Reference Manual

E82E
COMPLETE VEHICLE

Technical Training

Technical training.
Product information.

E82E Complete Vehicle

BMW Service

Edited for the U.S. market by:
BMW Group University
Technical Training
ST1101 1/1/2012

General information

Symbols used

In this document the following symbol/schematic diagram is used to facilitate better understanding or highlight very important information:

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Contains important safety information and information which is necessary for fault-free system functioning that must be observed.

Topicality and national-market versions

Vehicles in the BMW Group satisfy the highest safety and quality standards. Modified requirements in areas such as environmental protection, customer use or design result in a constant further development of systems or components. Deviations may arise between the content of this document and the vehicles available in training.

This document basically describes left-hand drive vehicles in the European version. In vehicles with right-hand drive, some operating elements or components are arranged differently than shown in the graphics of this document. Further deviations may arise as a result of market- or country-specific equipment specifications.

Additional sources of information

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

- in the Owner's Handbook
- in the "ISTA ActiveE" diagnosis system.

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.

Date of information: **May 2011**
VH-23/International Technical Training

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1. Introduction

The BMW Group presents the next big milestone on route to sustainable, CO_2-free mobility, the BMW ActiveE. After the MINI E, the BMW ActiveE is now the second electric vehicle to be introduced by the BMW Group. The BMW ActiveE demonstrates the dynamics and agility of a true BMW. With 125 kW/170 HP and a maximum torque of 250 Nm/184 lb ft, the vehicle accelerates from zero to 100 km/h/62mph in 9 seconds. While the latest design of lithium-ion batteries make possible a range of about 160 km (100 mls) in everyday use.

With a fleet of over 1,000 vehicles built at the Leipzig plant the BMW ActiveE will be available from 2011 in the USA, Europe and China and will offer further valuable findings and expertise from everyday use of the vehicle. The findings are used to enhance the knowledge already acquired on the use of vehicles with electric drives and to find out more about other customer requests. Customer feedback based on field reports from drivers of the MINI E and BMW ActiveE flows directly into the process of developing Mega City Vehicles for series production; the BMW Group will start marketing these vehicles as a new corporate brand under the BMW i brand name starting in 2013.

Similar to the MINI E, the BMW ActiveE is also referred to as a "Conversion Car" (an electric vehicle based on the bodyshell of an existing BMW vehicle with a combustion engine). The BMW ActiveE (whose development code is E82E) is based on the BMW 1-Series Coupe (E82). The BMW ActiveE features a fully electric powertrain which integrates components such as the high voltage battery, electrical machine and power electronics into a vehicle body, which was not originally intended for this. All this is achieved without compromising on space or comfort in the interior. The BMW ActiveE is thus the first electric vehicle from the BMW Group, which offers seating for four and a luggage compartment capacity of 200 liters.

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1. Introduction

1.1. Identifying features

1.1.1. Exterior

A range of distinctive features identify the exterior of the BMW ActiveE from the exterior of a traditional 1-Series Coupe. For example, the exclusive exterior color "Alpine White". In addition, distinctive graphics have been installed on roof, doors, hood and the trunk lid, which represent the electric conductor paths of a circuit board. These graphics are also functional, identifying the BMW ActiveE as an electric vehicle.

Identifying features of the exterior trim

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Index	Explanation
1	"Alpine White" paint
2	Power dome
3	"EDrive" writing
4	Door sill trims with "ActiveE" writing
5	Graphics with circuit board design (electric conductor paths)
6	"ActiveE" writing
7	16" wheel rims in double V-spoke design (standard equipment)
8	Latest generation of tires optimized for roll-resistance
9	Cover

The powerful curvature of the power dome on the hood indicates the installation location of one of the three high voltage batteries.

The "ActiveE" badging on the door sill trim, the quarter panels, as well as on the trunk lid clearly identify the ActiveE as an electric vehicle. In addition, the "EDrive" badge has also been installed on the front fenders.

Another feature of the BMW ActiveE is a distinctive panel mounted underneath the rear bumper cover. This panel is designed to conceal the openings for the exhaust system tail pipes because the conventional E82 bumper cover is used and the E82E naturally has no exhaust system.

To further increase the range, the BMW ActiveE rolls on wheels with the latest generation of tires that have been optimized for roll-resistance. Compared to the previous series tires, up to 20 percent less rolling resistance is achieved. The wheel of the BMW ActiveE is equipped with a lightweight double V-spoke design 16" wheel as standard. In addition, a 17-inch wheel assembly with different front and rear tire dimensions is offered as an optional extra.

1.1.2. Interior

The interior equipment of the BMW E82E also has some special identifying features. For example, the upholstery of the seats in white leather with blue accent stitching, which also serves as an indirect visible feature of the E82E.

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Interior features

Index	Explanation
1	Steering wheel pad in ”Alpine White” as well as the “ActiveE” emblem on the interior molding
2	Selector lever with chrome clips
3	Upholstery in white leather and blue accent stitching

In addition to the door sill trims with the "ActiveE" writing, the interior trim finishers and the steering wheel pad also differ to those of the conventional E82. In the E82E these are done in the "Alpine White" color while also featuring graphic elements similar to those found on the exterior (with conductor strips and the "ActiveE" emblem).

The selector lever with chrome links used for the E82E is known from vehicles with a double clutch transmission.

1.2. Electric powertrain

1.2.1. High voltage battery

In a combustion-driven vehicle the fuel and fuel tank assume the task of the energy storage. In contrast, in the E82E the energy storage device is a high voltage battery based on lithium-ion technology. While a full fuel tank of a E82 weighs about 60 kg/132 lb, the high voltage battery of the E82E has a total weight of about 510 kg/1124 lb. The high voltage battery of the E82E is divided into three high voltage battery units, which are connected in series. The first high voltage battery unit is located in the front of the vehicle, in the space generally occupied by the combustion engine. It is secured by the addition of a special support structure. The second high voltage battery unit is located in the transmission tunnel. The bodyshell has been reworked in this area in order to accommodate the high voltage battery unit without compromising the space of the passenger compartment. By positioning this battery in the transmission tunnel the existing design space of the E82 body was able to be used and the vehicle center of gravity lowered. The third high voltage battery unit is located in the rear of the vehicle. It takes up roughly the space of the fuel tank of a conventional E82. By distributing the three high voltage battery units over the entire vehicle, a good axle-load distribution was able to be realized with minimum changes to the vehicle concept.

The high voltage battery comprises a total of 192 individual cells. Ninety six (96) cell pairs are connected in series to generate a total voltage of 355.2 volts at a cell voltage of 3.7 volts.

High voltage battery units

Index	Explanation
1	High voltage battery unit at the front
2	High voltage battery unit in the transmission tunnel
3	High voltage battery unit at the rear

1.2.2. Electrical machine

Electrical machine

In a typical passenger car a combustion engine is used to generate the drive torque. In the E82E this is done by an electrical machine. The electrical machine is a permanently excited synchronous machine. Although significantly smaller than a combustion engine it has comparable power, developing a maximum of 125 kW/170HP and of 250 Nm/184 lb-ft. of torque. The electrical machine also has advantages over the combustion engine when it comes to weight. While an N52 engine weighs about 160 kg/353 lbs, the electrical machine of the E82E weighs about 58 kg/128 lb. It is thus possible to install the complete drive unit directly at the rear axle support. In comparison to the combustion engine the electrical machine has a speed range of over 11,000 RPM, which is available from when the vehicle is at a standstill. Here the maximum torque of 250 Nm/184 lb-ft is applied right from the first revolution.

The electrical machine can be operated as a motor and a generator. The electrical energy recovered from the kinetic energy of the vehicle can be used to charge the high voltage battery during travel using brake energy regeneration.

1.2.3. Power electronics

The power electronics is comprised of two main components: The electrical machine electronics (EME) and the comfort charge electronics (KLE).

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Electrical machine electronics

The electrical machine electronics (EME) of the E82E is the central link between the high voltage battery and the electrical machine. It is responsible for the energy supply of the low-voltage vehicle electrical system from the high voltage electrical system. The EME is installed above the electrical machine. Therefore the electrical connection between EME and the electrical machine is very short and enables efficient energy transfer. In addition, due to the proximity of the two components a compact and common cooling circuit was able to be realized. EME and electrical machine are together as one unit. Power electronics in the EME converts the direct current voltage of the high voltage battery into three phase AC voltage for the electrical machine. Energy flow is hereby possible in both directions, the high voltage battery is charged from brake energy regeneration or discharged for acceleration.

The EME is also connected to the low-voltage vehicle electrical system. The energy is transferred from the high voltage electrical system to the low-voltage electrical system via a DC/DC converter in the EME. Therefore this DC/DC converter assumes the function of the alternator and supplies the low-voltage vehicle electrical system with energy.

Two other high voltage consumers are connected directly to the EME: The electric heating unit and the electric cooling (A/C) compressor are supplied by the EME with DC (direct current) voltage. The comfort charge electronics (KLE) is also connected to the EME and is used to charge the high voltage battery.

The AC voltage supplied to the vehicle via the charging socket is converted to DC voltage in the comfort charge electronics.

These two power electronics components, EME and KLE, are cooled using (antifreeze) coolant.

1.3. Driving situations

Accelerator pedal positions

Index	Explanation
1	Acceleration
2	Coasting
3	Deceleration/regeneration

1.3.1. Acceleration

In order to accelerate the vehicle, the accelerator pedal must be pressed past “Coasting” range (when the readiness to travel is switched on). The electrical machine electronics receives a drive torque request and it sends energy from the high voltage battery to the electrical machine. The electrical machine (now working as a motor) converts the electrical energy into kinetic energy to drive the rear wheels via the transmission and the output shafts.

1.3.2. Driving and deceleration

The dynamic driving experience in the BMW ActiveE is even further enhanced by the accelerator pedal deceleration function. If the driver takes his foot off the accelerator pedal, the electrical machine assumes the function of a generator, which generates electrical energy from kinetic energy. At the same time, there is a braking torque, which leads to an effective “braking” of the vehicle. In city traffic roughly 75 percent of all deceleration events are performed without pressing the brake pedal. Intensive use of this energy recovery function also increases the overall range of the vehicle by up to 20 percent. If the driver requests more deceleration by pressing the brake pedal, the conventional service brake of the vehicle is applied.

1.3.3. Coasting

In contrast to the MINI E, the BMW ActiveE has a distinct "intermediate setting" of the accelerator pedal which allows the vehicle to “Coast”. The vehicle thus does not go into regenerate mode immediately when the driver backs off the accelerator, but "virtually de-clutches". The electrical machine then spins with no load so that the BMW ActiveE coasts without energy consumption. As part of a forward-thinking driving style, the "Coasting mode" offers a very comfortable possibility of generating slightly more speed.

Note: When the vehicle is in “Coasting” mode the E machine is (inactive) and thus does not consume nor generate energy.

1.4. Equipment and Technical Data

Motor and transmission	Unit	E82E
Design		Electric motor-generator
Motor type		Hybrid synchronous-drive motor
Maximum power	kW/hp	125/170
Torque (from standstill)	Nm/lb-ft	250/184
Maximum driving speed (restricted)	rpm	12,000

Vehicle performance	Unit	E82E
Power-to-weight ratio (DIN)	kg/kW	9.76
Acceleration 0 – 60 km/h	s	4.5
Acceleration: 0 –100 km/h (0 - 62 mph)	s	9.0
Maximum speed	mph	90.0
	km/h	145
Range (according to FTP 72)	km	240
	mls	150
Range in customer operation	km	160
	mls	100

Consumption (according to FTP 72, w/o charging)	Unit	E82E
Total	kWh/mls	0.19
	kWh/km	0.12
CO_2	g/mls	0
	g/km	0

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Dimensions and weight	Unit	E82E
Number of doors/seats		2/4
Length/Width/Height (empty)	mm	4360/1748/1438
	inch	171.65/68.82/56.6
Wheelbase	mm	2,660
	inch	104.7
Track width, front/rear	mm	1474/1507
	inch	58.03/59.33
Turning circle	M	10.7
	feet	35.1
Transmission oil incl. axle drive		Long term fill
Curb weight	kg	1,815
	lbs	4,001
Load capacity	kg	335
	lbs	739
Permissible total weight	kg	2,150
	lbs	4,740
Luggage compartment capacity (DIN)	liters/cubic feet	200/7.1

High voltage battery	Unit	E82E
Storable energy volume	kWh (gross)	32
Weight	kg	480 kg
	lbs	1,058 lbs
Charging time at 110 V / 16 A (1.3 kW)	h	16 to 20 hours
Charging time at 240 V / 32 A (7.7 kW)	h	4 to 5 hours
Installation		192 cells at 40 Ah in 25 modules in three individual housings (packs)
Maximum current-carrying capacity	A	400

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Chassis and suspension	Unit	E82E
Front axle		Double pivot spring strut front axle
Rear axle		HA5 multi-link independent rear axle, adapted to electric drive
Front brake		Single-piston floating caliper/ brake disc vented
Diameter	mm	300
	inch	11.8
Rear brake		Floating caliper/Brake disc vented
Diameter	mm	300
	inch	11.8
Drive stability systems		ABS incl. Dynamic Brake Control and Cornering Brake Control (CBC), Dynamic Stability Control (DSC) with additional functions
Steering		Electromechanical power steering
Overall ratio		14.4:1
Weight distribution	kg	Front/Rear 887/928
	lbs	Front/Rear 1956/2046
	%	Front/Rear 49/51
Tires		205/55R16 with emergency running properties/optimized for rolling resistance

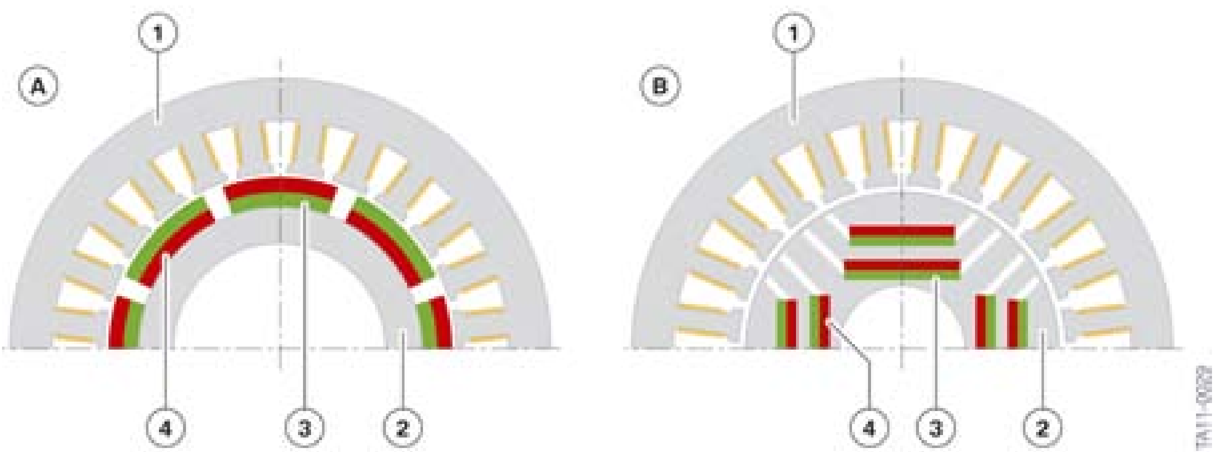
2. Electric Powertrain

2.1. Electrical machine

2.1.1. Technical data

The electrical machine in the E82E has been given its own "engine designation" similar to that of combustion engines. This engine designation is **IBOP25A**. As the standardization of the engine designation is not yet completed, the diagram of the designation may still need to be altered in the next vehicles with an electrical machine.

The electrical machine in the E82E is a synchronous machine. Its basic design and functioning principle correspond to a permanently excited synchronous machine with an internal rotor. The rotor is located on the inside and is equipped with permanent magnets. The stator is shaped like a ring and arranged on the outside around the rotor and is formed by the three-phase winding with iron cores. When three-phase AC voltage is applied to the stator winding, it generates a rotating magnetic field, which (in motor operation) pulls the magnets in the rotor.



Principal design of the synchronous machine

Index	Explanation
A	Conventional synchronous machine
B	Synchronous machine in the E82E
1	Stator
2	Lamination-stack rotor
3	South pole of a permanent magnet
4	North pole of a permanent magnet

The design of the rotor has been optimized to enhance the technical data. The rotor has a new arrangement of the permanent magnets and a lamination stack, which has a positive influence on the characteristics of the magnetic field lines. This results in a torque increase with lower current levels in the stator windings. Therefore enhancing efficiency in comparison to a conventional synchronous machine design.

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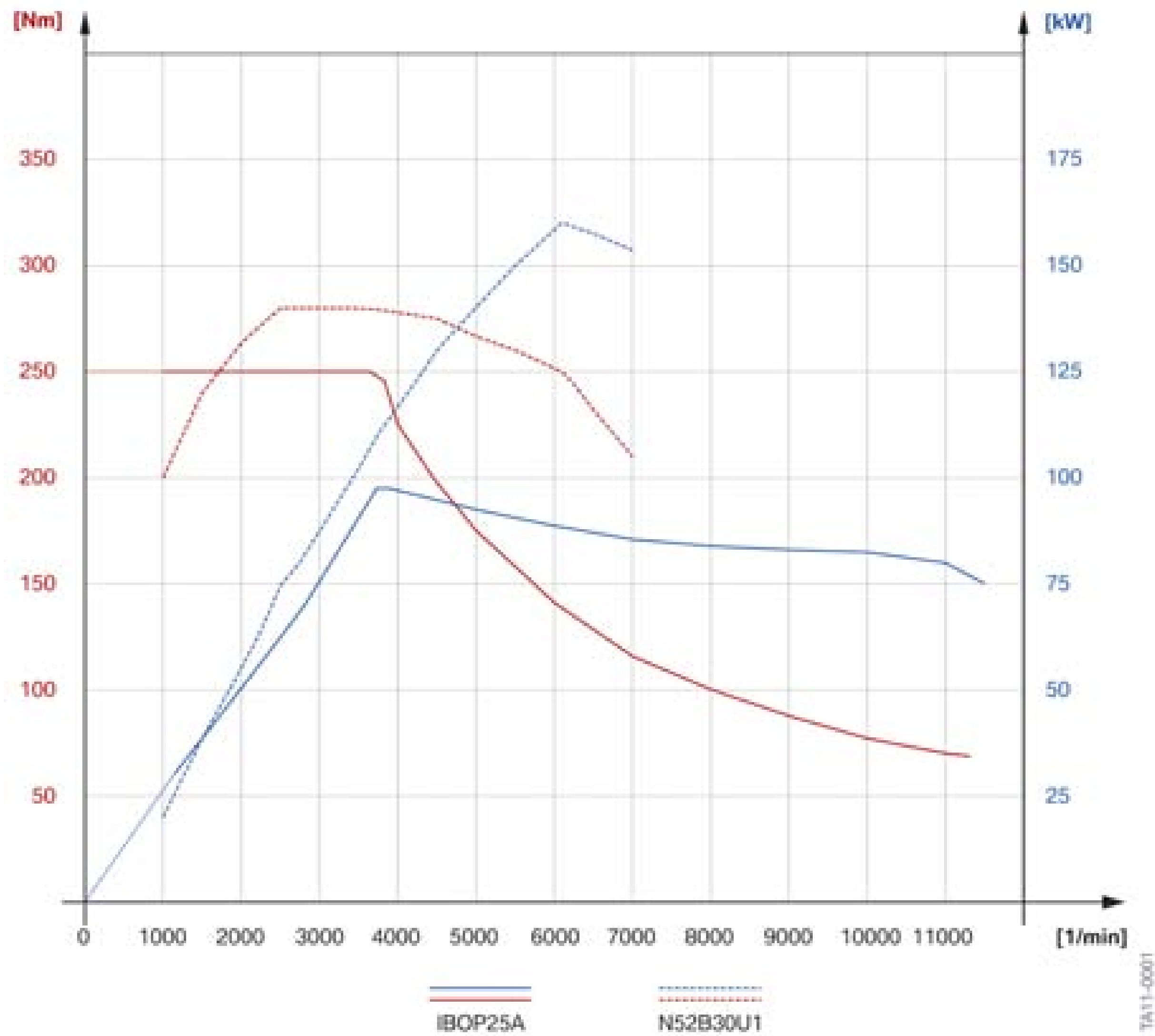
The impressive performance data is compiled in the following table.

Nominal voltage	360 V	
Nominal current	400 A	Effective value
Maximum peak power	125 kW / 170 hp	for a limited duration
Maximum continuous output	45 kW / 60 hp	continuous
Maximum torque	250 Nm/184 lb-ft	in the motor speed range 0 – 4,000 rpm
Maximum speed	12,000 rpm	

The maximum power of 125 kW/170 hp can only be supplied for a limited amount of time (about 30 s). Otherwise, the components of the powertrain would overheat and fail (this applies to the electrical machine, the high voltage battery and the electrical machine electronics). The maximum power applies to the motor operation which theoretically speaking it could also be used in the operation of the generator in brake energy regeneration. However, only a fraction of this maximum value is used in the practical operation of the generator. This restricts the braking torque at the rear axle so as not to influence driving stability through brake energy regeneration.



Power and torque diagram IBOP25A machine in comparison to the N52B30U1 engine

The power and torque diagram shown here does not represent the full load diagram. Instead the data has been recorded at a lower operating voltage with a partially charged high voltage battery. Despite this the electrical machine performance data is impressive in comparison to the N52B30U1 engine.

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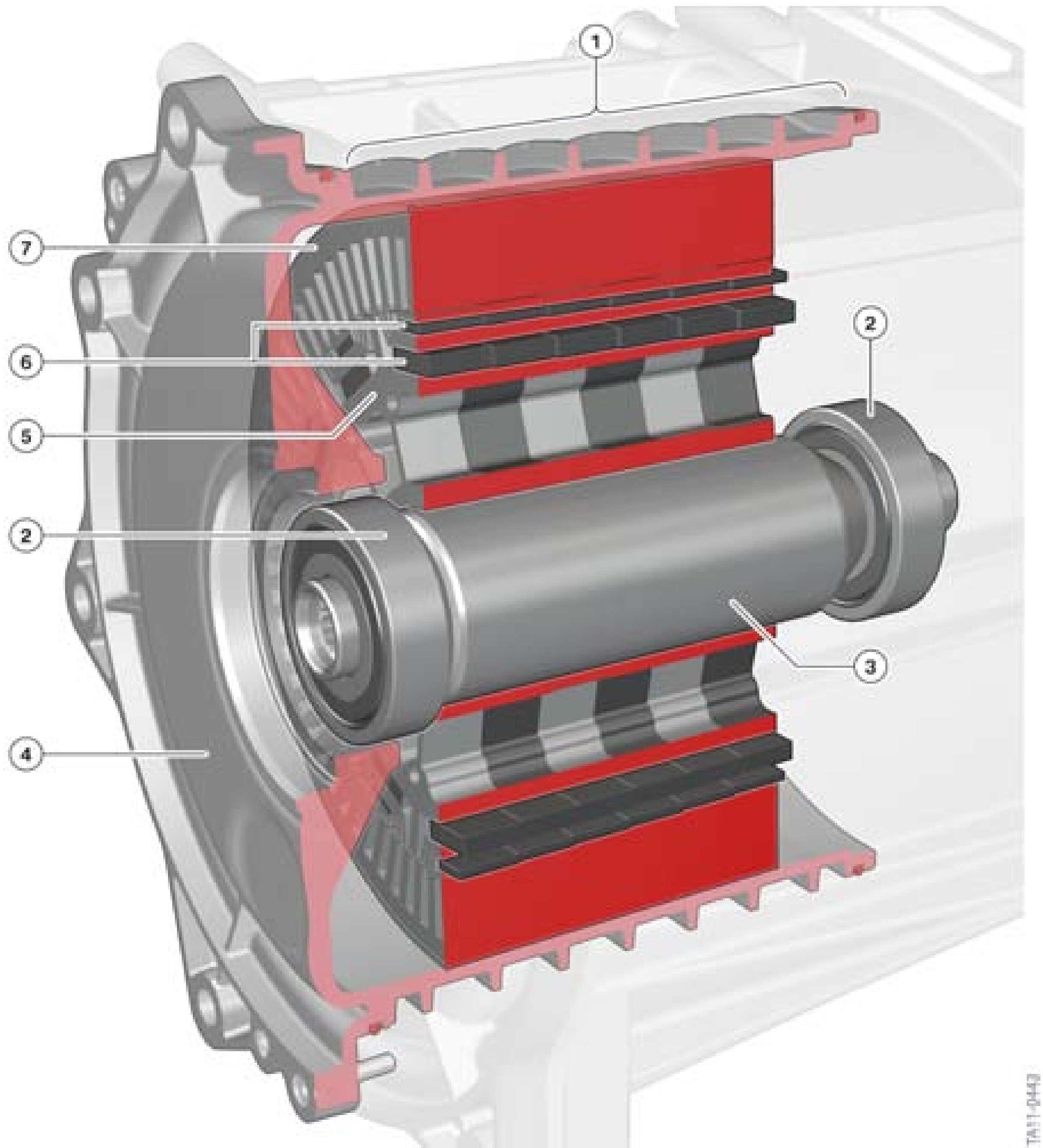
The following properties are characteristic of the electrical machine IBOP25A in the E82E:

- The maximum torque of 250 Nm/184 lb-ft is available from a standstill, as well as at average speeds. For this reason the drivetrain of the E82E does not require a clutch. In addition to this technical feature, the E82E has an impressive accelerating ability from standstill, which provides the typical BMW ultimate driving machine experience, especially in city traffic.
- The maximum torque decreases again only at higher speeds. However, it is still sufficient to overtake while in highway speed range.
- The maximum power characteristics can be derived from the maximum torque characteristics: In the engine speed range (in which the maximum torque is applied constantly) the maximum power increases in a straight line up to its maximum. In spite of the decreasing maximum torque at higher speeds, the maximum power only then decreases slightly up to the maximum speed.
- The usable motor speed range of the electrical machine ranges from 0 to nearly 12,000 rpm. Due to the motor speed range being almost double that of a combustion engine, the E82E gets by without a multiple-ratio transmission and achieves a remarkable maximum speed of 145 km/h/90 mph.

2.1.2. Design

Electrical machine



Design of the electrical machine (cut away view)

Index	Explanation
1	Coolant passages
2	Grooved ball bearing
3	Drive shaft
4	Housing cover
5	Lamination-stack in the rotor
6	Permanent magnets in the rotor
7	Iron core of the coils in the stator

The graphic only shows the iron core in the stator. The three-phase alternating current windings are arranged around the iron core. The rotor comprises a weight-optimized support in the inner part, a lamination stack and permanent magnets, which are arranged in two layers. The torque produced by the machine is thus increased. The rotor is shrink-fitted onto the drive shaft.

The terminal pair of 6 represents a good ratio between arguable complexity of the design and as constant as possible torque curve per revolution.

The electrical machine of the E82E uses no lubrication except for two grease filled grooved ball bearings (one on each end of the unit)(2). The cooling of the electrical machine is done by circulating coolant from the output of the electrical machine electronics into the electrical machine housing. The electrical machine coolant flows through a spiral-shaped coolant passage (1) which is machined on the housing cover (4) of the unit. Two O-rings (one on each end of the housing) seal the coolant passage. The inner components of the electrical machine operate completely "dry".

Cooling system of the electrical machine

Index	Explanation
1	Connection for coolant line (input of electrical machine, coming from the electrical machine electronics)
2	Housing
3	Connection for coolant line (output of electrical machine, to the coolant pump)
4	O-ring
5	Cooling passage

Although the electrical machine has less losses with the energy conversion than a combustion engine it has been designed to operate in a large temperature range. While the coolant can reach a temperature of up to 70° C/158 °F at the input (supply), the E machine housing may reach a temperature of up to 100° C/ 212 °F.

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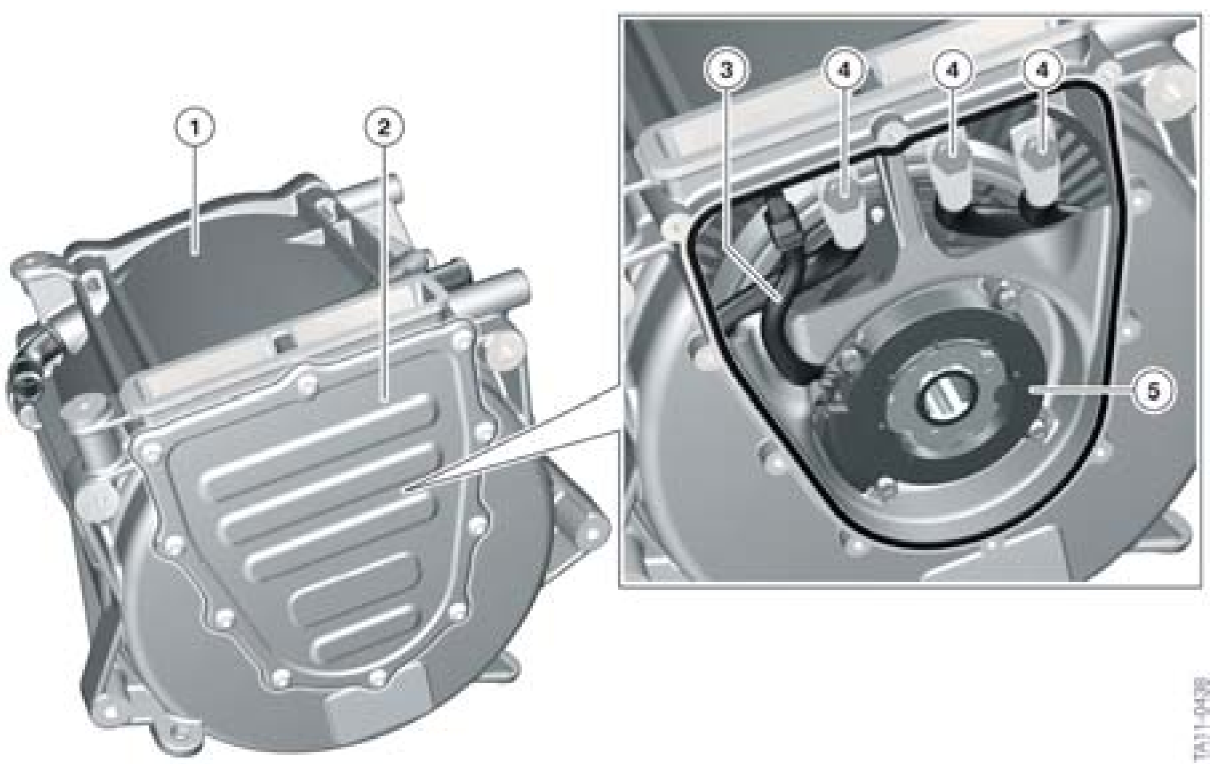
Be aware that the housing of the electrical machine can reach temperatures of up to 100° C /212 °F during operation. To avoid injury, allow sufficient cool down time before any work such as the removal of the drive unit is performed. Always follow proper repair instructions when working on BMW vehicles.

Sensors

In order to avoid damage to the components due to high temperature, there are two temperature sensors in the electrical machine of the E82E. These sensors are used to monitor the temperature of the windings (although the insulating varnish of the windings restricts high temperatures). The second sensor measures the temperature at one of the bearings to calculate the temperature of the rotor. The permanent magnets are more susceptible to damage from high temperature. The two temperature sensors are negative temperature coefficient (NTC) type sensors. Their signals are read in and evaluated as the one for the electrical machine electronics.

There is a rotor position sensor at the end of the drive shaft which is used to measure the precise angle setting of the rotor so that the voltages for the windings in the stator can be calculated and generated correctly (with regard to amplitude and phase location of the electrical machine electronics).



Electrical connections on the electrical machine

Index	Explanation
1	Housing
2	Housing cover – **Not to be opened by BMW Service!**
3	Low-voltage connection
4	High voltage connection
5	Rotor position sensor

The rotor position sensor works according to the tilt sensor principle. A defined AC voltage is fed to one coil on the rotor, which is fixed to the drive shaft. The stator coils of the sensor are arranged around the rotor of the sensor, i.e. around the E machine's drive shaft, and are each offset by 90°. The voltage induced in these coils provides information on the angle setting of the rotor. The rotor position sensor is fitted by the manufacturer of the electrical machine with corresponding alignment so that it is properly balanced. A precise adjustment of the rotor position sensor is done during manufacture after which the electrical machine is assembled to the electrical machine electronics. The adjustment values are saved in the electrical machine electronics control unit.

⚠

It is not allowed to adjust nor replace the rotor position sensor in the BMW Dealer Service workshop.

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The housing cover above the rotor position sensor must not be opened in the BMW Dealer Service workshop.

The electrical connection of the sensors of the electrical machine to the electrical machine electronics are shown on a wiring diagram in the "Electrical interfaces" section of this training material.

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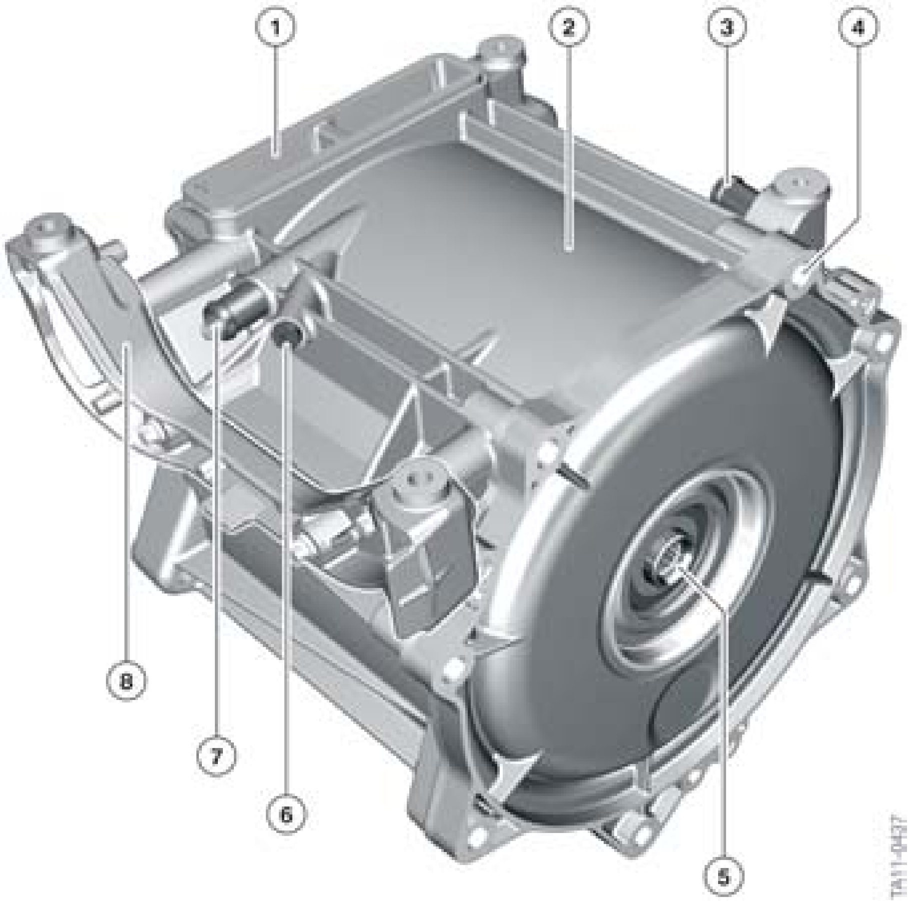
2.1.3. Features and mechanical interfaces



Features and mechanical interfaces of the electrical machine

Index	Explanation
1	Shaft for electrical connections to the electrical machine electronics
2	Housing
3	Connection for coolant line (input of electrical machine, coming from the electrical machine electronics)
4	Bore holes for mechanical connection to the transmission
5	Drive shaft
6	Bleed screw
7	Connection for coolant line (output of electrical machine, to the coolant pump)
8	Support structure for electrical machine electronics

The state of the electrical machine shown in this graphic (without any connection to other components) serves only as an overview. The electrical machine and the electrical machine electronics are treated as one unit and are to remain fixed to each other in the BMW Service.

