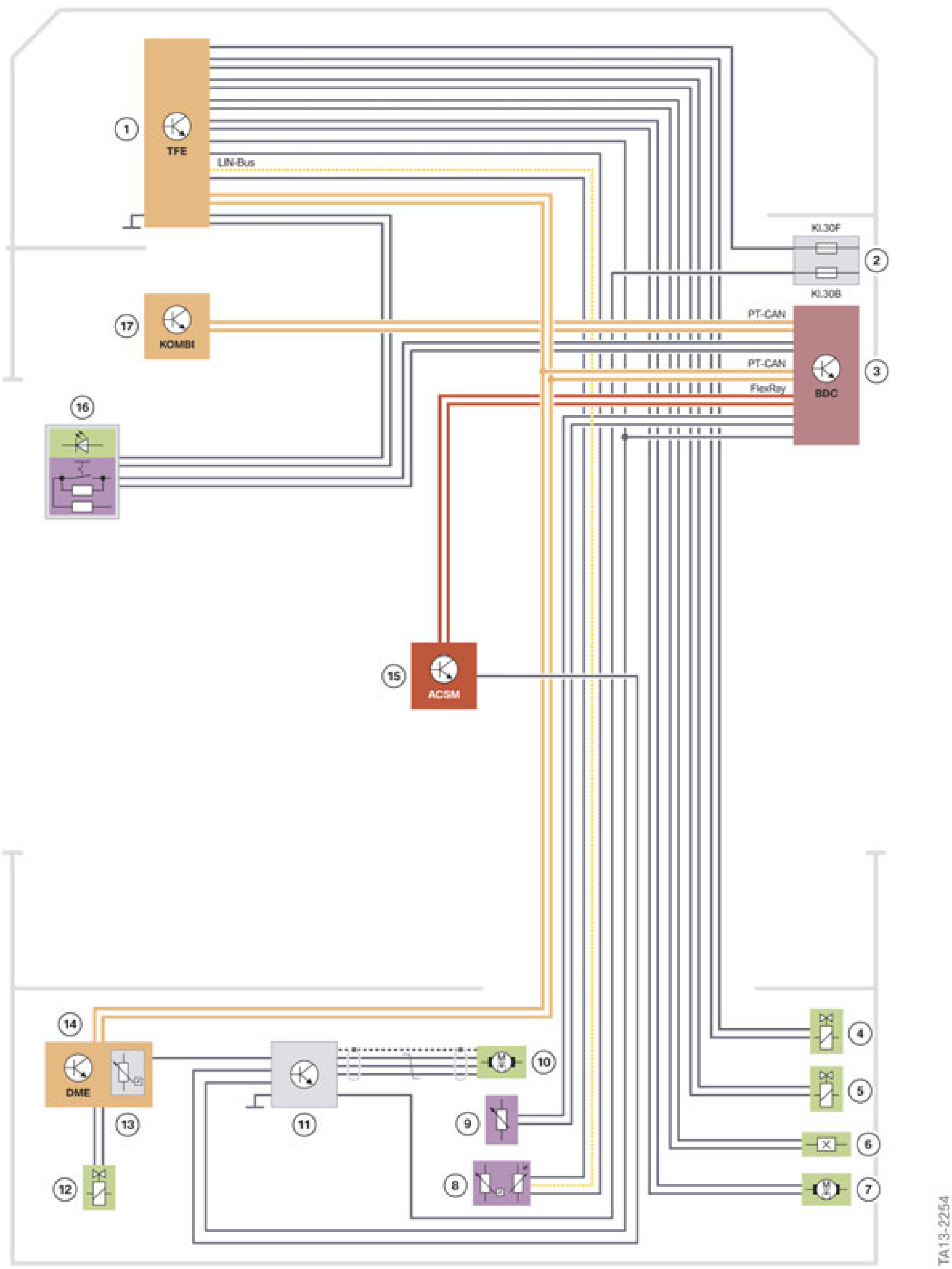


I12 pressurized fuel tank

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.

2.7. 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.

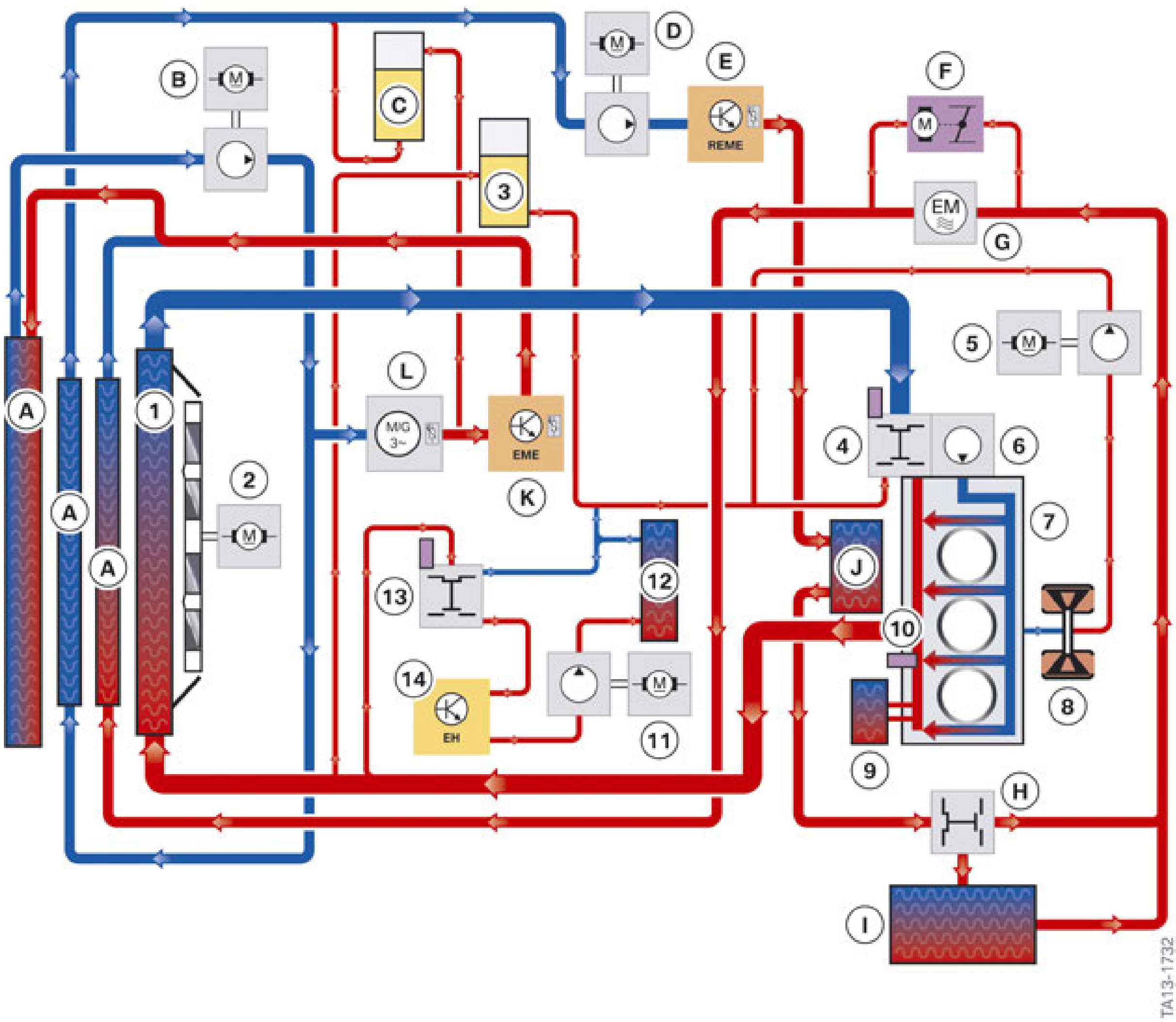
Due to the high efficiency of the electrical machines and power electronics, considerably less heat is emitted than with the combustion engine. For this reason the components to be cooled are incorporated (according to their heat dissipation and their cooling requirement) into corresponding cooling circuits. 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.

2.7.1. 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.

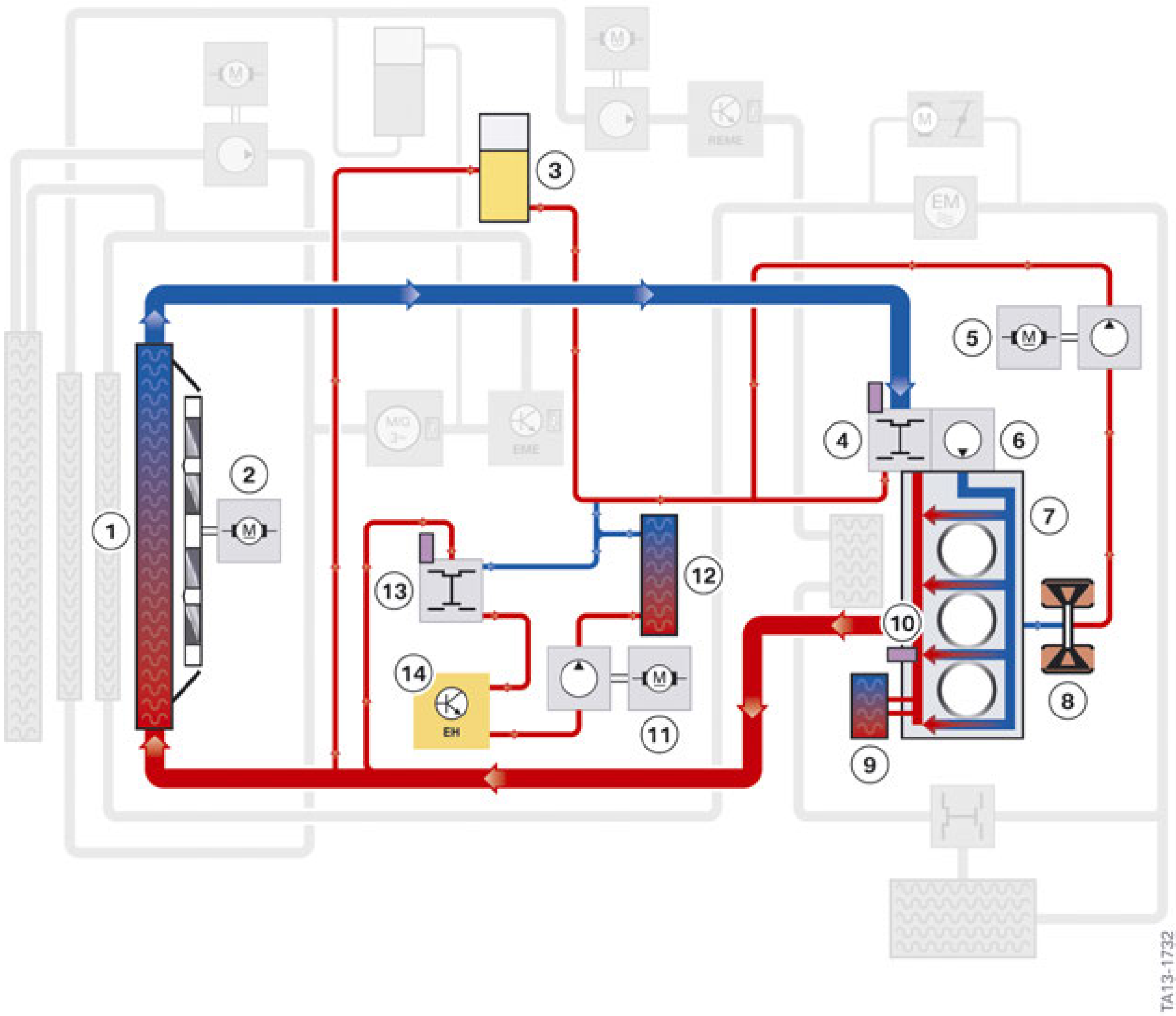


I12 System overview of the two cooling circuits

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

2. B38 Top Engine



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

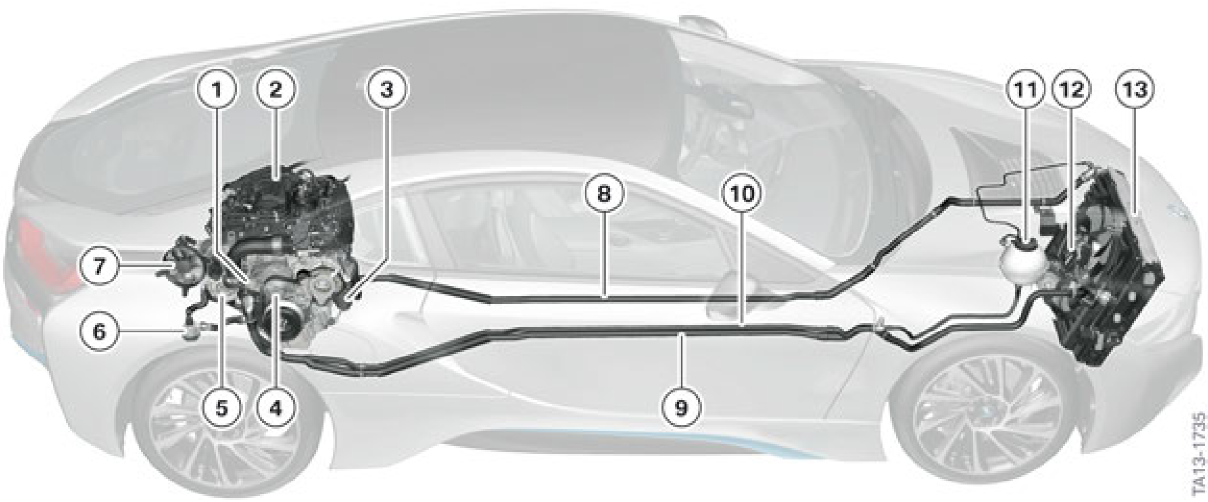
Index	Explanation
11	Coolant pump for electric heating
12	Heat exchanger
13	Changeover valve
14	Electric heating

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.

2.7.2. Components



I12 High-temperature cooling circuit - Installation locations

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.

2. B38 Top Engine

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.

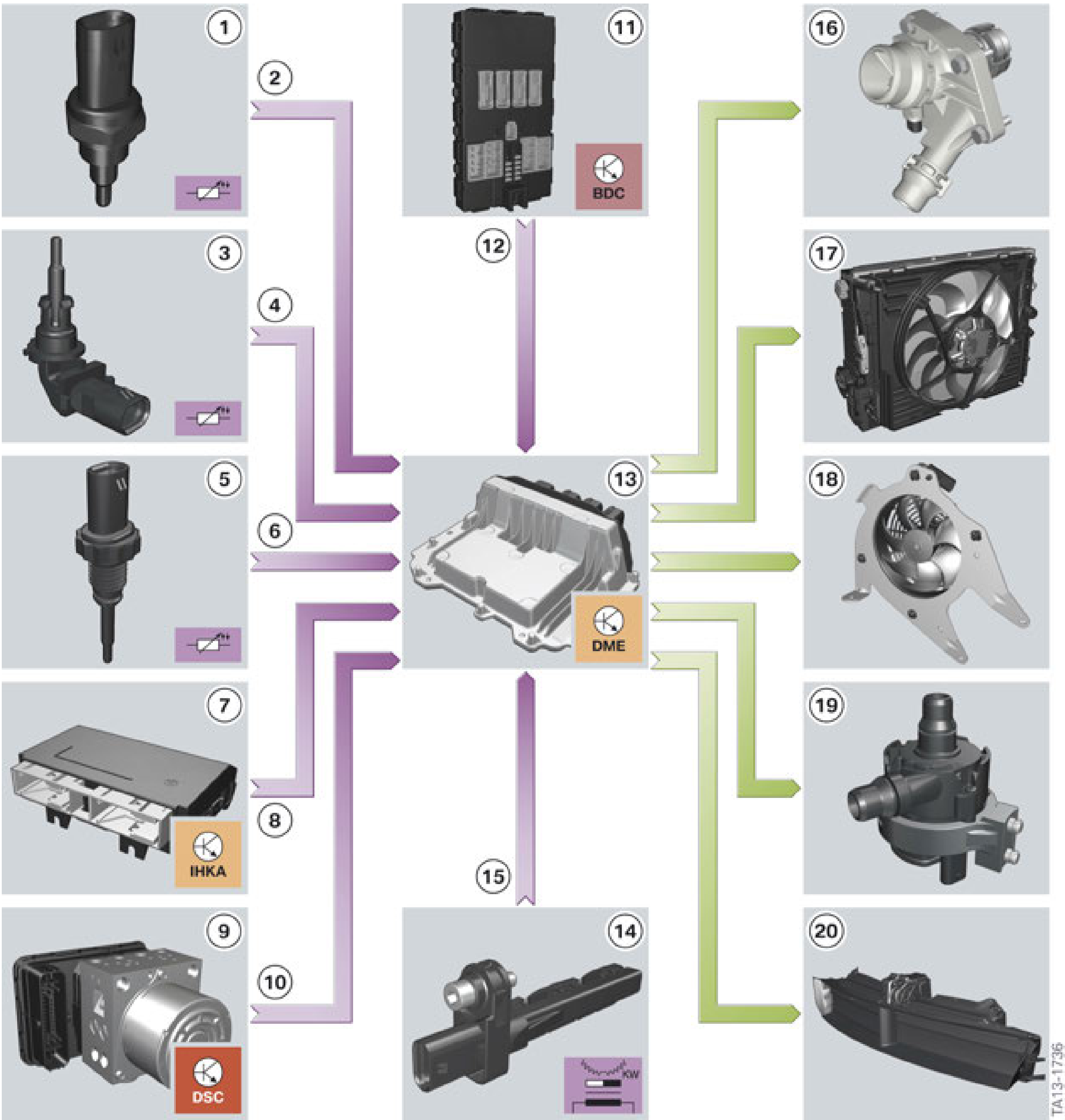
Requirements for opening the air flaps:

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

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

2.7.3. 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.