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The connection between the electrical machine and the electrical machine electronics must not be separated in the BMW Service.

The electrical machine electronics is located above the electrical machine. To achieve sufficient support, the housing of the electrical machine has been "extended" to the front with a support structure in the direction of travel.

The torque is transferred via a positive connection from the drive shaft of the electrical machine to the transmission input shaft. The two shafts have gearing for this purpose. However, there is no intended centering for the two shafts.

⚠

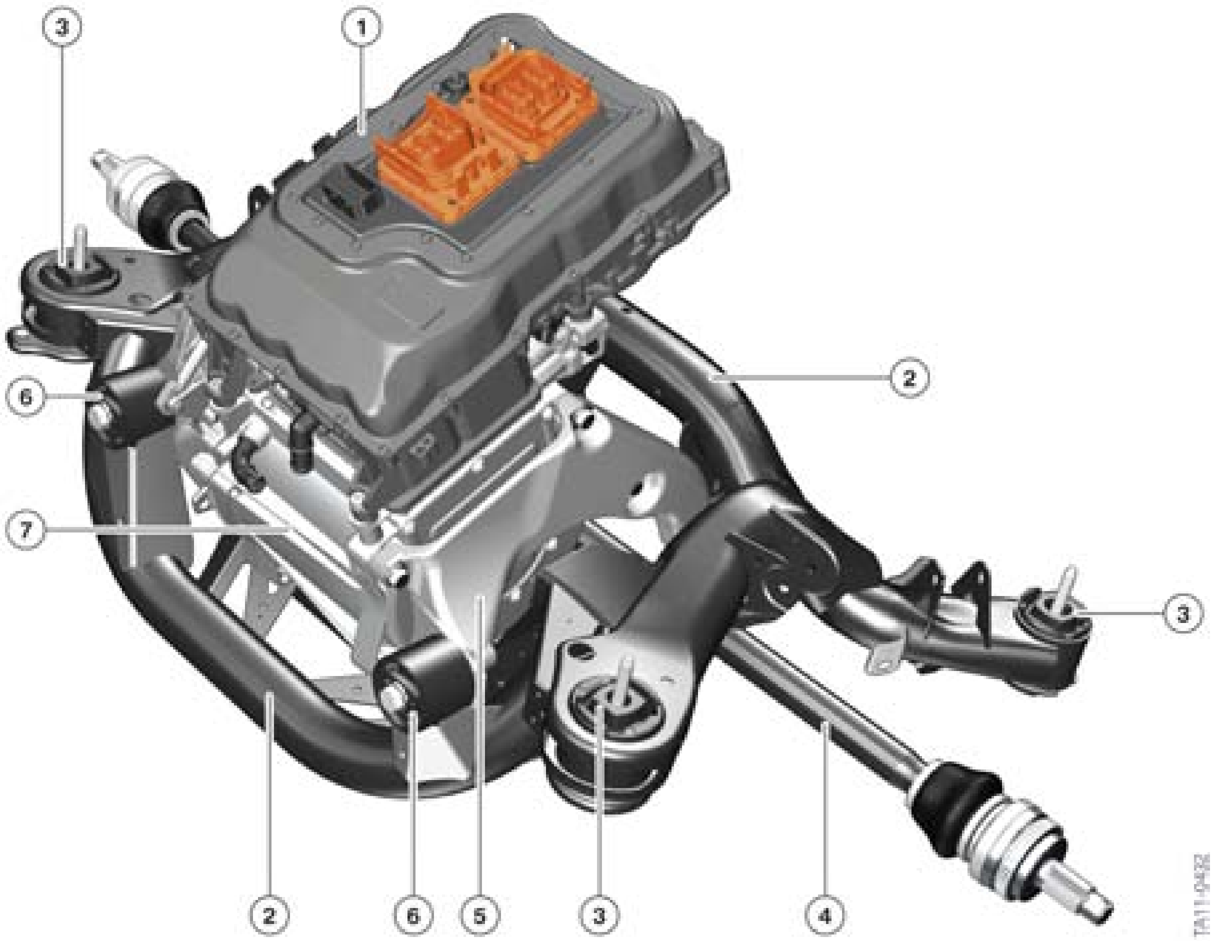
When joining the transmission and the electrical machine the procedure described in the repair instructions must be followed. Axial alignment of the transmission input shaft and the E machine drive shaft is extremely important during the assembly. In addition, the two gears must be greased before joining.

A sealing ring is located at the joining location between the housing of the electrical machine and the housing of the transmission, whose cross-section has the shape of an **"X".**

The two coolant lines integrate the electrical machine into the powertrain cooling circuit. This is described in detail in the "Cooling" chapter of this training material.

Due to its low installation location the housing of the electrical machine is designed to be air-tight and water-tight in order to avoid any water intrusion related damage. There is also a need for pressure compensation due to the large temperature differences which may arise during operation. This is realized via the shaft for electrical connections (#1 on the previous page) through which the electrical machine electronics is connected to the E machine.

The complete drive unit includes the electrical machine, transmission and electrical machine electronics.



Drive unit mounting locations

Index	Explanation
1	Electrical machine electronics
2	Rear axle support
3	Rubber mount for connection of the rear axle support to the body
4	Output shaft
5	New support for connection of the electrical machine and rear axle support
6	Rubber mount for connection of the drive unit and rear axle support
7	Housing of electrical machine

A recently developed aluminum support bracket (5) connects the housing of the electrical machine to the rear axle support. This support is used to hold the weight of the drive unit and to transfer the drive torque to the rear axle support and the body. The E82 rear axle support and the bearing have been modified to mount the drive unit. The other supports connect the transmission to the rear axle support and are therefore discussed in the "Transmission" section.

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If the electrical machine has to be dismantled, the complete rear axle has to be removed. The same also applies to the removal of the transmission and the electrical machine electronics. Only then can the supports be removed from the housing and the individual components removed.

2.1.4. Electrical interfaces

The electrical machine has only one electrical interface (for the electrical machine electronics). As both components cannot be separated in the BMW Dealer Service workshop, they are never seen by the Service Technicians. However, In order to create a better understanding, they are listed here together with a brief description.

There is a high voltage interface and a low-voltage interface. The high voltage interface incorporates three phases. A bi-directional DC/AC converter in the electrical machine electronics generates a three-phase AC voltage, which is transferred to the windings in the stator of the electrical machine. The electrical machine is controlled using this and its operating mode (as an motor or generator) specified.

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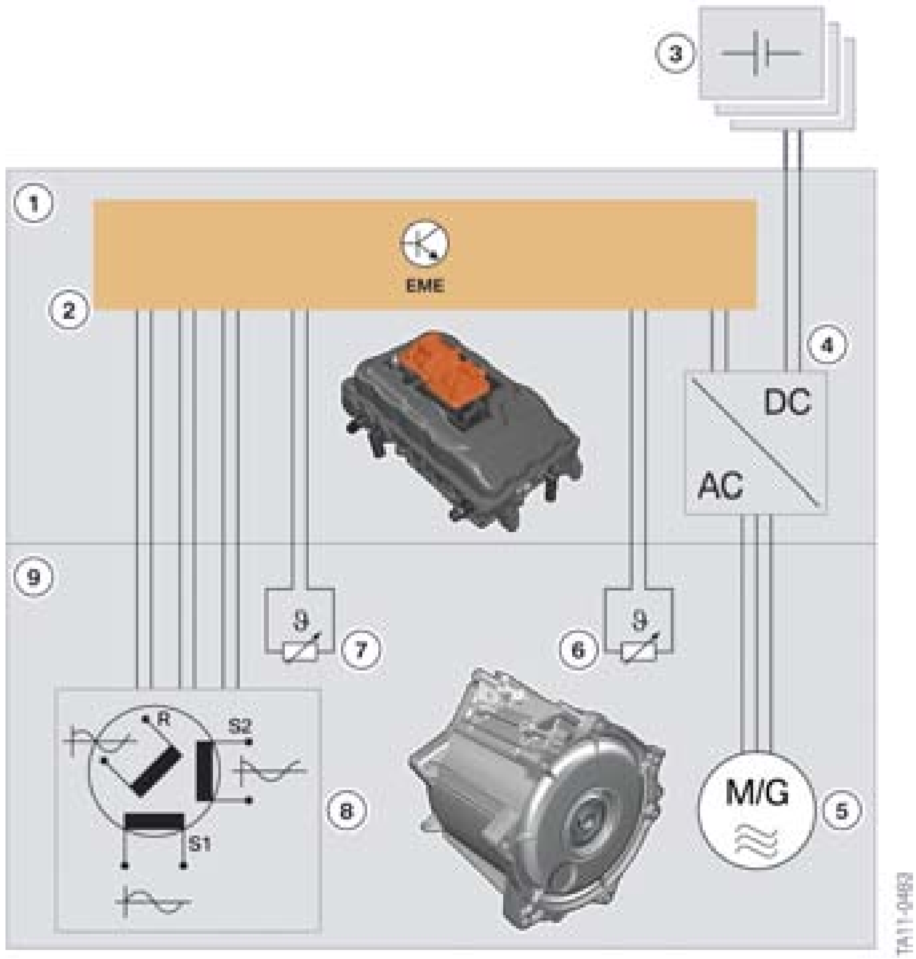
The electrical lines/connections are fastened together and concealed under a cover which cannot be opened by the Service employees.

The low-voltage interface incorporates the signal wires of the following sensors:

- Temperature sensor for stator winding
- Temperature sensor for rotor (on one bearing)
- Rotor position sensor

The electrical machine electronics measures the electrical resistance of the two temperature sensors (which are NTC resistors) and thus determines the temperatures at the two locations in the E machine. In addition, the electrical machine electronics supplies AC voltage to one of the rotor position sensor's coils and evaluates the induced AC voltage signals of other two coils of the sensor to determine the rotor position. The electrical connection incorporates a plug connection which is concealed under the same cover as the high voltage connection. The following graphic illustrates the electrical interfaces of the E machine to the electrical machine electronics.



Electrical interfaces between electrical machine and electrical machine electronics

Index	Explanation
1	Electrical machine electronics (complete unit)
2	EME control unit
3	High voltage battery
4	Bi-directional DC/AC converter
5	Actual electrical machine
6	Temperature sensor for stator
7	Temperature sensor for rotor
8	Rotor position sensor
9	Electrical machine (complete unit)

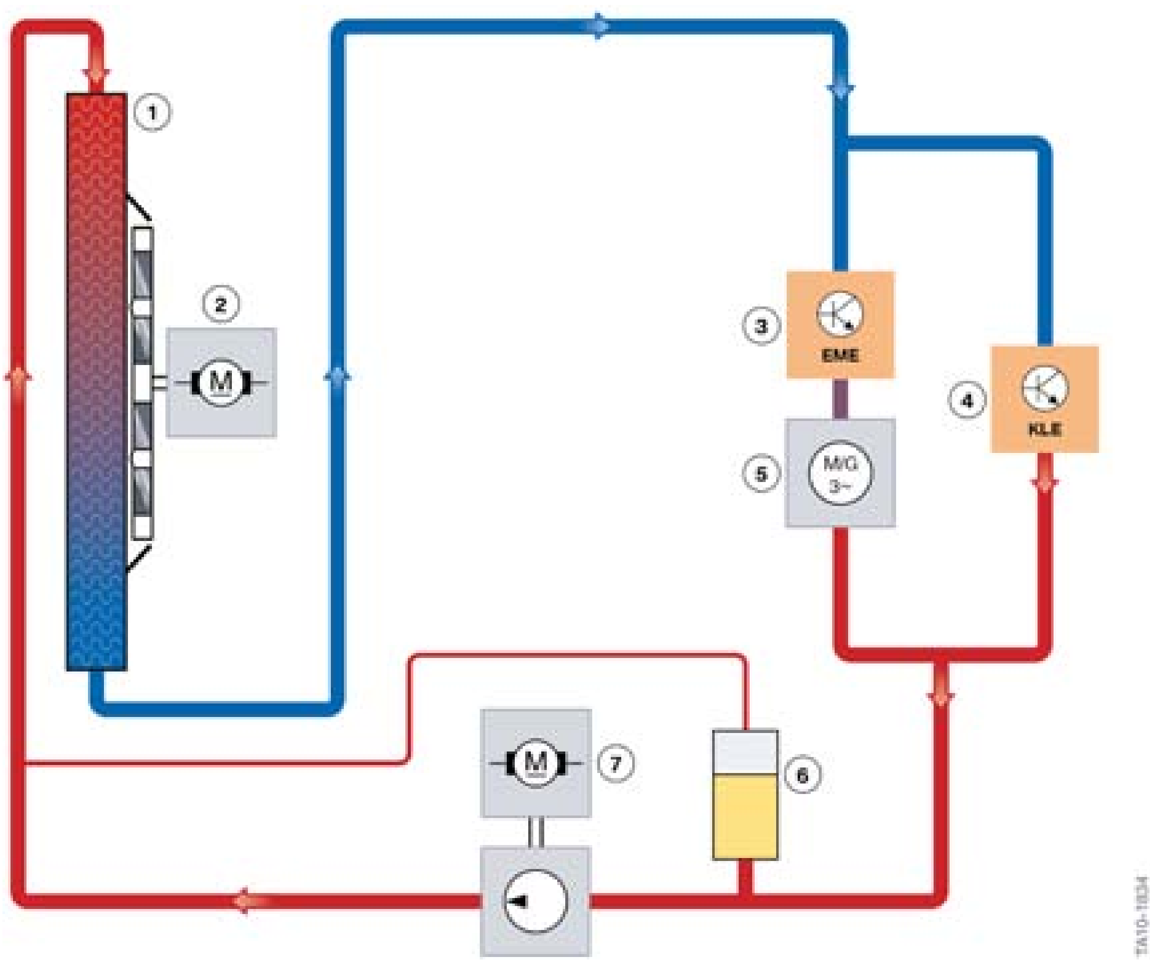
2.1.5. Cooling

There are several cooling circuits in the E82E. An overview of these is provided in the following table.

	Cooled components	Cooling medium	Components in the cooling circuit
Powertrain (drive unit)	Electrical machine, electrical machine electronics, comfort charge electronics	Coolant	Electric coolant pump, radiator, electric fan, expansion tank
High voltage battery	High voltage battery unit at the front, in the transmission tunnel and at the rear	Coolant	Electric coolant pump, coolant/refrigerant heat exchanger, changeover valve, expansion tank
Heating	Passenger compartment	Coolant	Electric coolant pump, electric heating, heat exchanger
Climate control	Passenger compartment, high voltage battery unit	Refrigerant	Electric coolant compressor, evaporator, coolant/refrigerant heat exchanger with expansion valve, Condenser, electric fan

The cooling system for the powertrain is described here in detail. Reference is made to this chapter in the chapters on the electrical machine electronics and the charge electronics.

System overview



Cooling system for the electric powertrain

Index	Explanation
1	Radiator
2	Cooling fan
3	Electric motor electronics (EME)
4	Comfort charge electronics (KLE)
5	Electrical machine
6	Powertrain cooling circuit expansion tank reservoir
7	Powertrain cooling circuit pump

The components to be cooled are arranged in the cooling circuit with regard to their specific cooling needs. A lower temperature is required for the electrical machine electronics than for the electrical machine, which is why the series connection was selected in this sequence. As the electric powertrain and the charge electronics are not in operation at the same time, the parallel circuit has been selected. Therefore the cooling system must not be rated for the sum of all heat outputs because in reality heat must only be dissipated in one of the parallel branches.

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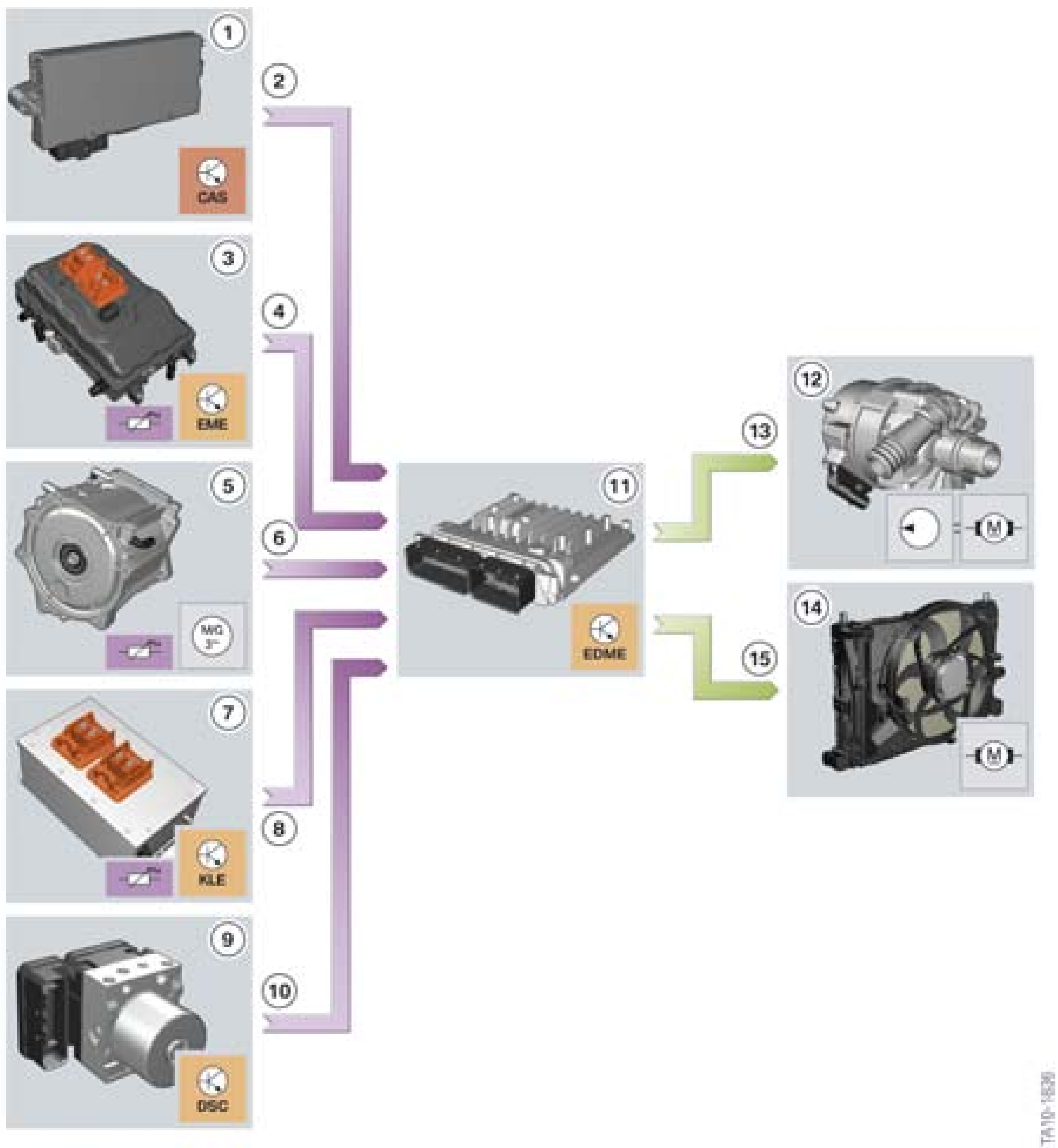
2. Electric Powertrain

Functions

As with current BMW combustion engines, the powertrain control in the E82E is also dependent on the cooling power requirement. This control is integrated in the Electrical Digital Motor Electronics (EDME).



Input/Output for control of the cooling system of the electric motor

Index	Explanation
1	Car Access System
2	Signal for terminal status
3	Temperature sensor in the electrical machine electronics
4	Signal temperature of power electronics in the electrical machine electronics
5	Temperature sensor in the electrical machine
6	Signal temperature of the electrical machine
7	Comfort charge electronics
8	Signal temperature of power electronics in the comfort charge electronics
9	Dynamic Stability Control (DSC)
10	Vehicle speed
11	Electrical Digital Motor Electronics
12	Electric coolant pump
13	Performance requirement of electric coolant pump
14	Electric cooling fan
15	Performance requirement of electric cooling fan

The following input signals are used for the control:

- Component temperature of electrical machine
- Component temperature of electrical machine electronics
- Component temperature of charge electronics
- Current power in the electric motor or in the charge electronics
- Vehicle speed.

In comparison to conventional vehicles cooling systems the **coolant temperature is not used** as an input variable for the control. Therefore there is no coolant temperature sensor in the cooling system for the electric motor of the E82E. Instead the electric coolant pump and the electric fan are dependent on the listed input variables and thus controlled subject to the current cooling requirement. The maximum coolant temperature is set to 80° C/176 °F (measured at outlet of the electrical machine). Although, this is much lower when compared to the cooling system temperature level for BMW combustion engines all the precautions for working on a cooling system must be observed.

⚠

Note: Please observe all precautionary measures before working on the cooling system of the E82E and always follow the proper repair instructions.

The activation of the coolant pump and electric fan is possible in the following vehicle conditions:

- Terminal 15 switched on, readiness to travel present
- Terminal 15 switched on, readiness to travel not present
- High voltage battery is charged.

The power electronics of the electrical machine electronics is already functioning when terminal 15 is switched on. Both the high voltage electrical system (electric A/C compressor and electric heating unit) and also the 12 V vehicle electrical system are supplied with energy by the DC/DC converter. If a cooling requirement is detected due to the resulting heat, coolant pumps and if necessary also the electric fan are switched on.

⚠

When terminal 15 is switched on coolant pumps and the electric fan may automatically be switched on. When working with the hood open or on the cooling module it is imperative terminal 15 is switched off.

While the high voltage battery is being charged, the power electronics in the charge electronics are active. The temperature increases considerably due to the large amount of electric power, which passes through the charge electronics. This must be dissipated using the cooling circuit. Therefore, the electric coolant pump and the electric fan are also switched on during charging to cool the charge electronics.

⚠

The coolant pump and the electric fan can be automatically activated when Terminal 15 is at "Power on" status as well as while the high-voltage battery is being charged.

The following preliminary operations must be completed prior to conducting service work on the electric fan in order to prevent possible injuries caused by a fan that suddenly starts automatically:

1. Disconnect the charge cable (if one is connected)
2. Deactivate power at Terminal 15
3. De-energizing the high-voltage system
4. Detach the plug from the electric fan.

⚠

While the high voltage battery is being charged, the coolant pump and electric fan are automatically switched on. When working with the hood open or on the cooling module the high voltage battery must not be charged.

The electric coolant pump for the powertrain cooling circuit and the electric fan are controlled by the Electrical Digital Motor Electronics. The coolant pump receives its control signal via a local interconnect network bus connection from the EDME. The coolant pump can be switched on an off or its speed can also be controlled. In the case of a fault with the local interconnect network bus, the EDME can switch on the coolant pump at full power via a hard wire connection. The electric fan can be switched on via a control signal from the EDME at different power stages. The EDME also controls a relay with which the voltage supply of the electric fan can be switched on and off separately.

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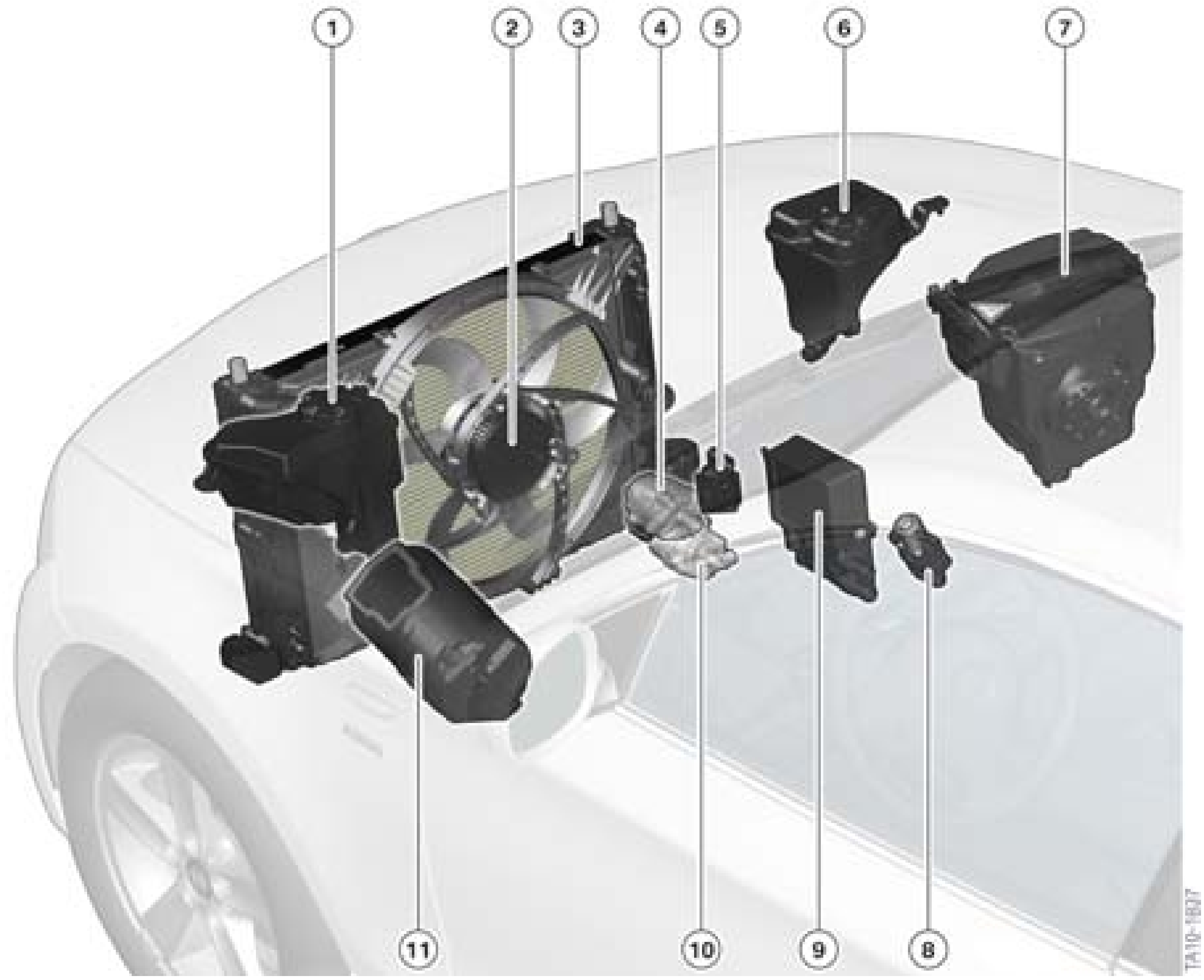
System components

The cooling module is located at the front of the vehicle and includes the A/C condenser, the radiator and the electric fan. The cooling module of the E82E is the same as that of a conventional E82 with an N52 engine (128i) and manual transmission.

The electric coolant pump is a well-known component in BMW vehicles. It is used for example in vehicles with a N63 engine in the low temperature cooling circuit for the charge air cooling (Manufacturer: Pierburg, part number 7 566 335, maximum electrical power 50 W). The coolant pump is controlled by the EDME control unit. For this, the coolant pump and the EDME control unit are connected via the local interconnect network bus and a hard wire connection. The voltage for the coolant pump is supplied via terminal 30g from the power distribution box in the junction box. The installation location of the coolant pump is located in the space under the hood. Another pump for the cooling circuit of the high voltage battery is also located here. The following graphic shows the components which are mounted under the hood.



Cooling system components located under the hood

Index	Explanation
1	Expansion tank in the cooling circuit of the high voltage battery
2	Electric fan
3	Cooling module with condenser and radiator
4	Electric coolant pump in the cooling circuit of the electric motor
5	Electric coolant pump in the heater circuit
6	Coolant expansion tank for cooling the electric motor
7	Electronics box
8	Changeover valve in the cooling circuit of the high voltage battery
9	Electric heating unit
10	Electric coolant pump in the cooling circuit of the high voltage battery
11	Electric coolant compressor

The expansion tank is also located in the space below the hood to the right of the direction of travel. It is similar to the expansion tank of a conventional E82 with the N52 engine. Also installed is an electric level sensor generating signals for processing in the Electronics Junction Box. The signal is sent to the Electric Digital Motor Electronics via a Bus message.

⚠

In the event of loss of coolant the temperature of the cooled components (electrical machine, electrical machine electronics, charge electronics) rises above the normal operating range. In this case, the power of the electric motor is reduced and a corresponding Check Control message is displayed.

The Service technician must check the following fault possibilities when troubleshooting:

- Loss of coolant (e.g. due to a leak in the system)
- Plugged radiator, causing a flow restriction
- Electric fan does not function or is restricted
- Coolant pump is not working
- Coolant lines or connections are damaged
- Components to be cooled are defective (electrical machine, electrical machine electronics, charge electronics).

⚠

If a high temperature is detected in the electric motor cooling system, there may be several reasons for this, including a loss of coolant. Therefore all components of the cooling system must be checked systematically during troubleshooting.

The mixture of water and antifreeze known for BMW vehicles is used as a coolant.

⚠

When filling the cooling circuit of the electric motor the special vacuum filling tool the must be used in accordance with the proper repair instructions.

After filling the cooling circuit the system must always be bled, especially after replacing any cooling circuit components.

When bleeding the electric motor cooling circuit in the E82E follow the same procedure as for the conventional E82. There is a Service function in the ISTA ActiveE diagnosis system for activating a bleeding procedure which includes the proper activation of the electric coolant pump (variable speed, specific duration). This bleeding procedure can also be activated without the ISTA ActiveE diagnosis system.

The following steps must be taken:

1 Activate the power at Terminal 15, but without activating the vehicle for actual highway operation
2 Press the accelerator pedal and brake pedal at the same time for roughly 10 seconds.

⚠

Before the high voltage battery is charged or the E82E is driven, the electric motor cooling system must be filled with coolant and bled. Otherwise, damage may occur to the charge electronics, the electrical machine or the electrical machine electronics.

2.2. Transmission

2.2.1. Introduction

The transmission of the E82E must perform the following tasks:

- Transmission of speed and torque from the electrical machine to the output shafts
- Speed equalization between the two output shafts
- Securing of the vehicle against rolling away.

The transmission contains the following components:

- Transmission gearing with two pairs of spur gears
- Differential integrated into the transmission housing
- Electromechanical parking lock.

As the electrical machine has a large motor speed range, the transmission of the E82E must provide a fixed gear ratio. In contrast to a combustion engine the electrical machine of the E82E is capable of delivering high torque from a standstill. Therefore, there is no clutch needed (for driving off nor for changing gears) in the drivetrain of the E82E.

The transmission in the E82E is operated via a selector lever with an electronic gear selector switch. Its external appearance is identical to the one used in vehicles with double clutch transmission (DCT). The selector lever offers the possibility of selecting the typical drive positions "P", "N", "R", "D" with the exception of the Sport program ("S") and Manual mode ("M") (because the E82E transmission only has one gear).

The following table shows how the individual drive positions are realized.

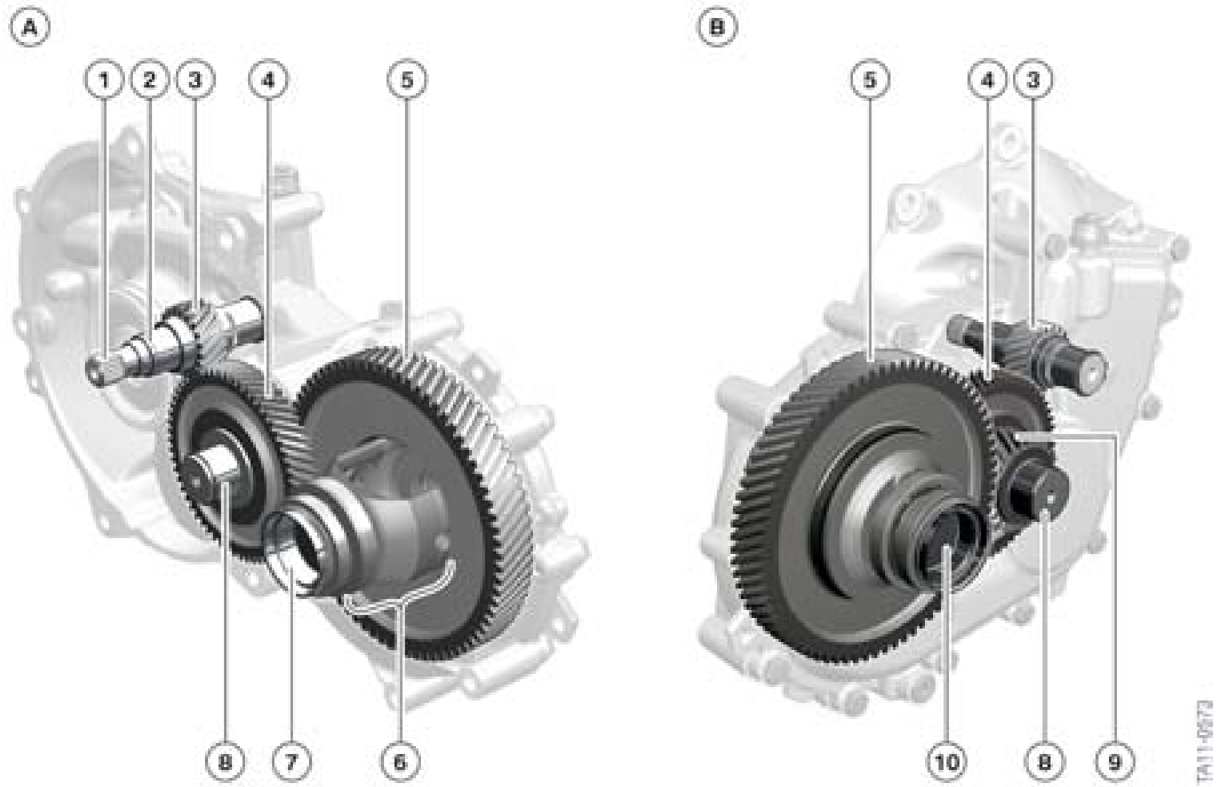
Drive position	Status of the parking lock	Activation of the electrical machine
P - Parking	Engaged	**De-energized**
N - Neutral	Released	**De-energized**
R - Reverse	Released	Motor/generator with reversed rotation direction
D - Drive	Released	Motor/generator with direction of rotation for forwards travel

Two control units are responsible for applying and releasing the parking lock. The EDME control unit contains the logic (the preconditions) for when the parking lock should be applied or released. The EDME control unit transfers the corresponding commands to the electrical machine electronics via the PT-CAN. The EME control unit controls the parking lock actuator directly. It also calculates the logic and controls the function of the "R" and "D" drive positions. The electrical machine electronics is responsible, for example, for controlling the electrical machine in reverse or forwards travel accordingly. Finally the transmission of the E82E also offers the shift lever interlock and interlock functions, whose logic is once again calculated in the EDME control unit.