⚠

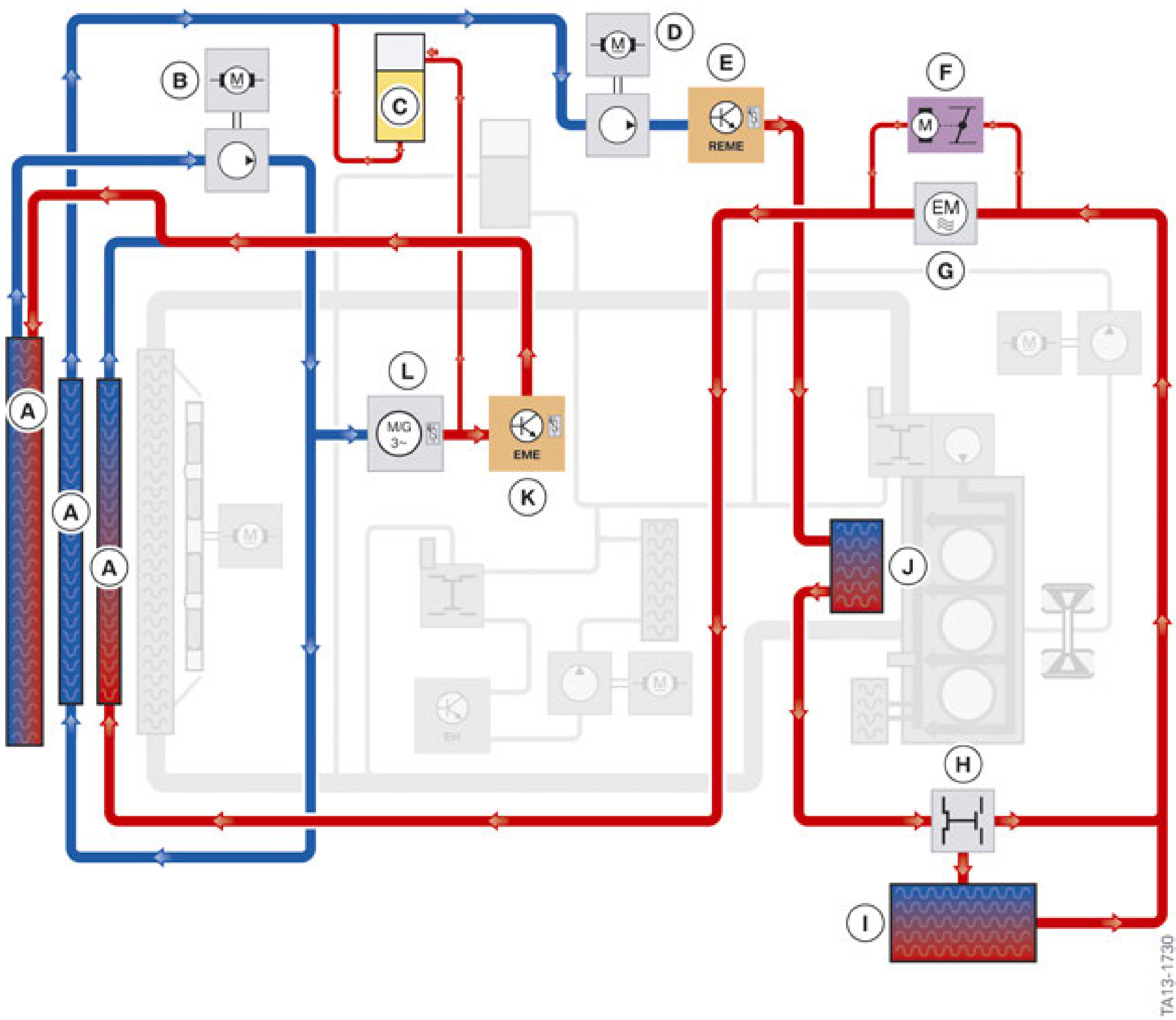
When terminal 15 is switched on the coolant pump and electric fan can be switched on automatically. A reason for this may be a cooling requirement in the low-temperature cooling circuit. Therefore always ensure terminal 15 is switched off when working with an open engine compartment lid or at the cooling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

2.8. Low-temperature cooling circuit

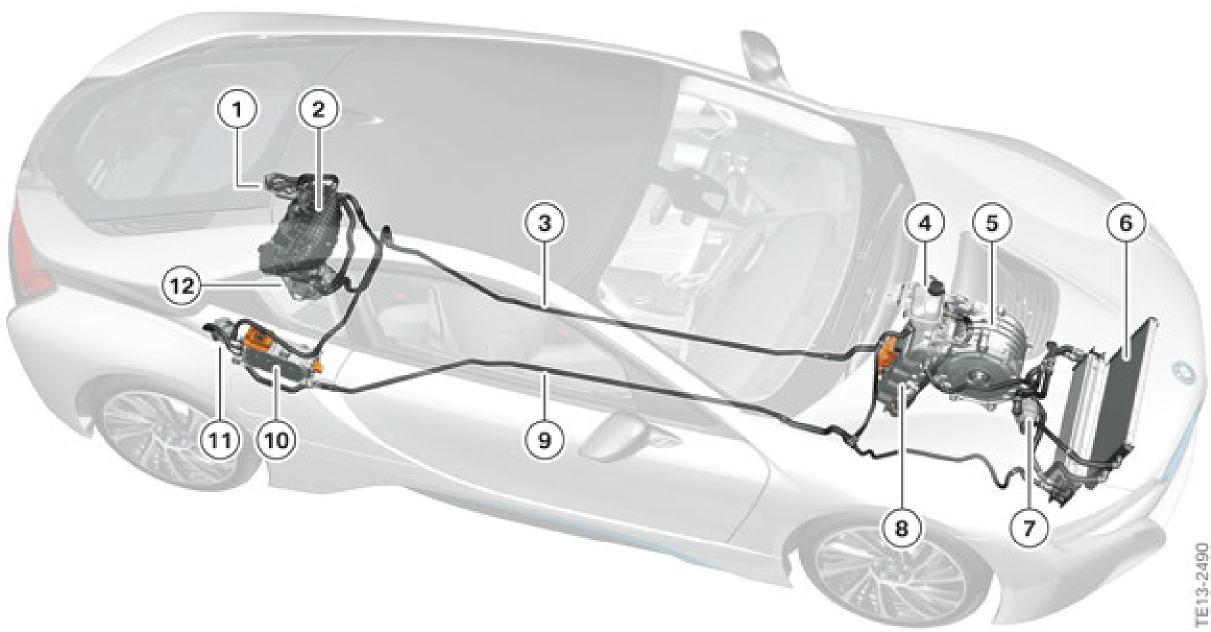
The low-temperature cooling circuit assumes the cooling of the high-voltage components (except the high-voltage battery unit) and the auxiliary units of the combustion engine. The cooling of the integrated charge air cooler is particularly important so that the combustion engine reaches its full power. 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)

Index	Explanation
F	Water-cooled throttle valve
G	High-voltage starter motor generator
H	Bypass valve for transmission oil cooler
I	Transmission oil cooler
J	Indirect charge air cooler
K	Electrical machine electronics (EME)
L	Electrical machine



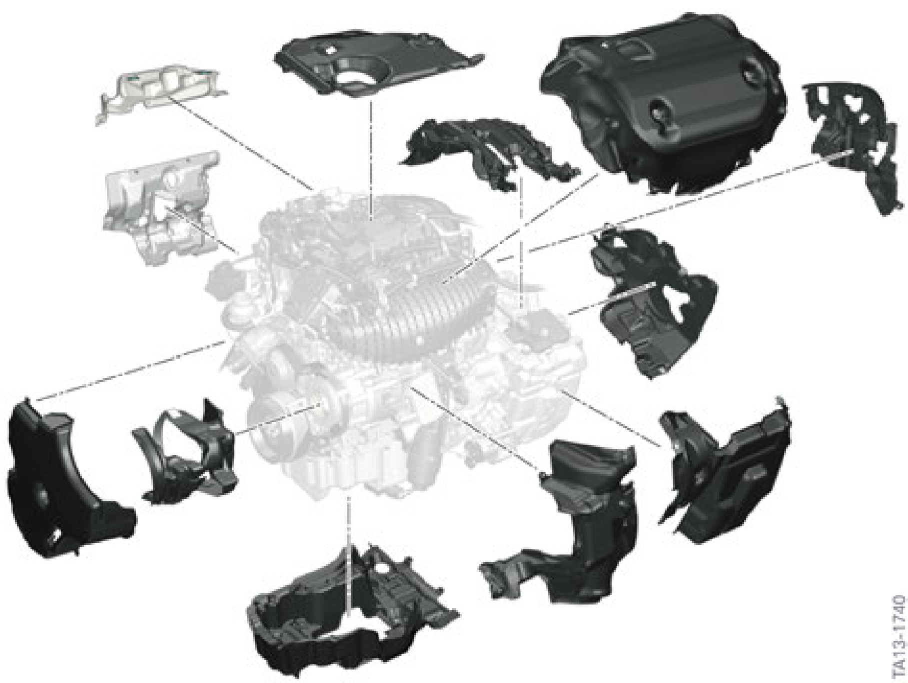
I12 Low-temperature cooling circuit - Installation locations

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)

Index	Explanation
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.

2.9. 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.

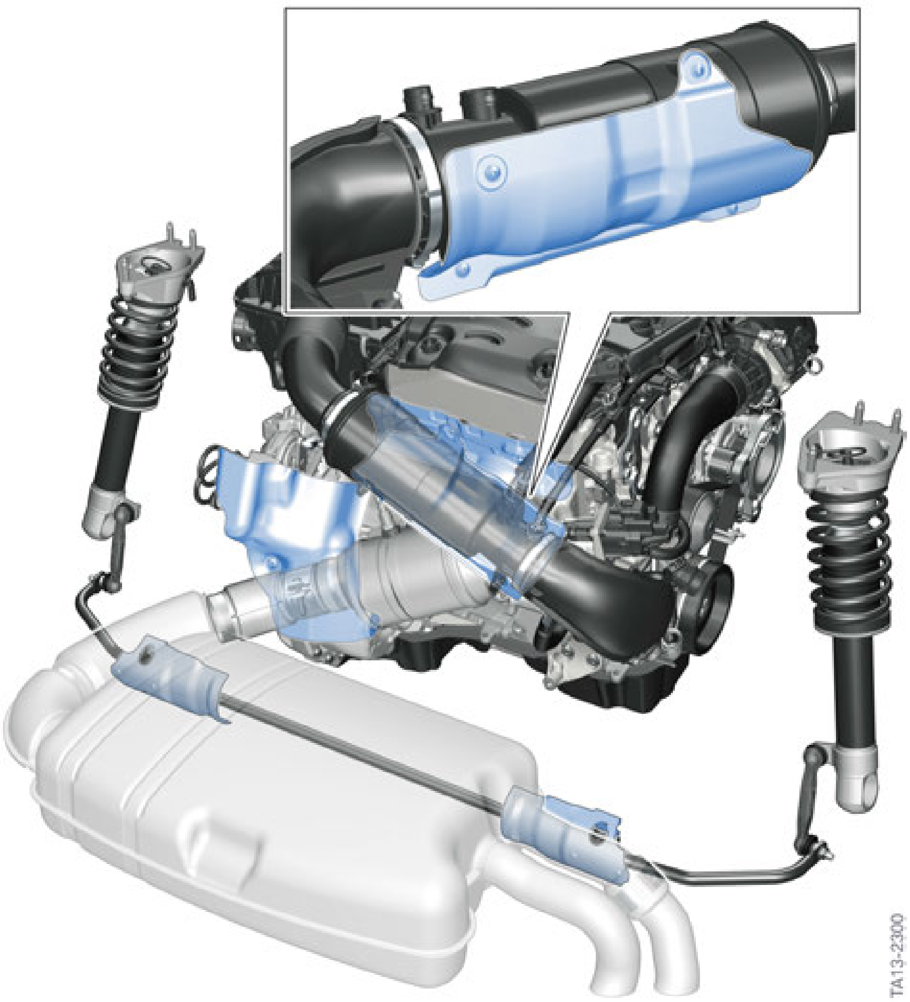
As a result of the use of acoustic covers directly at the drivetrain, other acoustic measures at the body were able to be deleted so that the overall vehicle weight could be reduced.

2.10. 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.



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.

2. B38 Top Engine

⚠

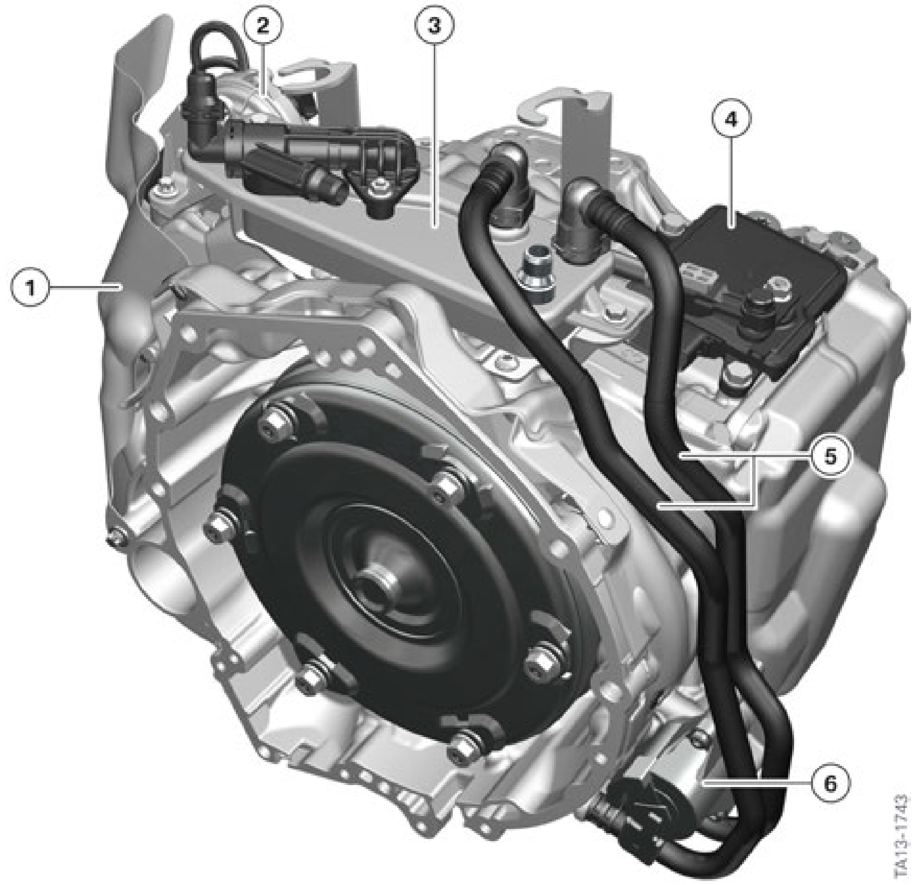
The repair instructions must be followed precisely when handling heat shields and acoustic covers. Incorrect handling, particularly during installation, can cause serious damage to components or the vehicle.

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.

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.

3. Automatic Transmission



I12 Automatic transmission (without acoustic covers)

Index	Explanation
1	Heat shield
2	Drive position actuator
3	Transmission oil cooler
4	Electronic transmission control (EGS)
5	Transmission oil lines
6	Electric transmission oil pump (with electric motor)

In the I12 the GA6F21AW automatic transmission is used for the first time in a BMW vehicle. This automatic transmission transmits up to 320 Nm / 258 lb ft and was especially adapted for use in the I12. It has six forward gears and a reverse gear.

The electronic transmission control (EGS) is located directly on the transmission housing. The selector lever position switch is designed as a hall effect sensor and integrated in the EGS. As a result of the mid-engine design there is no mechanical connection between the gear selector switch and the EGS. The selector shaft is operated using an electric motor with activation rod.

A transmission oil-coolant heat exchanger, which is mounted at the top side of the transmission housing, cools the transmission oil. It is integrated in the low-temperature cooling circuit. The coolant volumetric flow is adjusted by a bypass valve.

3. Automatic Transmission

An electric oil pump supplies the automatic transmission during electric driving and in engine start-stop phases with transmission oil.

The following measures enable a high degree of efficiency of the transmission:

- Transmission oil with low viscosity
- Lower transmission oil main pressure
- Low lubricant oil quantity
- Large steering axis inclination
- Accurate control of the multidisc converter lockup clutch at low loads by three line activation
- Automatic transmission designed for automatic engine start-stop function (electrical transmission oil pump)

The high ride and shifting comfort is realized with the following measures:

- Newly developed mechanical torsional vibration damper
- Optimized hydraulics with new valves
- Optimized clutch and brake control
- Improved direct shifting capability (explained in the following)

In the Sport program and Manual mode the shift point and shift speed have a more sporty dynamics than in drive position D.

Depending on the drive position (D = Automatic drive position, S = Sport program, M = Manual mode), the gearshifts are different in terms of their dynamic character, some have a more sportier dynamics. The maximum speed of 250 km/h / 155 mph is reached in 5th gear.

ConnectedShift

The ConnectedShift function, known from the F10 LCI, is also used in the I12. In SPORT and COMFORT mode the ConnectedShift characteristic is adapted to the respective driving program.

Launch Control

Launch control enables optimal acceleration when driving off on a smooth roadway. Forced upshifts are also performed without a reduction of the engine torque. This enables additional acceleration during the gearshifts.

To avoid premature component wear, launch control is limited to 100 times. The number of starts already performed with launch control can be read from the DME with help of the ISTA BMW diagnosis system.