2.2.2. Transmission overview

The transmission of the E82E has been developed by the BMW Group and is manufactured in the Dingolfing BMW plant.

The transmission has an overall ratio of 9.8:1. The speed on the transmission input is thus 9.8 times larger than the transmission output. This ratio is realized by two pairs of spur gears. In addition to the input shaft, there is also an intermediate shaft. The spur gear at the transmission output is fixed to the differential carrier and drives the differential. The differential distributes the torque to two outputs and makes possible the speed equalization between the two outputs. The design of the differential is identical to a front axle differential as used in BMW vehicles with four-wheel drive (VAG 156).

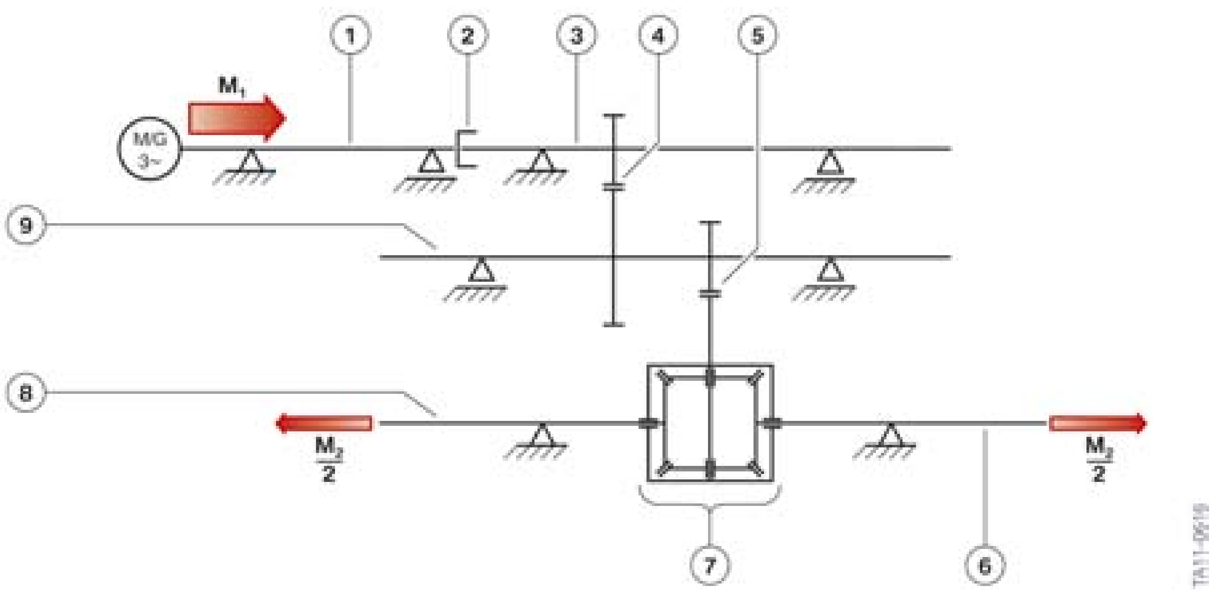


Structure of the transmission

Index	Explanation
A	General view of front left*
B	General view of front right*
1	Toothed shaft as connection to the drive shaft of the electrical machine
2	Transmission input shaft
3	Spur gear 1 on input shaft
4	Spur gear 2 on intermediate shaft
5	Spur gear 4 on transmission output
6	Differential
7	Connection for output shaft on right
8	Intermediate shaft
9	Spur gear 3 on intermediate shaft
10	Connection for output shaft on left

* To understand the graphic above it is important to know that the transmission output in the vehicle is located further to the front than the transmission input. The viewing direction of the components is from the front.

The following power flow diagram is a simplified representation and shows the transfer of torque within the transmission.



Power flow diagram of the E82E transmission

Index	Explanation
M_1	Torque of the electrical machine = Transmission input torque
M_2	Transmission output torque
$M_2/2$	Drive torque of an output shaft
1	Drive shaft of the electrical machine
2	Positive connection between electrical machine and transmission
3	Transmission input shaft
4	Pair between spur gear 1 and 2
5	Pair between spur gear 3 and 4
6	Output shaft, right
7	Differential
8	Output shaft, left
9	Intermediate shaft

The transmission is filled with conventional (Castrol BOT-448) gear oil , the same type as used in most current BMW vehicles. The transmission housing serves as an oil sump and contains a total capacity of 0.5 liters of oil. The spur gears and the differential run in the transmission oil and thus ensure lubrication of the entire transmission (oil sump lubrication). The transmission oil is designed as “long term” so that replacement of the transmission oil is not required during its service life. Despite this there is an oil drain plug, as well as an oil filler plug, with which the oil level can be checked. These are shown in a graphic in the "Mechanical interfaces" chapter of this training material.

The transmission is not integrated in the cooling system of the electric machine and therefore does not have any coolant line connections. The heat generated in the transmission during operation is marginal. Sufficient heat is dissipated via the air flowing through the transmission housing and the connection to the electrical machine. The temperature inside the transmission may reach a maximum of 120 °C /248 °F, well within the range for which the components and the transmission oil are designed. The transmission can also assume significantly lower temperatures, e.g. upon driving after a long sitting period and the components are at ambient temperature. Excess pressure or a vacuum may rise in a completely sealed housing as a result of the large temperature changes. In order to avoid this there is a ventilation opening at the top of the transmission housing. It has a cap to protect it against dirt and impurities. The ventilation opening is also shown in a graphic in the "Mechanical interfaces" chapter.

2.2.3. Mechanical interfaces

Mounting and drive torque supports

The mounting and support of the drive torque relates not only to the transmission itself, but also to the complete drive unit which includes the electrical machine, transmission and electrical machine electronics. The weight and drive torque are transferred via specially developed mounts to the rear axle support and from there to the body. The right side support connects the electrical machine to the rear axle support and has already been shown in the section "Electrical machine".

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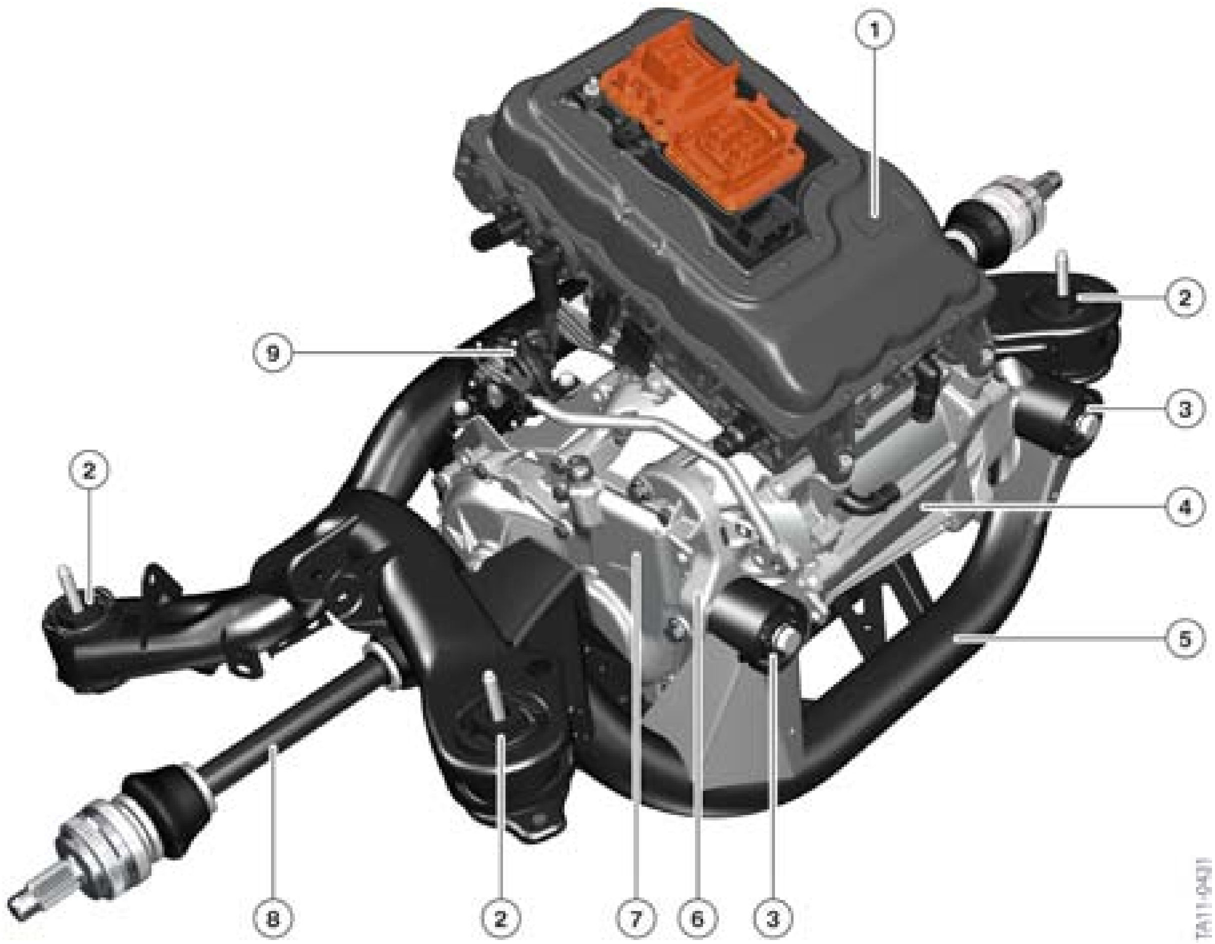
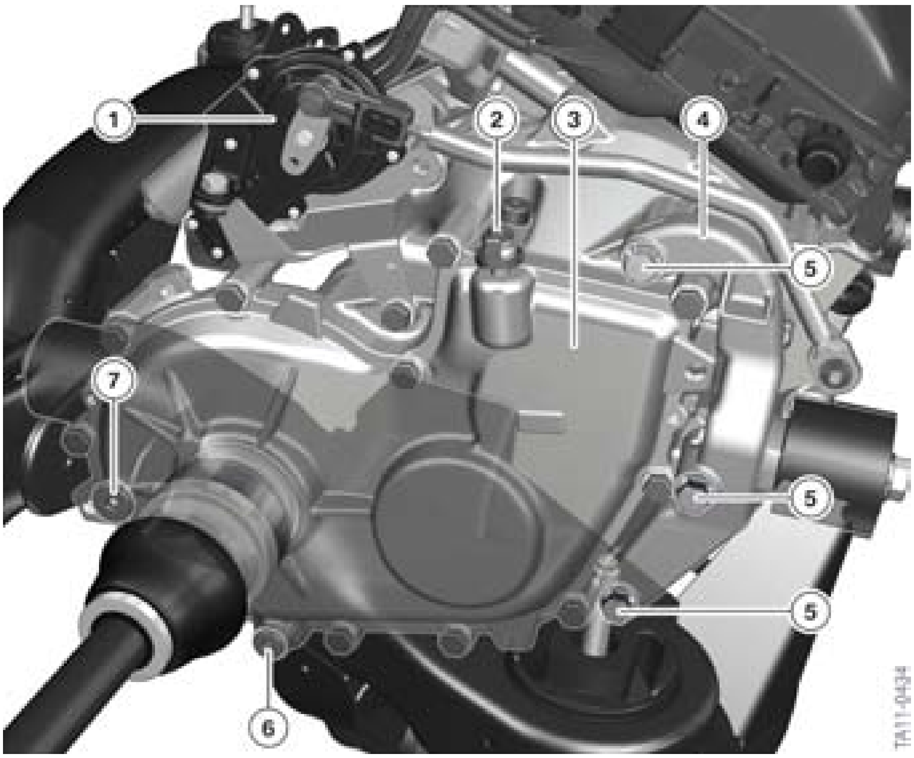
The following graphics show the transmission housing and the rear axle supports.



Mounts of the drive unit, top left rear view

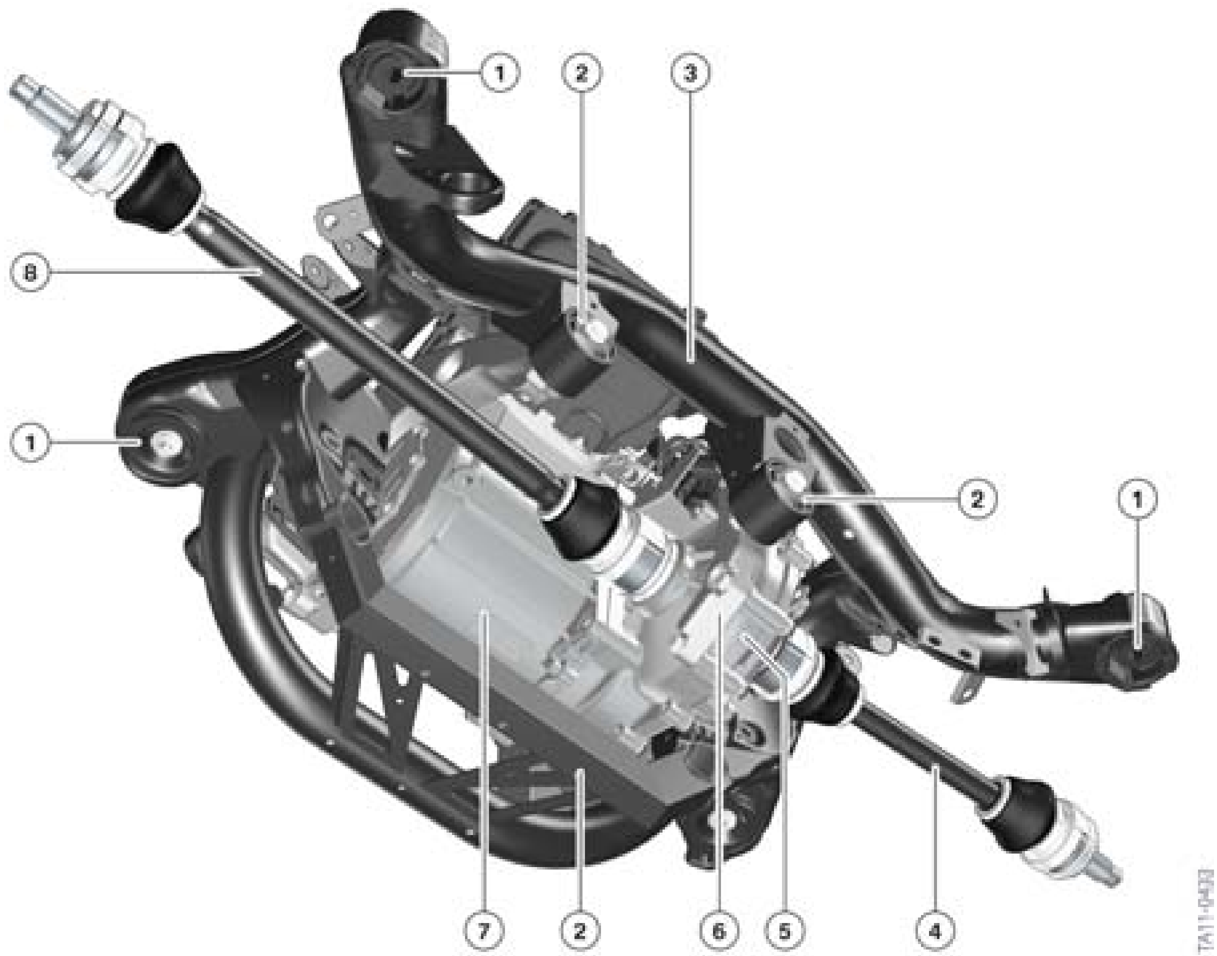
Index	Explanation
1	Electrical machine electronics
2	Rubber mount for connection of the rear axle support to the body
3	Rubber mount for connection of the drive unit and rear axle support
4	Housing of electrical machine
5	Rear axle support
6	New support for connection of the transmission and rear axle support
7	Output shaft, left
8	Transmission housing
9	Parking lock actuator

The following graphic shows the support again in detail, as well as the oil drain plug and the oil filler plug



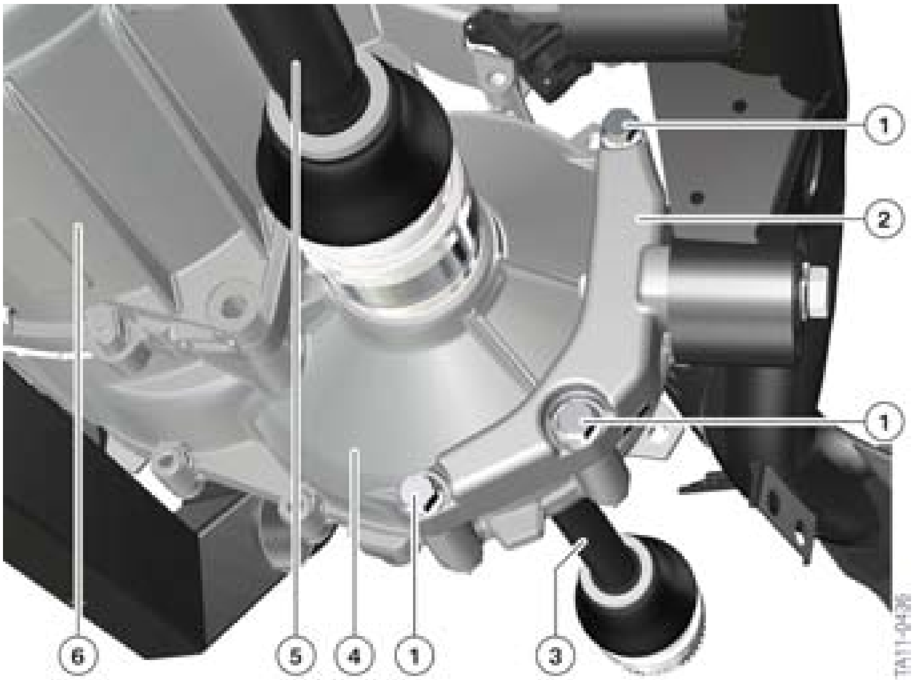
Index	Explanation
1	Parking lock actuator
2	Ventilation opening
3	Transmission housing
4	Transmission and rear axle support
5	Mounting bolts for support and transmission housing
6	Oil drain plug
7	Fluid filler plug

The following graphics show the transmission supports from below and likewise transfers the force to the rear axle support.



Drive unit mounting, viewed from the bottom front

Index	Explanation
1	Rubber mount for connection of the rear axle support to the body
2	Rubber mount for connection of the drive unit and rear axle support
3	Rear axle support
4	Output shaft, left
5	Transmission housing
6	New support for support of transmission below at rear axle support
7	Housing of electrical machine
8	Output shaft, right



Transmission mount viewed from below

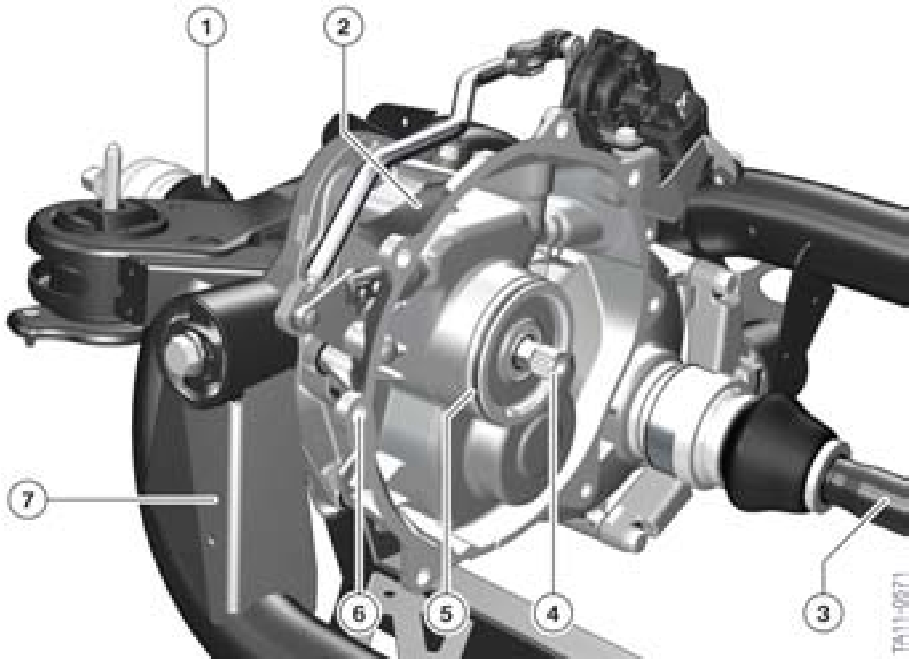
Index	Explanation
1	Mounting bolts for support and transmission housing
2	New support for support of transmission below at rear axle support
3	Output shaft, left
4	Transmission housing
5	Output shaft, right
6	Housing of electrical machine

Interface for electrical machine

The torque is transferred via a positive connection from the drive shaft of the electrical machine to the transmission input shaft. The two shafts both have gearing for this purpose. However, there is no intended centring for the two shafts.

⚠

The repair instructions procedure must always be followed when joining the transmission and the electrical machine. During assembly, axial alignment of the transmission input shaft and motor drive shaft is crucial. In addition, the two E machine gearings must be greased before joining.



Mechanical interfaces of the transmission

Index	Explanation
1	Output shaft, left
2	Transmission housing
3	Output shaft, right
4	Transmission input shaft with gearing
5	Sealing ring
6	Bore holes for mechanical connection to the electrical machine
7	Rear axle support

In the event of diving through a flooded area, water and dirt may penetrate inside the transmission “bell” housing area (shown in the graphic). This is not a problem for the transmission, however, water and dirt must be prevented from entering the electrical machine through this area. For this purpose, the sealing ring (5) in the graphic (which has the shape of an "X" in the cross-section) is used for sealing the E machine from the “bell” housing area of the transmission. It can be ordered separately but only needs to be replaced in response to visible damage.

A ring seal with a width of roughly 10 mm, manufactured in an elastic material, is located on the transmission's input shaft. It seals the electric motor's hub recess, which is filled with grease. The seal ring retains the grease charge applied during assembly within the hub recess to ensure lubrication extending throughout the vehicle's service life. Even when the connection between the transmission's input shaft and the electric motor's driveshaft is loosened there is no need to replace the ring, as it is subjected to virtually no physical stress or forces during operation.

Ring-shaped through-holes arranged on the transmission housing hold the bolts for connecting the housing of the transmission and electrical machine.

Interface for the output shafts

The output shafts are positioned in the outputs of the differential. The torque is transferred by the positive connection (gearing) between the output shafts and the differential. A radial shaft seal, as used in conventional BMW vehicles, seals the oil chamber of the transmission.

Sound deadening material

The graphics in this document show the electric motor-generator and the transmission without the sound deadening covering. In the standard production vehicles these components will be enclosed with a covering consisting of multiple individually molded felt parts. This serves for the acoustic insulation of the electric drivetrain and absorbs noises which may otherwise disturb the passengers.

Service Technicians must remove this sound deadening cover before performing work on the electrical machine and transmission components. For example, the covering must be removed before checking the transmission oil level as well as when the transmission is separated from the electrical machine.

2.2.4. Parking lock

Overview

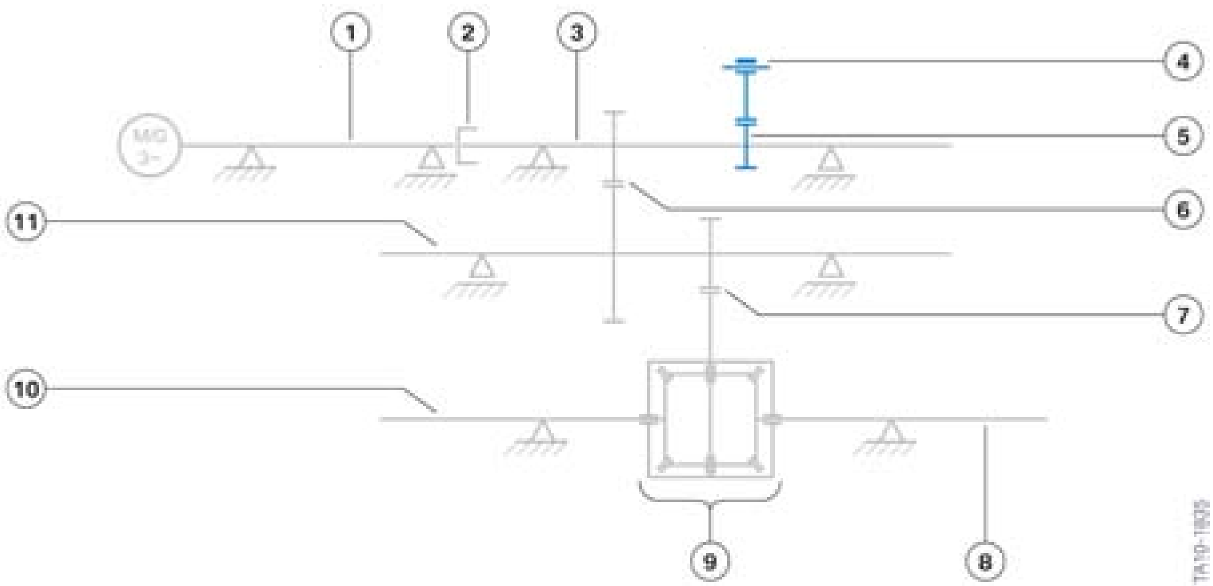
The parking lock secures the vehicle from rolling away, just like in a conventional vehicle with an automatic transmission. Even for large inclines/downhill gradients up to 32% the parking lock must be able to stop the E82E from rolling. However, just like in conventional cars, it is also recommended to secure the vehicle against rolling away by applying the parking brake.

The driver can apply the parking lock in the E82E using the “P” button on the selector lever. It is, however, automatically applied and namely under preconditions known in BMW vehicles with an electronic gear selector switch. For example, the parking lock is automatically applied when the driver's door is opened and the driver's seat belt is released. In contrast to conventional vehicles, there is an additional precondition, whereby releasing the parking lock is not possible in the E82E. This precondition prevents the driver unintentionally taking off as long as a charging cable is connected.

Note: The parking lock of the E82E cannot be released if a connected charging cable is detected.

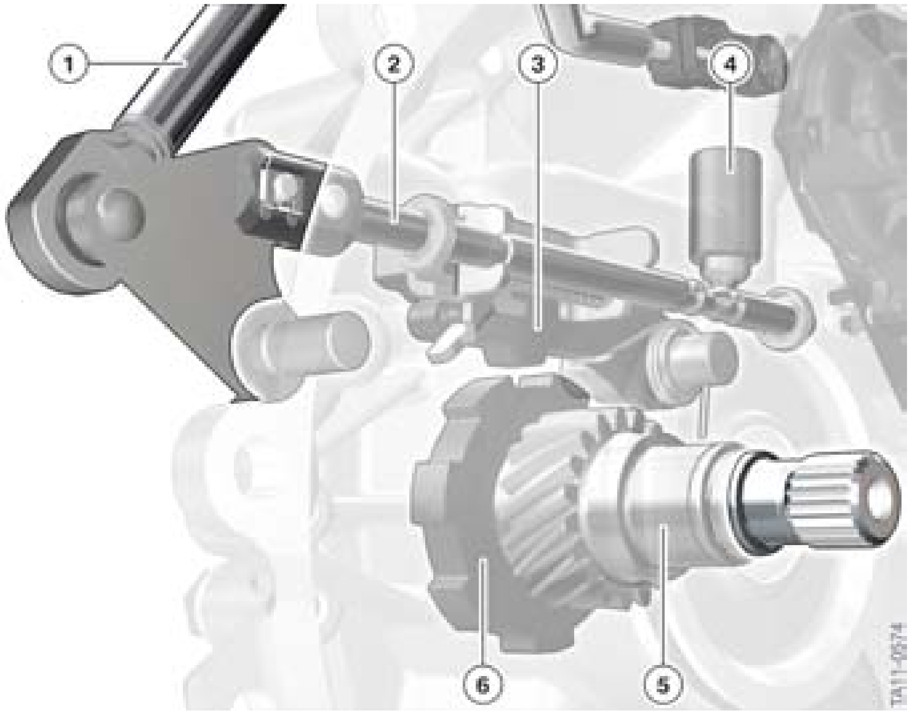
Structure and operating principle

The parking lock is comprised of electromechanical components (connecting rod and actuator for the parking lock) outside the transmission and a mechanical component (parking lock pawl and parking lock gear) inside the transmission housing. The mechanical components act on the transmission input shaft, as shown in the following diagram of the transmission and sectional view.



Position of the parking lock in the transmission diagram

Index	Explanation
1	Drive shaft of the electrical machine
2	Positive connection between electrical machine and transmission
3	Transmission input shaft
4	Parking lock pawl
5	Parking lock gear
6	Pair between spur gear 1 and 2
7	Pair between spur gear 3 and 4
8	Output shaft, right
9	Differential
10	Output shaft, left
11	Intermediate shaft



Structure of the mechanical components of the parking lock

Index	Explanation
1	Curved rod for connecting to the parking lock actuator
2	Straight rod for pressing the parking lock pawl
3	Parking lock pawl
4	Detent (fixing element)
5	Transmission input shaft
6	Parking lock gear

A rod moving in a longitudinal direction lowers or lifts the parking lock pawl together with a spring. It can thus engage in the parking lock gear and lock it or the parking lock pawl is lifted from the parking lock gear and released again. The rod is held in either the "engaged" or "released" position via a detent mechanism. The detent presses a spring-loaded ball into the corresponding grooves which are machined on the rod. Therefore the rod cannot be shifted from these positions by movements or forces from the transmission. Both positions are mechanically stable until voltage is supplied to the actuator.

⚠

The parking lock of the E82E is said to be “bi-stable” as it requires energy from an external source to change the state of the parking lock.

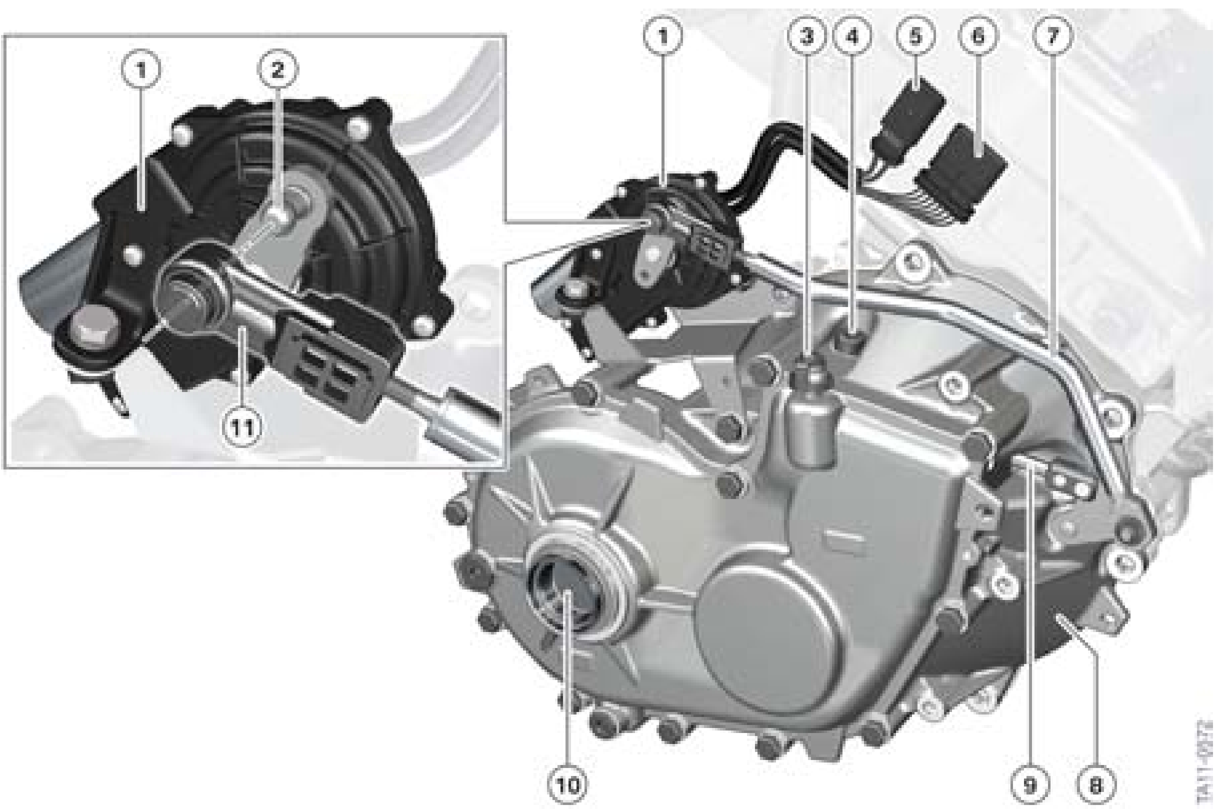
In order to move the mechanical components in the inside of the transmission, there is another curved rod and the electrical actuator for the parking lock mounted on the outside of the transmission. This rod is connected to the actuator using a ball joint connection.

⚠

To override the parking lock (e.g. in the event of a system fault) the ball joint connection between the parking lock actuator and the actuator rod can be removed and manually operated to release or apply the parking lock.

⚠

Note: The vehicle must then be secured against rolling using other measures (e.g. by pressing the parking brake or blocking tires with wheel chocks.)



Electromechanical components for the parking lock

Index	Explanation
1	Parking lock actuator
2	Ball joint
3	Ventilation opening for the transmission housing
4	Detent element for the parking lock mechanism
5	Electrical connection for the electric motor of the parking lock actuator
6	Electrical connection for sensors and solenoid of the parking lock actuator
7	Curved rod for connecting the parking lock actuator and mechanical part of the parking lock

Index	Explanation
8	Transmission housing
9	Straight rod for pressing the parking lock pawl
10	Connection for output shaft, left
11	Removable locking piece between the parking lock actuator and curved rod

In normal operation the actuator turns the lever 90° to engage or release the parking lock. This process is done is less than 1 second so that the parking lock of the E82E reacts quickly, similar to that in conventional automatic transmissions. The rotational movement of the lever at the parking lock actuator is transferred via the curved rod to the mechanical part of the parking lock in the transmission, where the parking lock pawl is then engaged or released.

In the case of the actuator for the parking lock itself it is a DC electric motor with a planetary gear train, a solenoid and two path sensors. All these components are located in a housing to form one unit.

⚠

The parking lock actuator can be replaced in the BMW Dealer Service workshop.