3. Automatic Transmission

3.1. Designation

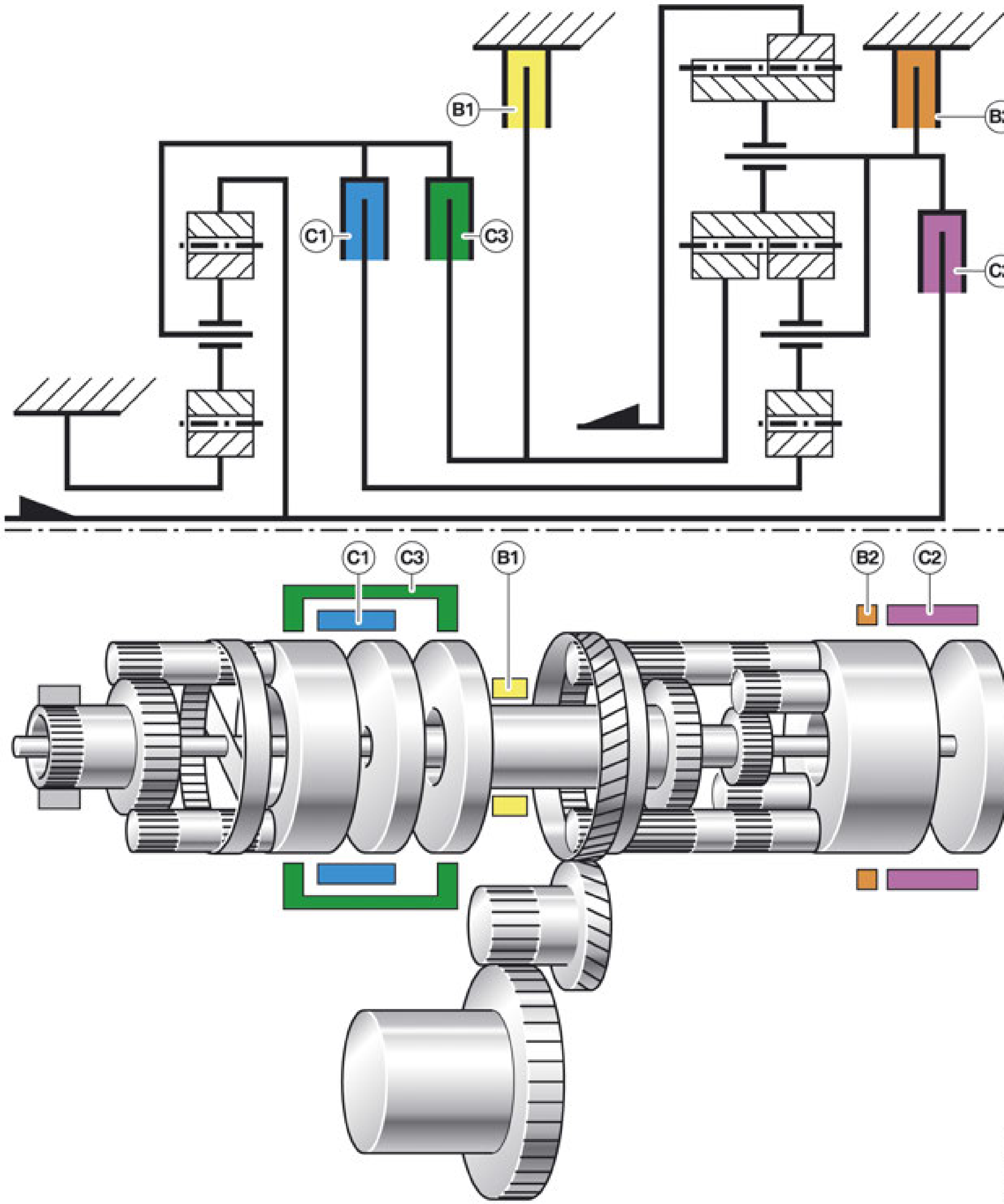
The transmission designation in the technical documentation allows it to be uniquely identified. In frequent cases, however, only a short designation. This short form is used so the transmission can be assigned to a transmission family. The GA8HP transmission family, consisting of the GA8HP45Z, the GA8HP70Z and the GA8HP90Z transmissions, among others, is often mentioned.

The transmission designation GA6F21AW comprises the following:

Position	Meaning	Index	Explanation
1	Designation	G	Transmission
2	Type of transmission	A	Automatic transmission
3	Number of gears	6 8	Six forward gears Eight forward gears
4 – 7*	Individual designations*	HP L R F 19 F21A I12G 26 32 45 (Zahnradfabri Friedrichshaf 45 (General Motors Powertrain) 70 90 390	Hydraulic planetary gear Designation of General Motors Powertrain Designation of General Motors Powertrain Designation of AISIN Warner 300 Nm gasoline engine Designation of AISIN Warner Designation of GKN 600 Nm gasoline engine 720 Nm gasoline engine 450 Nm gasoline engine, 500 Nm diesel engine 350 Nm gasoline engine 700 Nm gasoline engine and diesel engine 900 Nm gasoline engine 390 Nm, 4th gear 410 Nm, gasoline engine
8	Manufacturer	A G J K R W Z H	AISIN Getrag Jatco GKN General Motors Powertrain AISIN Warner Zahnradfabrik Friedrichshafen In-house part

* Numbers 4 – 7 serve for individual designation. A transmission variant, size, transferable torque and technical update can be represented here.

3.2. Function diagram



I12 Function diagram of automatic transmission

3. Automatic Transmission

Index	Explanation
B1	Brake band B1 (blocks the front sun gear of the rear planetary gear set)
B2	Brake clutch B2 (blocks the planet carrier of the rear planetary gear set)
C1	Drive clutch C1 (connects the planet carrier of the front planetary gear set to the rear sun gear of the rear planetary gear set)
C2	Drive clutch C2 (connects the intermediate shaft to the planet carrier of the rear planetary gear set)
C3	Drive clutch C3 (connects the planet carrier of the front planetary gear set to the front sun gear of the rear planetary gear set)

3.3. Ratios

	GA6F21AW
1st gear	4.459
2nd gear	2.508
3rd gear	1.556
4th gear	1.142
5th gear	0.851
6th gear	0.672
Reverse gear	3.185
Final drive ratio	3.683

3.4. Direct shifting

With the new automatic transmission of the I12 in most cases direct shifting to the desired gear is possible. This also applies if gears are skipped.

A direct gear change is always possible if the status has to change for one of the switched clutches or brakes. Otherwise, a two-stage gear change is effected. However, in general the customer does not notice this due to the optimized transmission control unit.

The following table shows the switched brakes and clutches for each gear.

Gear	Brake B2	Brake B1	Clutch C2	Clutch C1	Clutch C3
N	X				
1	X			X	
2		X		X	
3				X	X
4			X	X	

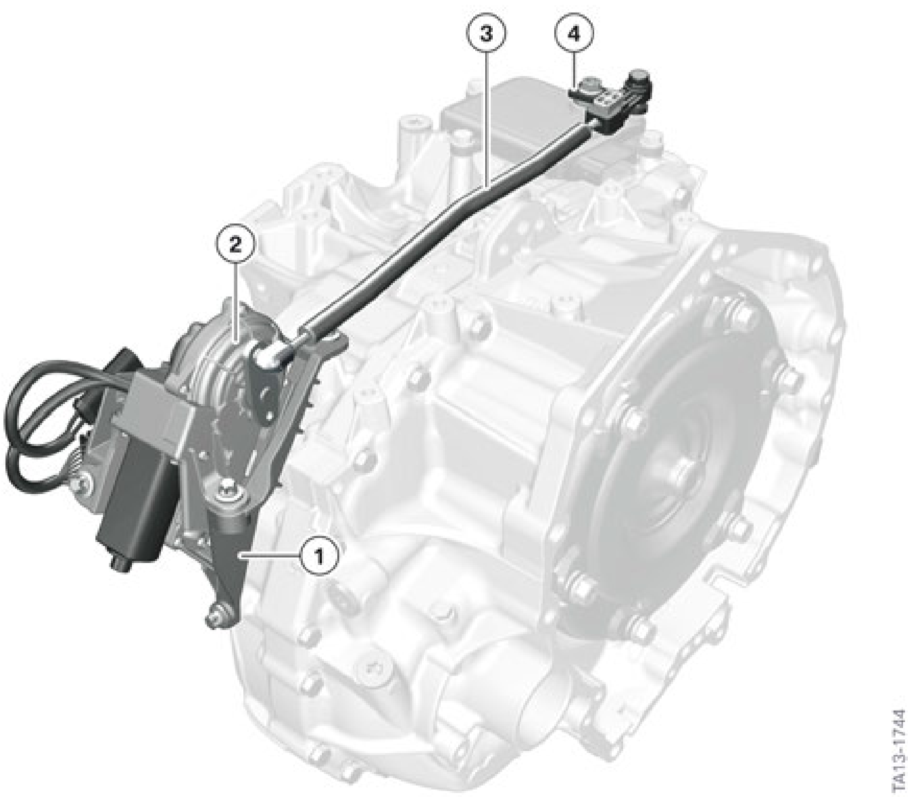
3. Automatic Transmission

Gear	Brake B2	Brake B1	Clutch C2	Clutch C1	Clutch C3
5			X		X
6		X	X		
Rw	X				X

Examples:

- Direct shift is possible from 4th to 2nd gear, as the clutch C1 does not have to be shifted.
- Direct shift is **not** possible from 5th to 2nd gear as both the brake B1 and the clutch C1 have to be switched.

3.5. Drive position actuator



I12 Drive position actuator

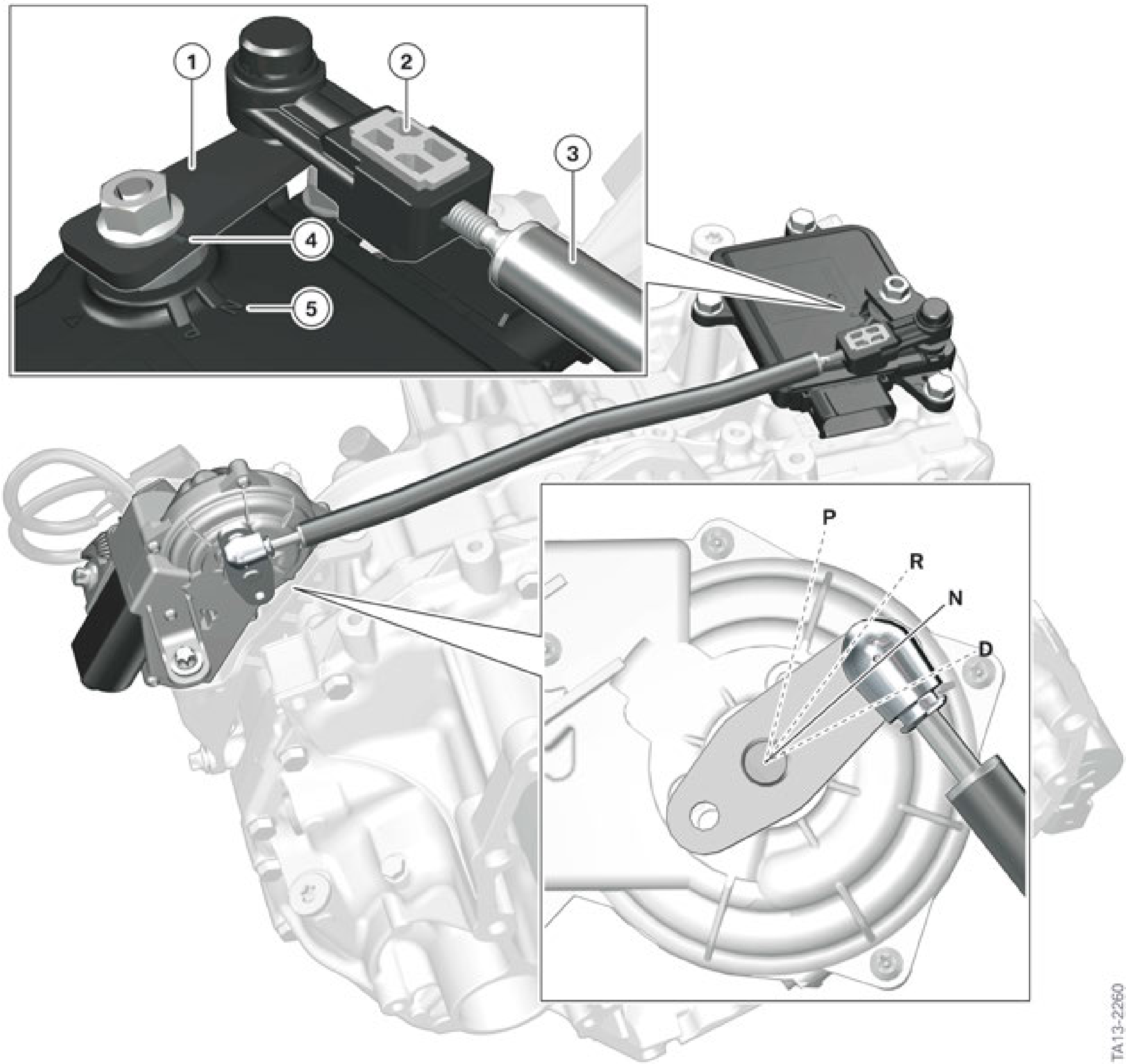
Index	Explanation
1	Holder/Mount
2	Drive position actuator
3	Activation rod
4	Drive position lever

3. Automatic Transmission

To rotate the selector shaft of the transmission, an activation rod and a drive position actuator are attached outside the transmission. The activation rod is connected on both sides via a ball joint to a lever of the drive position actuator and the drive position lever. The swivel motion of the operating lever at the drive position actuator is transferred to the drive position lever via the activation rod and the drive position is engaged. Changing the drive position from P to D takes less than half a second.

The drive position actuator is a direct current electric motor with planetary gear and two position sensors. All components are located in a housing and form one unit. The electric motor in the drive position actuator is activated directly by an output stage in the electrical machine electronics. The output stage is current-limited to protect against damage by a short circuit. In order not to overload the electric motor, the power consumption is also measured and a current limitation performed in the software of the electrical machine electronics.

The electric motor is supplied with current until the travel sensors display that the drive position actuator has adopted the desired condition. The travel sensors work according to the hall-effect principle and record the movement in the transmission of the drive position actuator. For reasons of redundancy, two travel sensors are used and their values are adjusted to those of the selector lever position switch.



I12 Installation position of the drive position actuator

Index	Explanation
1	Drive position lever
2	Locking element
3	Activation rod
4	Alignment mark
5	Selector lever position N

The connection between the activation rod and drive position lever can be removed. In this way the parking lock can be manually unlocked by the Service employee in the event of a fault. The drive position lever must be put into selector lever position N. This is only possible when the intake silencer is removed. There is no option planned for the customer to perform an emergency operation of the parking lock.

3. Automatic Transmission

⚠

Unlocking the parking lock serves only to be able to move the vehicle in an emergency. The I12 **cannot** be towed away in the traditional way. It can only be transported on a flatbed truck.

The EME performs several self-diagnosis functions in order to ensure the proper function of the drive position actuator and to protect the components against damage. These self-diagnosis functions are:

- Monitoring of lines for the electric motor, the travel sensors and the solenoids for short circuit against ground and supply voltage, as well as for open circuit.
- Monitoring of the current level for the electric motor with regards to the maximum value and plausibility for the signals of the travel sensors.
- Monitoring of the signals of the travel sensors (plausibility of the two signals to each other).

The drive position actuator must be taught in using the diagnosis system, if:

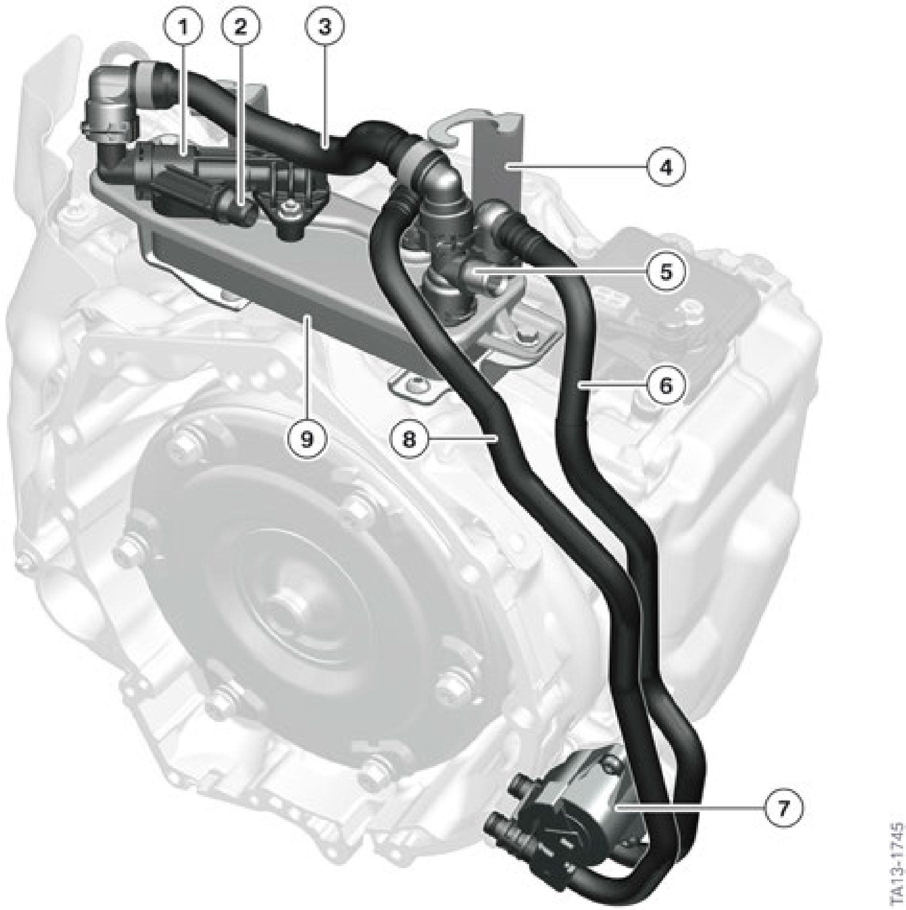
- the automatic transmission has been replaced
- the activation rod has been removed or replaced
- the drive position actuator has been replaced
- the EME or the EGS has been replaced
- the software of the EME has been updated

Before the initialization via the diagnosis system, several prerequisites must be satisfied:

- The vehicle must be secured against rolling away.
- The drive position actuator and the drive position lever are secured properly.
- The drive position actuator and the drive position lever at the transmission are at position N.
- The locking element at the thread of the activation rod is engaged.
- The high-voltage system is deactivated.
- Terminal 15 is switched on.