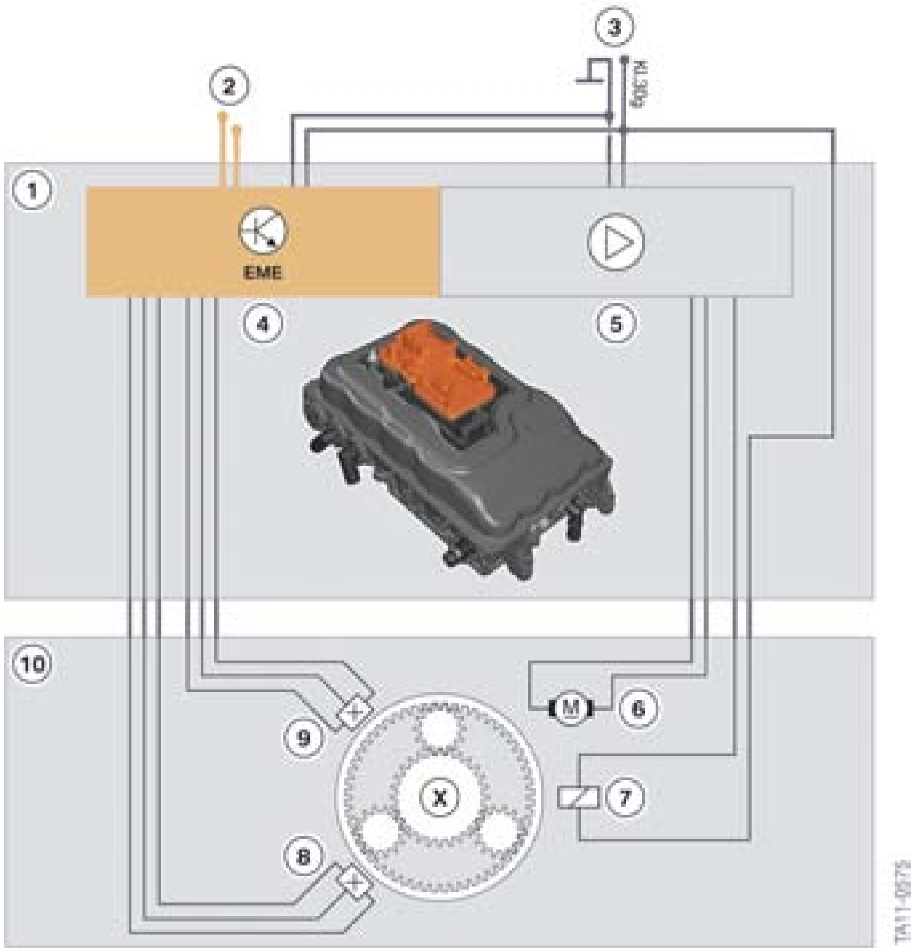
The electric motor in the parking lock actuator is controlled directly by an output stage in the electrical machine electronics. The current of the output stage is limited to protect against damage in the event of a short circuit. To not overload the electric motor the software in the electrical machine electronics monitors the power consumption and performs current limitations if needed.

The electric motor is supplied with current until the path sensors show that the parking locks have reached the desired state. The path sensors work according to the Hall principle and record the movement of the parking lock actuator inside the transmission. Due to safety reasons, two redundant path sensors are used to ensure reliability. If a sensor signal fails due to a fault (a currently active) engaging or releasing process can still be completed. The path sensors generate PWM signals, which are evaluated by the electrical machine electronics.

As the path sensors record the movement of the parking lock actuator and not the movement of the actual parking lock mechanism, an initialization procedure must be carried out to align the sensor signals to the state of the parking lock (see the "Service instructions" chapter for more information).

In normal operation the solenoid in the parking lock actuator is not supplied with power. The transmission in the parking lock actuator has a 1:1 ratio as it implements one turn of the electric motor to one turn of the outside lever. For diagnosis purposes, the parking lock actuator solenoid can be supplied with current and electrically activated without the parking lock mechanism in the transmission being activated. A second reason for applying current supply of the solenoid is if the outer lever on the parking lock sensor is to be manually operated.

The following graphic shows the electrical structure of the parking lock actuator and the electrical connection to the electrical machine electronics.



Electrical interfaces between the parking lock actuator and electrical machine electronics

Index	Explanation
1	Electrical machine electronics (EME) (complete unit)
2	PT-CAN connection
3	Voltage supply
4	EME control unit
5	Output stage for the parking lock actuator
6	Electric motor
7	Solenoid
8	First path Hall sensor
9	Second path Hall sensor (operates in the opposite direction to the first)
10	Parking lock actuator (complete unit)

Service instructions

The EME control unit performs several self-diagnosis functions in order to ensure the proper functioning of the parking lock actuator and to protect the components against damage.

These self-diagnosis functions are:

- **Monitoring the connection to the electric motor** (path sensors and solenoid) for short circuit to ground and supply voltage, as well as for open circuit
- **Monitoring of the current level to the electric motor** with regard to maximum value and the plausibility of the path sensors signals.
- **Monitoring of the signals from the path sensors** (PWM signal in the specified area and plausibility of the two signals to each other).

If one of the self-diagnosis functions detects a fault, an entry in the fault memory is made in the EME control unit, from which the fault cause can be derived. Depending on the severity of the fault detected the parking lock will either continue to work or remain in its current position. In each case, a fault entry is generated and the customer is requested by a Check Control message to have the vehicle inspected by BMW Service.

If the cause for a malfunction cannot be determined using the fault entry, the service technician may perform the following checks and locate the cause:

- Remove the rod at the ball joint from the parking lock actuator and manually activate the rod in order to check the operation of the mechanical components of the parking lock.

- Check the voltage supply of the electric motor and the solenoid at the output of the electrical machine electronics.

- Check the wiring harness section for open/short circuit.

The ISTA ActiveE diagnosis system for the E82E also offers Service Functions that can be applied in the troubleshooting. The most important Service function is the initialization of the parking lock. During initialization the parking lock actuator approaches its end position several times. Here the signals from the path sensors and the current of the electric motor are observed. Due to the force that the detent element exerts on the locking grooves, the force of the electric motor and its current must be adapted. This is monitored by the EME control unit to determine the positions, at which the parking lock is correctly engaged and released. The respective signal values of the path sensors are stored in the EME control unit on a permanent basis and are available from this time for the control of the parking lock operation.

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The initialization of the parking lock is necessary in the following cases:

- the transmission has been replaced,
- the parking lock actuator has been replaced or
- the electrical machine electronics has been replaced.

If the parking lock actuator is to be replaced, please note that the new part is supplied in the "Parking lock released" position.

To install the new parking lock actuator proceed as follows:

1 Secure the vehicle against rolling using the parking brake
2 Manually bring the parking lock mechanism to the "Parking lock released" state. (This can be done by pulling at the rod of the parking lock mechanism which protrudes from the transmission housing).
3 Install the new parking lock actuator
4 Position the curved rod (which should connect the parking lock actuator to the parking lock mechanism) with the removed locking pieces on the rod of the parking lock mechanism and the parking lock actuator
5 Using the removed locking pieces set the correct length of the curved rod and then allow the locking pieces to engage.

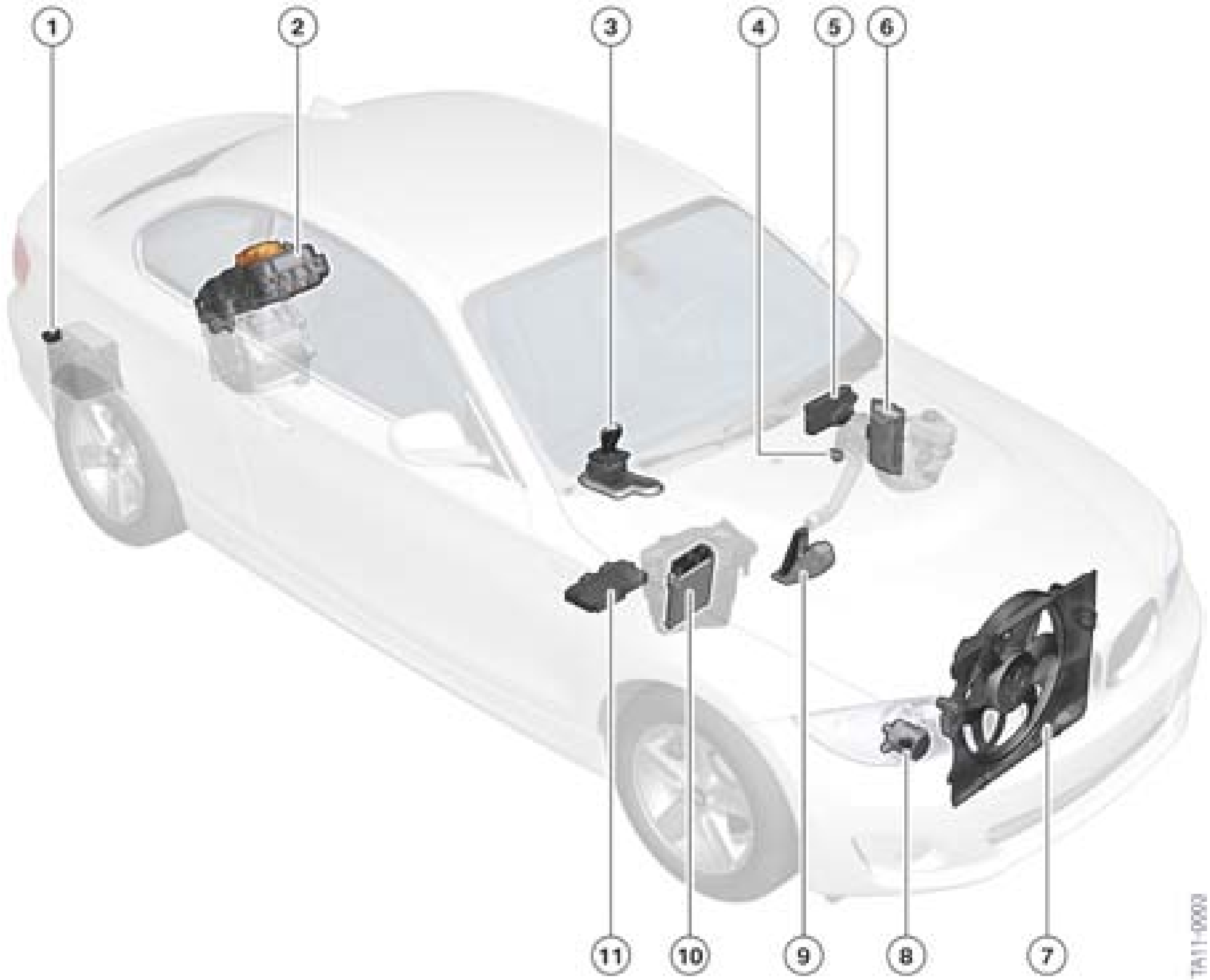
2.3. Drive control

The electric motor of the E82E is a distributed system with a variety of components. The same applies to the electronic part of the drive control as several control units are involved. The master role for the control of the electric motor in the E82E is assumed by the motor control. "Electrical Digital Motor Electronics" (EDME) performs in similar fashion as the DME in vehicles with gasoline engines. As the most important partner control unit of the EDME the electrical machine electronics (EME) assume the activation of the electrical machine and supplies the low-voltage vehicle electrical system with energy. Other partner control units of the EDME are the battery management electronics (SME) and the charge electronics (AC Charge Electronics_ACE).

2.3.1. System overview

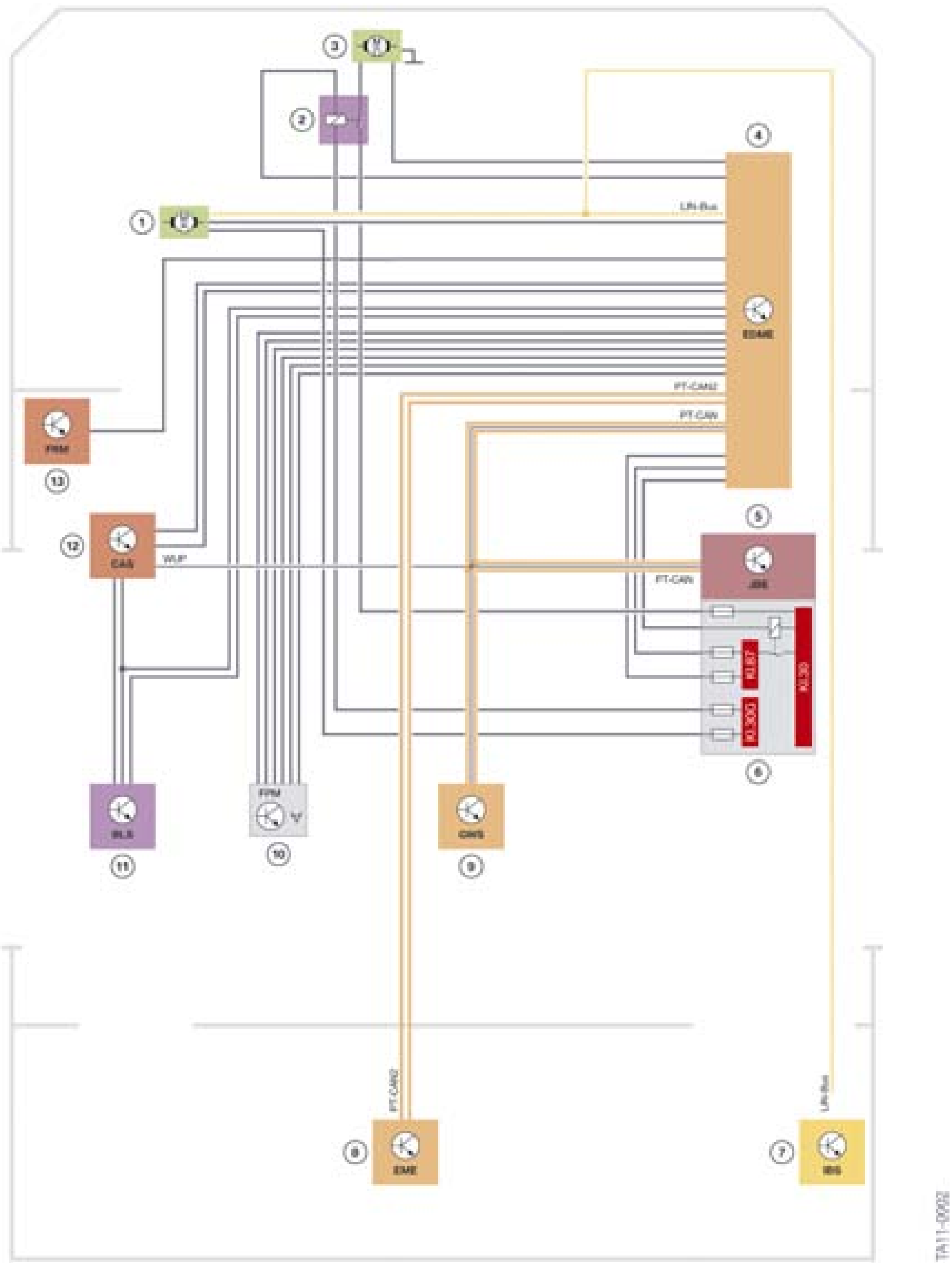
The following graphics show the installation locations and the electrical connection of the most important electrical and electronic components of the drive control.

E82E Complete Vehicle
2. Electric Powertrain



Installation locations of the electrical components of the drive control

Index	Explanation
1	Intelligent battery sensor (IBS)
2	Electrical machine electronics (EME)
3	Electronic gear selector switch (GWS)
4	Brake light switch
5	Car Access System (CAS)
6	Footwell module (FRM)
7	Electric fan
8	Electric coolant pump
9	Accelerator pedal module
10	Electrical Digital Motor Electronics (EDME)
11	Junction box (junction box electronics and power distribution box, front)



System wiring diagram for drive control

Index	Explanation
1	Electric coolant pump
2	Relay for switching on the electric fan
3	Electric fan
4	Electrical Digital Motor Electronics (EDME)
5	Junction box electronics
6	Power distribution box at front in the junction box
7	Intelligent battery sensor (IBS)
8	Electrical machine electronics (EME)
9	Electronic gear selector switch (GWS)
10	Accelerator pedal module
11	Brake light switch
12	Car Access System (CAS)
13	Footwell module (FRM)

The following list describes these interfaces:

- 12 V voltage supply of the EDME control unit (terminal 30, terminal 87 and terminal 31)
- Accelerator pedal module with two Hall-effect sensors: Supply voltage, ground and sensor output signals with output voltage range of 0 – 2.5 V and 0 – 5.0 V
- Brake light switch and brake light test switch: inverted, redundant signals (active/not active), supply via terminal R
- Local interconnect network bus: Reading of the signals from the intelligent battery sensor (IBS) and control of the electric coolant pump (cooling circuit of electrical machine/electrical machine electronics and charge electronics) and
- Control of terminal 87 relay
- Control of electric fan: The power of the electric fan can be controlled via a PWM signal from the EDME. For emergency operation there is a relay with which the electric fan can be switched on at full power by the EDME.
- CAS (start enable)
- Control of charge LED
- Control of relay for 12 V charging sockets
- PT-CAN (no terminating resistor in the EDME)
- PT-CAN2 (terminating resistor in the EDME)

2.3.2. Functions

The drive control includes the following primary functions:

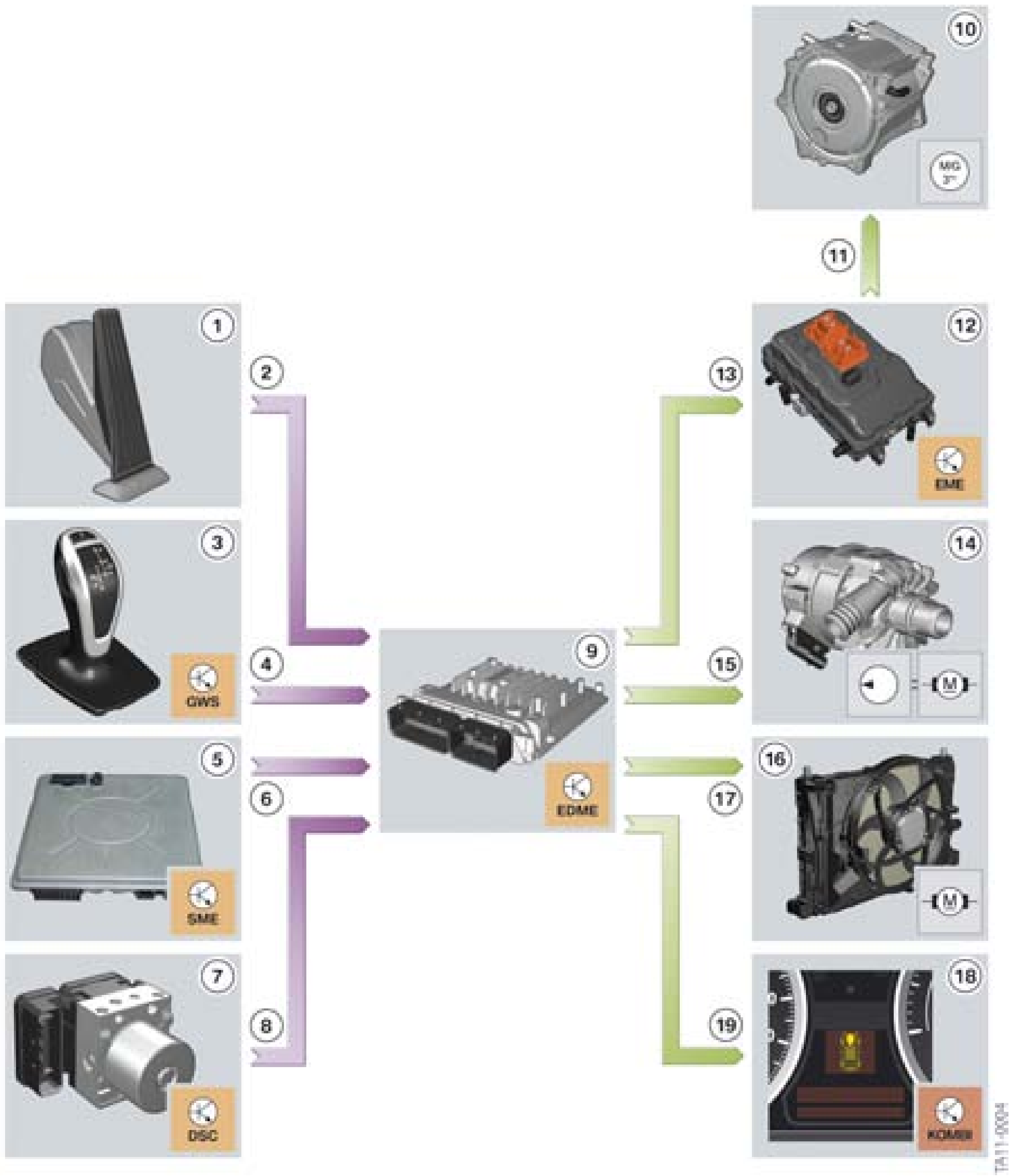
- Evaluation of the driver's demand (accelerator pedal)
- Coordination of torque requests
- Operating strategy including behavior in emergency operation
- Activation of the electrical machine
- Heat management
- Evaluation of the electronic gear selector switch (Shift-by-Wire function).

However, there is still a range of additional functions which are also part of the drive control or are effected by the drive control units.

These additional functions are:

- Power management for the low-voltage vehicle electrical system
- Power management for the high voltage vehicle electrical system
- Controls the charge indicator lamp
- Activation of the vacuum pump.

Activation of the electrical machine



Inputs/Outputs of the drive control

Index	Explanation
1	Accelerator pedal module
2	Signal from accelerator pedal angle
3	Electronic gear selector switch (GWS)
4	Operating signals from the electronic gear selector switch
5	Battery management electronics (SME)
6	Signals on the state of charge and the available electric power of the high voltage battery
7	Dynamic Stability Control (DSC)
8	Signals on the driving dynamic state, such as driving speed for example
9	Electrical Digital Motor Electronics (EDME)
10	Electrical machine
11	Phase voltages for the windings of the electrical machine
12	Electrical machine electronics (EME)
13	Required drive torque (motor/generator)
14	Electric coolant pump
15	Power requirement of electric coolant pump
16	Electric fan
17	Power requirement of electric fan
18	Instrument panel
19	Display information on the state of the electric motor and of Check Control messages in the event of a fault

This graphic shows that the EDME control unit which acts as master and coordinator for the primary functions of the drive control.

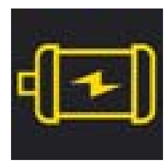
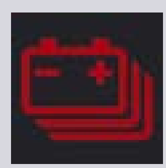
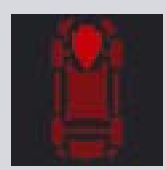
Before drive torque is implemented, the EDME must check whether there is readiness to travel. The preconditions for readiness to travel are described in detail in the "Display and operation" section. In addition, the EDME will ask if all subsystems of the electrical drivetrain are functioning fault-free, which is also a prerequisite for the provision of a drive torque. Finally, the EDME must still take into consideration the available electric power for the motor, which is generally determined by the state of the high voltage battery. The SME control unit communicates this state to the EDME control unit via the corresponding data bus telegrams. As a result of these checks the EDME identifies whether a drive torque can be provided and if yes to what extent. For fault statuses or in the event of limited availability, the EDME outputs a corresponding Check Control message via the instrument panel. The functions described can be summarized under the term "Operating strategy".

An important input signal for the determination of the drive torque is the accelerator pedal angle, which is transferred from the accelerator pedal module to the EDME via a hardwire connection. The EDME uses this signal to determine the torque request of the driver. This and any pending torque requests, such as from the cruise control or the Dynamic Stability Control for example, must be compared and coordinated by the EDME. With this input information the EDME can calculate the drive torque that is actually required of the electrical machine.

In order for the electrical machine to generate the drive torque, the phase voltages must be generated at the windings of the electrical machine. This task is assumed by the electrical machine electronics (EME) and not by the EDME itself. The EDME sends the required drive torque to the EME via the PT CAN2 as bus signals. The EME control unit then calculates the phase voltages and the power electronics of the EME (located in the same housing) generates the phase voltages.

Operating strategy

The aim of the operating strategy is to maximize the service life of the high voltage battery and protect it from damage during operation. At the same time, all customer requirements in driving and during charging should be met. Another element of the operating strategy is also the behavior of the motor in the event of a fault. The states of the operating strategy that are relevant for the customer and the Service technicians are listed and briefly described below.

State	Features	Reason/Precondition	Display
Driving without restrictions	The full power of the electric motor is available for acceleration. Brake energy regeneration is possible to its full extent. All air-conditioning functions are available.	State of charge of the high voltage battery should be in optimal range. Temperature of the high voltage battery should be in optimal range.	Normal functional displays such as state of charge of the high voltage battery for example, drive performance during acceleration or deceleration
Driving with limited drive performance	The drive performance is reduced to protect components. Air-conditioning functions are not fully available due to circumstances.	State of charge of the high voltage battery is very low Temperature of the high voltage battery is extremely low or extremely high (power reduction between about 40 °C/104 °F and 60 °C/140 °F cell temperature)	 
High voltage system deactivated	Electric motor and air-conditioning functions no longer work because the high voltage system can no longer supply any energy.	High voltage system powered down high voltage battery dead or damaged.	  
Charging at full power	The high voltage battery can be charged quickly within four to five hours.	Charging cable and power network deliver sufficient electric power. No electrical energy for other high voltage consumers is required. The high voltage battery can absorb the full charge power (cell temperature in the optimal range).	Charge indicator light flashes at a consistent low frequency (about 0.5 Hz)

State	Features	Reason/Precondition	Display
Charging not possible	It is not possible to recharge the high-voltage battery.	One or several conditions for charging have not been satisfied (such as failure to engage the park lock) or a malfunction that prevents charging is present.	The charge indicator light flashes three times in succession, after which there is an extended pause. Then the sequence is repeated.
Air-conditioning when vehicle is at a standstill	The passenger compartment and/or the high voltage battery are heated or cooled.	Customer activates the function at the vehicle or using the "My BMW Remote App" Vehicle is connected to the AC power supply via a charging cable	In the central information display and in the IHKA display.
Brake energy regeneration not possible	The vehicle does not decelerate/regenerate using the electric motor.	The high voltage battery cannot absorb any electrical energy (because it is full or the cell temperature does not permit it).	

Shift-by-Wire function

Another important function of the drive control is the Shift-by-Wire function. This function evaluates the electronic gear selector switch and other signals in order to simulate the drive positions of a conventional automatic transmission (P, R, N, D).

The change between the drive positions in the E82E is realized much in the same way as in conventional vehicles with an automatic transmission and an electronic gear selector switch.

Some important preconditions and functions are listed below:

- Interlock: Change from P to another drive position only with readiness to travel switched on
- Shift lever interlock: Change from P or N to D or R only while simultaneously pressing the brake pedal
- Change from P or R to N or D only with simultaneously pressing the unlock button on the selector lever
- Automatic engaging of P: P is automatically engaged from the other drive positions if neither the brake pedal nor the accelerator pedal is pressed, the driver's door is open and the driver's seat belt is not in the seat belt buckle. P is also automatically engaged if the readiness to travel is switched off and the remote key is removed from the insertion slot (terminal 0)
- Car wash function: When the readiness to travel is switched on, engage drive position N, switch off readiness to travel and leave the remote key in the insertion slot. N thus remains engaged.

As the transmission of the E82E only has one fixed transmission ratio, there are no gears and thus also no adaptive transmission control unit, no Sport nor Manual programs. The transmission also has no clutch. A reverse gear is also not used in the transmission of the E82E as the electrical machine can simply be operated in reverse direction in that case.

The following table shows how the drive control in the EDME realizes the individual drive positions:

Drive position	Activation of the electrical machine	Actuator for parking lock
D - Drive	Forward direction of rotation, motor or generator operation depends on accelerator pedal activation	Released
R - Reverse	Reverse direction of rotation, motor or generator operation depends on accelerator pedal activation	Released
N - Neutral	Direction of rotation is specified by vehicle movement direction, torque is controlled at 0 Nm	Released
P - Parking	Standstill, torque = 0 Nm	Engaged

The selector lever position N (neutral) is thus not realized by opening a clutch in the transmission. Instead the electrical machine is controlled so that it does not generate torque (motor or generator). One can imagine as if the windings of the stator were open and no voltage is generated. In fact, there is naturally a voltage, generated by the electrical machine electronics although the amplitude, frequency and phase of which are controlled so that the rotor can turn without a load (torque = 0 Nm).

The difference between the drive positions N and P lies solely in the state of the parking lock actuator. While in N it is in released state and in P its engaged.

Power management function

For historical reasons and due to the use of an electric motor, other functions are integrated in the drive control units, especially in the EDME control unit.

For many years the electrical power management of conventional vehicles has been integrated as a function in the engine control. The evaluation of the battery state of charge via the intelligent battery sensor (IBS), the control of the alternator power and the consumer shutdown are examples of this power management function. This tradition has also been continued in the E82E. The EDME control unit performs the power management function both for the low-voltage vehicle electrical system and for the high voltage electrical system.

The power management in the low-voltage vehicle electrical system includes the following sub-functions:

- Determination of the current energy requirement of the electrical consumers (data in the form of bus signals, e.g. ON state, the exterior lights of the footwell module)
- Determination state of the health, state of charge and charge current/discharge current of the 12 V battery (signals from IBS)
- Control of the power of the DC/DC converter
- Monitoring of the standby current
- Shutdown of terminals or consumers in order to protect the 12 V battery against too strong a discharge.

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In the E82E the DC/DC converter in the electrical machine electronics assumes the job of the conventional 12 V alternator. For this reason the power management in the EDME requests the corresponding power from the electrical machine electronics depending on the power requirement via data bus signals.

The power management for the high voltage electrical system includes two sub-functions: One for driving and one for charging mode. **When driving** the energy flows from the high voltage battery to the high voltage consumers.

For this the following calculation steps are performed by the EDME and constantly repeated:

1 Request status report on power available from the high-voltage battery (Signal provided by SME)

2 Request status report on power requested by the electric motor (signal source: EDME)

3 Query of the power requested for climate control (electric heating unit, electric A/C compressor, IHKA)

4 Decision on the distribution of the electric power and communication to the control units of the consumers

In charging mode the high voltage power management assumes a different task. It controls the energy flow from outside the vehicle via the high voltage charge electronics to the high voltage battery and if required to the electric heating unit or to the electric A/C compressor.

The constantly repeated process in the EDME includes the following individual steps:

1 Request status of available power from external source (signal source: comfort charge electronics_KLE)

2 Query of the power the high-voltage battery can absorb (SME)

3 Query of the power required for climate control (IHKA)

4 Request for required power from the comfort charge electronics (KLE)

5 Communication of the available part powers to the receivers high voltage battery (SME control unit) and climate control system (IHKA control unit)

The power available from outside cannot reach any level, but is restricted by the power network and the high voltage charge electronics. For this reason, the available power must be queried first before it is distributed. The high voltage battery cannot (depending on its state of charge) absorb a great deal of power for example which is why this value must also be queried initially. Depending on the temperature of the high voltage battery or a climate control request by the driver, the climate control system also requires electric power, whose size is the third most important input signal for the high voltage power management in charging mode. Using this information the power requested from outside is controlled and distributed to the consumers.

In charging mode the EDME also controls the flashing LED on the inside mirror. The LED used in conventional vehicles for displaying alarm systems also displays information on the charging mode in the E82E. A differentiation is made between the following signals:

- LED OFF: Charging procedure not active or completed
- LED flashes slowly: Charging procedure active
- LED flashes quickly: Charging procedure not possible.

Activation of the vacuum pump

Current vehicles with a combustion engine are equipped with a mechanical vacuum pump. Vacuum is used to activate components of a combustion engine like, for example, the wastegate valve. The brake booster enhances the brake pedal force of the driver with help of the vacuum. The E82E brakes require just as much vacuum booster assistance as a conventional E82, therefore, an electric vacuum pump is used for this purpose. For the activation of the vacuum pump the current value of the prevailing vacuum is required as an input signal. For this there is a separate brake vacuum sensor in the brake booster, which is hard wired directly to the electrical machine electronics.

The electric vacuum pump is activated once the vacuum falls below a specific threshold. The electric vacuum pump is switched off again once the required vacuum level has been reached. Its power and speed cannot be controlled as it can only be switched on and off.

The power and speed of the pump cannot be controlled. It can only be switched on and off. The vacuum pump is also hard wired directly to the electrical machine electronics. The closed-loop control is integrated within the EDME control unit.

2.3.3. Electrical Digital Motor Electronics (EDME)

The designation "Electrical Digital Motor Electronics (EDME)" reflects the electric motor in the E82E (compared to the conventional drive with combustion engine). The manufacturer of the EDME control unit is "Delphi Electronics Group". The manufacturer's internal designation is "DCM 3.8" – this Delphi motor control unit is used by other vehicle manufacturers and has been adapted for the E82E with regard to the electrical interfaces.

The EDME control unit is mounted in the E box under the hood. The installation location is shown in the following graphic:

Installation location of the Electrical Digital Motor Electronics

Index	Explanation
1	E box
2	Electrical Digital Motor Electronics (EDME)

Active cooling of the EDME is not necessary as there is a significantly lower temperature under the hood of the E82E as a result of the omission of a combustion engine. In addition, the EDME control unit contains considerably less output stages in comparison to an engine control for combustion engines and thus less heat loss arises in the control unit.

The electrical interfaces of the EDME control unit are documented in the form of an overview in the system wiring diagram in the "System overview" chapter.

The following list describes these interfaces:

- 12 V voltage supply of the EDME control unit (terminal 30, terminal 87 and terminal 31)
- Accelerator pedal module with two Hall-effect sensors: Supply voltage, ground and sensor output signals with output voltage range of 0 – 2.5 V and 0 – 5.0 V
- Brake light switch and brake light test switch: inverted, redundant signals (active/not active), supply via terminal R
- Local interconnect network bus (LIN-bus): Reading of the signals from the intelligent battery sensor (IBS) and control of the electric coolant pump (cooling circuit of electrical machine/electrical machine electronics and charge electronics) and
- Control of terminal 87 relay
- Control of electric fan: The power of the electric fan can be controlled via a PWM signal from the EDME. For emergency operation there is a relay with which the electric fan can be switched on at full power by the EDME.
- CAS (start enable)
- Control of charge LED
- Control of relay for 12 V charging sockets
- PT-CAN (no terminating resistor in the EDME)
- PT-CAN2 (terminating resistor in the EDME)

The functions of the drive control have already been described in detail in the "Functions" chapter.

The following list summarizes those functions again which the EDME control unit calculates and performs.

- Torque coordination (driver's choice, assist system)
- Operating strategy
- Shift-by-Wire
- High voltage power management
- Low-voltage power management
- Heat management
- Activation of the vacuum pump
- Fault management and emergency operation.

E82E Complete Vehicle

3. High Voltage Battery

3.1. Overview

The high voltage battery of a vehicle with an electric motor is the equivalent of the fuel tank in a conventional engine-driven vehicle. It is the energy storage for the electric motor. The E82E incorporates three high voltage battery units. In order to achieve the desired range of the vehicle a high volume of stored energy is needed, this is why the volume for the energy storage in this vehicle is also large. The distribution of a high voltage battery unit in the front of the vehicle, one in the transmission tunnel and one in the rear has the following advantages:

- The weight of the high voltage battery units is distributed between the two axles, which has a positive influence on the driving dynamic characteristics
- The housing of a high voltage battery unit in the transmission tunnel lowers the vehicle's center of gravity (advantage for driving dynamics)
- The vehicle concept and the body of the E82 only had to be adapted to a limited extent
- The customer still has a functional luggage compartment.

3.1.1. Technical data

Each of the three high voltage battery units incorporate their own control units (battery management electronics), cell monitoring electronics and cell modules which include the actual battery cells. The battery cells are supplied by SB Li Motive (a merger of the companies Samsung and Bosch) to the BMW Dingolfing plant. There the cell modules are assembled from the battery cells and mounted together with the other components to become complete high voltage battery units. The manufacturer of the control units and cell monitoring electronics is Preh.

The battery cells used in the E82E are a type of **lithium-ion battery** and are designated as NMC cells. The anode material in the positive terminal of lithium-ion batteries is generally lithium metal oxide. The designation "NMC cell" refers to the metals used in this cell type (Nickel, Manganese and Cobalt). The characteristics of the high voltage battery for use in an electric vehicle were able to be optimized (with regard to high energy density, large cycle number) through the selection of this anode material. As usual, graphite is used as the material for the cathode (negative terminal), in which the lithium-ion is stored during discharge. The total nominal voltage of a single battery cell is **3.7 V** as a result of the materials used.

The following table summarizes some important technical data of the high voltage battery units in the E82E.

Voltage	355.2 V (nominal voltage) 259.2 V – 393.6 V (voltage range)
Battery cells	Total of 192 (2 cells parallel) 96 cell pairs connected in series
Storable energy	32 kWh (gross) 28 kWh (net, practically used)
Maximum power (discharge)	147 kW (temporary) 40 kW (permanent)

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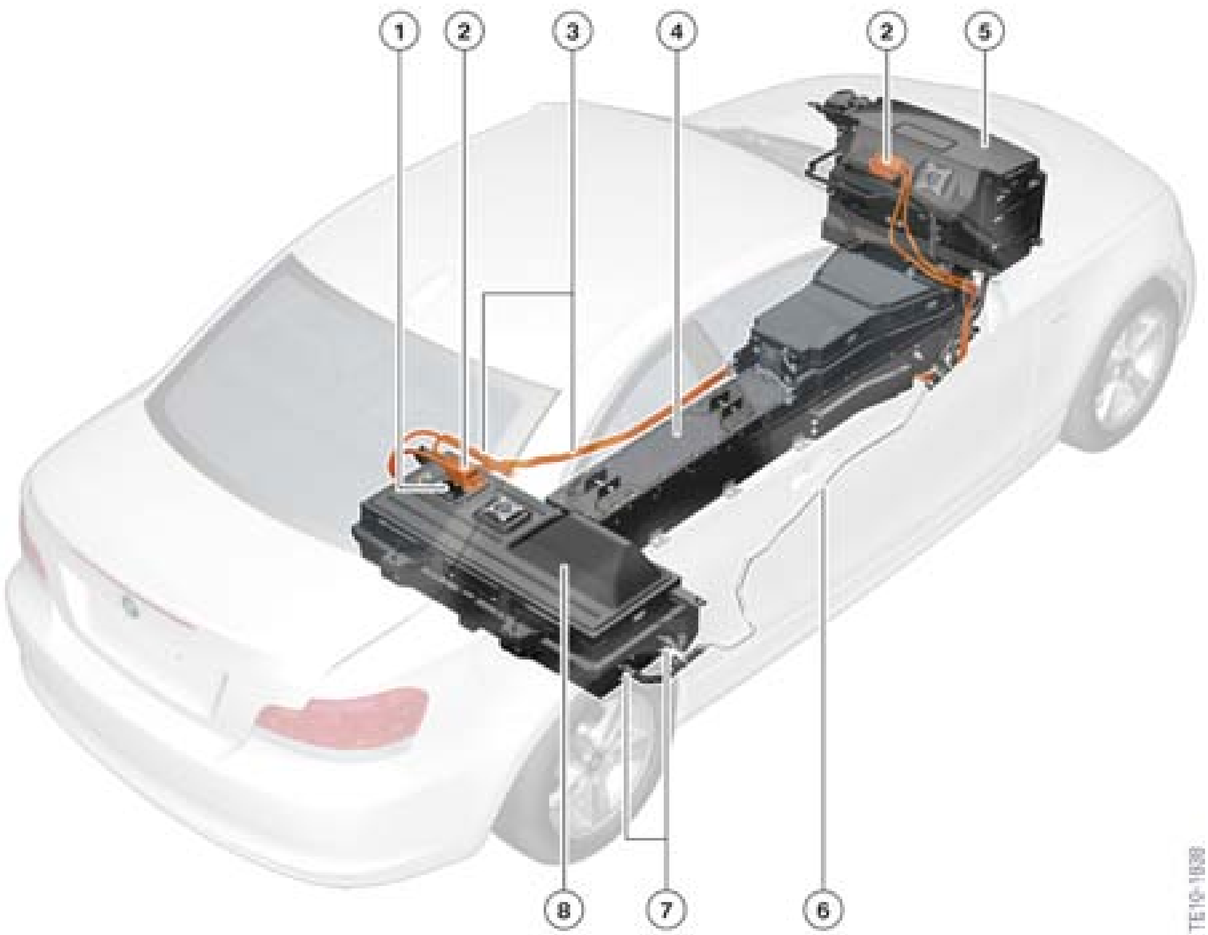
3. High Voltage Battery

Maximum power (charge)	About 19 kW (not fully used in the E82E)
Total weight	480 kg (1,058 lbs) (of which about 110 kg / 243 lbs is the housing)
Cooling system	Separate cooling circuit with interface for the A/C refrigerant circuit

3.1.2. Installation locations and external features



Installation locations of the high voltage battery units

Index	Explanation
1	Low-voltage connection to high voltage battery unit at the rear
2	High voltage connection
3	High voltage cables
4	High voltage battery unit in the transmission tunnel

Index	Explanation
5	High voltage battery unit at the front
6	Coolant lines
7	Connections for coolant lines
8	High voltage battery unit at the rear

The most important external features of the high voltage battery units are:

- High voltage cables and connections
- Low-voltage lines and connections
  Signal connector (bus systems, voltage supply for control units, voltage supply for switch contacts, high voltage interlock loop)
- Coolant lines and connections
- Warning stickers
- Vent holes.

The three high voltage battery units are connected in series, which is also noticeable by the routing of the high voltage line. Each high voltage battery unit has a low-voltage connection in addition to the high voltage connection. The integrated control units are supplied with voltage, data buses, sensor and monitoring signals via these connections. The high voltage battery units are fed with coolant (via dedicated HV battery cooling system) in order to always operate the battery cells in an optimal temperature range. The warning stickers on the high voltage battery units provide the people who work with these components with information on possible electric and chemical risks.

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Note: The removal and installation of the high voltage battery units, is intended only for the BMW Service Hub (National Workshop) and NOT for BMW Dealer Service Centers.

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The electrical voltage of each of the three high voltage battery units is over 60 V.

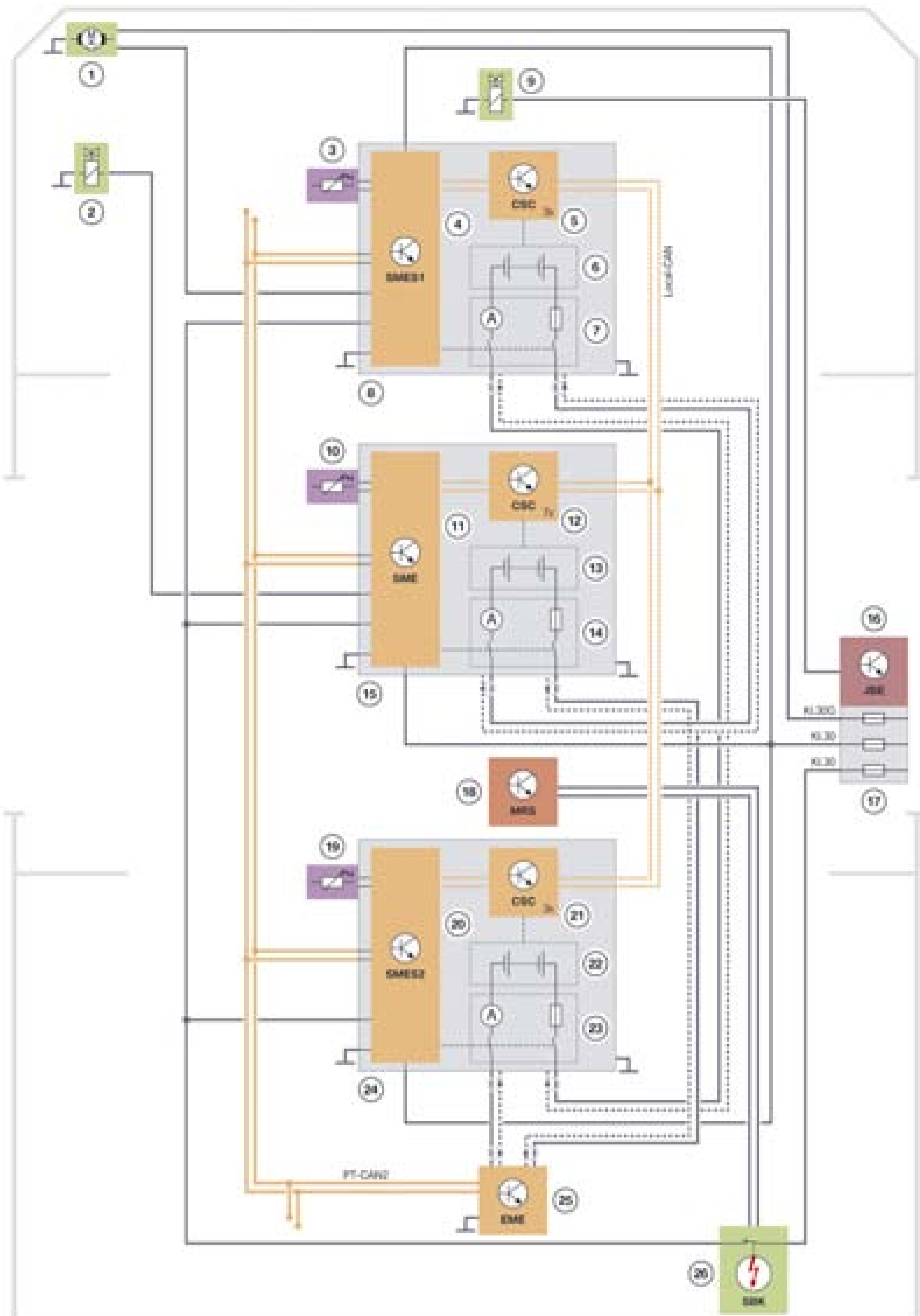
Please observe the **electrical safety rules before** any work is started on any high voltage battery unit:

1 **De-energize** the high voltage system
2 **Secure** against restart/connection
3 **Verify** that the HV power is off.

All three high voltage battery units are located outside the passenger compartment. In contrast to the lithium-ion battery of the F04, there is no vent pipe at the high voltage battery units of the E82E. If the battery cells generate excess pressure due a massive fault, the resulting gases do not have to be transported out of the vehicle via a venting pipe. A vent opening (at each high voltage battery unit) is sufficient to enable pressure compensation.

In contrast to the F04, the high voltage safety connector is **not** incorporated in one of the high voltage battery units. It is located in the luggage compartment near the 12 V battery.

3.1.3. System wiring diagram

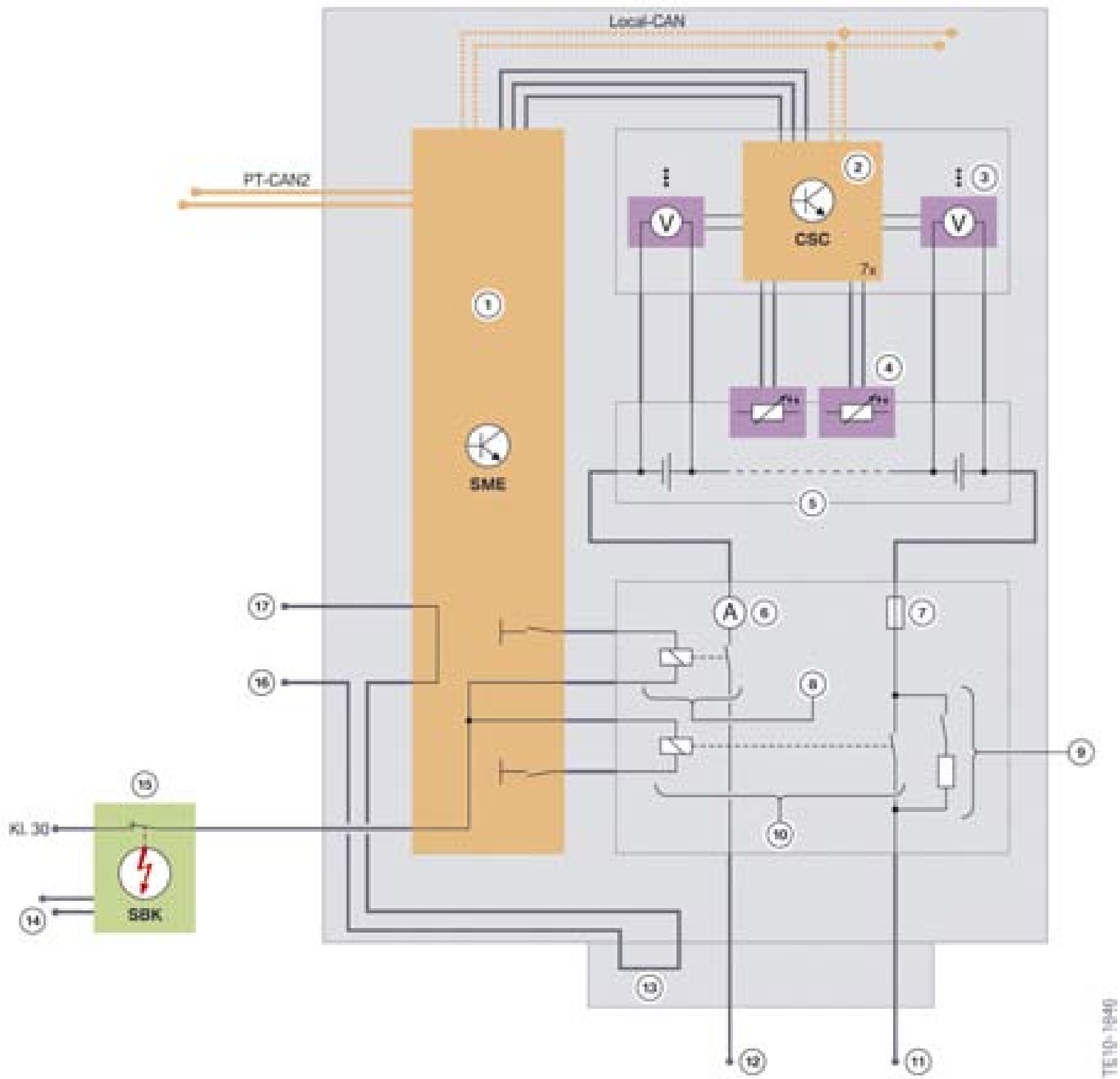


System wiring diagram for high voltage battery units

Index	Explanation
1	Electric coolant pump (cooling circuit of high voltage battery units)
2	Combined expansion and shutoff valve in the refrigerant circuit
3	Coolant temperature sensor (outlet for high voltage battery unit, front)
4	SMES1 control unit in the high voltage battery unit at the front
5	Cell monitoring electronics in the high voltage battery unit at the front (x3)
6	Cell modules in the high voltage battery unit at the front
7	High voltage interface of the high voltage battery unit at the front, outwards
8	High voltage battery unit at the front
9	Changeover valve between cooling circuit and heater circuit of the high voltage battery units
10	Coolant temperature sensor (inlet of high voltage battery unit in the transmission tunnel)
11	SME control unit in the high voltage battery unit in the transmission tunnel
12	Cell monitoring electronics in the high voltage battery unit in the transmission tunnel (x7)
13	Cell modules in the high voltage battery unit in the transmission tunnel
14	High voltage interface of the high voltage battery unit in the transmission tunnel, outwards
15	High voltage battery unit in the transmission tunnel
16	Junction box electronics (JBE)
17	Fuse carrier at the front (in junction box)
18	Multiple restraint system control unit (MRS)
19	Coolant temperature sensor (outlet for high voltage battery unit, rear)
20	SMES2 control unit in the high voltage battery unit at the rear
21	Cell monitoring electronics in the high voltage battery unit at the rear (x3)
22	Cell modules in the high voltage battery unit at the rear
23	High voltage interface of the high voltage battery unit at the rear, outwards
24	High voltage battery unit at the rear
25	Electrical machine electronics
26	Safety battery terminal

3.2. General structure

The following wiring diagram is representative of the inner electrical structure of the high voltage battery unit in the transmission tunnel.



Wiring diagram: Inner structure of the high voltage battery unit in transmission tunnel

Index	Explanation
1	Battery management electronics
2	Cell monitoring electronics (with 7 Cell Supervisory Circuits)
3	Sensors for measuring the cell voltage
4	Sensors for measuring the cell temperature
5	Actual high voltage battery comprising several cell modules
6	Sensor for measuring the current level in the minus line of the high voltage battery unit
7	Over current fuse in the plus line of the high voltage battery unit

Index	Explanation
8	Electromechanical switch contactor in the minus line of the high voltage battery unit
9	Pre-charge circuit
10	Electromechanical switch contactor in the plus line of the high voltage battery unit
11	Plus line of the high voltage battery unit
12	Minus line of the high voltage battery unit
13	Bridge in the circuit of the high voltage interlock loop (element of the high voltage connection)
14	Control lines from the multiple restraint system for blasting the safety battery terminal
15	Safety battery terminal
16	Output of the circuit of the high voltage interlock loop
17	Input of the circuit of the high voltage interlock loop

This wiring diagram shows that each of the three high voltage battery units include the following electrical/electronic components, in addition to the actual battery cells (integrated in the cell modules):

- Control unit for battery management electronics (SME)
- Several cell monitoring electronics (Cell Supervisory Circuits)
- Interface box with switch contactors, sensors and overload fuse.

These internal components, as well as the high voltage connection and the high voltage safety connector, are described in the following chapters.

3.2.1. Battery management electronics

High demands are placed on the service life of the high voltage battery as it should last the service life of the vehicle. To satisfy these requirements the high voltage battery is operated in a precise and defined manner so that its performance and service life are maximized.

This includes the following conditions:

- Operating cells in the optimal temperature range (heating/cooling and limiting the current level if required)
- Adjusting the state of charge of the individual cells if required
- Use the storable energy of the battery in a certain area.

To adhere to these conditions, there is a battery management electronics (SME) control unit, in each of the high voltage battery units. These are differentiated by their code designation:

3. High Voltage Battery

High voltage battery unit	Code designation	Function
In the transmission tunnel	SME	Primary (Master)
In the front of the vehicle	SMES1	Secondary
In the rear	SMES2	Secondary

The SME primary control unit must complete the following tasks:

- Control the start and shut-down of the high voltage system upon request by the Electrical Digital Motor Electronics (EDME)
- Control the SMES1 and SMES2 secondary control units
- Evaluation of the measurement signals for voltage and temperature of all battery cells, as well as the current level in the high voltage circuit
- Control of the cooling system for the high voltage battery units
- Determination of the state of charge (SoC) and the state of health (SoH) of the high voltage battery
- Determination of the available power of the high voltage battery and if required request to limit at electrical machine electronics
- Safety functions (e.g. high voltage interlock loop, isolation monitoring)
- Detection of fault statuses, filing fault entries and communication of fault statuses to the Electrical Digital Motor Electronics (EDME).

The EDME assumes the role of master/primary control unit in relation to the control of the high voltage system and the function of the low-voltage power management.

Upon request by the SME primary control unit, the SME secondary control units (SMES1 and SMES2) implement the control of the electromechanical switch contactors in the high voltage battery units in the front and the rear of the vehicle. They also communicate the measured values of the current sensor and the coolant temperature sensor to the SME primary control unit.

All SME control units (primary and 2 secondary) are generally responsive and also programmable via the ISTA ActiveE diagnosis system. For troubleshooting it is important that only the SME primary control unit has one fault memory which can be read using the ISTA ActiveE diagnosis system. If faults occur in the other two high voltage battery units, these are communicated in the form of data bus signals by the SMES1/SMES2 control units to the SME primary control unit and entered in its fault memory. In this case the fault entry refers to the sending SMES1/SMES2 control unit or the respective high voltage battery unit.

The fault entries can be divided into different categories, which are dependent on the severity and the available functionality:

- Immediate shutdown of the high voltage system:
  If the safety of the high voltage system is affected by the fault or there is a risk that the high voltage battery will be damaged as a result of the fault, the high voltage system is shut down immediately and the contacts of the electromechanical switch contactors opened. In this case

the driver can let the vehicle roll and for example park it on side of the road. Steering servo, brake booster assistance and DSC control operation are guaranteed by energy from the 12 V vehicle electrical system.

- Limited power and range:
  If the high voltage battery can no longer supply the full power or the full energy, the power output and the range are limited to protect the components. In this case the driver can continue on for a short distance at significantly reduced driving power and is best off going to the next BMW Dealer Service workshop or parking the vehicle at a safe location of his choice.
- Faults without a direct effect for the customer:
  If, for example, the communication between the SME control units or CSC control units is temporarily interrupted, this means no functional restriction or risk to safety of the high voltage system. Although no Check Control message nor limited functionality is apparent to the customer in this case a fault entry is still generated, which must be analyzed by BMW Dealer Service workshop using the E82E ISTA ActiveE diagnosis system.

The SME control units are not accessible from the outside thus replacement is not possible at the BMW Dealer Service workshop, only at the BMW Service Hub (National Workshop).

The electrical interfaces of the external SME control units are:

Signal	SME (transmission tunnel)	SMES1 (front of vehicle)	SMES2 (rear of vehicle)
12 V supply for SME control unit (terminal 30 from junction box and terminal 31)	x	x	x
12 V supply for switch contactors (terminal 30 from safety battery terminal)	x	x	x
PT-CAN2	x	x	x
Local CAN	x	x	x
Wake-up line from the CAS control unit	x	x	x
Input and output for high voltage interlock loop	x	x	x
Line for activation of the shutoff and expansion valve at the chiller unit	x		
Measuring lines to the respective coolant temperature sensor	x	x	x
Activation line for electric coolant pump		x	

The Local Controller Area Network connects all SME control units and the cell monitoring electronics CSC to each other (please refer to the next chapter for more information).

3.2.2. Cell monitoring

For the fault-free operation of the LMC batteries used in the E82E, certain marginal conditions (as with all lithium-ion batteries) must be observed. The cell voltage and the cell temperature may not fall below or exceed certain values as otherwise the battery cells may suffer permanent damage. For this reason each high voltage battery unit contains several CSC (Cell Supervisory Circuits).

Cell monitoring electronics

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The cell monitoring electronic units are located in the inside of each high voltage battery unit. Therefore, they are not accessible to Service Technicians. Work on the cell monitoring electronics is not permitted in BMW Dealers Service workshop, only in the BMW Service Hub (National workshop).

The cell monitoring electronics perform the following functions:

- Measurement and monitoring of the voltage of each individual battery cell (or cell pair)
- Measurement and monitoring of the temperature at a location on each cell module (the temperature of the battery cell itself can be determined from this)
- Communication of the measured variables to the SME primary control unit
- Perform the process of adjusting the cell voltage of the battery cells.

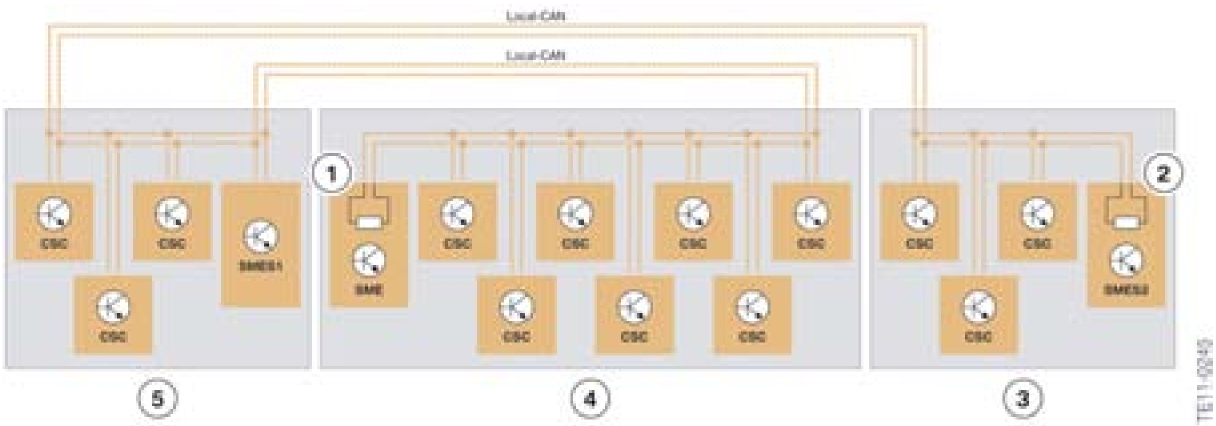
The measurement of the cell voltage is effected at a very high sampling rate (a measurement every 20 ms). With the voltage measurement the end of the charging procedure, as well as the discharging procedure, can be detected. The temperature sensors are arranged in the cell modules in such a way that the temperature of the individual battery cells can be derived from the overall measured temperature. Overloading or an electrical fault can be detected by monitoring the cell temperature. In such a case the current level must be reduced immediately or the high voltage system shut down completely in order to avoid further damage to the battery cells. In addition, the measured temperature is used to control the cooling system in order to constantly operate the battery cells in the temperature range which is optimal for their performance and service life. As the cell temperature represents such an important parameter, the signals of the NTC temperature sensors are processed redundantly.

Local CAN

The cell monitoring electronics communicate the values measured via a Local Controller Area Network. This Local CAN connects all cell monitoring electronics to each other (beyond the limits of the high voltage battery units) and to the SME control units. The measured values are evaluated in the SME primary control unit and a response is triggered if required (e.g. control of the cooling system).

The Local CAN works at a transmission speed of 500 kBit/s and the data bus lines are twisted to limit electromagnetic interference. In addition, there are terminating resistors at its two ends. The terminating resistors required are each 120 to 140 Ω and are installed in the following locations:

- in the SME primary control unit (transmission tunnel) and
- in the SMES2 control unit (rear).



Principle wiring diagram for the Local CAN of the high voltage battery units

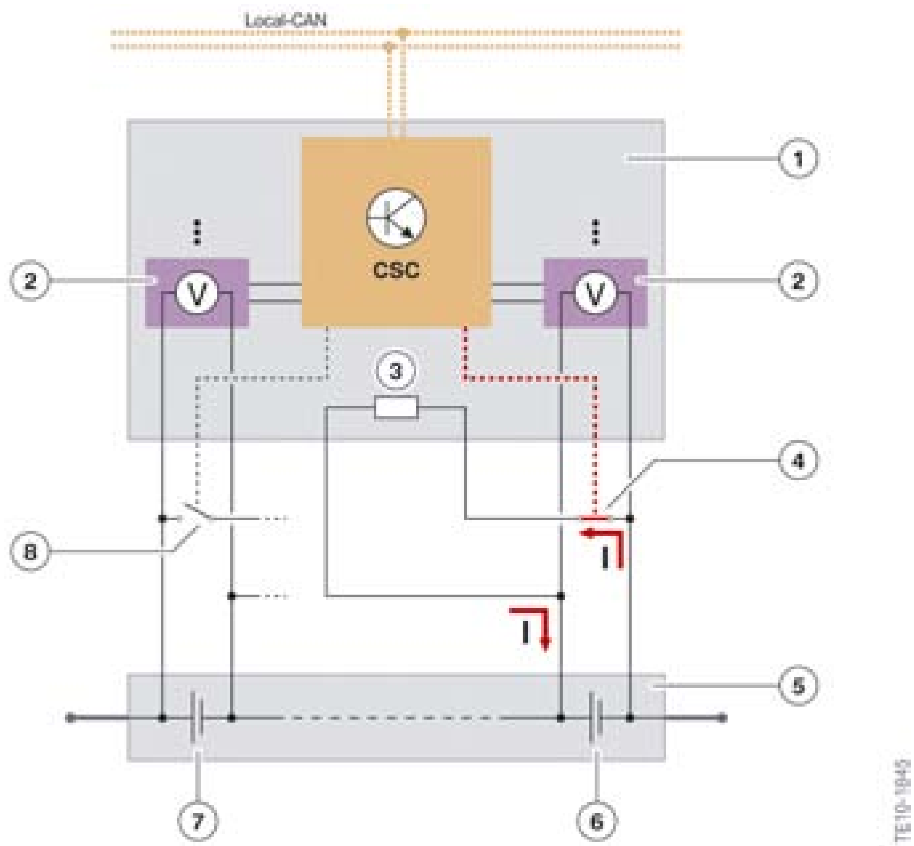
Index	Explanation
1	Terminating resistor in the SME control unit
2	Terminating resistor in the SMES2 control unit
3	High voltage battery unit at the rear
4	High voltage battery unit in the transmission tunnel
5	High voltage battery unit at the front

If one measures the resistance at the Local CAN as part of troubleshooting, then one obtains a value of about 60 Ω if all bus components are connected and the terminating resistors are OK.

Adjustment of the cell voltages

If one or several battery cells has a significantly lower cell voltage than all the other battery cells, the usable energy of the high voltage battery is restricted. The energy output limit during discharging is determined by the "weakest" battery cell. If the voltage of the weakest cell has fallen to the discharge limit, the discharge procedure must be terminated, also if the other battery cells do not have sufficient energy stored. However if the discharging procedure is continued the weakest battery cell may thus suffer permanent damage. For this reason, there is a function to adjust the cell voltage to approximately the same level. This process is called "cell equilibration".

For this the SME primary control unit compares all cell voltages. As the adjustment of the cell voltages can only be done through specific discharging of individual battery cells. The cells with a significantly higher cell voltage (SOC) are selected as opposed to the weaker ones. Upon a request via the Local CAN to the cell monitoring electronics belonging to these battery cells, the discharging procedure is started and performed until the voltage level is adjusted. The discharge current flows via an ohmic resistor, which is integrated in the cell monitoring electronics.



Principal wiring diagram: Adjustment of the cell voltages

Index	Explanation
1	Cell monitoring electronics
2	Sensor for measuring the cell voltage
3	Discharge resistor
4	Closed (active) contact for discharging a battery cell
5	High voltage battery
6	Battery cell whose cell voltage is reduced through discharging
7	Battery cell that is not discharged
8	Open (not active) contact for discharging a battery cell

The adjustment of the cell voltages reduces the voltage in the cell with the highest SOC to the voltage level of the weaker ones within the battery, essentially, slightly degrading the “stronger” cells to equalize the overall state of the battery. Although it creates loses by wasting a small amount of the available energy (at the cells with highest SOC) it is necessary for maximizing the range of the vehicle.

This process can of course only performed when the vehicle is at a standstill and all the preconditions are satisfied.

The following are the preconditions for adjusting the cell voltages:

- Terminal 15 switched off and vehicle or vehicle electrical system at rest
- High voltage system shut-down
- Deviation of the cell voltages or the individual cell SoCs is greater than a threshold value
- Total SoC of the high voltage battery is greater than a threshold value.

The adjustment of the cell voltages is carried out automatically only if all the specified preconditions are satisfied. A Check Control message is not displayed in this case, therefore the customer is not aware the process has taken place.

Should the cell voltages display an excessive level of deviation, or should the cell-voltage synchronization process fail to achieve the desired result, a DTC is generated for storage in the SME primary control unit. The customer is made aware of this fault status by a Check Control message. The fault memory must then be evaluated and repaired using the ISTA ActiveE diagnosis system.

If the cell voltages deviate too much or the adjustment of the cell voltages is not successful, this leads to a fault entry in the SME primary control unit. After consultation with the BMW Service Hub it is decided whether the fault can be eliminated using the Service function in the ISTA ActiveE diagnosis system or if a cell module has to be replaced. The replacement of a cell module can only be performed in the BMW Service Hub.

3.2.3. External interface (S box)

In each high voltage unit there is an interface unit with its own housing which is referred to as the "switch box" or "S box" for short. As it is located in the inside of the high voltage battery unit, it must **not** be replaced in the BMW Dealer Service workshop, but only in the BMW Service Hub.

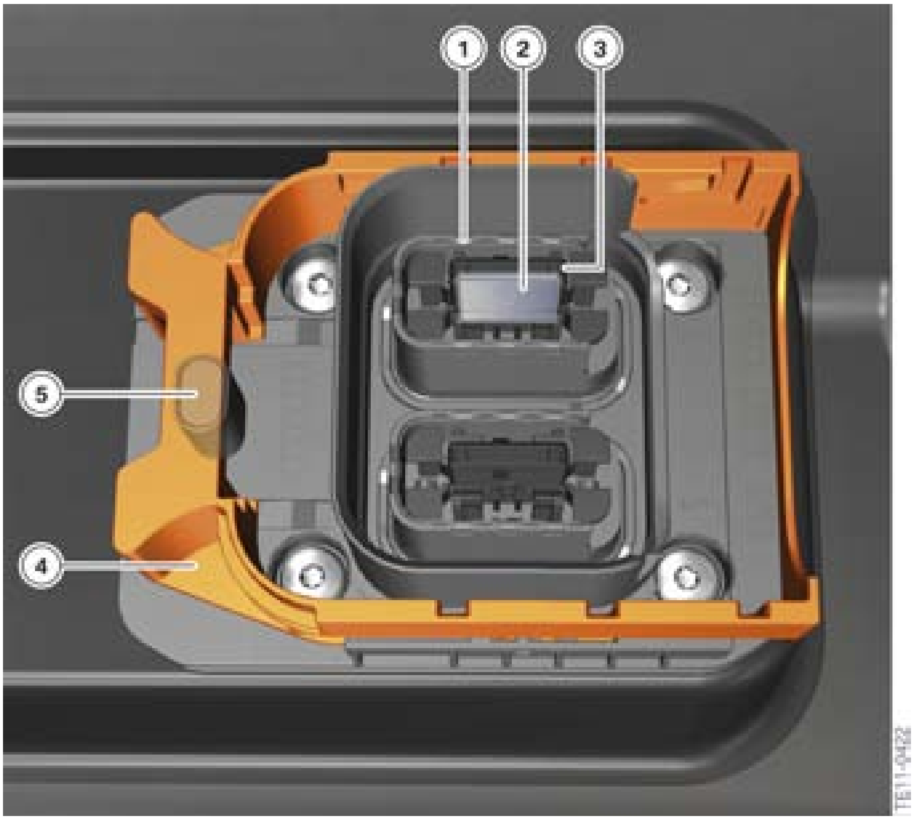
The following components are integrated in the interface unit:

- Current sensor in the current path of the negative battery terminal
- Safety fuse in the current path of the positive battery terminal
- Two electromechanical switch contactors (one switch contactor per current path)
- Pre-charge circuit for slow start-up of the high voltage system (only in the high voltage battery unit in the transmission tunnel)
- Voltage sensors for monitoring the switch contactors and for measuring the overall battery voltage.

These components and their electrical connections are shown in the internal wiring diagram of the high voltage battery units at the start of this chapter.