3.6. Transmission oil supply

The electrical transmission oil pump and the external transmission oil-coolant heat exchanger with bypass valve are the two special features of the transmission oil supply. Both components are mounted at the housing of the automatic transmission.



I12 Transmission oil supply

Index	Explanation
1	Bypass valve
2	Coolant supply connection
3	Bypass
4	Holder/bracket (for intake silencer)
5	Coolant return connection
6	Transmission oil feed line
7	Electric transmission oil pump (with electric motor)
8	Transmission oil return line
9	Transmission oil cooler

3.6.1. Electrical transmission oil pump

Similar to all automatic transmissions, in the GA6F21AW an internal mechanical transmission oil pump at the transmission input assumes the oil supply of the hydraulic system. However, there are driving situations in which the combustion engine is switched off and the electric motor is used. This means for the automatic transmission no speed at the transmission input (resulting in no oil supply by the mechanical transmission oil pump), but a speed at the transmission output via the wheels. This difference in speed is reduced in the automatic transmission and requires lubrication.

Due to the internal leakage, the oil in the transmission mechatronics flows back to the oil sump. This effect must be prevented upon a restart of the combustion engine (automatic engine start-stop function or from electric driving to driving with combustion engine) so that gears can be changed as quickly as possible.

In order to be able to perform these two necessary functions, an additional electrical transmission oil pump with a power rating of 80 W is installed.

The entire system of the electrical transmission oil pump is similar to a power steering pump (internal gear pump) and the electric motor at the converter housing, as well as the control electronics for the transmission oil pump, which is designed as a separate control unit. It sits at the rear axle module directly above the range extender electrical machine electronics and does not have diagnostic capability. The electric motor of the electrical transmission oil pump is supplied with AC voltage (low voltage). The inverter (DC/AC converter) required for this is in the control electronics for the transmission oil pump.

I12 Control electronics for the transmission oil pump

The following faults of the electrical transmission oil pump can be identified:

- Line disconnections
- Short circuit to ground
- Internal short circuit
- Faulty electric motor

The electrical transmission oil pump is constantly in operation during electric driving. It is controlled as required depending on the transmission oil temperature and the driving speed. The EGS calculates the necessary power and requests this from the control electronics for the transmission oil pump.

3.6.2. Transmission oil cooler

The transmission oil cooler is designed as an oil-to-water heat exchanger and sits directly on the transmission housing below the intake noise damper. It is integrated in the low-temperature cooling circuit. In addition to the coolant and oil connections, it has a bypass valve. This bypass valve is open at cold transmission oil temperatures so that no coolant runs via the transmission oil cooler. An optimal operating temperature of the transmission oil is thus reached more quickly. The bypass valve closes at a transmission oil temperature of about 76 °C / 168 °F. The coolant flows through the transmission oil cooler and can then absorb heat energy from the transmission oil.

The bypass valve is controlled using a wax element, which is heated by the transmission oil, expands and closes the bypass valve.

3.7. Notes for Service

The following components of the automatic transmission are available as spare parts in addition to various retaining and sealing elements:

- Drive position actuator
- Drive position lever
- Electronic transmission control (EGS)
- Activation rod
- Oil filler plug
- Electrical wiring set
- Gearbox input-speed sensor
- Hydraulic shift unit
- Cover (hydraulic shift unit)
- Transmission oil cooler
- Oil drain plug (with overflow)
- Torque converter
- Radial shaft seals for transmission input shaft, as well as left and right axle shaft

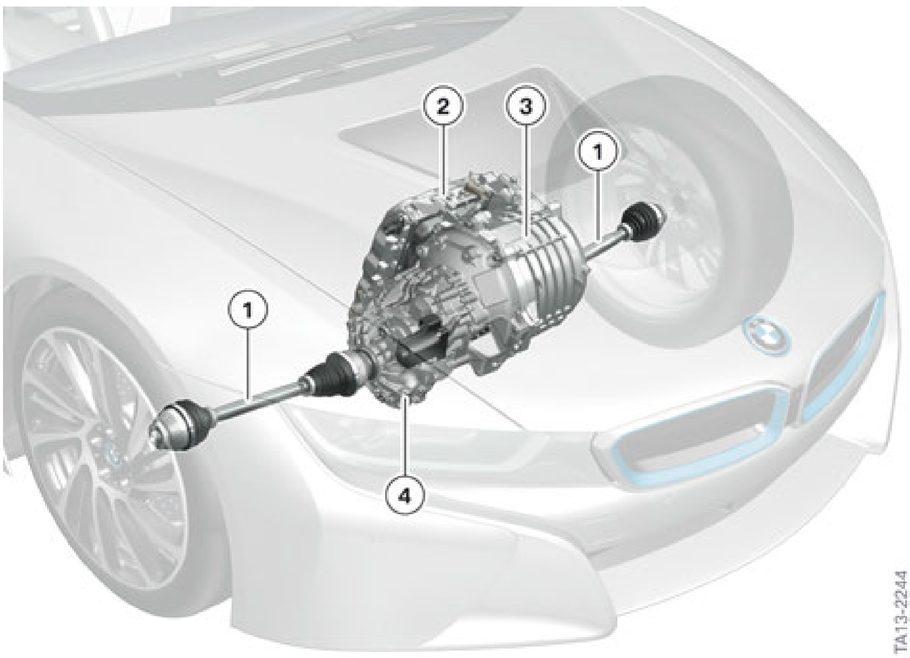
When replacing the EGS an initialization of the selector lever position switch must be carried out.

I12 Powertrain

4. Electric Motor

4.1. Introduction

The electric motor of the I12 sits in the front axle carrier and drives the front wheels. It includes the electrical machine, the Electrical Machine Electronics (EME), the 2-speed manual gearbox and the output shafts. There is no mechanical connection with the combustion engine.



I12 Electric motor

Index	Explanation
1	Output shafts, front axle
2	Electrical machine electronics (EME)
3	Electrical machine
4	2-speed manual gearbox

4.2. Electrical machine

I12 Electrical machine

The electrical machine in the I12 provides the necessary torque for the drive at the front axle. It can also charge the high-voltage battery with electrical energy through brake energy regeneration (energy recovery).

The differences to the electrical machine in the I01 are minimal. The two variants only differ in the design of the housing (flange and assembly connection) and in their performance data. The mountings for the EKK and the anti-roll bar link are also deleted in the I12. The electrical machine in the I12 provides a peak performance of 96 kW (131 HP) and a torque of 250 Nm (184 lb ft). The inner structure, the operating principle and the cooling of the housing are identical.

Several components and control units are involved in the drive control:

- Digital Engine Electronics (DME), master control unit for the drive
- Electrical machine electronics (EME)
- Battery management electronics (SME)
- Range Extender Electrical Machine Electronics (REME)
- Dynamic Stability Control (DSC)

The DME detects the driver's desired load via the accelerator pedal. As a result, it calculates, depending on the current driving mode, state of charge and temperature of the high-voltage battery and current driving situation, the corresponding drive torques and requests these from the drive units.

4. Electric Motor

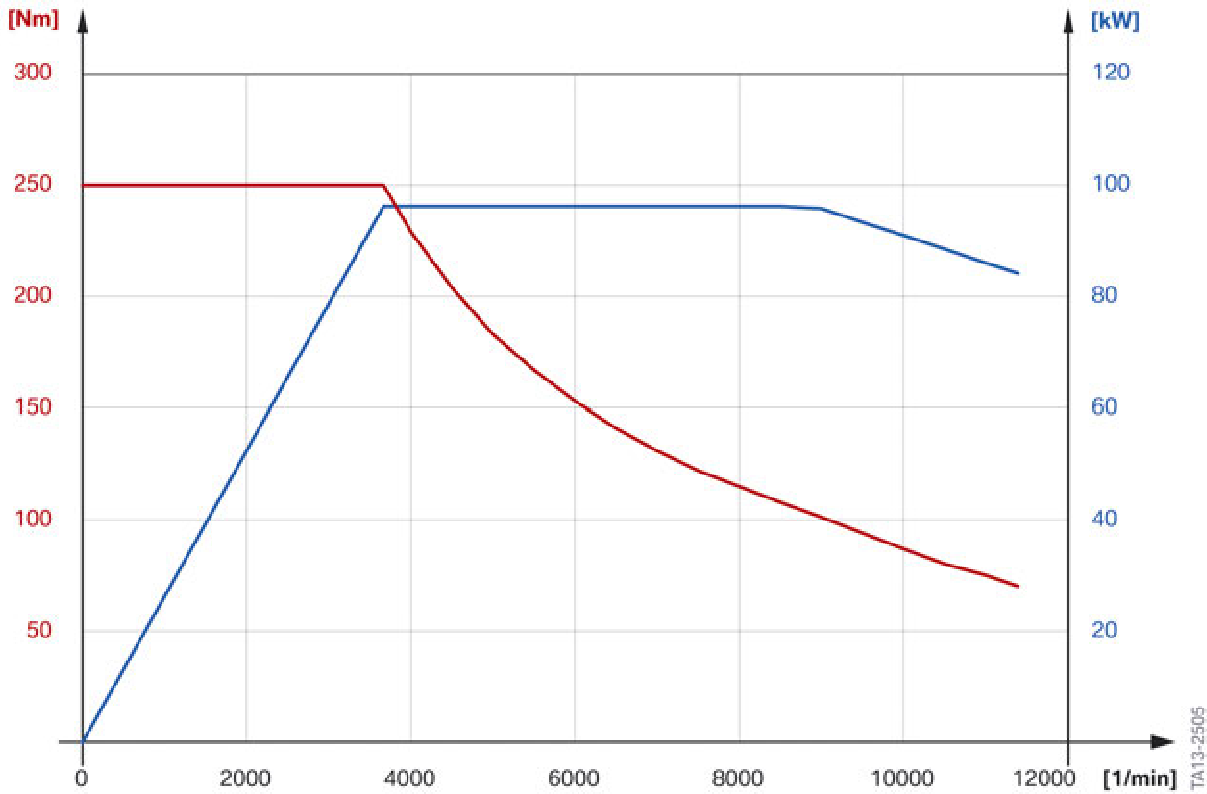
The DSC continuously sends the wheel slip via the FlexRay to the DME and the EME. The DME includes this in the torque request. The EME can independently restrict the torque of the electrical machine in the case of unstable driving conditions. The deceleration request comes from the DSC for brake energy regeneration. The DME activates the electrical machine electronics accordingly.

The electrical machine is able to drive the vehicle along or support the combustion engine (Boost function).

The precise operating and energy recovery strategies are explained in detail in chapter 6 "Operating strategy".

Nominal voltage	360 V	
Nominal current	400 A	Actual value
Maximum peak output	96 kW (131 hp)	for a maximum duration of 5 s
Maximum continuous output	25 kW (33 hp) (restricted by the high-voltage battery)	continuous
Maximum torque	250 Nm (185 lb ft)	in the engine speed range 0 – about 5,000 rpm.
Maximum engine speed	about 11.400 rpm.	
Weight	~ 49.5 kg (109 lbs)	

The maximum power of 96 kW (130 hp) can only be made available for a maximum duration of 5 s. Otherwise, the components of the electric motor would be damaged through overheating – this affects not only the electrical machine, but also the high-voltage battery and the electrical machine electronics. The maximum power applies for motorized mode. In alternator mode, however, only some of this maximum value is used in order not to overload the high-voltage battery and have a negative influence on the driving characteristics.



Power and torque diagram for the electrical machine in the I12

The power and torque diagram shown here is the full load diagram under optimal conditions. This means that the high-voltage battery is fully charged and the operating temperature of all relevant components is in the normal range.

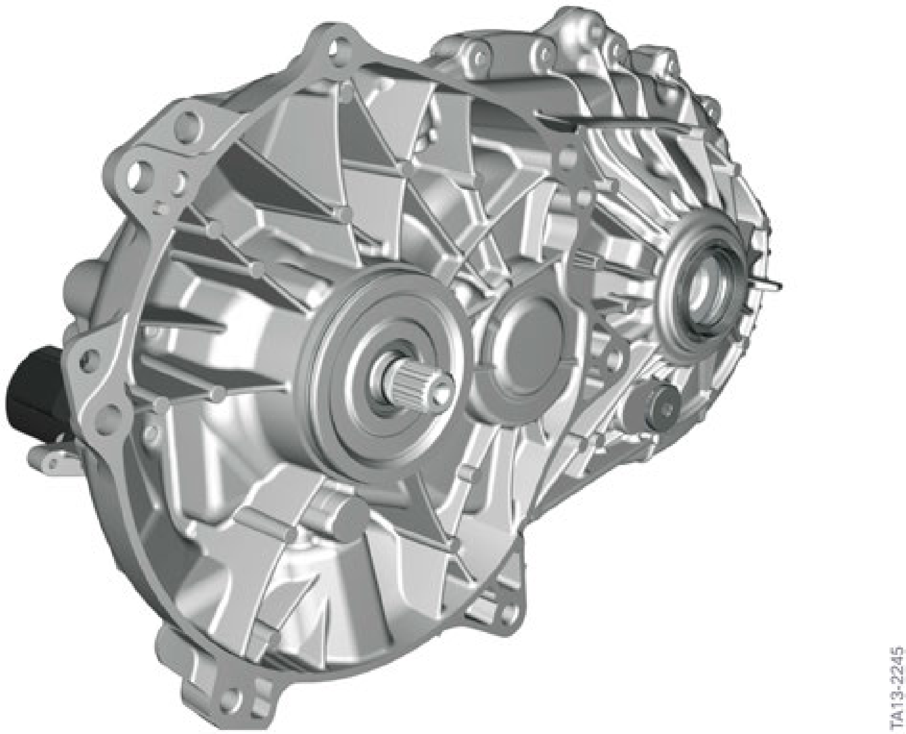
⚠

The electrical machine is a high-voltage component. Work on the electrical machine can only be carried out by Service employees with the relevant certification. ST1408 I12 Complete Vehicle training class.

Detailed information on the identification, inner structure and cooling the electrical machine can be found in the "I12 High-voltage Components" training manual.

4. Electric Motor

4.3. 2-speed manual gearbox



I12 2-speed manual gearbox

The 2-speed manual gearbox of the I12 must complete the following tasks:

- Transmission of speed and torque from the electrical machine to the front output shafts
- Speed adjustment between the two output shafts or sprockets

To fulfil these tasks the 2-speed manual gearbox contains the subcomponents listed below:

- Transmission gearing with two gears and an intermediate shaft
- Bevel gear differential integrated in the transmission housing
- Gear selector actuator

Technical data	GE2I12GK
Maximum torque	250 Nm (185 lb ft)
Ratio 1st gear	11.3
Ratio 2nd gear	5.85
Synchronisation	Blocking synchronisation with double cone
Weight	27 kg (60 lbs) (incl. oil)

4. Electric Motor

4.3.1. Designation

The transmission designation in the technical documentation allows it to be uniquely identified. In frequent cases, however, only a short designation. This short form is used so the transmission can be assigned to a transmission family.

The transmission designation GE2I12GK comprises the following:

Position	Meaning	Index	Explanation
1	Designation	G	Transmission
2	Type of transmission	E	Transmission for electric vehicles
3	Number of gears	2 8	Two forward gears Eight forward gears
4 – 7*	Individual designations*	HP L R F 19 F21A I12G 26 32 45 (Zahnradfabrik Friedrichshafen) 45 (General Motors Powertrain) 70 90 390	Hydraulic planetary gear train Designation of General Motors Powertrain Designation of General Motors Powertrain Designation of AISIN Warner 300 Nm gasoline engine Designation of AISIN Warner Designation of GKN 600 Nm gasoline engine 720 Nm gasoline engine 450 Nm gasoline engine, 500 Nm diesel engine 350 Nm gasoline engine 700 Nm gasoline engine and diesel engine 900 Nm gasoline engine 390 Nm, 4th gear 410 Nm, gasoline engine
8	Manufacturer	A G J K R W Z H	AISIN Getrag Jatco GKN General Motors Powertrain AISIN Warner Zahnradfabrik Friedrichshafen In-house part

* Numbers 4 – 7 serve for individual designation. A transmission variant, size, transferable torque and technical update can be represented here.

4.3.2. Function

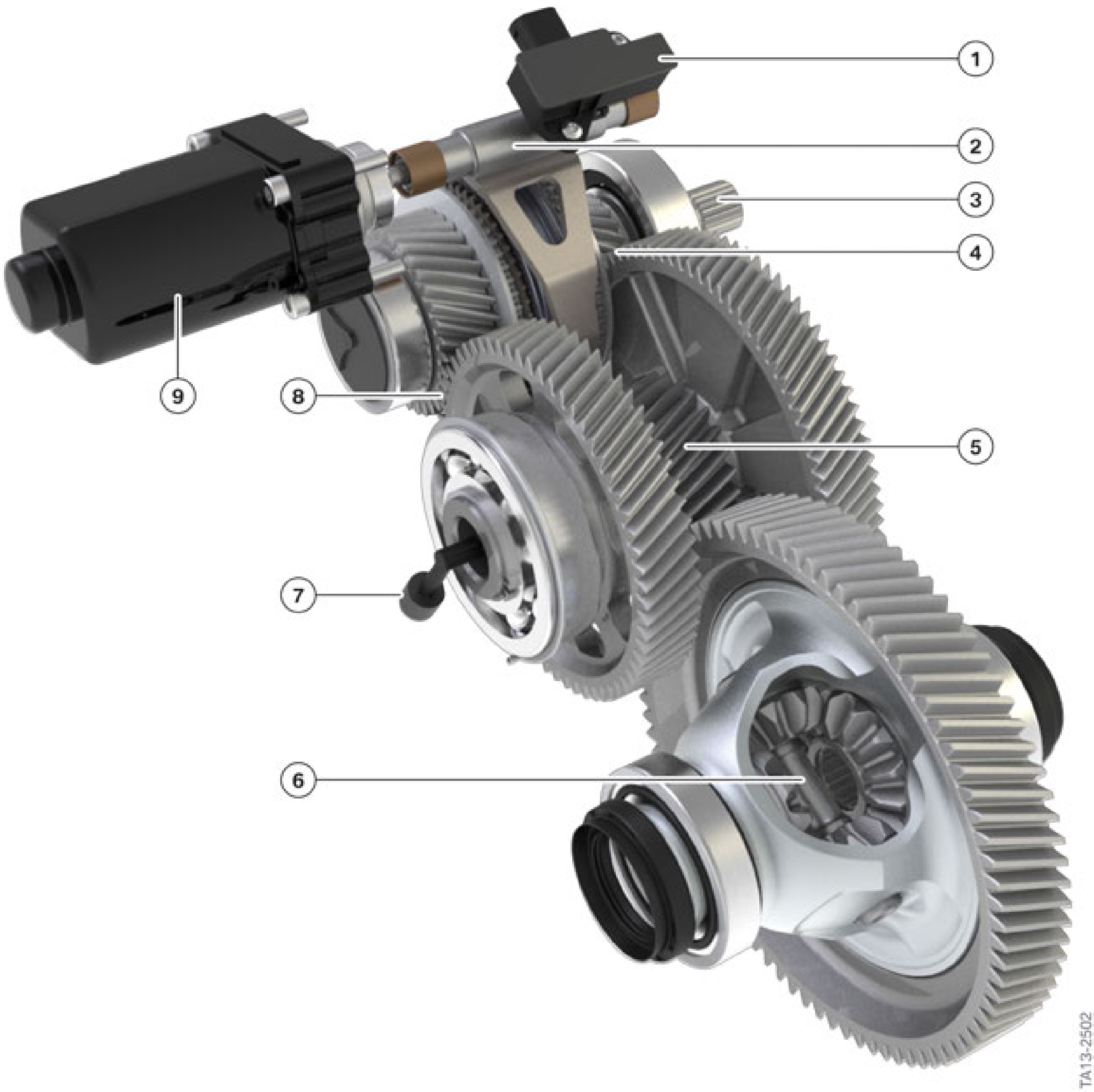
The GE2I12GK is an electromechanically actuated 2-speed manual gearbox. The driver can only influence the gear shift indirectly through the selection of the driving mode. The EME activates a gear selector actuator which engages the gears. The transmission does not have a clutch or parking lock function. The parking lock function is assumed by the automatic transmission.

Overview of the engaged gears depending on the driving mode selected:

Drive mode	1st gear	2nd gear
COMFORT		X
ECO PRO		X
SPORT		X
Max eDrive	X	

To highlight the sporty character of the I12, first gear is engaged in Max eDrive mode. A gear shift is only effected upon activation or deactivation of the Max eDrive mode.

The torque generated by the electrical machine reaches the transmission input shaft via the positive connection. From there the first or second gear is switched via a selector sleeve. The torque then reaches the differential via the respective gear set and an intermediate shaft. The differential distributes the torque to two outputs and enables the engine speed adjustment between the two drive gears.

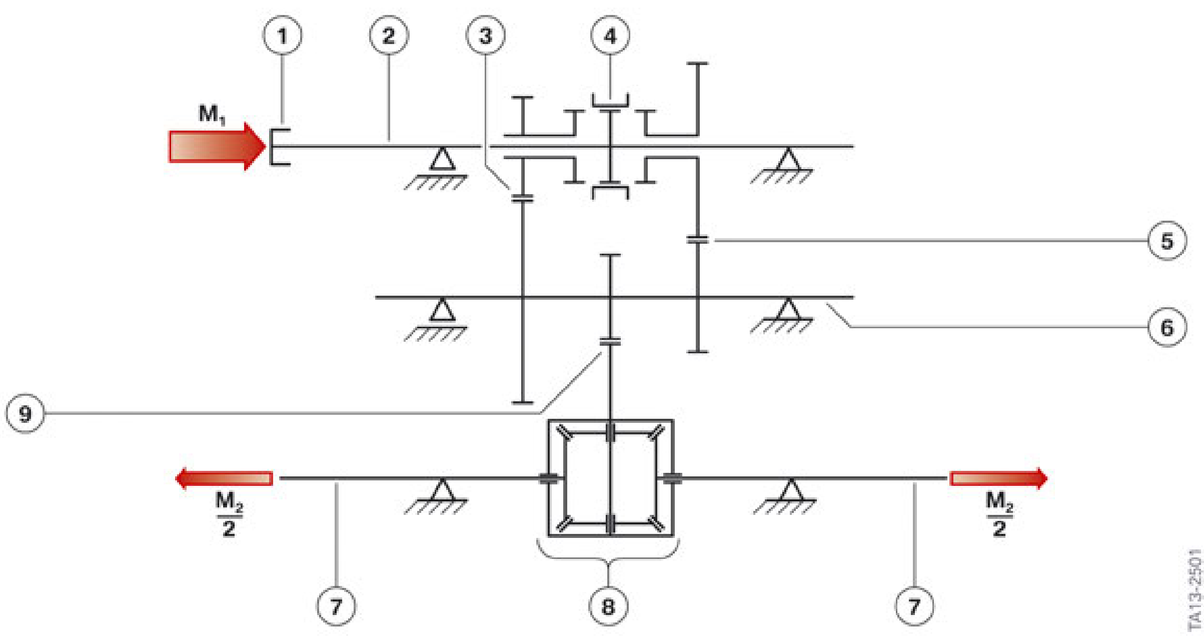


I12 Structure of the 2-speed manual gearbox

Index	Explanation
1	PLCD sensor
2	Gearshift fork
3	Transmission input shaft
4	Gear set, 1st gear
5	Intermediate shaft

Index	Explanation
6	Differential
7	Breather
8	Gear set, 2nd gear
9	Gear selector actuator

The following graphic is a simplified diagram and shows the torque distribution in the transmission.

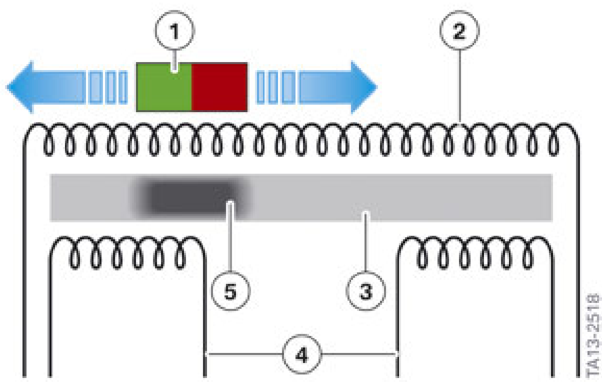


I12 diagram of 2-speed manual gearbox

Index	Explanation
M1	Torque of the electrical machine = Transmission input torque
M2	Transmission output torque
$M^2/2$	Drive torque at an output shaft
1	Positive connection between electrical machine and transmission
2	Transmission input shaft
3	Gear set, 1st gear
4	Selector sleeve
5	Gear set, 2nd gear
6	Intermediate shaft
7	Output shaft
8	Differential
9	Combination between spur gear and differential

PLCD sensor

The position of the gearshift fork is captured by a PLCD sensor (Permanentmagnetic Linear Contactless Displacement). The PLCD sensor generally consists of a special core made from soft magnetic material. The entire length of the core is wrapped with a coil (primary coil) and has an evaluation coil at the ends.



I12 PLCD sensor

Index	Explanation
1	Permanent magnet (secured at the gearshift fork)
2	Primary coil
3	Magnetic core
4	Evaluation coil
5	Saturated area

A permanent magnet at the gearshift fork results in local magnetic saturation and with it a virtual division of the core.

When a suitable alternating current is applied to the primary coil, a voltage dependent on the position of the saturated area is induced in the evaluation coils. This enables the length of the virtual division of the core and thus the position of the saturated area to be determined.

The supply of the sensor and the processing of the signals are effected by the EME. The AC voltage necessary for the primary coil is made available by the PLCD sensor.

Example of a PLCD sensor (from clutch slave cylinder E60 M5)

4. Electric Motor

Gear shift

The shifting of the two gears is assumed by the gear selector actuator. This consists of a 12 V direct current motor and a spindle gear. The spindle gear converts the circular movement of the engine into a linear movement and moves the gearshift fork.

The gears are always shifted without a load. Before the gear shift the load of the electrical machine is withdrawn. After the gear is disengaged by the gear selector actuator, the speed of the electrical machine is adjusted to the gear being shifted. The speed adjustment and the activation of the electrical machine is effected by the EME. Then the gear selector actuator engages the new gear. Only after the PLCD sensor confirms the engaging of the gear and the speed of the electrical machine has been adapted by the EME, is the load of the electrical machine increased again. The driver can generally not notice the entire gear shift. In the event of a failure of the gear selector actuator or the EME, the gearshift fork remains in the current position.

The gear selector actuator must be taught in using the diagnosis system, if:

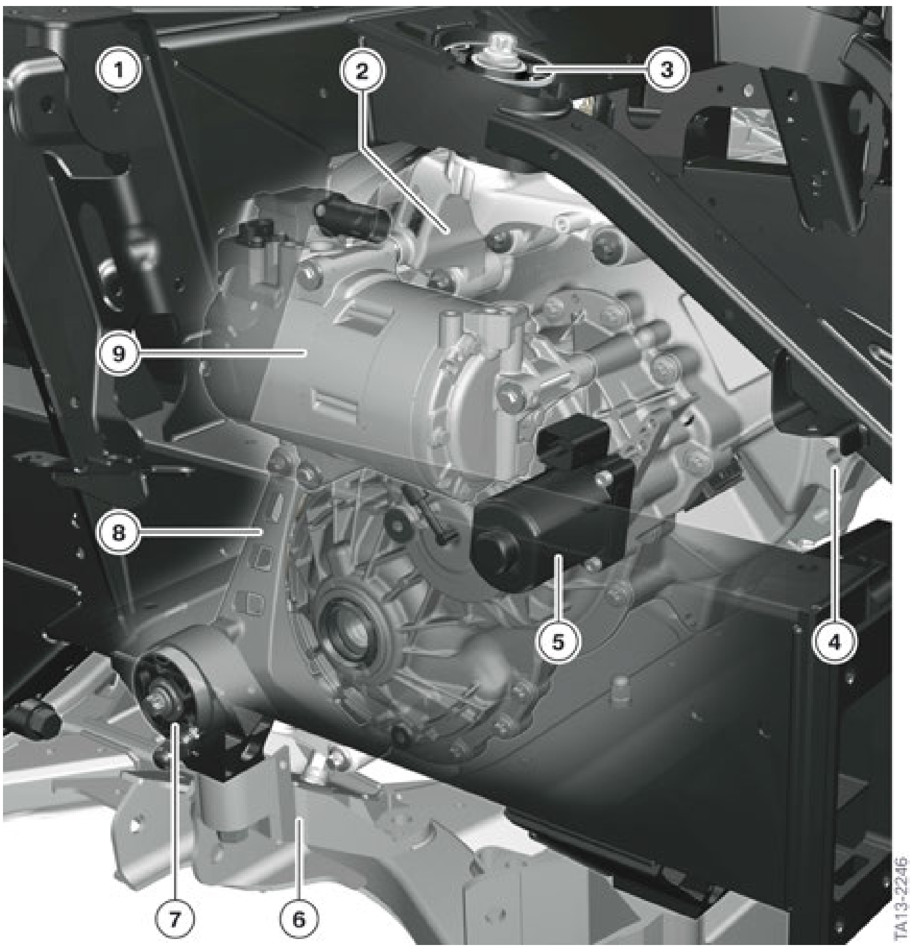
- the 2-speed manual gearbox has been replaced,
- the electrical machine electronics has been replaced.

Transmission oil

A manual gearbox oil known from BMW vehicles is used as a transmission oil (Castrol BOT 338). The transmission housing made from die-cast aluminum is also used as an oil sump and holds the full capacity of about 0.65 l transmission oil. The spur gear of the intermediate shaft and the differential run in the transmission oil and ensure the entire transmission is lubricated (oil sump lubrication). The transmission oil is designed for the operating life of the I12 meaning there is no need for a replacement of the transmission oil.

4.3.3. Interfaces

Mounting and torque support



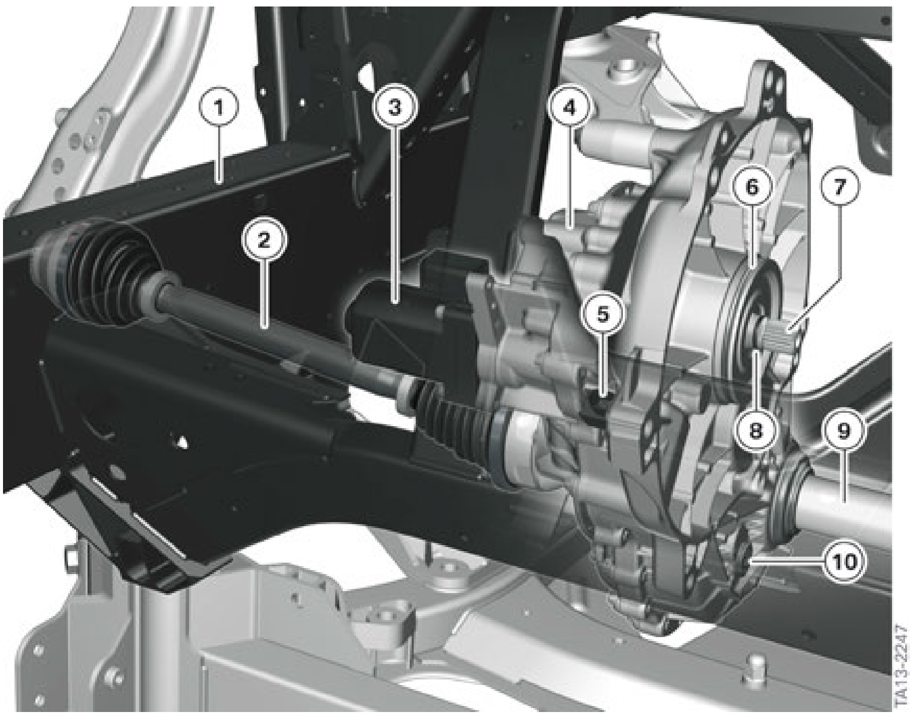
I12 Mounting of the 2-speed manual gearbox

Index	Explanation
1	Front axle module
2	Upper engine support arm
3	Upper transmission mount
4	Mounting point with electrical machine (total of 6)
5	Gear selector actuator
6	Front axle support
7	Lower transmission mount
8	Lower engine support arm
9	EKK

4. Electric Motor

The 2-speed manual gearbox is secured at three places. On the electrical machine and on the other via two engine support arms. The upper engine support arm supports the 2-speed manual gearbox by a bearing at the front axle carrier. Using the lower engine support arm the transmission is connected to the front axle carrier. This design allows the deletion of the anti-roll bar link known from the I01. The upper and lower engine support arms are each screwed on at the transmission housing using three screws. The housing of the 2-speed manual gearbox also serves as a fixture for the EKK and the gear selector actuator.

Mechanical interfaces



I12 Mechanical interfaces of the 2-speed manual gearbox

Index	Explanation
1	Front axle module
2	Output shaft, right
3	Gear selector actuator
4	Transmission housing
5	PLCD sensor
6	X-sealing ring
7	Transmission input shaft
8	O-sealing ring
9	Output shaft, left
10	Fluid filler plug

The torque is transmitted by a positive connection from the drive shaft of the electrical machine to the transmission input shaft. For this purpose, both shafts have gearing.

⚠

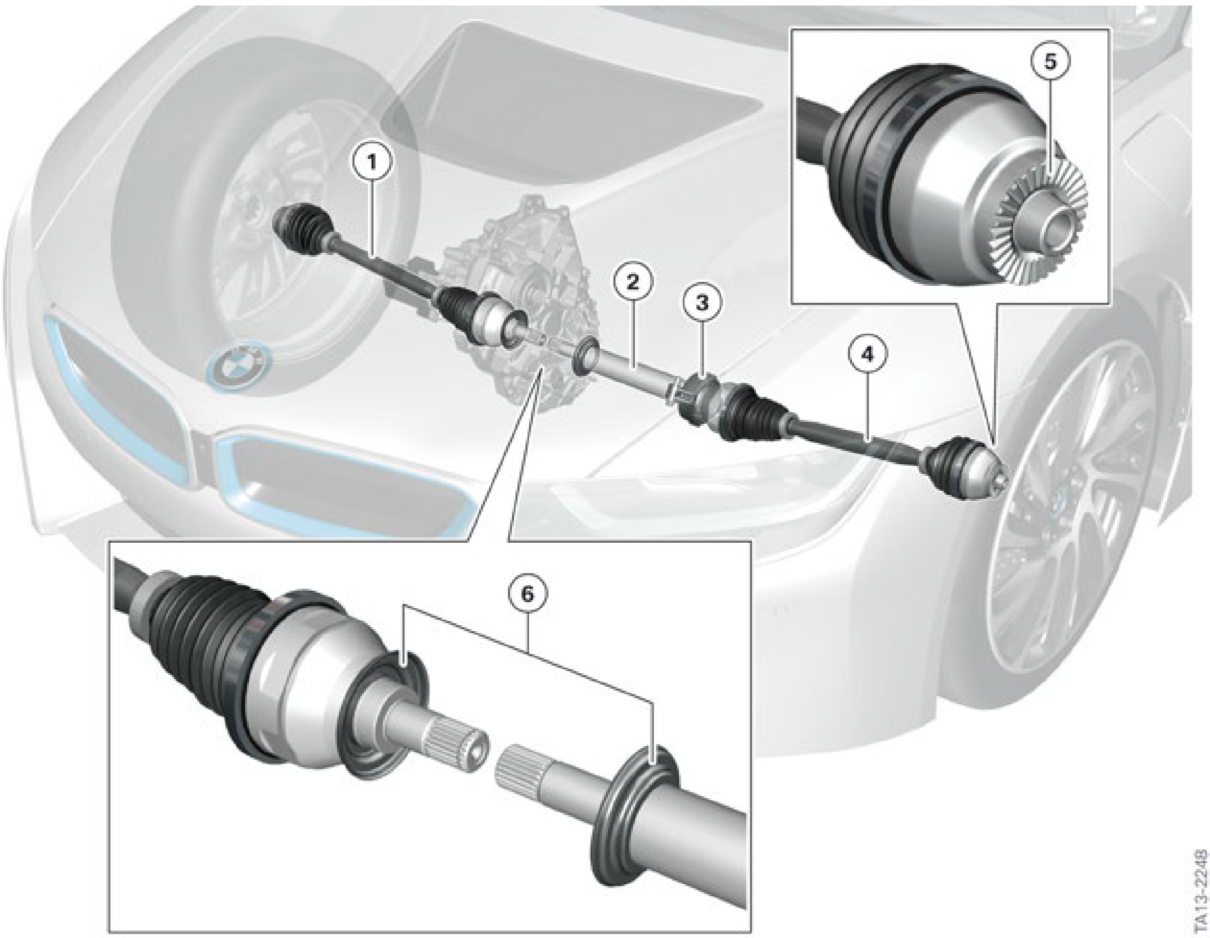
When joining the transmission and the electrical machine the procedure described in the repair instructions must be followed. Ensure axial alignment of the transmission input shaft and output shaft to avoid distortion during assembly. In addition, the two gearings must be greased before joining. Do not exceed the specified quantity of grease!