3.2.4. High voltage connection

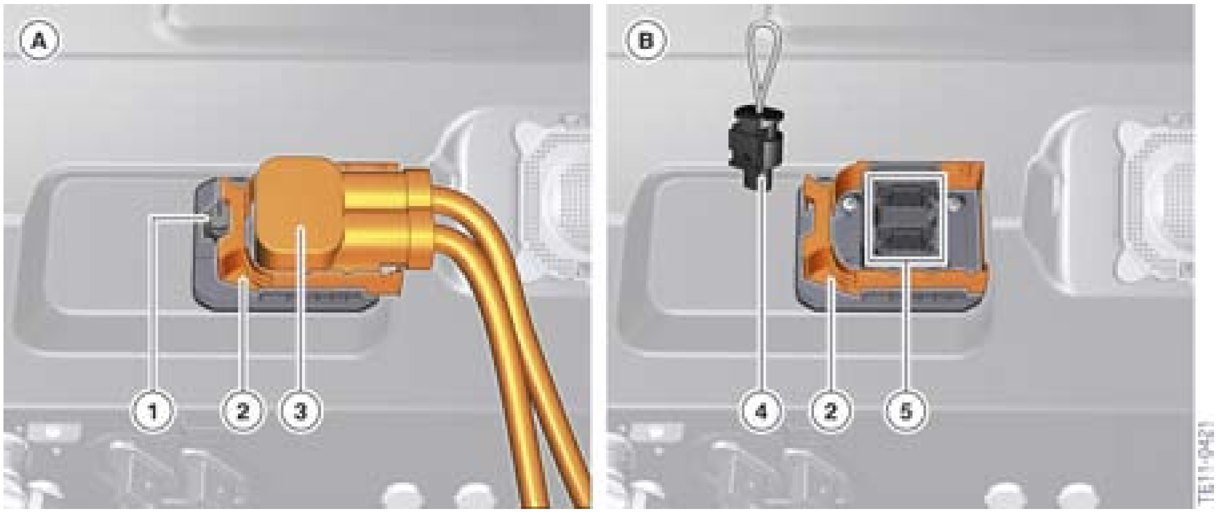
At each high voltage battery unit there is a 2-pin high voltage connection.



high voltage connector at the front high voltage battery unit

Index	Explanation
1	Electrical contact for shielding
2	Electrical contact for high voltage cable
3	Shock protection
4	Mechanical lock
5	Bushing with connection for bridge in the circuit of the high voltage interlock loop

The high voltage connection connects the high voltage cables to the high voltage battery unit. The high voltage connection offers protection against making contact with live parts. The actual contacts are covered with a plastic cover so that a person cannot touch them directly. Only when the line is connected is the cover pushed away and the contact established. The plastic connector has an integrated sliding mechanical latch mechanism. It also performs an additional safety function, when the high voltage cable is not connected the sliding connector blocks the high voltage interlock loop bridge connection. Only when the high voltage cable is properly connected and the connector is locked, is this connection accessible and the interlock loop bridge can be connected. This will ensure that only when a high voltage cable is connected the circuit of the high voltage interlock loop closed. This principle applies to all high voltage connections in the E82E, i.e. those at the three high voltage battery units, at the electrical machine electronics and at the comfort charge electronics. This way the high voltage system can only be active if all high voltage cables are connected. This provides additional protection against contact with live connections.

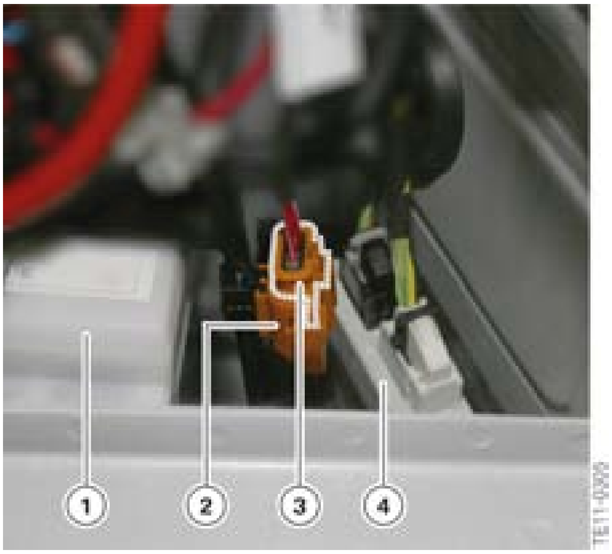


High voltage connection

Index	Explanation
A	High voltage connection with connected high voltage cable
B	High voltage connection with disconnected high voltage cable
1	Bridge for high voltage interlock loop (connected)
2	Mechanical slide
3	High voltage connector of high voltage cable
4	Bridge for high voltage interlock loop (disconnected)
5	High voltage connection at the high voltage battery unit

3.2.5. High voltage safety connector

The high voltage safety connector of the E82E is not directly integrated into high voltage battery unit. Instead it is mounted separately near the 12 V battery and thus is accessible on the right side of the luggage compartment.



Installation location of the high voltage safety connector right side of the luggage compartment

Index	Explanation
1	12 V battery
2	Bushing of the high voltage safety connector
3	Connector with bridge of the high voltage safety connector
4	PDC control unit

As with active hybrid vehicles, the high voltage safety connector has two main functions:

- De-energizing the high voltage system
- Securing against restart.

The bridge of the high voltage safety connector is part of the high voltage interlock loop circuit. If the high voltage safety connector plug is disconnected, the circuit of the high voltage interlock loop is interrupted the high voltage system then automatically shuts down and is de-energized.

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The connector and the plug of the high voltage safety connector cannot be completely disconnected from each other. To interrupt the high voltage interlock loop circuit it is sufficient to pull the two parts apart just enough so that the pad lock can be used to secure against reconnection.

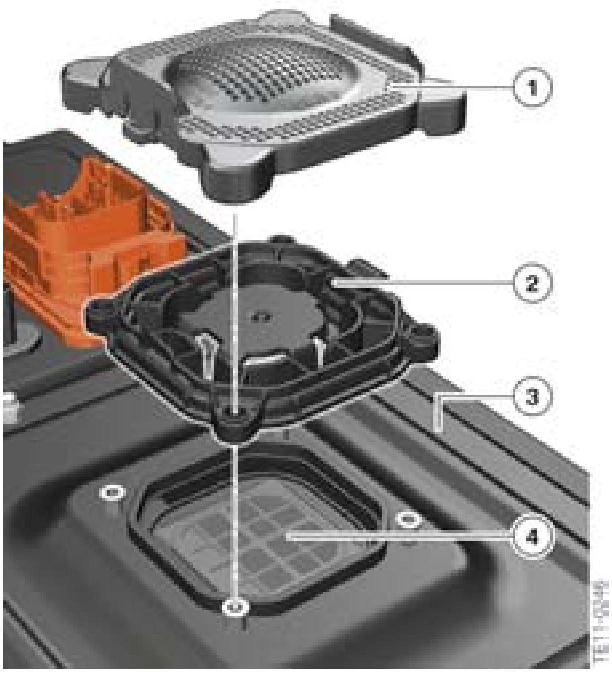
⚠

Note: The exact procedure for de-energizing the high voltage system described in the "Working safely on the high voltage system" chapter of this training material.

3.2.6. Vent opening

The vent opening is used to balance large pressure differences between the inside and the outside of the high voltage battery unit. Such pressure differences can only arise in the event of a damaged battery cell. For safety reasons the housing of the cell module with the damaged battery cell is opened to reduce the pressure. The gases are located initially in the housing of the high voltage battery unit. From there they can escape into the air via the vent opening.

The vent opening contains a diaphragm for this purpose, which is permissible for gases, but not for liquids. Outside the diaphragm there is a two-piece cover, whereby the diaphragm is protected against rough dirt and impurities.



Exploded view of the vent opening

Index	Explanation
1	Dust guard cover
2	Carrier plate
3	Housing of the high voltage battery unit
4	Actual diaphragm for pressure compensation

⚠

A replacement of the vent opening is only necessary if it has fulfilled its purpose once and has reduced the excess pressure arising in the housing. This only occurs in the event of a defective cell module and results in the repair of the respective high voltage battery unit in the BMW Service Hub. As this repair cannot be performed in the BMW Dealer Service workshop, the vent opening must also not be replaced there.

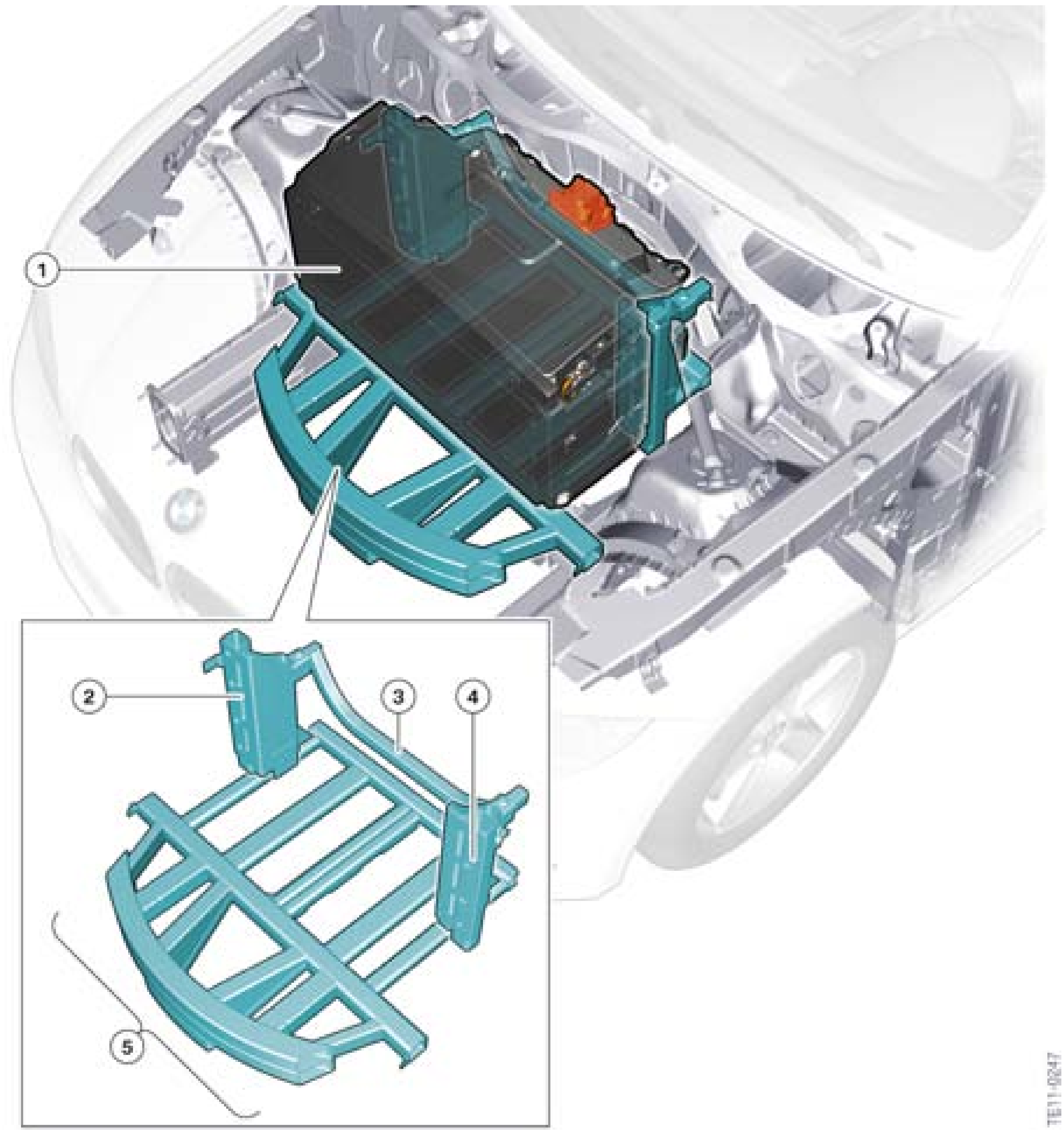
3. High Voltage Battery

The positions of the vent openings on the housing of the high voltage battery units are different. For this reason, the vent opening is shown together with the other external features of each individual high voltage battery unit in the following chapters.

3.3. High voltage battery unit at the front

The high voltage battery unit at the front is located under the hood of the E82E. A structure comprising two vertical steel supports is used to fix the unit and hold the weight. A horizontal structure made from welded steel profiles is arranged underneath this. It is deformed in the event of an accident in the longitudinal direction and thus absorbs the energy from the crash. It therefore protects the high voltage battery unit against damage.

E82E Complete Vehicle
3. High Voltage Battery



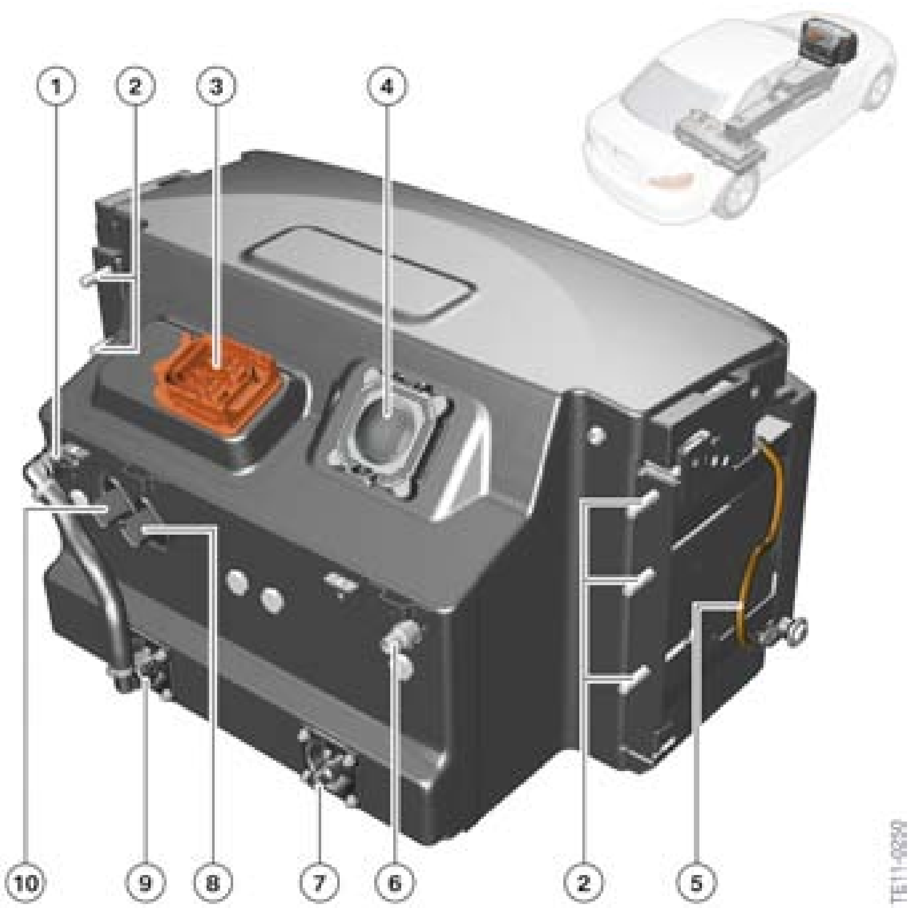
Installation location of the high voltage battery unit at the front

Index	Explanation
1	High voltage battery unit at the front
2	Vertical support, right
3	Cross-member between vertical supports
4	Vertical support, left
5	Structure for holding the longitudinal forces in the event of an accident

E82E Complete Vehicle

3. High Voltage Battery

The following graphic shows the most important external features and connections of the high voltage battery unit at the front.



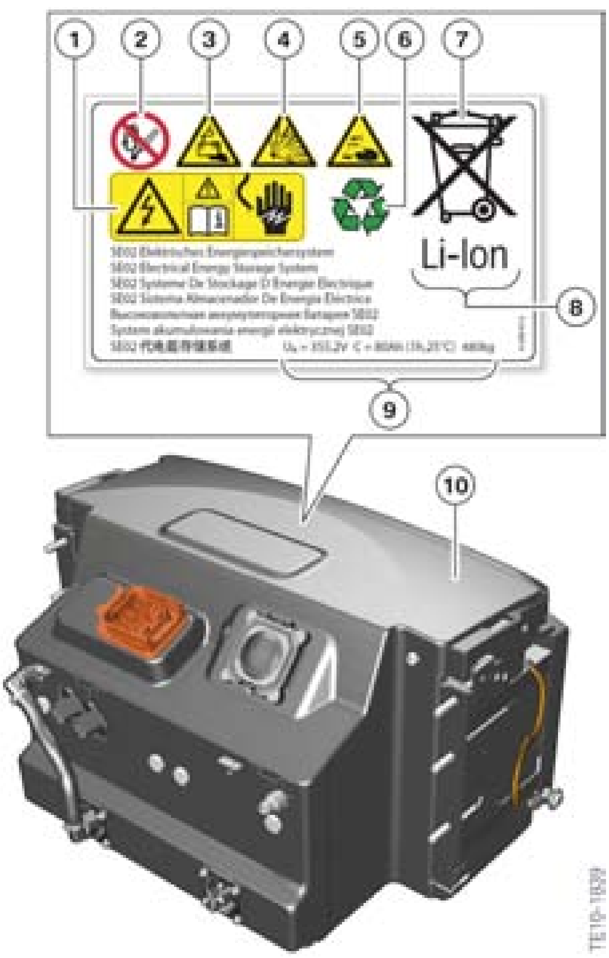
External features of the high voltage battery unit at the front

Index	Explanation
1	Connection for coolant line, top left (supply 2)
2	Bolts for mounting at the vertical supports
3	High voltage connection
4	Vent opening
5	Electrical line for potential compensation
6	Connection for coolant line, top right (return 2)
7	Connection for coolant line, bottom right (supply 1)
8	Low-voltage connection 1
9	Connection for coolant line, bottom left (return 2)
10	Low-voltage connection 2

Using the external features and connections, some further details on the internal structure of the high voltage battery can be seen. The cell modules are arranged on two levels, one on top of another. So that each level is adequately cooled, the coolant passages in the unit are also distributed over two levels, one top and one bottom. The coolant initially flows through the coolant passages in the bottom level, then is conveyed via an external coolant line to the top level and finally flows through the coolant lines there. The coolant line branches from the connection at the return at the top: Part of the line leads to the intake side of the coolant pump, another part is the ventilation line and ends in the coolant expansion tank.

The externally-visible cable for potential compensation connects the two internal connection levels of the cell modules (top and bottom, or housing floor panel and intermediate level).

To be able to use the known standard connector, the low-voltage signals have been divided into to two connections. The cables/signals that connect the SMES1 control unit to the vehicle's electrical system (such as PT-CAN2 bit also voltage supply) are located at low-voltage connection 1. Low-voltage connection 2 contains the cables and signals that provide the interconnections between the electronic CSC Cell Supervisory Circuits. An example would be the local CAN.



Warning sticker on high voltage battery unit at the front

Index	Explanation
1	Safety sign for high voltage components: Warning against high electrical voltage. Follow repair instructions
2	Prohibition sign: Fire, naked light and smoking are prohibited
3	Warning sign: Warning against risks associated with batteries
4	Warning sign: Warning against explosive materials
5	Warning sign: Warning against corrosive substances
6	Information on disposal of the high voltage battery unit: Recycling possible
7	Information on disposal of the high voltage battery unit: Must not be disposed of in household waste.
8	Information on technology used: Lithium-ion battery
9	Nominal voltage, nominal capacity and weight of the high voltage battery (total of all three high voltage battery units)
10	Housing of the high voltage battery unit at the front

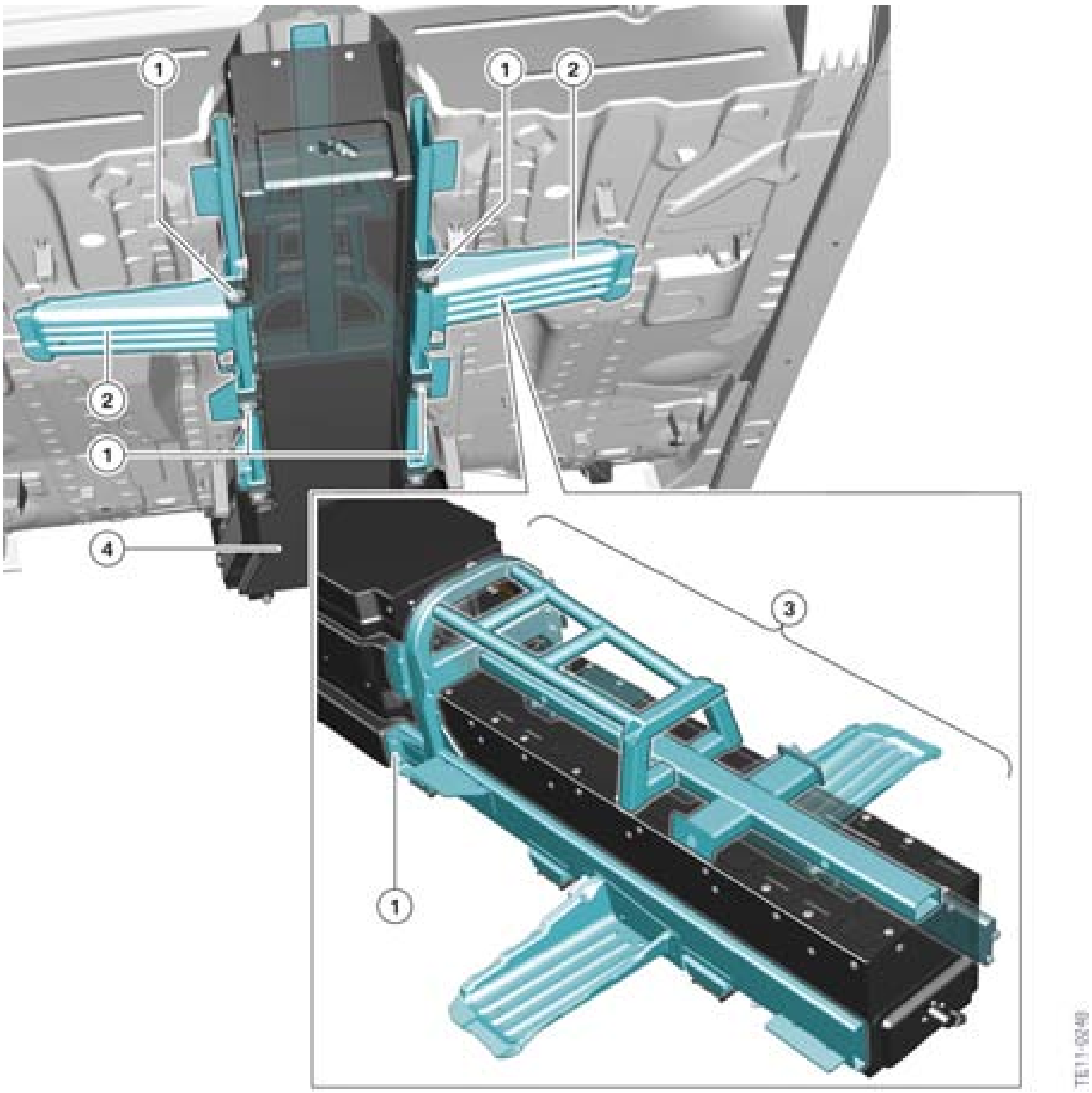
The most important technical data of the high voltage battery unit at the front is included.

No. of battery cells	50
No. of cell modules	6
Nominal voltage	92 V
Weight	120 kg (265 lbs)
Volume	123 l (4.35 cu ft)
No. of cell monitoring electronics	3
SME control unit	SMES1 (secondary)
Directly connected sensors	Coolant temperature sensor (NTC resistor)
Directly connected actuators	Electric coolant pump

The SMES1 control unit in the high voltage battery unit at the front "only" has a secondary function: It performs the primary commands of the SME primary control unit for opening and closing the electromechanical switch contactor. In addition, the SMES1 control unit activates the electric coolant pump using a PWM signal upon request by the SME primary control unit. This type of activation makes possible not only switching on and off of the pump, but also power control depending on the input variables of the heating/cooling system. The SMES1 control unit also evaluates the signal of the NTC resistor, with whose help the coolant temperature is determined at the outlet of the high voltage battery unit at the front. This signal is sent as a data bus telegram via the PT-CAN2 to the SME primary control unit, where the control of the heating/cooling system is effected.

3.4. High voltage battery unit in the transmission tunnel

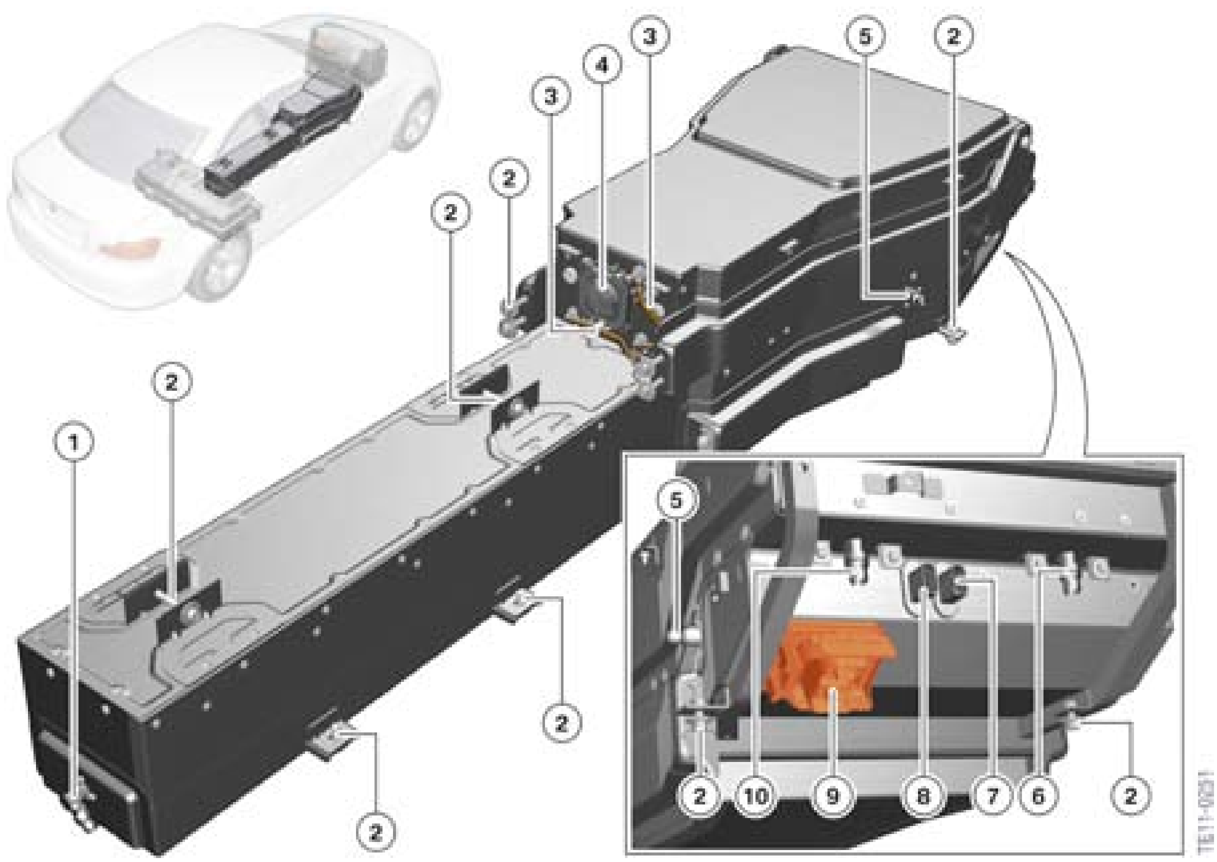
The high voltage battery unit in the transmission tunnel is the largest and heaviest of the three high voltage battery units. It takes up the space reserved in a conventional vehicle for the propeller shaft, the manual transmission and parts of the combustion engine. The space in the E82E has been enlarged in comparison to the conventional E82 in order to house this unit completely.



Installation location of the high voltage battery unit in the transmission tunnel

Index	Explanation
1	Mounting bolts for the high voltage battery unit with support structure
2	Reinforcing element
3	Carrier bracket
4	Bore hole for mounting of support structure to bodyshell
5	High voltage battery unit in the transmission tunnel

In order to be able to mount the high voltage battery unit securely in the transmission tunnel in the E82E, not only the body panel in the undercarriage has been enhanced, but new body components have also been developed. The most striking feature is the support structure made from steel profiles, which are welded together and screwed to the bodyshell. In addition to the support structure, there are reinforcing elements, which are used to either increase the rigidity or improve the crash characteristics. The reinforcing element in the graphic is an example of the reinforcement of the side cross-member and thus helps protect the occupant and the high voltage battery unit in the transmission tunnel in the event of a side collision. The external features of the high voltage battery unit in the transmission tunnel are shown in the following graphic.



External features of the high voltage battery unit in the transmission tunnel

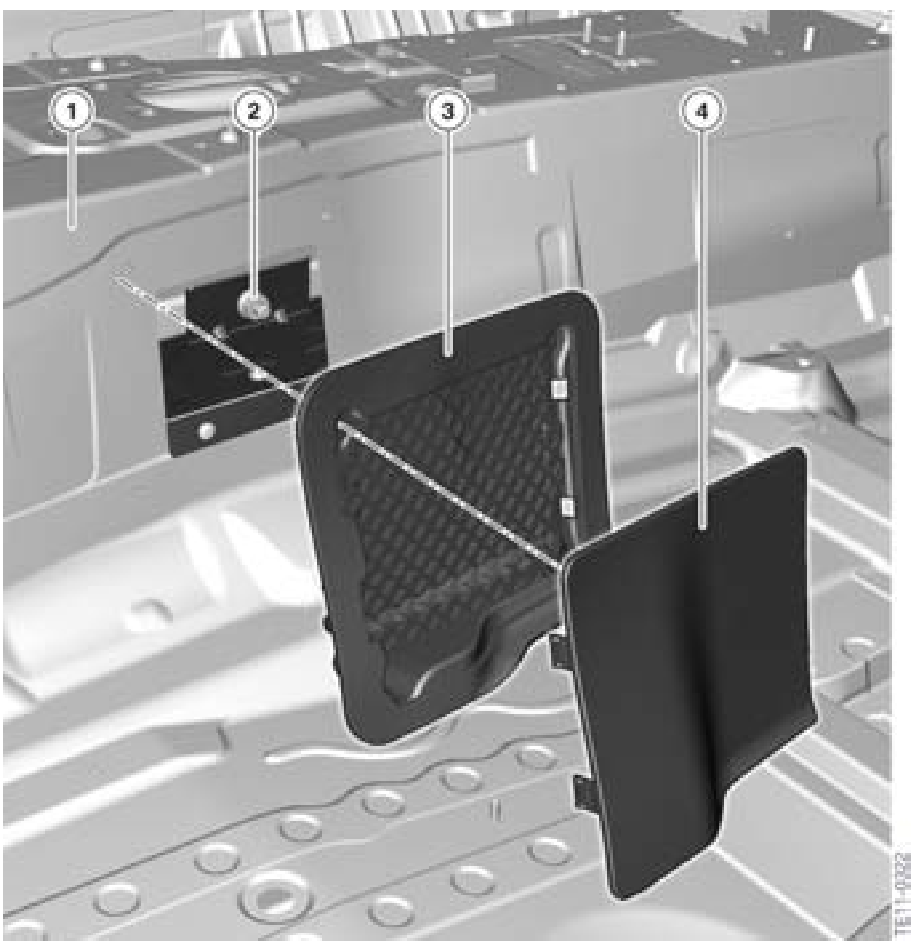
Index	Explanation
1	Connection for coolant line, bottom rear (return 2)
2	Mounting bolts for the high voltage battery unit to support structure
3	Electrical line for potential compensation
4	Vent opening
5	Connection for coolant line, bottom front right (supply 2)
6	Connection for coolant line, top front left (supply 1)
7	Low-voltage connection 1
8	Low-voltage connection 2
9	High voltage connection
10	Connection for coolant line, top front right (return 2)

The high voltage battery unit in the transmission tunnel is also divided internally into a bottom and a top level of cell modules. For this reason, there are also two levels of internal running coolant lines here and accordingly four connections for the coolant lines. The two levels of the coolant passages are not **connected in series**, as opposed to those in the high voltage battery unit in the front. Instead the two levels of the coolant passages of the high voltage battery unit in the transmission tunnel are located in two parallel running branches of the cooling circuit (please also refer to the chapter entitled "Cooling system").

The externally-visible cable for potential compensation links the two internal connection levels of the cell modules (top and bottom, or housing floor panel and intermediate level).

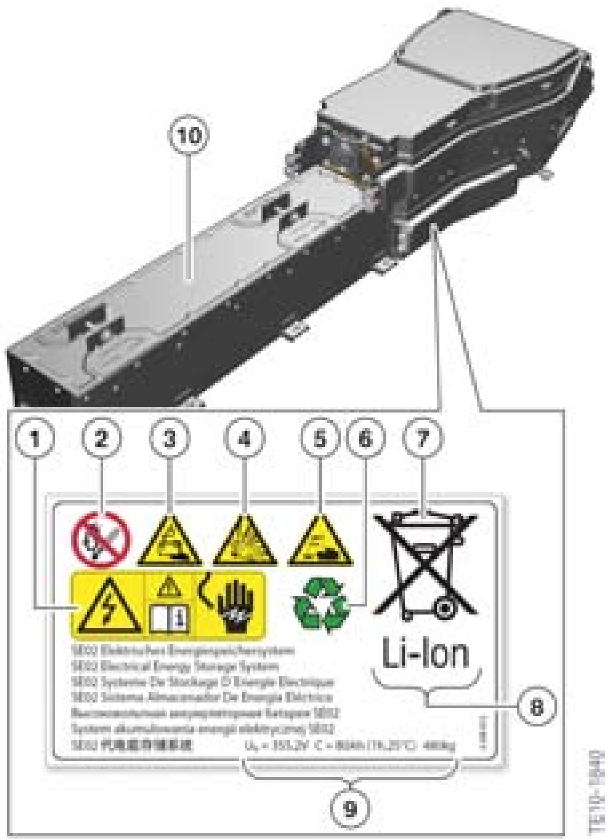
Low-voltage signals are also distributed to two standard connectors at the high-voltage battery unit in the transmission tunnel. The cables/signals that connect the SME control unit to the vehicle's electrical system are located at low-voltage connection 1. Low-voltage connection 2, on the other hand, contains the cables and signals that interconnect the electronic CSC Cell Supervisory Circuits.

The high voltage battery unit in the transmission tunnel is not screwed directly to the vehicle body, but to the support structure. The mounting bolts on the bottom side are also accessible from the vehicle floor. The mounting bolts on the top side are accessible via openings in the interior trim and in the bodyshell in the area of the transmission tunnel.