There is a sealing ring at the joining connection between housings of the electrical machine and the transmission, whose cross-section is shaped like the letter "X". This X-sealing ring and the O-sealing ring on the transmission input shaft must be wet with the oil before joining.

The transmission is not integrated in the cooling system of the electric motor and therefore has no connections for coolant lines. Sufficient heat is discharged via the air flowing by at the transmission housing and the connection for the electrical machine. Due to temperature fluctuations, excess pressure and a vacuum would occur in a completely sealed housing. To avoid this, there is a vent in the area of the intermediate shaft. The vent has a cap to protect against contamination.

I12 Powertrain
5. Output Shafts

5.1. Front axle



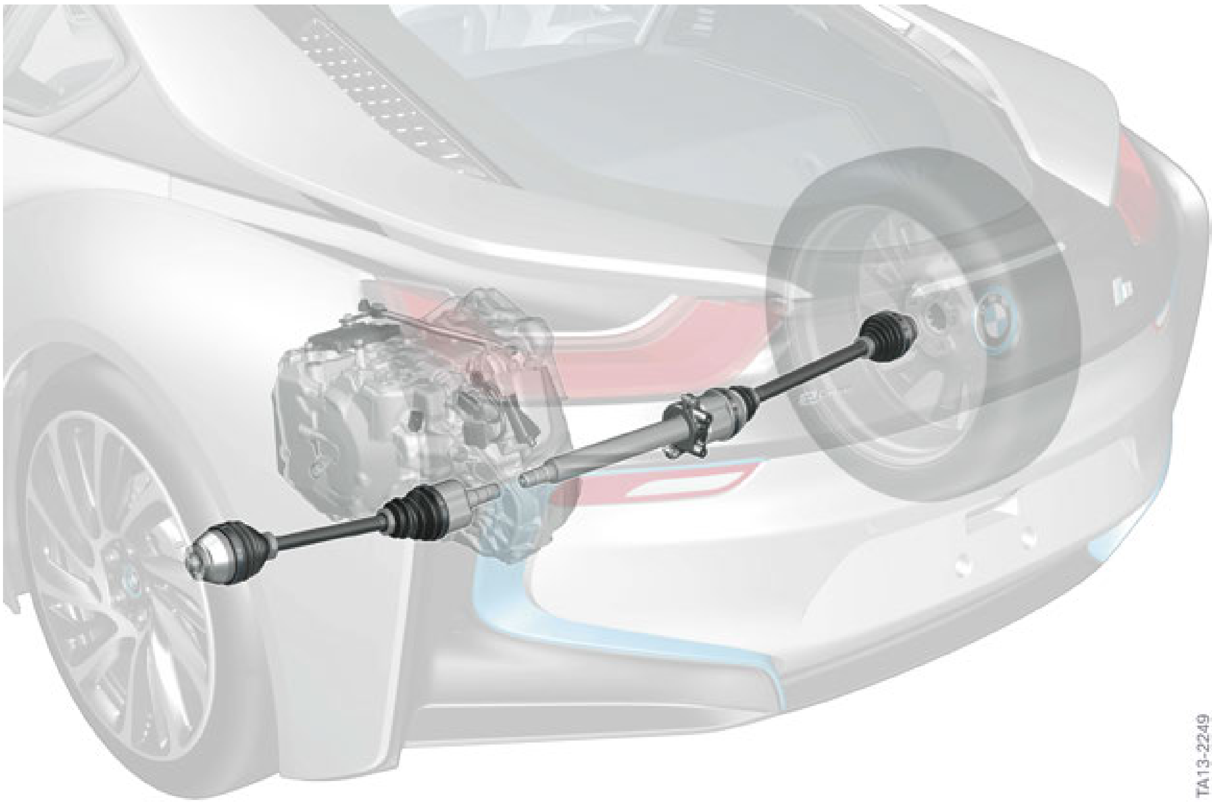
I12 Output shafts, front

Index	Explanation
1	Output shaft, right
2	Intermediate shaft
3	Support bearing
4	Output shaft, left
5	Spur gearing
6	Stainless steel caps

The output shafts at the front have three main components. The actual output shafts on the left and right and the intermediate shaft with support bearing on the left. The support bearing connects the intermediate shaft to the motor support arm of the electrical machine. The output shafts are designed as hollow shafts and are symmetrical to each other.

The wheel-side connection is done via a spur gearing. Stainless steel caps at the connection to the transmission protect the radial shaft seals against contamination.

5.2. Rear axle

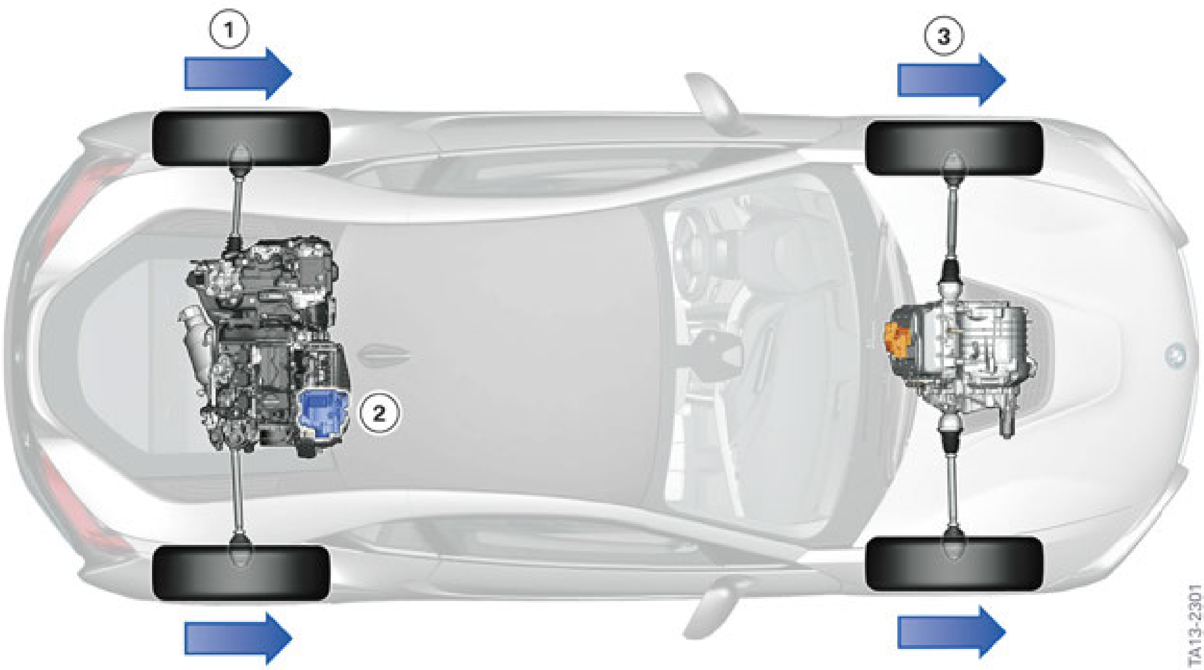


I12 Rear output shafts

The output shafts at the rear also have three main components. The intermediate shaft with support bearing is connected at the right output shaft. The support bearing is bolted on to the crankcase of the B38 Top engine by a holder. The wheel-side connection is also a spur gear connection. The output shafts are connected at the transmission end.

I12 Powertrain

6. Operating Strategy



I12 Operating strategy

Index	Explanation
1	Drive torque, rear axle
2	High-voltage starter motor generator
3	Drive torque, front axle

6. Operating Strategy

6.1. Introduction

Following the explanation of the structure and the functions of the individual components in the previous chapters, this chapter describes their interaction. The following table provides a brief overview again:

Function	Combustion engine	Electrical machine	High voltage starter motor generator	Automatic transmission	Front axle differential
Drive Front axle		X			X
Drive Rear axle	X		X	X	
Charging the high-voltage battery		X	X		
Starting the combustion engine			X		
Boost function		X	X		

The goal of the operating strategy is to guarantee a high degree of efficiency and driving dynamics of the vehicle. It enables intelligent and innovative interaction of the drive components and makes the I12 diverse. This diversity is also seen in the driving modes, with which the driver can always have a direct influence on the operating strategy and thus the drivability of the I12. The driving modes are divided into:

- COMFORT
- ECO PRO
- SPORT

In COMFORT mode the driver's torque requirement for example is divided between the electrical machine and the combustion engine depending on the situation, so that the vehicle is always driven at maximum efficiency. Upon request the driver can drive using pure electric means (Max eDrive).
In contrast, in SPORT mode the full system power is available and the electric motor supports the combustion engine with the Boost function.

The driving modes thus have a direct influence on different performance features:

- Selection of the driven axle
- System power
- Driving dynamics
- Range
- Load point increase
- Boost function
- Energy recovery

I12 Powertrain
6. Operating Strategy

6.2. Overview

	COMFORT	ECO PRO	SPORT	Activation Max eDrive
Activation by	driving experience switch (This mode is always activated upon a restart)	Driving experience switch	Gear selector switch	eDrive button
Energy recovery	normal	normal	maximum	normal
Boost function	normal	reduced	maximum	——
Switch off combustion engine for electric journey	Operation of brake pedal and < 100 km/h (62 mph)	Release of accelerator pedal and < 100 km/h (62 mph)	never	always
Start up combustion engine	Operation of accelerator pedal and > 90 km/h (55 mph)	Operation of accelerator pedal and > 90 km/h (55 mph)	runs constantly	only with kickdown
Drives used	both	both	both	Electric motor
Gear shifted in the 2-speed manual gearbox	2nd gear	2nd gear	2nd gear	1st gear

6.3. Driving modes

6.3.1. COMFORT mode

COMFORT mode is the standard mode. It is activated each time the vehicle is started and can be selected using the driving experience switch.

I12 Driving experience switch

Index	Explanation
1	Driving experience switch

Depending on the position of the accelerator pedal, a situation-dependent torque distribution is effected between the electric motor and the combustion engine with regard to efficiency, traction, energy recovery and dynamics. When the high-voltage battery is fully charged up to a speed of about 90 km/h (55 mph) the electric motor is mainly used and the high-voltage battery is discharged. This driving condition is also called Auto eDrive and is used in urban environments. The combustion engine is then switched off. Through energy recovery by the front electrical machine, e.g. when approaching a red light, traffic, electrical energy is fed to the high-voltage battery and stored there.

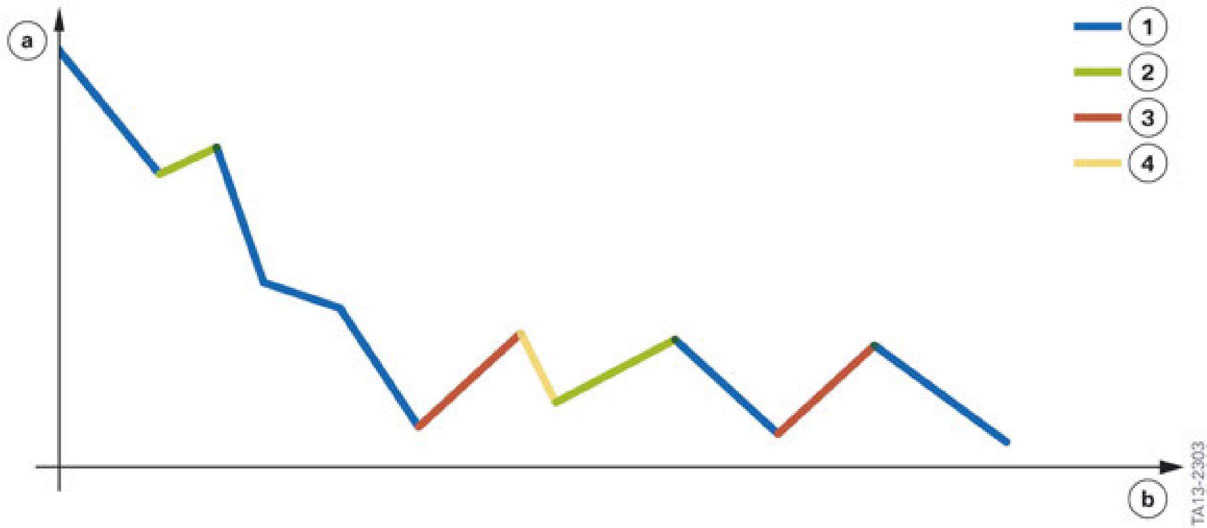
6. Operating Strategy

I12 Example of an operating strategy in COMFORT mode, driving in an urban environment

Index	Explanation
a	State of charge of the high-voltage battery
b	Distance travelled
1	Electric driving
2	Energy recovery

The combustion engine is only switched on automatically in the case of an increase in the driver's desired load.

Outside the urban environment the combustion engine is used more frequently than the electric motor and the high-voltage battery is charged at the same time. The state of charge is then maintained in a certain range in order to be able to provide sufficient electrical energy for the Boost function. The deceleration which occurs during energy recovery is approximately at the level of the normal engine drag torque for conventional vehicles.



I12 Example of an operating strategy in COMFORT mode, cross-country

Index	Explanation
a	State of charge of the high-voltage battery
b	Distance travelled
1	Electric driving
2	Energy recovery
3	Combustion engine on (charging via high-voltage starter motor generator)
4	Boost function

The combustion engine is switched on in the following situations:

- Speed greater than about 90 km/h (55 mph)
- Quick operation of the accelerator pedal
- High load requirement (large accelerator pedal angle)
- Very low state of charge
- Kickdown

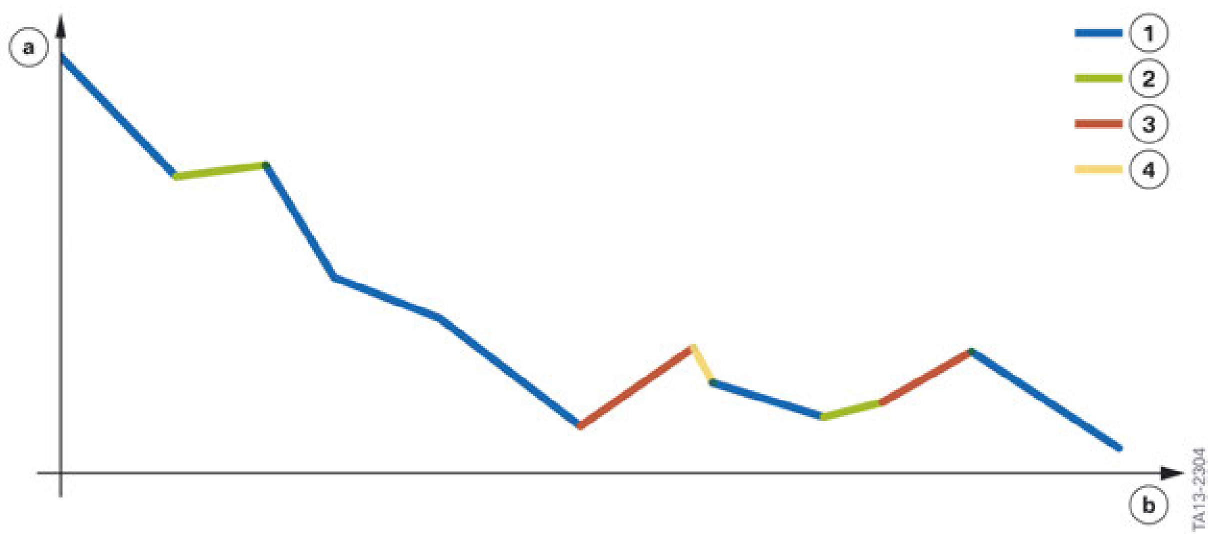
The combustion engine is switched off in the following situations:

- Operation of the brake pedal and driving speeds below 75 km/h (46 mph)
- Vehicle standstill (automatic engine start-stop function)

6.3.2. ECO PRO mode

The driver of a I12 can drive his vehicle even more efficiently upon request. The ECO PRO mode consistently supports a driving style at reduced consumption levels and ensures coordination of the hybrid drive for achieving maximum range of the vehicle. ECO PRO mode is activated using the driving experience switch. Essentially the following measures help to increase the range:

- A modified accelerator pedal characteristic curve and shift program with automatic transmission helps the driver adopt a driving style that optimizes fuel consumption.
- In order to use the Boost function a larger accelerator pedal angle is necessary (due to the modified accelerator pedal characteristic curve).
- Power reduction of the electrical comfort consumers (e.g. mirror heating).
- Power reduction of heating/air-conditioning system.



I12 Example of operating strategy in ECO PRO mode

Index	Explanation
a	State of charge of the high-voltage battery
b	Distance travelled
1	Electric driving
2	Energy recovery
3	Combustion engine on (charging via high-voltage starter motor generator)
4	Boost function

Reduction of electrical comfort consumers

In ECO PRO mode a certain measure of reduction in comfort is tolerated. Under certain conditions the power of the following comfort consumers can be reduced:

- Mirror heating
- Heated seats
- Heated rear window

Power reduction of heating/air-conditioning system

For the climate control an operating strategy with lower energy consumption at acceptable comfort restrictions are used. The air-conditioning works in a more efficient manner with reduced drying of air and less air cooling. Less electrical energy is used.

The cooling of the high-voltage battery always has top priority and is not affected by the activation of ECO PRO mode.

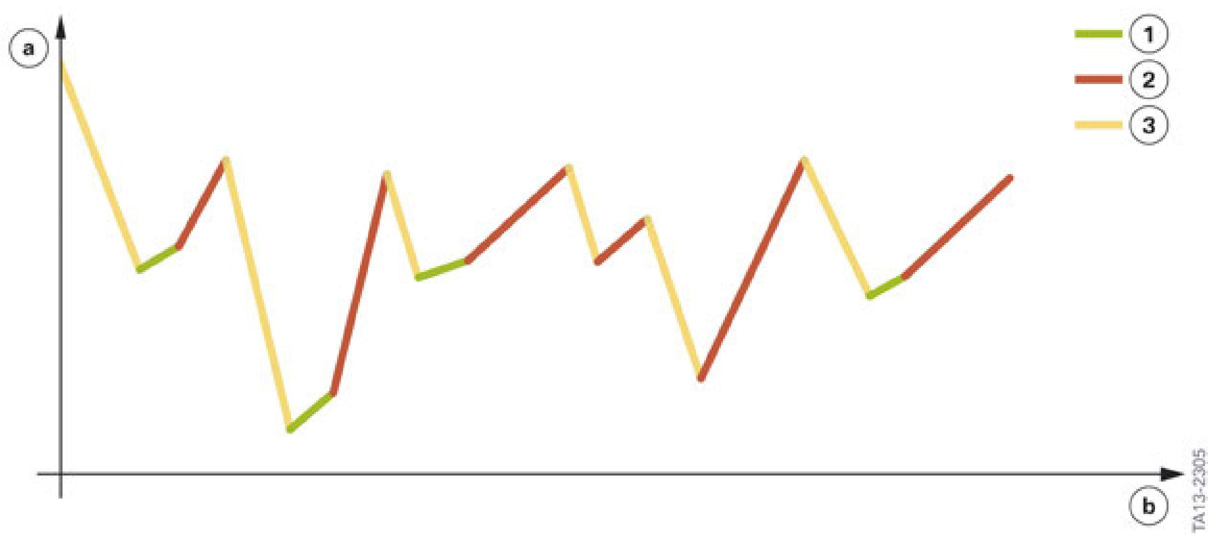
If the required temperatures can be achieved without the air conditioner compressor, the electric A/C compressor is switched off.

I12 Power reduction of heating/air-conditioning system

6.3.3. SPORT mode

In SPORT mode the I12 can develop its full system power of 266 kW (362 HP). The driver must move the gear selector switch to the left. Manual shifting of the gears in the automatic transmission is also possible. In SPORT mode the combustion engine is always active. The automatic engine start-stop function is deactivated.

The electrical machine is used in SPORT mode for the Boost function. In this driving mode purely electric driving is not possible. The high-voltage battery can be actively charged via the high-voltage starter motor generator so that there is always sufficient energy available for the Boost function. The state of charge is thus maintained at a higher level than is the case for other driving modes.



I12 Example of operating strategy in SPORT mode

Index	Explanation
a	State of charge of the high-voltage battery
b	Distance travelled
1	Energy recovery
2	Combustion engine on (charging via high-voltage starter motor generator)
3	Boost function

The energy recovery and Boost power (electrical machine and high-voltage starter motor generator) are at their maximum in this driving mode.

If in SPORT mode the state of charge of the high-voltage battery drops too much as a result of a driving situation with few energy recovery phases and the high-voltage starter motor generator no longer delivers sufficient electrical energy, the front electrical machine is activated in order to generate electrical energy. This situation occurs for example during a long uphill journey, which is handled in SPORT mode. Some of the drive generated by the combustion engine is used directly in order to charge the high-voltage battery during driving via the front axle.

In this situation the deceleration which occurs at the front axle by the energy recovery of the electrical machine is accepted in order to avoid a significant drop in the state of charge.

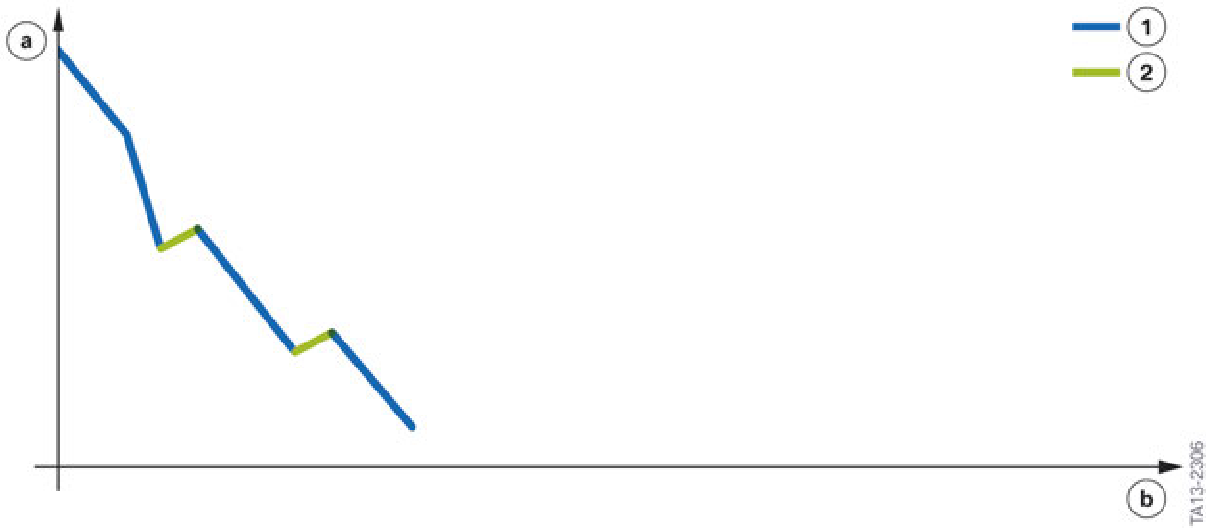
6.3.4. Max eDrive mode

Upon request the driver can drive using purely electrical means up to 120 km/h (75 mph) using Max eDrive mode. The range is about 37 km (23 miles). For the activation the eDrive button below the start/stop button must be pressed. Max eDrive mode can be activated in COMFORT and ECO PRO mode in order to prevent the combustion engine starting up.

I12 eDrive button

Index	Explanation
1	eDrive button

6. Operating Strategy



I12 Example of operating strategy in Max eDrive mode

Index	Explanation
a	State of charge of the high-voltage battery
b	Distance travelled
1	Electric driving (Max eDrive)
2	Energy recovery

With a kickdown the combustion engine is switched on and deactivates the Max eDrive mode. In the process COMFORT mode is automatically activated.

The electrical range that can be attained is heavily dependent on the driving style (acceleration and speed) and the ambient temperature – and the secondary consumers. In order to reach a maximum electrical range, a preheating/precooling of the passenger compartment should be carried out during external charging. The energy which would be required for this during the journey can then be used for a higher electrical range.

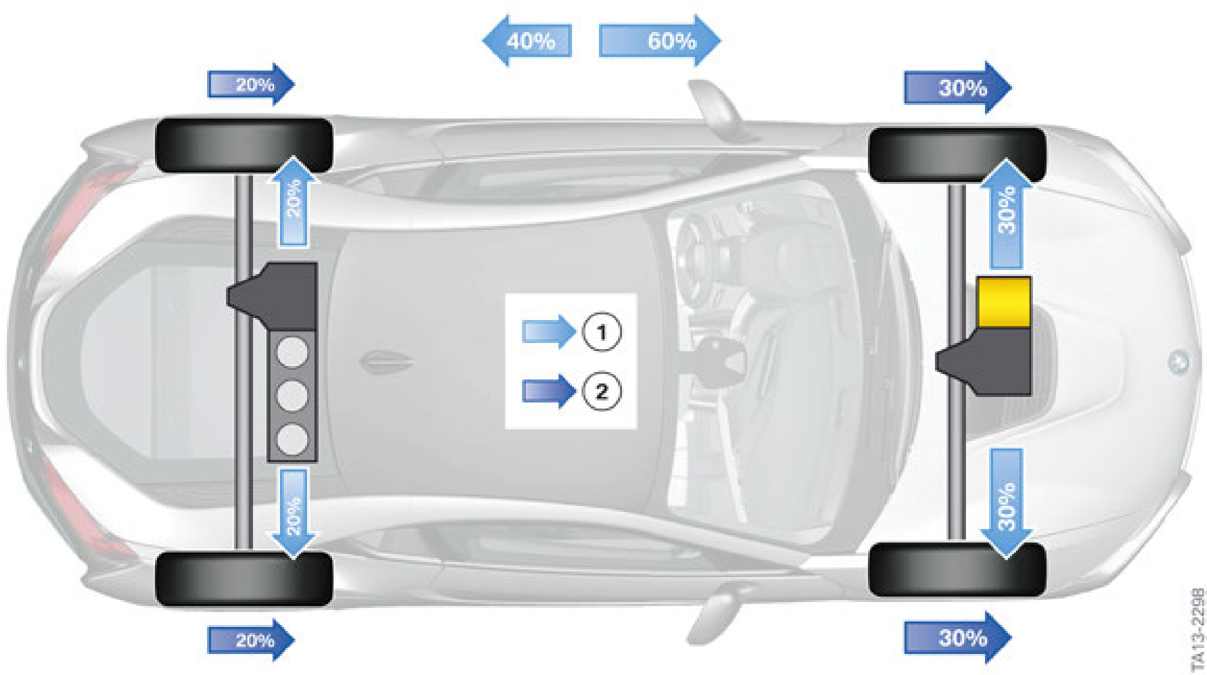
If the vehicle is started in Max eDrive mode after a long stationary off period and very cold ambient temperatures, it may cause a power reduction of the electric motor. A reason for this may be an excessively low cell temperature in the cell modules of the high-voltage battery unit.

6. Operating Strategy

6.4. Drive control

Depending on the position of the accelerator pedal and the speed at which it is pressed, the DME calculates the desired drive torque. The drive torque is thus always distributed variably to the individual axles depending on the situation, so that there is always an optimal balance between dynamics, driving safety, traction and efficiency. The DME is the master control unit for the drive control.

With a low accelerator pedal angle the electric motor is used for driving off (except in SPORT mode). If a higher drive torque is requested via the accelerator pedal, the combustion engine is switched on and provides the drive. If the combustion engine is switched on, the front axle assumes the drive part, should this be required for example due to traction reasons or by the Boost function. The front and rear transmissions distribute drive torque to the same components on both sides.

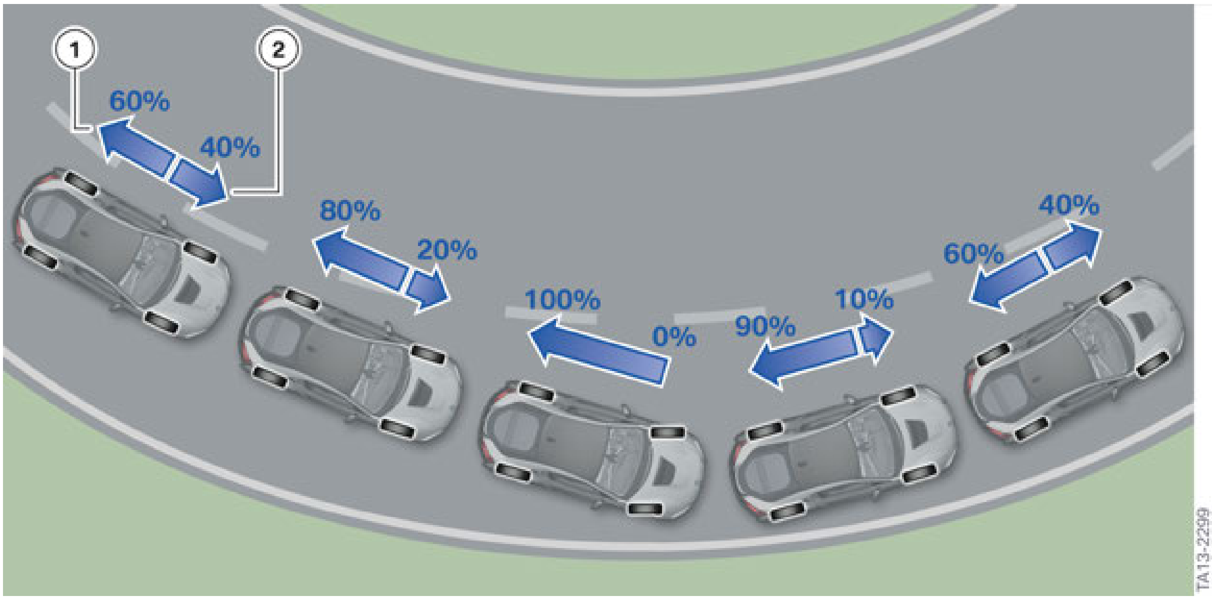


I12 Example of longitudinal distribution of the drive torque

Index	Explanation
1	Drive torque distributed by the DME
2	Drive torque available at the wheel

The intelligent torque distribution of the axle hybrid also results in typical all-wheel drive behavior. Up to 100% variable torque distribution between the front and rear axle can actively influence the self-steering response and the driving dynamics. The axle hybrid enables a neutral and safe drivability up to the limit range. Upon initial instability, e.g. understeering, the drive torque is also distributed between the front and rear axle, this prevents sliding by the front axle. The drive torque at the front axle is reduced and the drive torque at the rear axle increased.

This is clarified using the example of driving around a sharp bend in which the front axle is also driven by the Boost function when entering the bend.



I12 Example of longitudinal distribution of the drive torque in the case of understeering

Index	Explanation
1	Drive torque at the rear axle
2	Drive torque at the front axle

The optimal traction can also be achieved in bends, whereby quicker acceleration from the bend is possible.

If the driving stability reaches the limit ranges, it may naturally bring about a DSC intervention. However, the DSC intervention is carried out more rarely, whereby the ride comfort is noticeably improved.

The DSC plays a role not only in the dynamic handling characteristics of limit ranges, but also supplies the maximum transferable torque to the DME at any time. Both during acceleration and energy recovery. These torque specifications are processed in the DME and always considered in the drive torque distribution. For example, the Boost or energy recovery power of the front electrical machine is always adapted to the driving situation and reduced if necessary. In contrast, the negative torque from the energy recovery can also be specifically used to intervene for driving stability. In this way the different drive systems are constantly working on a common objective and complement each other.

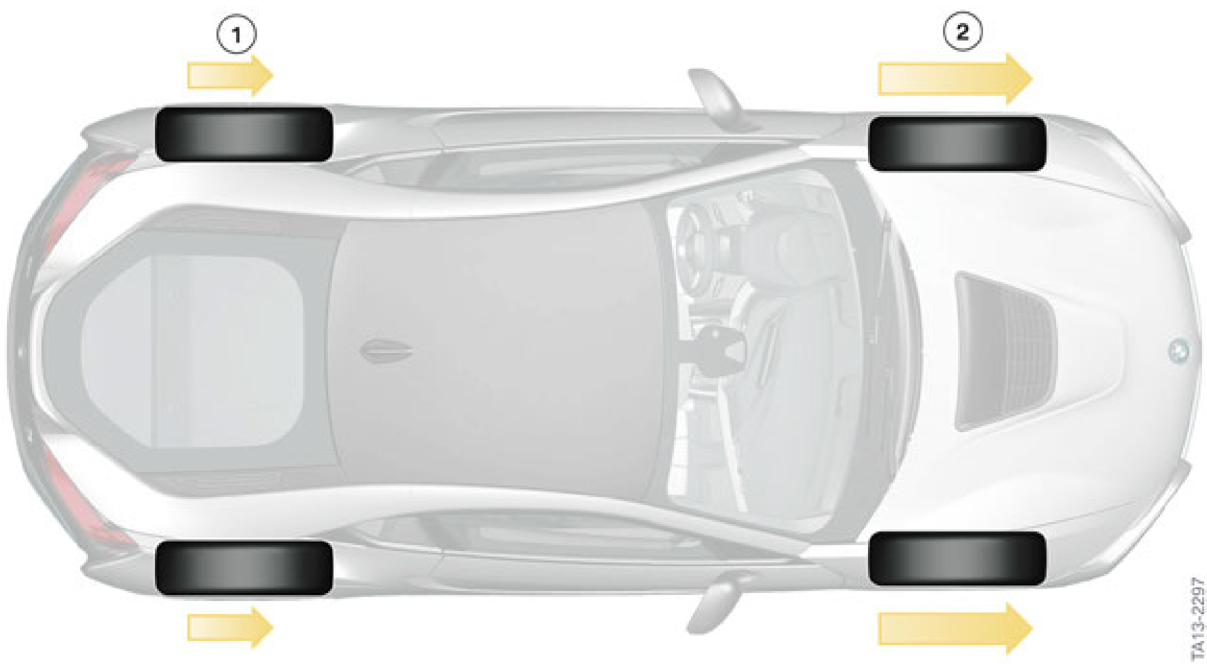
Kickdown

The kickdown is a special position within the drive control. Kickdown means that all drive sources are activated to enable the maximum drive. These include:

- Combustion engine
- Electrical machine
- High-voltage starter motor generator

6.4.1. Boost function

In the I12 the front electrical machine and the high-voltage starter motor generator can be used to support the combustion engine. The function is called the Boost function. This process differs from the previous hybrid cars by the fact that the support of the combustion engine is provided individually and independently for the respective axle.