Accessibility of mounting bolts of the high voltage battery unit in the transmission tunnel

Index	Explanation
1	Bodyshell in transmission tunnel
2	Mounting bolt for the high voltage battery unit to support structure
3	Plastic cover
4	Cover of interior trim



Warning sticker for high voltage battery unit in the transmission tunnel

Index	Explanation
1	Safety sign for high voltage components: Warning against high electrical voltage. Follow repair instructions
2	Prohibition sign: Fire, naked light and smoking are prohibited
3	Warning sign: Warning against risks associated with batteries
4	Warning sign: Warning against explosive materials
5	Warning sign: Warning against corrosive substances
6	Information on disposal of the high voltage battery unit: Recycling possible

Index	Explanation
7	Information on disposal of the high voltage battery unit: Must not be disposed of in household waste.
8	Information on technology used: Lithium-ion battery
9	Nominal voltage, nominal capacity and weight of the high voltage battery (total of all three high voltage battery units)
10	Housing of the high voltage battery unit in the transmission tunnel

The following table summarizes the most important technical data of the high voltage battery unit in the transmission tunnel.

No. of battery cells	86
No. of cell modules	13
Nominal voltage	159 V
Weight	220 kg (485 lbs)
Volume	204 l (7.20 cu ft)
No. of cell monitoring electronics	7
SME control unit	SME (primary)
Directly connected sensors	Coolant temperature sensor (NTC resistor)
Directly connected actuators	Combined expansion and shutoff valve in the refrigerant circuit

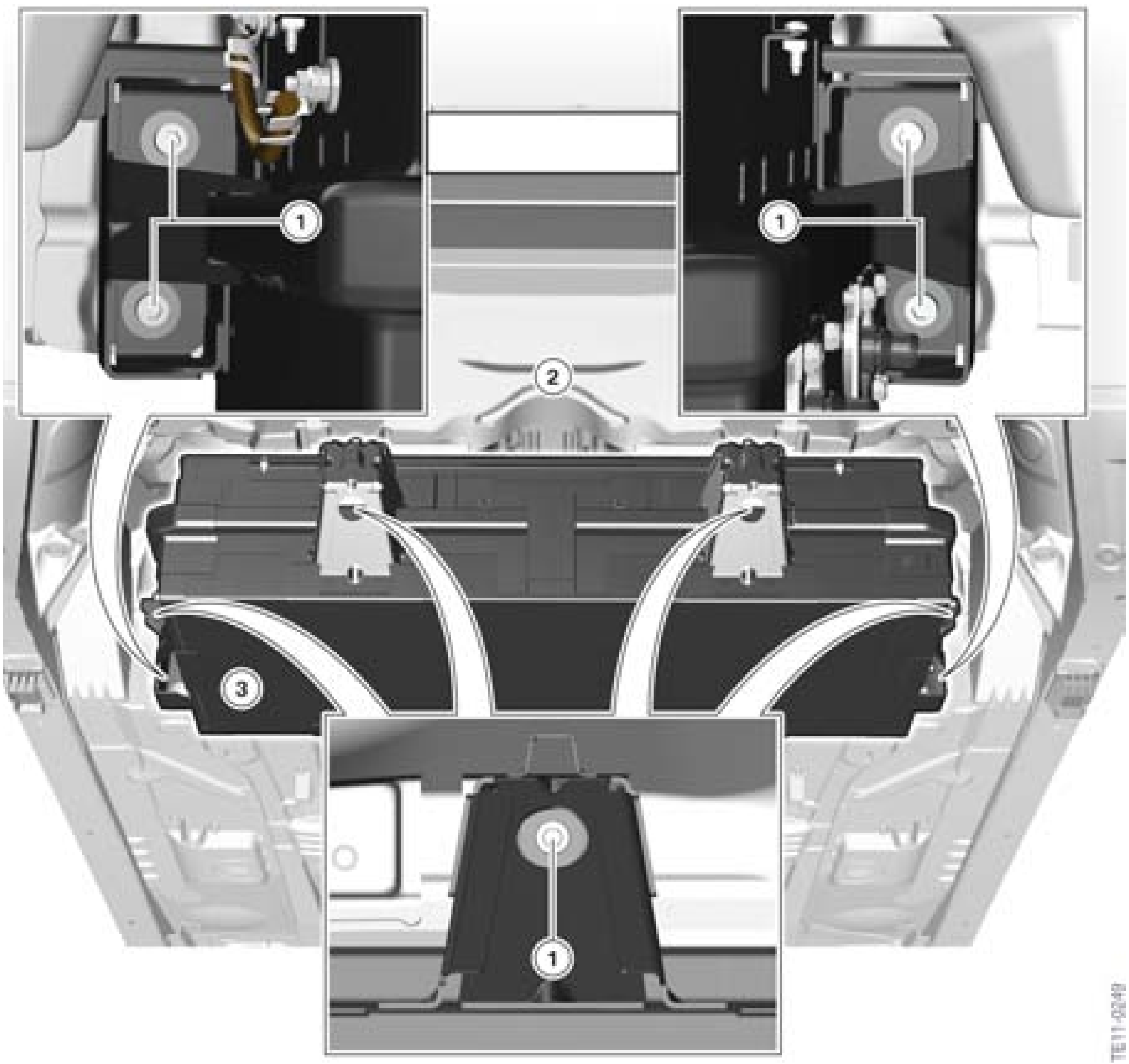
The SME control unit in the high voltage battery unit in the transmission tunnel has the full function of the primary. As described in the chapter entitled "Battery management electronics", the SME primary control unit performs the following functions:

- Control of the starting and shutting-down of the high voltage system upon request by the Electrical Digital Motor Electronics (EDME)
- Control of the SME secondary control units
- Evaluation of the measurement signals for voltage and temperature of all battery cells, as well as the current level in the high voltage circuit
- Control of the cooling system for the high voltage battery units
- Determination of the state of charge (SoC) and the state of health (SoH) of the high voltage battery
- Determination of the available power of the high voltage battery and if required request to limit at electrical machine electronics
- Safety functions (e.g. high voltage interlock loop, isolation monitoring)
- Detection of fault statuses, filing fault entries and communication of fault statuses to the Electrical Digital Motor Electronics (EDME).

In addition to the measurement signals, which the SME control unit receives via the PT CAN2 from the two high voltage battery units, it also evaluates the signal from the directly wired NTC resistor. The coolant temperature at the input, i.e. before the inlet in the coolant passages (the top level) of the high voltage battery unit in the transmission tunnel, is measured using this. An actuator is also connected directly at the SME control unit: The combined expansion and shutoff valve in the refrigerant circuit. If cooling is effected via the chiller unit, the SME control unit emits voltage of 12 volt to order to open the valve.

3.5. High voltage battery unit at the rear

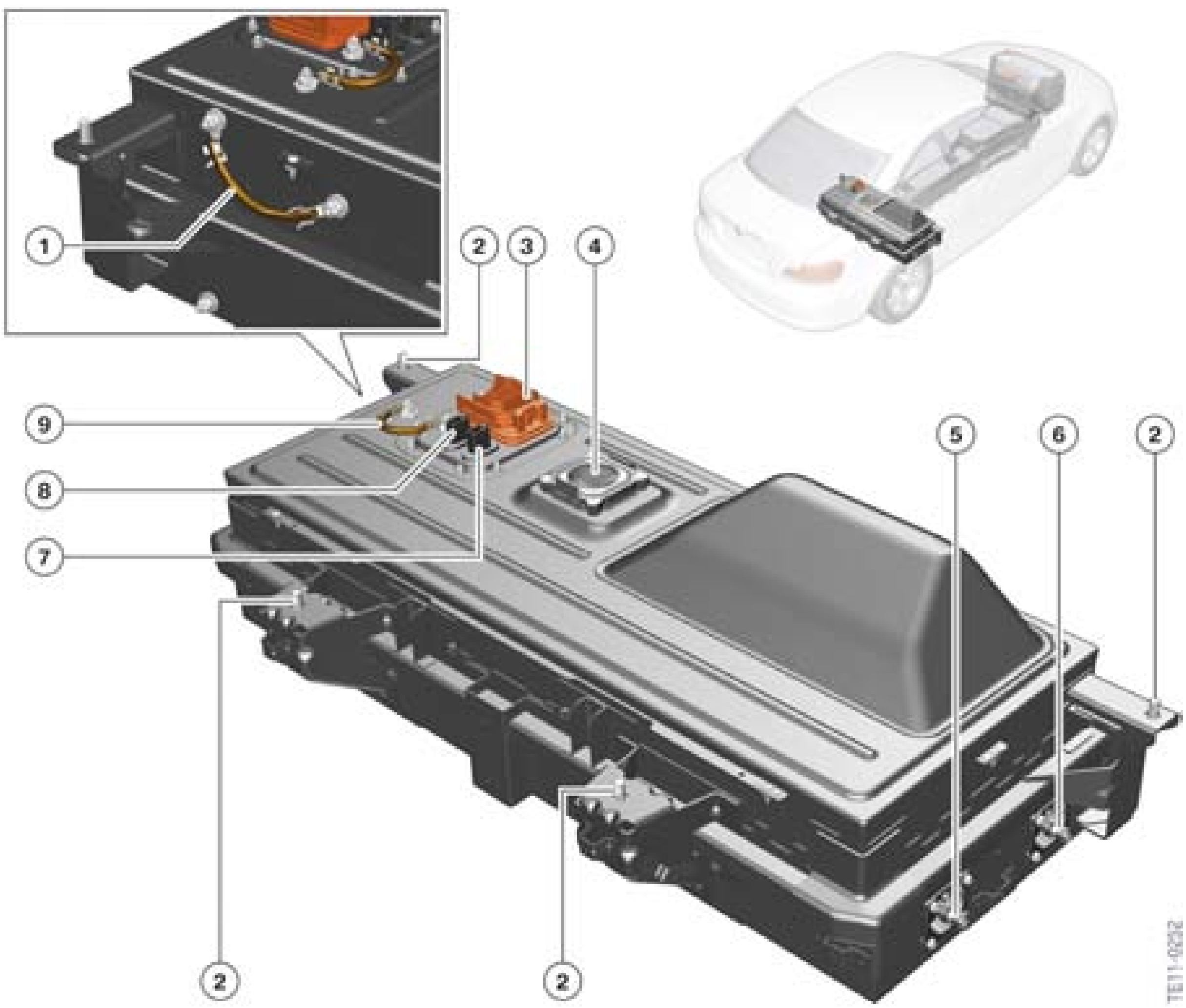
The high voltage battery unit at the rear is integrated in the E82E where the fuel tank is housed in a conventional E82. This available space of the conventional E82 is thus optimally used. In addition, this space is very well protected against deformation in the event of an accident.



Installation location of the high voltage battery unit at the rear

Index	Explanation
1	Mounting bolts for the high voltage battery unit to the body
2	Body (floor panel at rear)
3	High voltage battery unit at the rear

The mounting of the high voltage battery unit at the rear is effected using bolts and the high voltage battery unit is connected directly to the vehicle body – this has been reinforced (e.g. the floor panel at the rear). This reinforcement is necessary due to the high weight of the high voltage battery unit in comparison to a conventional fuel tank.



Index	Explanation
1	Electrical line for potential compensation
2	Mounting bolts for the high voltage battery unit to the support structure
3	High voltage connection
4	Vent opening

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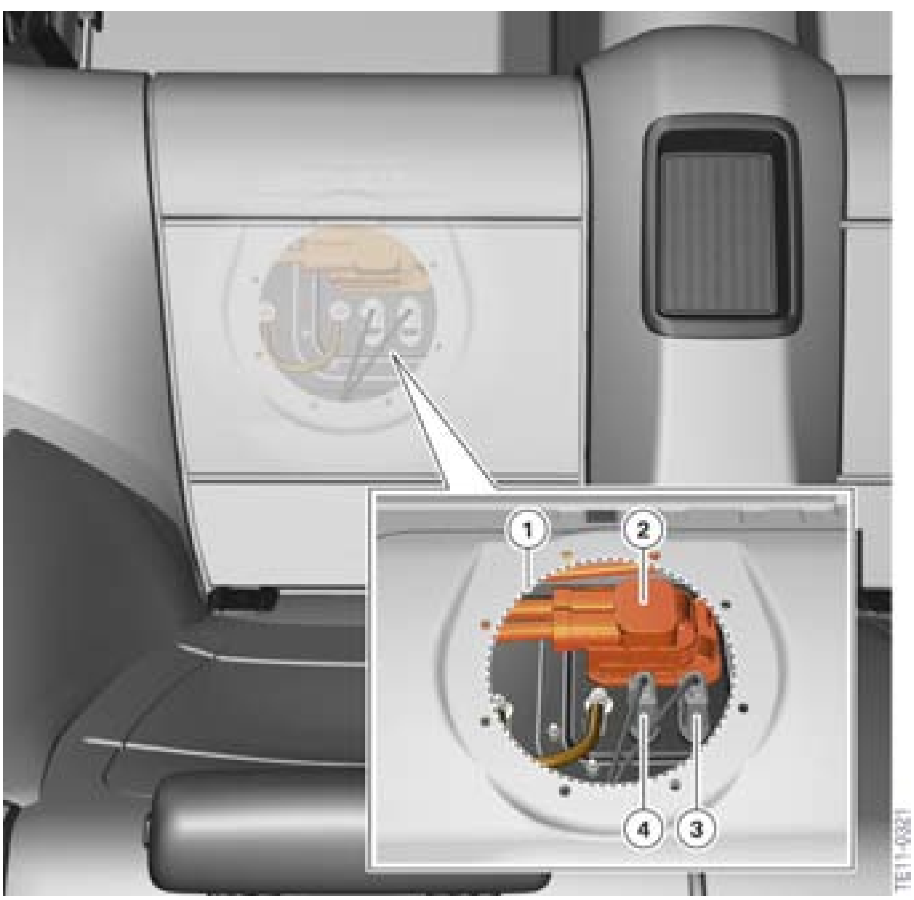
3. High Voltage Battery

Index	Explanation
5	Connection for coolant line, bottom (return)
6	Connection for coolant line, front (supply)
7	Low-voltage connection 1
8	Low-voltage connection 2
9	Electrical line for potential compensation

In comparison to the other two high voltage battery units, the high voltage battery unit at the rear contains one level of cell modules and it incorporates two connection fittings (instead of four) for the coolant lines. The coolant line at the output contains a coolant temperature sensor in direct proximity to the connection (please also refer to the chapter entitled "Cooling system").

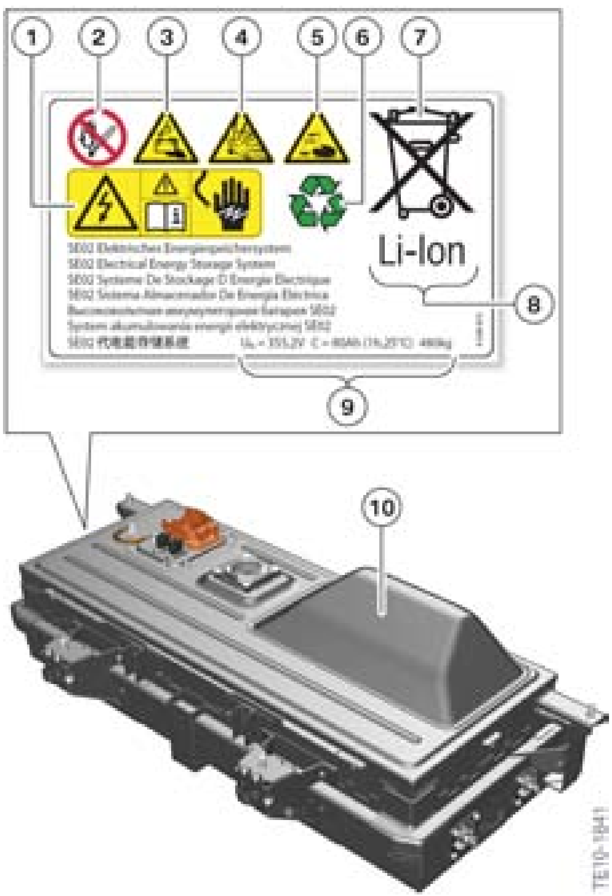
The low-voltage signals are distributed to two standard connectors at the high-voltage battery unit at the tail, similar to the other two high-voltage battery units. The cables/signals that link the SMES2 control unit with the vehicle's electrical system are located at low-voltage connection 1. Low-voltage connection 2, on the other hand, contains the cables and signals that interconnect the electronic Cell Supervisory Circuits (CSC).

The high voltage connection and the low-voltage connections are accessible via the seat bench at the rear and the left opening in the floor panel at the rear.



Access to the electrical connections of the high voltage battery unit at the rear

Index	Explanation
1	Opening in the floor panel
2	High voltage connection
3	Low-voltage connection 1
4	Low-voltage connection 2



Warning sticker for high voltage battery unit at the rear

Index	Explanation
1	Safety sign for high voltage components: Warning against high electrical voltage. Follow repair instructions
2	Prohibition sign: Fire, naked light and smoking are prohibited
3	Warning sign: Warning against risks associated with batteries
4	Warning sign: Warning against explosive materials
5	Warning sign: Warning against corrosive substances
6	Information on disposal of the high voltage battery unit: Recycling possible

Index	Explanation
7	Information on disposal of the high voltage battery unit: Must not be disposed of in household waste.
8	Information on technology used: Lithium-ion battery
9	Nominal voltage, nominal capacity and weight of the high voltage battery (total of all three high voltage battery units)
10	Housing of the high voltage battery unit at the rear

The most important technical data for the high voltage battery unit at the rear is summarized in a table.

No. of battery cells	56
No. of cell modules	6
Nominal voltage	103 V
Weight	140 kg (307 lbs)
Volume	92.4 l (3.26 cu ft)
No. of cell monitoring electronics	3
SME control unit	SMES2 (secondary)
Directly connected sensors	Coolant temperature sensor (NTC resistor)
Directly connected actuators	None

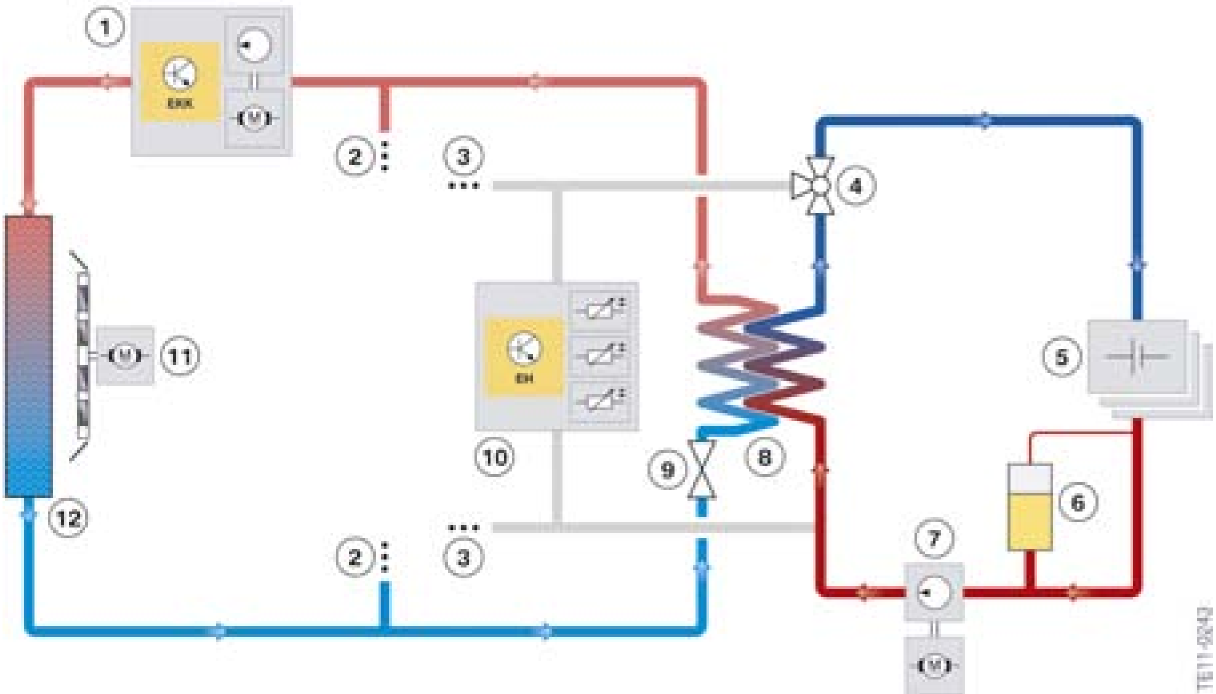
The SMES2 control unit in the high voltage battery unit at the rear has a secondary function: It performs the primary commands of the SME primary control unit for opening and closing the electromechanical switch contactors. No actuator is directly connected at the SMES2 control unit. The SMES2 control unit, just like the other SME control units, also evaluates the signal of the NTC resistor, with whose help the coolant temperature is determined at the outlet of the high voltage battery unit at the rear. This signal is sent as a data bus telegram via the Local Controller Area Network to the SME primary control unit, where the control of the cooling system is effected.

3.6. Heating/Cooling system

3.6.1. Overview

Complete heating/cooling system

If the cells of the high voltage battery emit or absorb electric power and this happens at too high or too low a temperature, this reduces its service life significantly. Also damage may occur with the result of reduced storable energy. The heating/cooling system for the high voltage battery completes the most important task of maintaining the battery cells in a strict optimal temperature range. The cooling system must therefore be able to both **cool** and **heat** the battery cells. The optimal cell temperature is 20° C/68° F; the battery cells should not exceed a maximum temperature of 40° C/104° F. The following graphic provides an overview of the complete heating/cooling system of the high voltage battery.



Complete heating/cooling system of the high voltage battery

Index	Explanation
1	Electric coolant compressor
2	Refrigerant circuit for passenger compartment
3	Heater circuit for passenger compartment
4	Changeover valve for heating/cooling the high voltage battery
5	High voltage battery
6	Coolant expansion tank
7	Electric coolant pump
8	Coolant/Refrigerant heat exchanger (element of the chiller unit)
9	Combined expansion and shutoff valve in the refrigerant circuit (element of the chiller unit)
10	Electric heating unit
11	Electric fan
12	Condenser in the refrigerant circuit

The heating/cooling system is divided into a total of three circuits:

1 Cooling system

2 Heater circuit

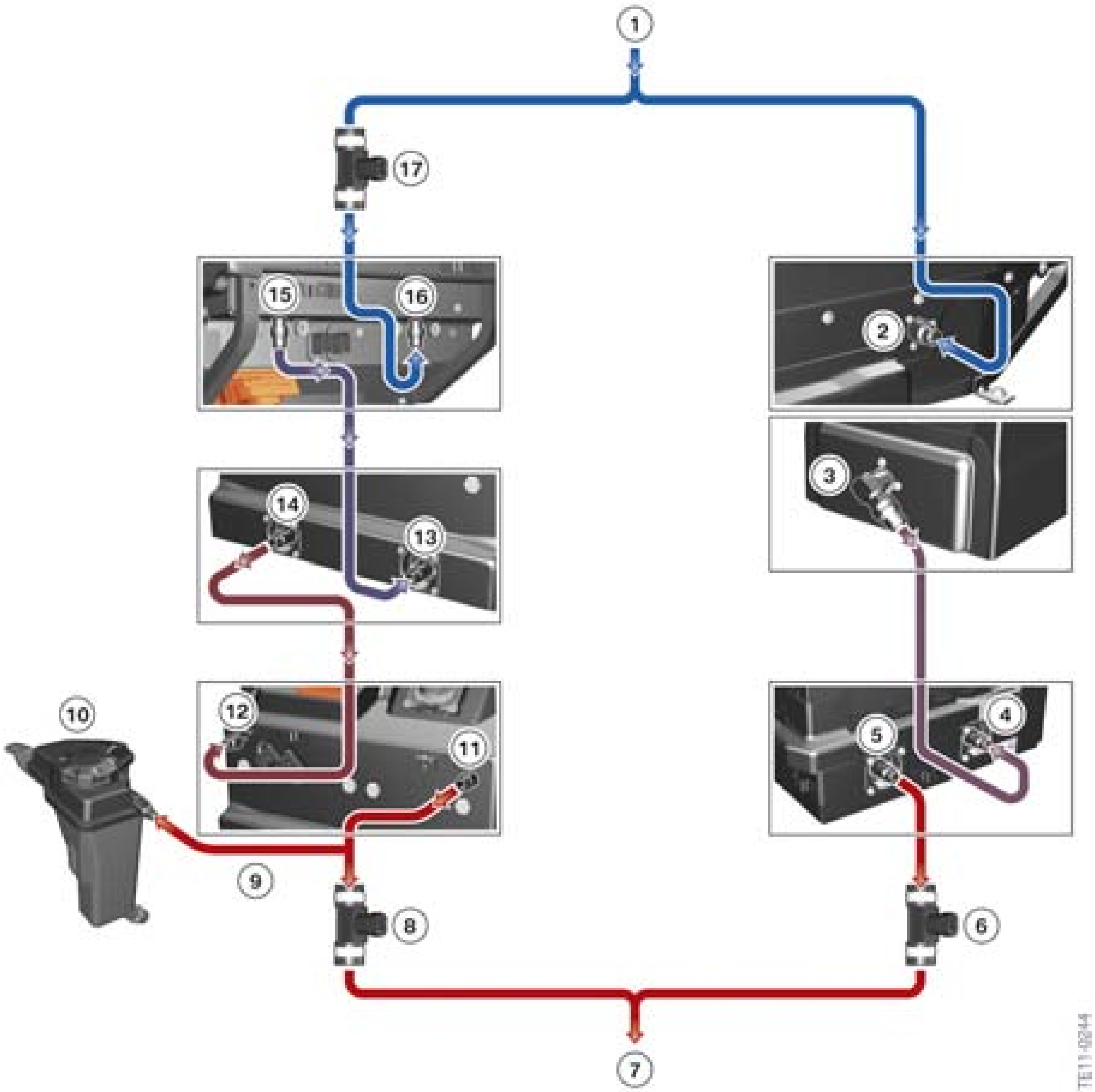
3 Refrigerant circuit.

The coolant is "driven" by an electric coolant pump and pumped through the high voltage battery. Here heat energy flows from the warmer to the cooler body. During cooling the battery cells deliver heat energy to the coolant. As long as the coolant is colder than that of the battery cells, these can be cooled solely by circulating the coolant. The temperature of the coolant thus increases and is no longer sufficient to keep the temperature of the battery cells in the desired range. The temperature of the coolant must then be lowered which is done by using a coolant/refrigerant heat exchanger called a chiller unit. This is the interface from the cooling circuit to the refrigerant circuit of the air-conditioning unit. If the combined expansion and shutoff valve in the refrigerant circuit is activated electrically and thus opened, liquid refrigerant flows into the chiller unit and evaporates. It extracts heat energy from its surrounding area and thus also the coolant, which flows through in the cooling circuit. The electric coolant compressor compresses the refrigerant again and in the condenser it passes into the liquid state again. The refrigerant is thus once again in the position to absorb heat energy. A maximum cooling power of about 1,200 W can thus be generated or in other words: a heat output of up to 1,200 W can be dissipated from the high voltage battery. This maximum cooling power is of course only necessary at a very high ambient temperature or, at the same time, high motor power.

In the reverse situation, if the E82E was left in the open for several days at temperatures under 0° C/32° F for example, it makes sense to heat the battery cells before departure to their optimal temperature level. The customer can use this option when the vehicle is connected to the AC power grid for charging and the interior temperature control function of the vehicle has been selected. To heat the battery cells coolant is once again pumped through the high voltage battery. The changeover valve is activated so that the coolant no longer flows through the chiller unit but through the electric heating unit. The switched-on electric heating unit heats the coolant and the heated coolant in turn heats the battery cells. The electric heating unit and its circuit are used for the interior temperature control of the passenger compartment, just like the refrigerant circuit of the air-conditioning unit.

Cooling circuit for high voltage battery units

Up to now it was simply stated that coolant is pumped through the high voltage battery. The high voltage battery is comprised of three high voltage battery units. The coolant must thus be pumped through these three high voltage battery units. How they are integrated in the cooling circuit is described in this chapter. The following graphic shows an operating condition in which the high voltage battery is cooled. The coolant is marked in blue when it has a low temperature. Red indicates a high temperature of the coolant.



Detailed representation of the cooling circuit for high voltage battery units

Index	Explanation
1	Supply with cold coolant coming from the chiller unit
2	High voltage battery unit in the transmission tunnel, connection for the coolant line, bottom front right (supply)
3	High voltage battery unit in the transmission tunnel, connection for the coolant line, bottom rear (return)
4	High voltage battery unit at the rear, connection for the coolant line, front (supply)

Index	Explanation
5	High voltage battery unit at the rear, connection for the coolant line, rear (return)
6	Coolant temperature sensor at output of high voltage battery unit at the rear
7	Return with heated coolant for the coolant pump
8	Coolant temperature sensor at the output of the high voltage battery unit at the front
9	Tank ventilation line
10	Coolant expansion tank
11	High voltage battery unit at the front, connection for the coolant line, top right (return)
12	High voltage battery unit at the front, connection for the coolant line, top left (supply)
13	High voltage battery unit at the front, connection for the coolant line, bottom right (supply)
14	High voltage battery unit at the front, connection for the coolant line, bottom left (return)
15	High voltage battery unit in the transmission tunnel, connection for the coolant line, top front right (return)
16	High voltage battery unit in the transmission tunnel, connection for the coolant line, top front left (supply)
17	Coolant temperature sensor at the input of the high voltage battery

The cooling circuit is divided into two branches for the high voltage battery units. The two branches have been designed in such a way that the pressure difference (which arises when the coolant is flowing through the high voltage battery units) is the same. This ensures that both branches have the same coolant volumetric flow. Thanks to the same volumetric flow the same amount of heat can be dissipated in both branches. The graphic also shows that the high voltage battery units in the transmission tunnel and at the front each have two independent cooling levels. The two cooling levels of the high voltage battery unit in the transmission tunnel are located in different branches of the cooling circuit. This distribution also serves to allow the volumetric flow to become the same in both branches.

There are coolant temperature sensors located both at the input (before the coolant flows into the high voltage battery) and at the two outputs of the two coolant branches. Their signals also serve as input signals for the control of the heating/cooling system, just like the temperature sensors at the cell modules.

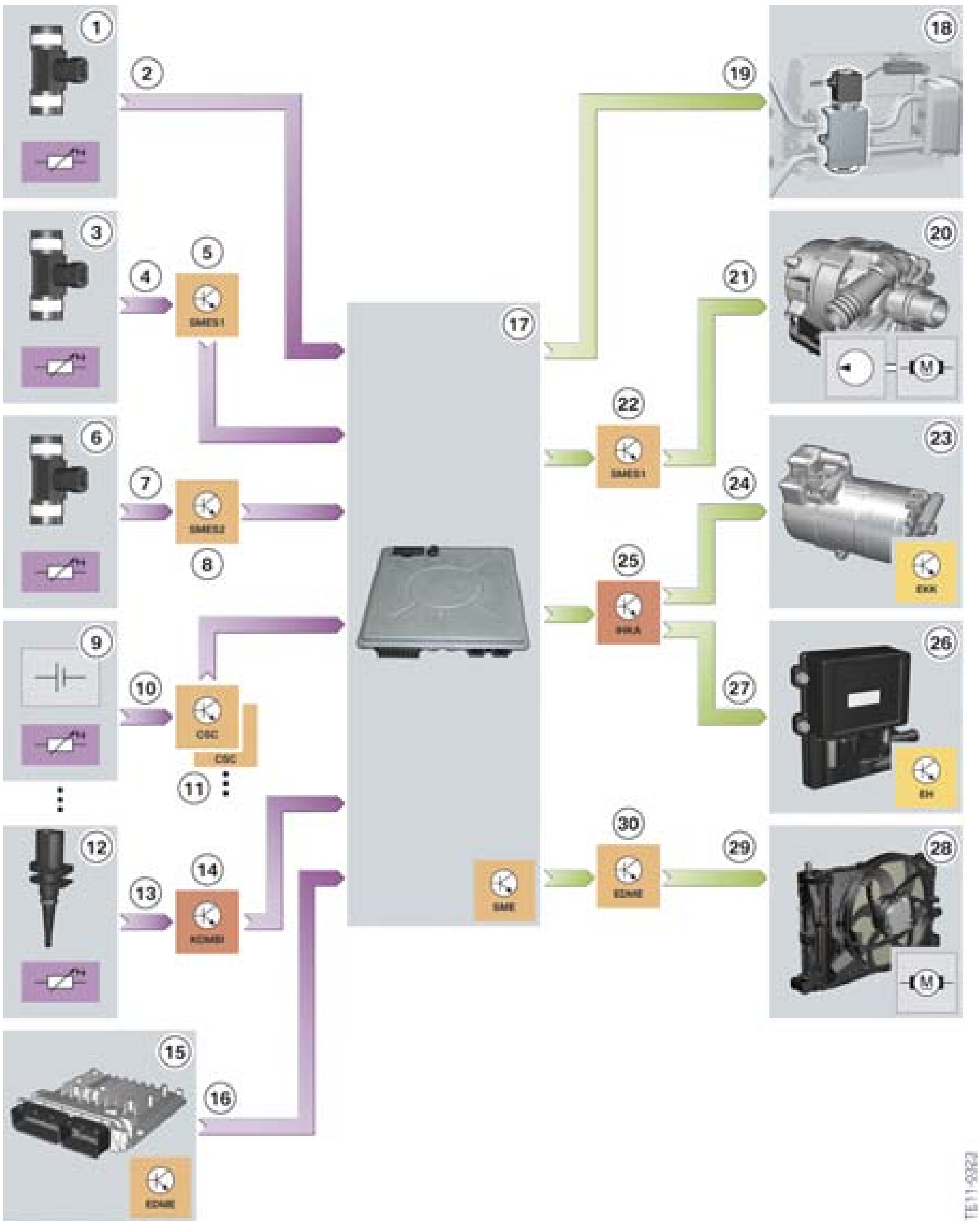
3.6.2. Functions

Distributed functions

The heating/cooling system of the high voltage battery in the E82E can have the following operating conditions:

1 Circulation
2 Heating
3 Cooling.

These operating conditions are dependent on the cell temperatures, the coolant temperature, the ambient temperature and the power which is extracted from or supplied to the high voltage battery. The SME primary control unit decides what operating condition is necessary depending on these input variables. The following graphic shows the input variables already mentioned, the role of the SME primary control unit and what actuators the heating/cooling system uses for controlling the heating/cooling system.



Inputs/Outputs of heating/cooling system of the high voltage battery

E82E Complete Vehicle
3. High Voltage Battery

Index	Explanation
1	Coolant temperature sensor at the input of the high voltage battery (high voltage battery unit in the transmission tunnel)
2	Coolant temperature at the input of the high voltage battery (high voltage battery unit in the transmission tunnel)
3	Coolant temperature sensor at the output of the high voltage battery unit at the front
4	Coolant temperature sensor at the output of the high voltage battery unit at the front
5	SMES1 control unit in the high voltage battery unit at the front
6	Coolant temperature sensor at output of high voltage battery unit at the rear
7	Coolant temperature sensor at output of high voltage battery unit at the rear
8	SMES2 control unit in the high voltage battery unit at the rear
9	Temperature sensor at the cells of the high voltage battery
10	Cell temperatures
11	CSC control units (cell monitoring electronics)
12	Ambient temperature sensor
13	Ambient temperature
14	Instrument panel
15	EDME control unit
16	Currently required electric power in the high voltage electrical system
17	SME control unit in the high voltage battery unit in the transmission tunnel
18	Combined expansion and shutoff valve
19	Signal for activation of the combined expansion and shutoff valve
20	Electric coolant pump in the cooling circuit of the high voltage battery
21	PWM signal for activation of the electric coolant pump
22	SMES1 control unit in the high voltage battery unit at the front
23	Electric AC compressor
24	Signal via local interconnect network bus for activating the electric AC compressor
25	Integrated automatic heating / air-conditioning
26	Electric heating unit
27	Signal via LIN-bus for activating the electric heating
28	Electric fan
29	PWM signal for activating the electric fan
30	EDME control unit

"Circulation" operating condition

The operating condition "Circulation" is assumed when the cell temperatures are already in the optimal range (around 20 °C/68° F) or the cells in the three high voltage battery units have very varying temperatures. This can happen when exposed to direct sunlight during charging for example because the high voltage battery unit in the front of the vehicle is heated up more than the other two as a result. "Circulation" mainly occurs when the high voltage battery is charged at the power network or the vehicle is moved when there is a moderate ambient temperature and at low power.