I12 Boost function

Index	Explanation
1	Drive torque at the rear axle
2	Drive torque at the front axle

The support of the combustion engine and thus the rear axle is carried out in COMFORT, ECO PRO and SPORT modes. In COMFORT and in ECO PRO modes only in the lower engine speed range of the combustion engine is the high-voltage starter motor generator used as a support (with corresponding torque requirement via the accelerator pedal).

The kickdown is an exception. In this case the full power of the high-voltage starter motor generator is provided over the entire engine speed range (Overboost). In order to be able to request the full system power of the I12 in SPORT mode, the full power of the high-voltage starter motor generator is available in this driving mode from the beginning.

The level of additional acceleration generally depends on:

- State of charge (SOC) of high-voltage battery
- Driving mode selected
- Temperature of the respective components
- Torque that can be transmitted between wheel and road
- Driving speed

At a very low state of charge of the high-voltage battery, the Boost power is reduced in a linear fashion independent of the driving mode selected.

6.4.2. Load point increase

Raising the load of the combustion engine at consistent engine speed is called load point increase. This results in an increase in performance and the option to operate the combustion engine in the optimal range.

The arising resistance, which counteracts the combustion engine, must be compensated so that on the one hand the load of the engine increases, and on the other hand the speed remains constant. An example here is switching on the heating and air-conditioning system or the heated rear window. The compensation of the additional resistance is assumed by the DME. The DME supplies the combustion engine with more fresh air by activating the throttle valve. The injected fuel quantity is also increased. The load of the combustion engine increases and is in a more optimal range in terms of efficiency and fuel consumption. However, this control happens so precisely that there is no engine speed increase, but only the occurring resistance is compensated.

In the I12 the high-voltage starter motor generator in alternator mode generates a counter-torque in the belt drive. As described above, the DME compensates this counter-torque and the combustion engine is operated more optimally. The electrical energy gained is used to charge the high-voltage battery. In this way the combustion engine is also positively influenced during charging of the high-voltage battery.

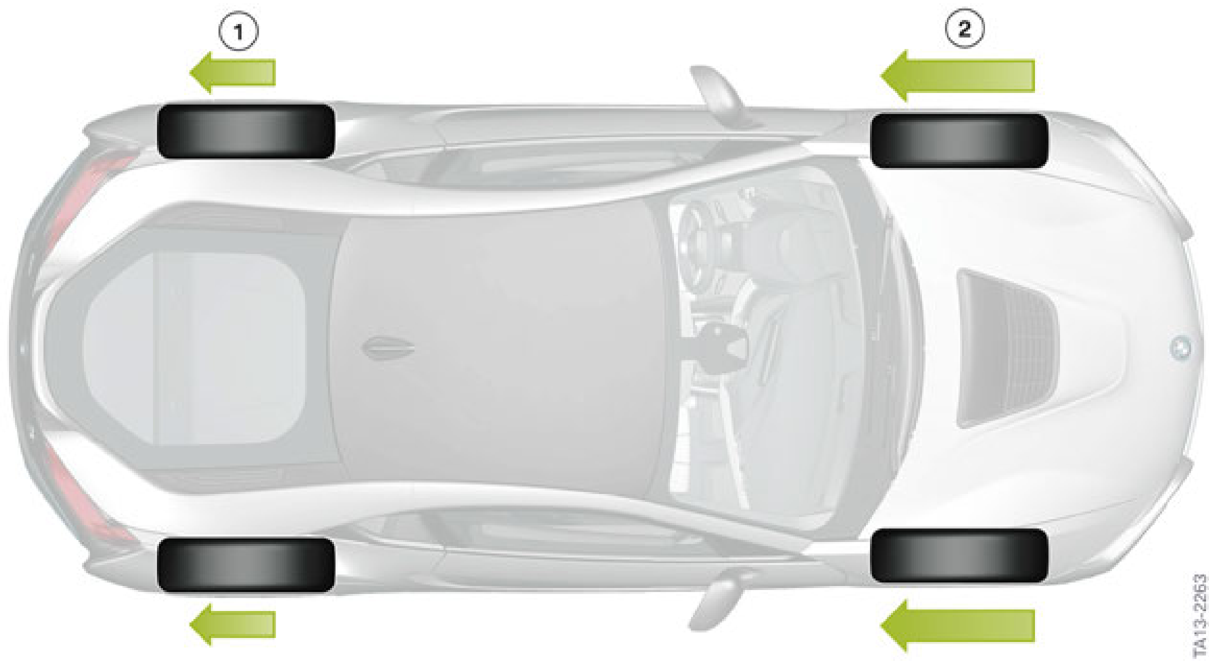
The B38 Top engine in the I12 is not operated at any time as a range extender, unlike the W20 engine in the I01. The combustion engine only runs when drive torque should be transferred to the rear axle. The load point increase happens in addition to the already existing power requirement. This process is unnoticeable to the driver.

Factors which are decisive over time and level of the load point increase:

- State of charge of the high-voltage battery
- Drive mode
- Load of the combustion engine
- Temperature of the combustion engine

6.4.3. Energy recovery

In the I12 brake energy regeneration (energy recovery) takes place both via the front and rear axle. Power ratings up to 50 kW can be recovered via the electrical machine at the front axle. The braking power which can be generated at the rear axle via the high-voltage starter motor generator is considerably lower. This means that the wear of the brake discs and brake pads will be extremely low, providing a forward-thinking driving style is adopted.



I12 Energy recovery

Index	Explanation
1	Deceleration torque at the rear axle
2	Deceleration torque at the front axle

The energy recovery generally functions in coasting (overrun) mode similar for BMW hybrid cars. If the DME detects an accelerator pedal angle of 0°, the electrical machine electronics (EME) and the range extender electrical machine electronics (REME) are requested to start energy recovery in coasting mode by activating the electrical machines accordingly. In this way the electrical energy is generated and stored in the high-voltage battery.

A special feature in the I12 is the different strengths of energy recovery in coasting mode. It is primarily dependent on the respective driving mode and the state of charge of the high-voltage battery. The maximum deceleration is achieved in SPORT driving mode, while it is lower in COMFORT, ECO PRO and Max eDrive modes (slightly above the level when it causes the engine drag torque in conventional vehicles).

If the driver has a stronger deceleration request and presses the brake pedal, the DSC control unit detects the level of the desired deceleration by the brake pedal travel sensor and transfers the information to the DME. The DME calculates the power requirement for the electrical machine and the high-voltage starter motor generator corresponding to the deceleration request and activates a stronger energy recovery by the EME and the REME. The wheel brakes are not operated until the maximum energy recovery is reached. Only for a higher deceleration request, is the service brake also used. If the recuperative braking system is omitted, for example by emergency braking, a fault in the high-voltage system or a fully charged high-voltage battery, the necessary brake force is only made available by the service brake. The driver does not notice this change at the brake pedal.

Parallel to this, the DSC control unit also permanently monitors the driving situation during energy recovery and intervenes where necessary. Before an unstable driving situation occurs during energy recovery, the DME is requested by the DSC control unit to reduce the negative torque at the respective axle. If this is not sufficient to re-establish a stable driving situation, the energy recovery is completely adjusted and a DSC intervention via the brake occurs.

6.5. Driving and energy recovery strategy

The main objective of the driving and energy recovery strategy is the provision of a sufficiently high state of charge of the high-voltage battery over the entire driving time. "Sufficient" means providing enough electrical energy for the electric motor. Only this way is the maximum system power of the vehicle during driving guaranteed. Electrical energy is generated via:

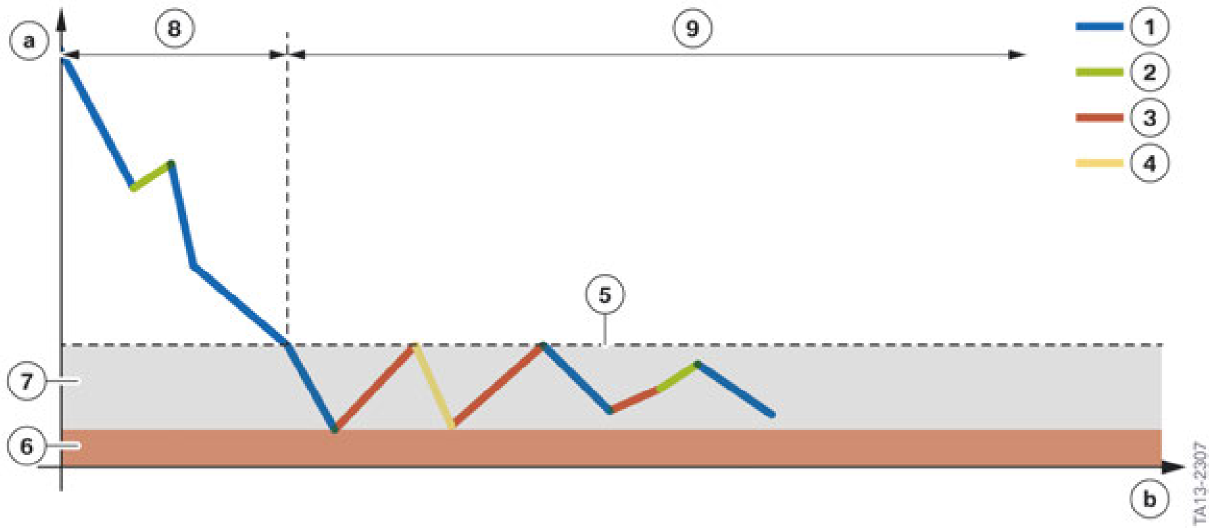
- Energy recovery (electrical machine and high-voltage starter motor generator)
- Load point increase of the combustion engine (high-voltage starter motor generator)

It is not the objective of the driving and energy recovery strategy to increase the state of charge of the high-voltage battery to 100% during driving. This is what external charging is used for. In the case of a high state of charge (SoC), the energy is used by the high-voltage battery to keep the electrical part of driving as high as possible or to drive purely using electrical means.

With a reducing state of charge the proportion of electrical driving also reduces so that the combustion engine, irrespective of the pedal sensor position or the speed driven, is often switched on in order to take over the drive and charge the high-voltage battery. This range serves to maintain the state of charge. If the state of charge continues to fall, e.g. by more frequent use of the Boost function, there is a reduction of the electrically driven speed from 60 km/h to 50 km/h (37 mph to 31 mph) and an acceleration of the electric motor. This reduction sets in depending on the driving style at a state of charge of about 25%.

Shortly before reaching a critical value the energy for electric driving and the Boost function is withdrawn in a linear fashion. The automatic engine start-stop function is also deactivated so that the combustion engine can also charge the high-voltage battery at a standstill.

6. Operating Strategy



I12 Example of energy recovery strategy

Index	Explanation
a	State of charge of the high-voltage battery
b	Distance travelled
1	Electric journey
2	Energy recovery
3	Combustion engine on (charging via high-voltage starter motor generator)
4	Boost function
5	Threshold value for maintaining the state of charge
6	Range in which electric driving and Boost function are withdrawn
7	Range in which the state of charge is maintained
8	Energy withdrawal from the high-voltage battery
9	Energy generation during the journey

The threshold value from which the state of charge is maintained depends on several factors:

- Activation of SPORT mode
- Setting for maintaining the state of charge
- Active route guidance of the navigation system

As described in SPORT mode, the high-voltage battery is actively charged in order to be able to provide sufficient electrical energy for the Boost function. The threshold value for maintaining the state of charge of the high-voltage battery is therefore higher.

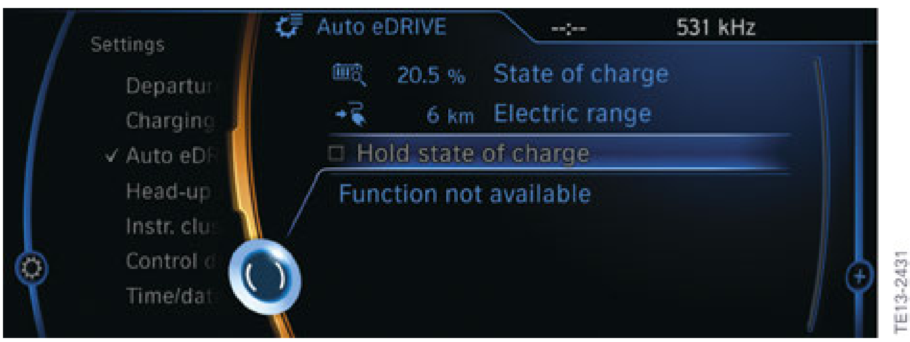
I12 Powertrain

6. Operating Strategy

Maintain state of charge

Should it become necessary, for example to use the stored electrical energy at a later stage of the journey, a corresponding selection can be made via iDrive under the menu item "Settings" and "Auto eDrive". The current state of charge of the high-voltage battery and the electrical range are displayed in the menu. The prerequisites for the selection of the "Maintain state of charge" function are:

- COMFORT or ECO PRO modes are deactivated
- State of charge is higher than about 10 %



I12 Maintain state of charge

Upon activation of the function the combustion engine switches on more frequently in order to be able to maintain the state of charge of the high-voltage battery via the high-voltage starter motor generator. An activation is already possible with a fully charged high-voltage battery. However, the state of charge is reduced minimally in order to be able to absorb electrical energy during energy recovery, for example.

Depending on the driving style the state of charge can be maintained at the current level. With the "Maintain state of charge" function it is not possible to increase the state of charge at the time of activation. The following events lead to the deactivation of the "Maintain state of charge" function:

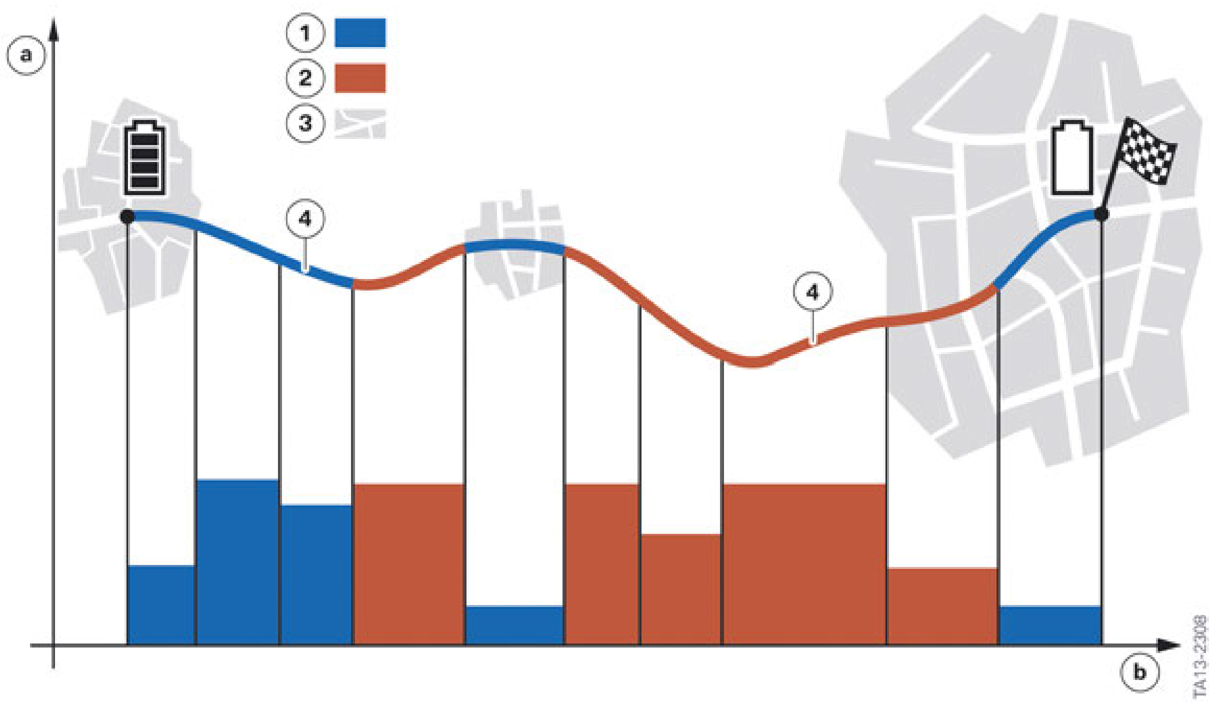
- Deactivation via iDrive
- Activation of SPORT or Max eDrive mode
- Terminal change

While the "Maintain state of charge" function is activated, the automatic engine start-stop function is available. If the current level of the state of charge equals the level to be maintained, the combustion engine is shut down at a vehicle standstill. If the current level of the state of charge is below the level to be maintained, the combustion engine is not shut down during a vehicle standstill.

Route guidance of the navigation system

With active route guidance by the navigation system the route is analyzed and the operating strategy adapted to the topography. The navigation data of the individual distances permit a calculation of the power required to cover the distances. Based on these power forecasts and the state of charge of the high-voltage battery, a decision is made on whether the combustion engine or the electric motor is used for this distance. The aim is to increase the electrical energy for the destination zone and the urban environment. There are three situations which reacts proactively to the operating strategy:

- **Low speed zone**
  An attempt is made to guarantee electric driving in a low speed zone. If necessary, the high-voltage battery must be actively charged beforehand.
- **Downhill gradients**
  With a fully charged high-voltage battery and oncoming downhill gradients, there is a reduction of the state of charge in order to be able to use the entire electrical energy from the energy recovery during the downhill gradient. Reduction of the state of charge is effected before the downhill gradient by the high-voltage starter motor generator, where it supports the combustion engine (Boost function).
- **Destination zone**
  An attempt is made to guarantee electric driving before reaching the destination and at the destination. If necessary, the high-voltage battery must be actively charged beforehand.



I12 Example of driving and energy recovery strategy using active route guidance

Index	Explanation
a	Power forecast for the respective distance
b	Distance travelled
1	Use of the electric motor
2	Use of the combustion engine
3	Built-up area
4	Cross-country trip

During the journey the driver receives a message in the energy flow diagram of the CID that the stored electrical energy is provided for a later stage.

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