The components of the cooling system work as follows during "Circulation":

- The electric coolant pump in the cooling circuit of the high voltage battery runs.
- The changeover valve is switched so that the cooling circuit of the high voltage battery is closed. There is no connection to the cooling circuit of the electric heating.
- The electric coolant compressor is not in operation or not used for cooling the high voltage battery. It can, however, be used if the passenger compartment has to be cooled.
- The combined expansion and shutoff valve in the chiller unit is closed.

The power of the electric coolant pump in the cooling circuit of the high voltage battery is controlled depending on the sensor signals and must therefore not run at full power.

A small amount of heat energy is transported from the high voltage battery unit via the circulated coolant. In addition, the cells of all high voltage battery units are brought to more or less the same temperature level so that their temperature-dependent performance is also the same.

"Heating" operating condition

The cooling system can also be used for heating the cells of the high voltage batteries if their temperature is significantly below the optimal operating temperature of 20° C/68° F. In this case, its performance is temporarily limited and the efficiency of the energy conversion would not be optimal. For this reason, the energy required for heating the high voltage battery is used sensibly. "Heating" is activated when the vehicle with the charging cable is connected to the AC voltage supply and the customer has selected the interior temperature control function of the vehicle. How to select this function is described in detail in the chapter entitled "Climate control", as this is primarily about pleasant climate control of the passenger compartment before the start of the journey (independent ventilation, auxiliary heater, parked-car air-conditioning).

The components of the heating system work as follows during"Heating":

- The electric coolant pump in the cooling circuit of the high voltage battery runs.
- The changeover valve is switched so that the cooling circuit of the high voltage battery and that of the electric heating are connected.
- The electric coolant compressor is not in operation.
- The combined expansion and shutoff valve in the chiller unit is closed.
- Power is supplied to the electric heating unit.

The coolant is heated via the heater output of the electric heating unit and pumped into the circuit of the high voltage battery via the electric coolant pump. Heat energy is thus fed to the high voltage battery and the cells are heated.

This operating condition is of course only assumed when the high voltage power management in the EDME control unit permits this. Here the electrical energy available at the respective time, among other factors, are taken into consideration.

"Cooling" operating condition

If the battery cells reach temperatures of approx. 30° C/68° F, cooling of the high voltage battery begins. The cooling requested by the SME control unit has an even lower priority here. It can be rejected by the high voltage power management in the Electrical Digital Motor Electronics. In the event of a higher cell temperature, the cooling request for the high voltage battery obtains top priority and is always performed.

The components behave as follows in the "Cooling" operating condition:

- The electric coolant pump in the cooling circuit of the high voltage battery runs.
- The changeover valve is switched so that the cooling circuit of the high voltage battery is closed. There is no connection to the cooling circuit of the electric heating.
- The electric coolant compressor is in operation.
- The combined expansion and shutoff valve in the chiller unit is open. Refrigerant can thus make its way to the chiller unit and evaporate there.

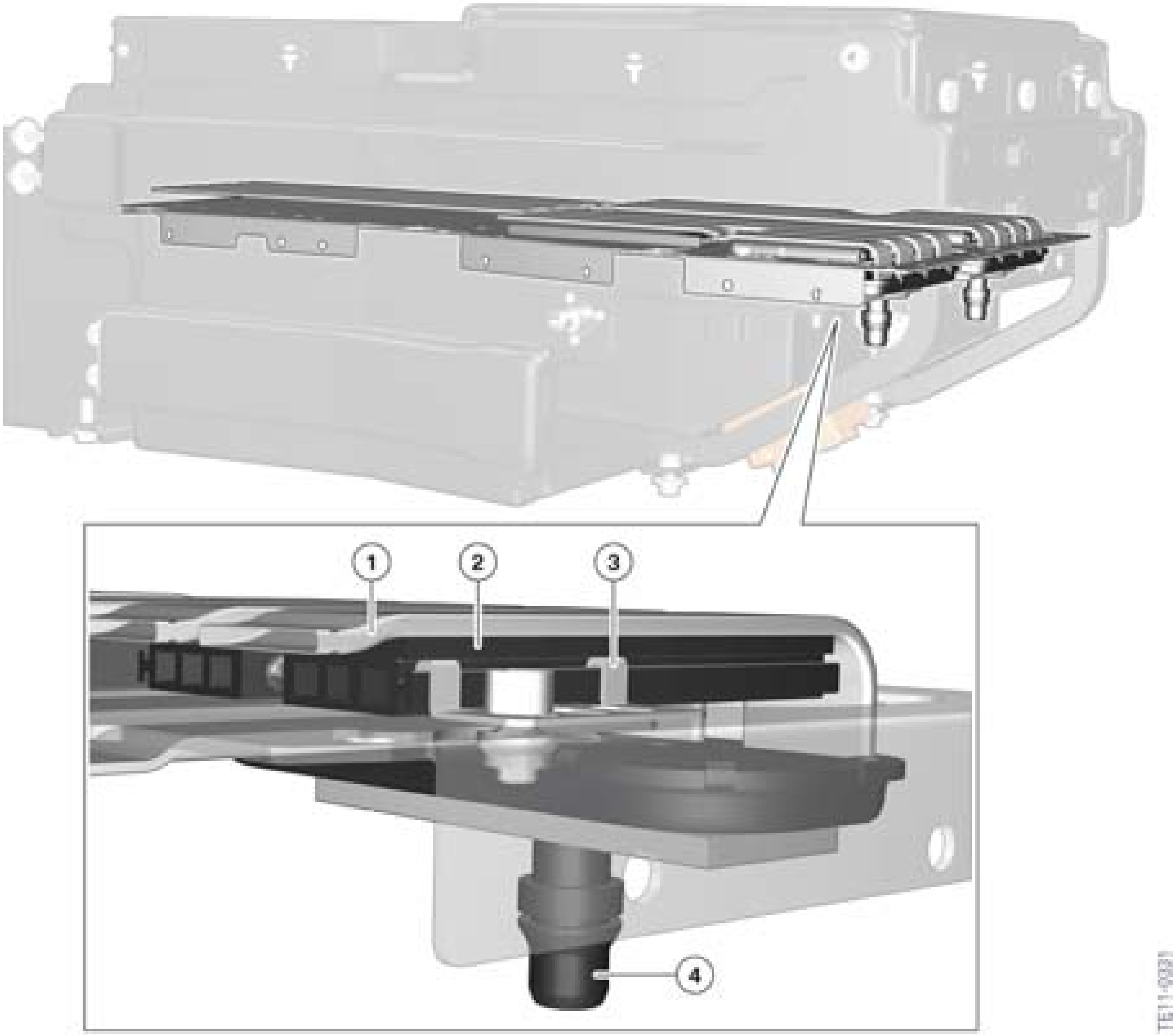
The heat energy is extracted by the evaporating refrigerant as the coolant flows through the chiller unit. The cooled coolant returns to the high voltage battery units and once again absorbs heat energy from the battery cells. The battery cells are thus cooled. To be able to dissipate a sufficient amount of heat energy, the electric coolant pump is operated in this operating condition generally at full power.

3.6.3. System components

Coolant passages in the high voltage battery units

In the inside of the high voltage battery units the coolant flows through coolant passages made from aluminium. These coolant passages are pressed against the cell modules at a defined force. In addition, during assembly a layer of elastomer foam (so-called EPDM foam) is compressed. This layer is adhered to the coolant passages and in fact to the side from which the cell modules are turned away. The coolant duct and the cell modules are in direct material contact. The soft aluminium of the coolant duct deforms slightly due to the contact pressure and may even out any existing unevenness, for example on the housing of a cell module. This enables the creation of a complete contact and heat transfer with a slight thermal resistor.

3. High Voltage Battery

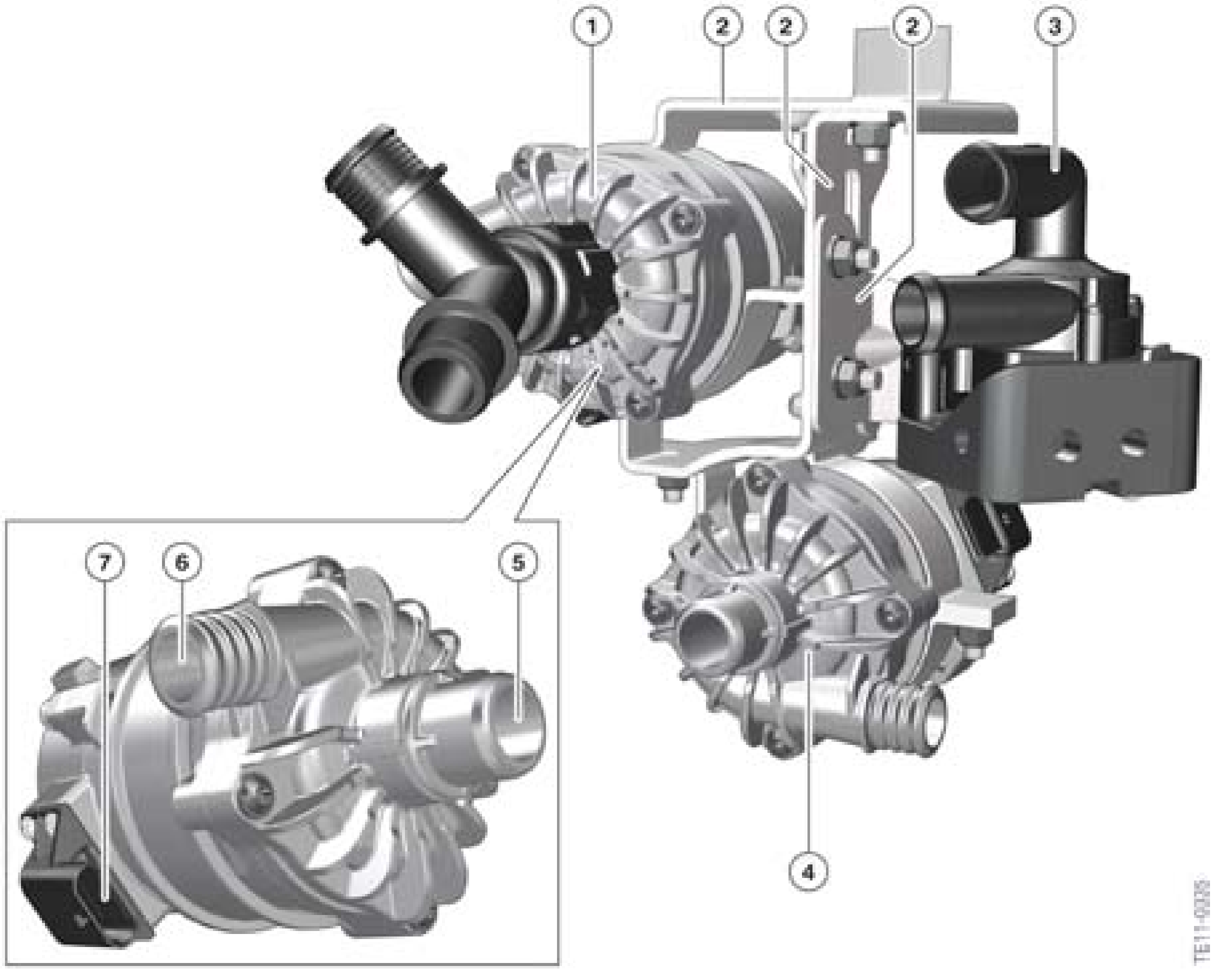


Coolant duct in the high voltage battery unit in the transmission tunnel

Index	Explanation
1	Aluminium coolant duct
2	Elastomer plastic
3	Fixing unit
4	External connection for coolant line

Electric coolant pump

The electric coolant pump in the cooling circuit of the high voltage battery has a maximum power of 50 W, similar to the one in the electric powertrain cooling circuit. These two coolant pumps and the pump of the heater circuit for the passenger compartment are mounted on a multi component metal bracket and are located in the front right in the space below the hood.



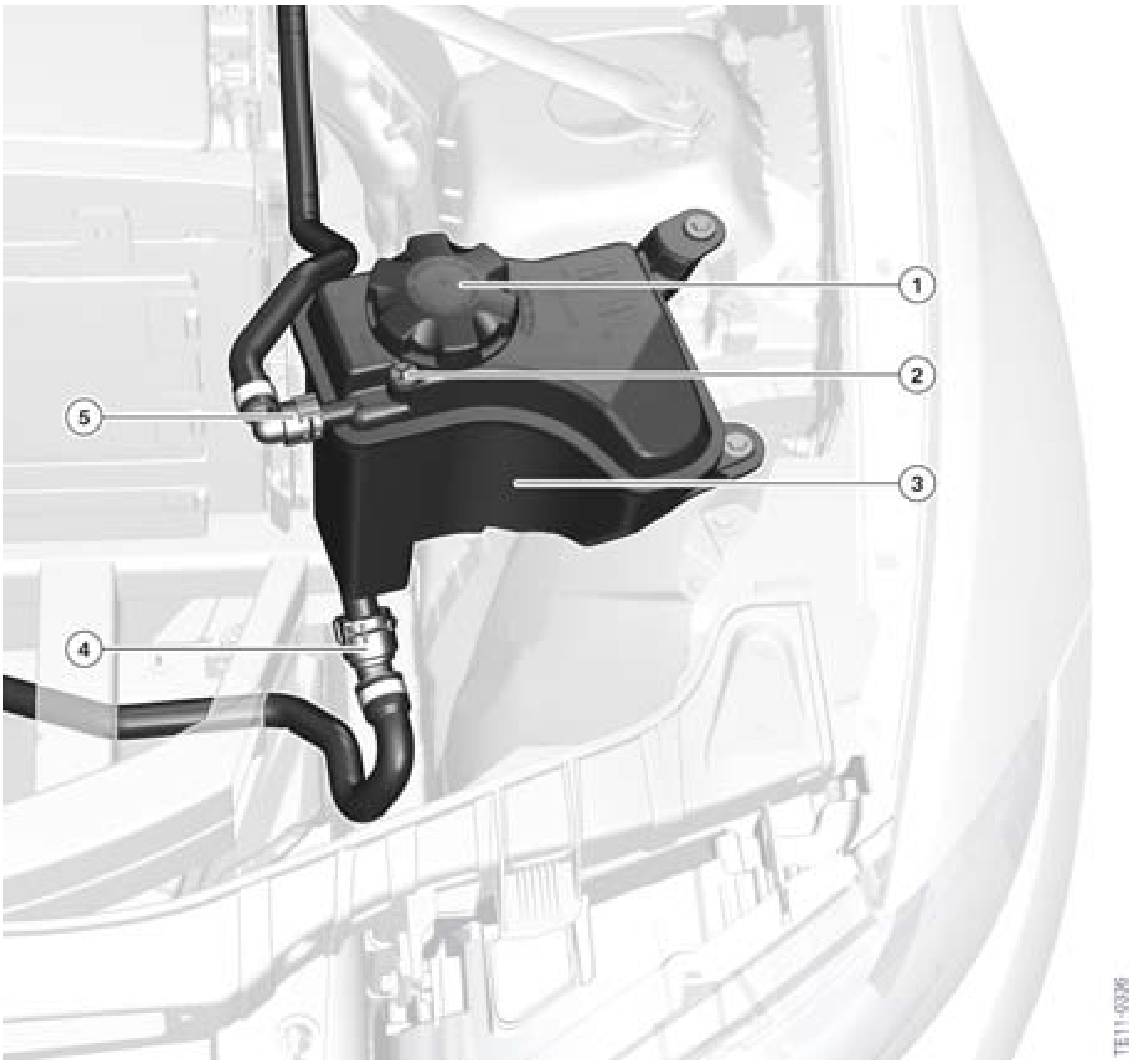
Installation location of the coolant pumps

Index	Explanation
1	Electric coolant pump in the cooling circuit of the high voltage battery
2	Multi component metal bracket
3	Electric coolant pump for the heater circuit
4	Electric coolant pump in the cooling circuit of the electric powertrain
5	Connection for coolant line on intake side
6	Connection for coolant line on pressure side
7	Electrical connection

The electric coolant pump for the high voltage battery, compared to the pump for the electric motor, is not controlled via a local interconnect network bus, but by a PWM signal. The SMES1 control unit (high voltage battery unit at the front) generates this PWM signal. The voltage supply of the coolant pump is effected via terminal 30 g from the junction box.

Coolant expansion tank

The expansion tank is also located in the space below the hood to the left of the direction of travel.



Installation location of the coolant expansion tank

Index	Explanation
1	Sealing cap
2	Bleed screw
3	Coolant expansion tank
4	Connection for the coolant line on intake side
5	Connection for ventilation line

3. High Voltage Battery

This expansion tank is familiar from the BMW 1-Series and 3-Series. However, the electric level sensor installed as standard equipment is removed at the factory or in the service facility prior to installation in the vehicle. This is necessary due to the more restricted installation space in the E82E. The signal from the electric level sensor is not needed to support standard operation of the heating and cooling system for the high-voltage battery. The following feature, however, is important for Service:
A loss of coolant, for example due to a leak in the cooling system, is not detected directly by the control units in the vehicle. Instead in the event of a loss of coolant the temperature of the high-voltage battery increases above the normal operating range. In this case, the power of the electric motor is reduced considerably and a corresponding Check Control message is triggered. To find the cause of this Check Control message or the malfunction of the heating/cooling system, the Service employee should check the following fault possibilities:

- Loss of coolant, for example due to a leak
- Refrigerant circuit components in the air-conditioning unit are defective (e.g. electric AC compressor, chiller unit)
- Coolant pump is not working
- Coolant lines or connections damaged
- One of the high voltage battery units is defective.

⚠

If excess temperature is displayed in the cooling system of the high voltage battery, then there may be several reasons for this, including a loss of coolant, etc. During troubleshooting all components of the heating/cooling system must therefore be checked systematically.

The mixture of water and antifreeze and corrosion inhibitor (blue/green fluid, part # 9 407 454) known for BMW vehicles is used as a coolant.

⚠

When filling the cooling circuit of the high voltage battery the special tool for filling the vacuum must be used in accordance with the repair instructions.

After filling the cooling circuit, but also after replacement of the components in the cooling circuit, the bleeding procedure must be performed.

The bleeding of the cooling circuit for the high voltage battery of the E82 E is possible by performing a Service function in the ISTA ActiveE diagnosis system. As is also the case in the electric powertrain cooling circuit, appropriate activation of the electric coolant pump is also performed here (variable speed, certain period).

⚠

Before the high voltage battery is charged or the E82 E is driven, the heating/cooling system of the high voltage battery must be filled with coolant and ventilated. Otherwise the high voltage battery may suffer damage.

Coolant temperature sensors

The signals of all three coolant temperature sensors are input signals for the control of the heating/cooling system for the high voltage battery. In the case of the sensors these are temperature-dependent electrical resistors, so-called NTC resistors. The sensor signal is read via a two-wire connection between each sensor and the next control unit (SME, SMES1, SMES2). To be able to process all three temperature signals centrally in the SME primary control unit, they are made available by SMES1 and SMES2 as data bus telegrams on the Local Controller Area Network.

The coolant temperature sensors are integrated in the coolant lines. Their installation location and the control unit to which they are wired are summarized in the following table. The exact installation location can be taken from the graphics in the chapter "Overview" of the heating/cooling system.

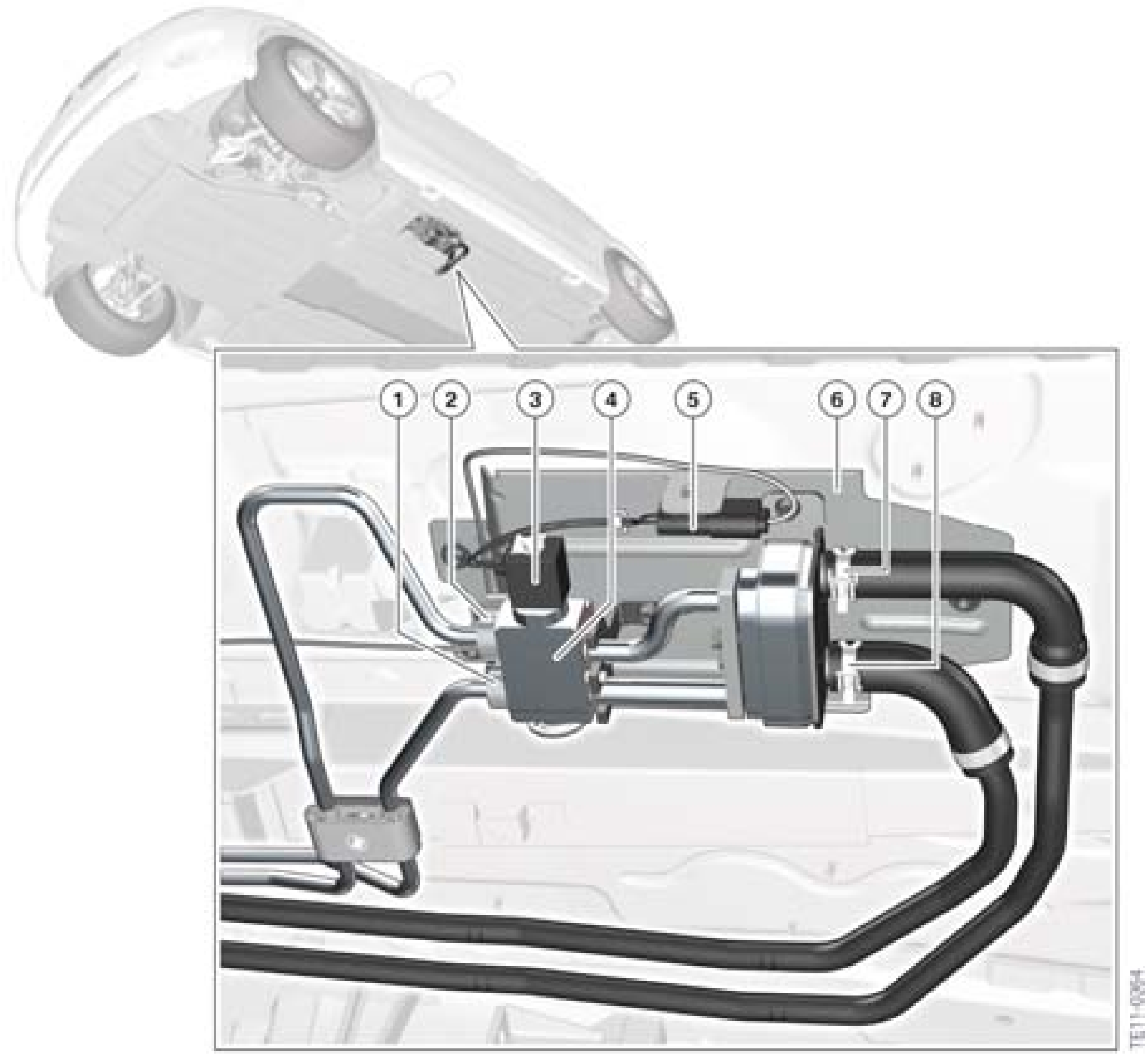
Sensor at the input (supply) to the high voltage battery, and in the branch of the coolant line to the top level of the high voltage battery unit in the transmission tunnel	SME control unit (in the high voltage battery unit in the transmission tunnel
Sensor at the output (return) of the high voltage battery unit at the front, after the branching of the coolant line to the expansion tank	SMES1 control unit (in the high voltage battery unit at the front)
Sensor at the output (return) of the high voltage battery unit at the rear	SMES2 control unit (in the high voltage battery unit at the rear)

Chiller unit

The function of the chiller unit is to cool the coolant in the cooling circuit of the high voltage battery using refrigerant. For this reason, it comprises a coolant/refrigerant heat exchanger and a combined expansion and shutoff valve (in the refrigerant circuit). The combined expansion and shutoff valve is activated via direct wiring by the SME control unit. The electrical activation knows two states: A control voltage of 0 V means that the valve remains closed. A control voltage of 12 V opens the valve. As known in conventional expansion valves in air-conditioning units, this expansion and shutoff valve also automatically controls its opening depending on the coolant temperature.

If the combined expansion and shutoff valve is open, refrigerant can flow into the heat exchanger. It expands in the process, then evaporates and thus extracts heat energy from its surrounding area. This effect is fully utilized to cool the coolant flowing in the second circuit of the heat exchanger. This active principle is known from the cooling system of the high voltage battery in the E72 (BMW active hybrid X6).

The installation location of the chiller unit is also similar to that in the E72: It is located in the undercarriage, near the side sill on the left.



Installation location of the chiller unit

Index	Explanation
1	Refrigerant line from the chiller unit to the electric coolant compressor (intake pipe)
2	Refrigerant line to the chiller unit from the shutoff valve in the passenger compartment (pressure line)
3	Solenoid for activating the valve
4	Combined expansion and shutoff valve
5	Electrical connection of the solenoid
6	Carrier plate
7	Coolant line from the chiller unit to the changeover valve (return line)
8	Coolant line from the coolant pump to the chiller unit (feed line)

Cooling system

The mixture of water and antifreeze (blue/green fluid, BMW part #9 407 454) is used as a coolant.

The connections for coolant lines at the high voltage battery units are snap fasteners with the known VDA couplings.

⚠

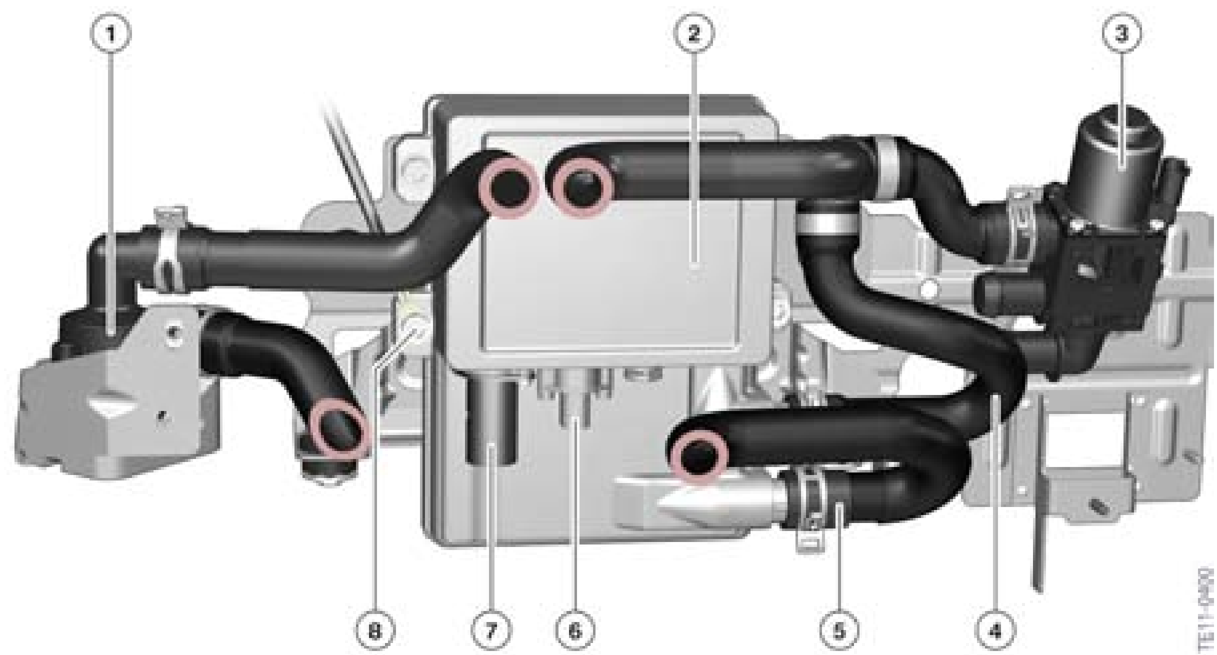
Dummy plugs must be fitted when removing coolant lines from a high voltage battery unit. This prevents coolant leaking from the high voltage battery units.

Refrigerant circuit

The refrigerant circuit for cooling the passenger compartment has been expanded in the E82E with a parallel connected branch. The chiller unit is located in this branch in order to extract heat energy from the coolant for cooling the high voltage battery. The refrigerant circuit with its components and operating fluids is described in detail in the section entitled "Climate control".

Changeover valve

The changeover valve is fitted in the space below the hood on the same bracket as the electric heater and near the right frame rail support.



Installation location of the changeover valve

Index	Explanation
1	Electric coolant pump (20 W)
2	Electric heating unit
3	Changeover valve
4	Connection for coolant return line
5	Connection for coolant supply line
6	Signal connector (low-voltage connector)
7	High voltage connector
8	Ground connection

Using the changeover valve the coolant is fed into the branch required for the respective operating condition. In the operating conditions "Circulation" and "Cooling" the changeover valve is switched so that the coolant flows through the chiller unit. The changeover valve is de-energized in this position. However, If the changeover valve is energized the branch through the chiller unit is blocked and the coolant flows through the electric heating unit instead in order to heat the high voltage battery (operating condition "Heating").

The activation of the changeover valve is effected by the junction box electronics. A hard-wired line between the two components enables this. The junction box electronics receives this request from the SME control unit, which controls the heating/cooling system for the high voltage battery centrally.

Electric heating

The electric heating is used not only for heating the passenger compartment. It also enables heating of the high voltage battery at extremely low ambient temperatures in order to guarantee complete performance of the electric motor. The request whether a heater output is required, and if yes which heater output, is transferred by the SME control unit via data bus telegrams to the IHKA control unit. The IHKA control unit coordinates this heat request with the request for the passenger compartment and controls the electric heating unit via a LIN-bus. As the electric heating unit is a high voltage consumer, the high voltage power management in the EDME control unit performs an inspection and only releases the electric power required for heating when it is also currently available.

The electric heating unit is installed in the space below the hood, mounted on the right side frame rail. A graphic in the previous chapter on the changeover valve shows the installation location. The structure and operating principle of the electric heating are described in detail in the section entitled "Climate control".

3.7. Functions

The primary control unit for the control of the high voltage system is the Electrical Digital Motor Electronics (EDME).

⚠

In the E82E the central functions of the high voltage system are controlled and coordinated by the Electrical Digital Motor Electronics (EDME). This is different to the BMW active hybrid vehicles E72 and F04, in which the power electronics (hybrid controller processor or electrical machine electronics) assume this primary role.

3. High Voltage Battery

As the high voltage battery and the SME control units are very important for the central functions of the high voltage system, they are described in this chapter. These are:

- Starting
- Regular shutdown
- Quick shutdown
- Battery management
- Charging the high voltage battery
- Monitoring functions.

3.7.1. Starting

The sequence for starting the high voltage system is always the same regardless of which of the following events triggered the start-up:

- Terminal 15 is switched on or readiness to travel is established
- Charging the high voltage battery should start
- "Preparation" of the vehicle for the journey (climate control of the high voltage battery or the passenger compartment).

The individual steps for starting the high voltage system are:

1. EDME control unit requests start-up via data bus telegram at the PT CAN2
2. The high voltage electrical system is checked by the self-diagnosis functions
3. The voltage in the high voltage circuit is continuously increased
4. The contacts of the switch contactors are fully closed.

The high voltage electrical system is checked mainly by the EME control unit and the SME control units. Here safety criteria such as the circuit of the high voltage interlock loop or the insulation resistance for example are checked. But functional preconditions such as the operating readiness of all subsystems must also be satisfied for start-up.

Because the high voltage circuit has capacitors with high capacity values (link capacitors in the power electronics), the contacts of the electromechanical switch contactors cannot all be closed at the same time. Extremely high current pulses would damage both the high voltage battery, as well as the link capacitors and the contacts of the switch contactors. To restrict the switch-on current and continuously increase the voltage, all contacts of the switch contactors are therefore closed one after the other except the switch contactor at the positive terminal in the high voltage battery unit in the transmission tunnel. There is a switchable current path with a resistor in parallel to the aforementioned contact. This is now activated and a switch-on current restricted by the resistor charges the link capacitors. If the voltage of the link capacitors has roughly reached the value of the battery voltage, the last contact of the switch contactor at the positive terminal of the high voltage battery in the transmission tunnel is closed. The high voltage system is now fully ready for operation.

The consecutive closing of the switch contactors during start-up is audible in the vehicle and does not indicate a malfunction.

If there is no fault in the high voltage system, the complete start-up of the high voltage system is completed in approx. 0.5 seconds. There is no resulting disadvantage for the customer compared to vehicles with a conventional powertrain.

The SME primary control unit communicates the successful start-up as a data bus telegram via the PT CAN2 to the EDME control unit. Fault statuses are communicated in the same way if for example a contact of a switch contactor was not able to be closed.

3.7.2. Regular shutdown

During shutdown of the high voltage system a differentiation is made between regular shutdown and quick shutdown. Regular shutdown, as described here, protects all relevant components on the one hand, and includes monitoring of safety components of the high voltage system on the other.

If the following preconditions or criteria are present, the high voltage system undergoes a regular shutdown:

- Terminal 15 is switched off by the driver and the after-running period has lapsed (controlled by EDME)
- End of the functions "parked car air-conditioning" and "conditioning of high voltage battery"
- End of the charging procedure of the high voltage battery.

The sequence for regular shutdown, regardless of the triggered event, is principally the same in the following individual steps:

1. EDME orders the shutdown via data bus telegrams at the PT CAN2 once the after-running period has lapsed
2. The systems at the high voltage electrical system (EME, KLE, EKK, EH) reduce the currents in the high voltage electrical system to zero
3. Opening of the switch contactors in the three high voltage battery units (controlled by SME, SMES1, SMES2)
4. Discharging of the high voltage circuit, i.e. active discharging of the link capacitor (EME and KLE), short-circuit of the windings of the electrical machine (EME), short-circuit of the windings of the electric AC compressor (EKK)
5. Check of the high voltage system, e.g. whether the contacts of the electromechanical switch contactors have been opened properly.

Both the after-running period after the switching-off of terminal 15, as well as the shutdown itself, can take a few minutes. The automatic monitoring functions, for example, are a reason for this. Regular shutdown is aborted if either a request for a re-start is received in the meantime or a precondition which demands a quick shutdown occurs.

3.7.3. Quick shutdown

The top priority here is to shut down the high voltage system as quickly as possible. This quick shutdown is always performed when the voltage in the high voltage system has to be reduced to a safe level as quickly as possible for safety reasons. The following list describes the triggering preconditions, as well as the functional chain, which lead to the quick shutdown.

- Accident: Multiple restraint system (MRS) detects an accident. Depending on the severity of the accident, the shutdown is requested via data bus telegrams or is forced by the disconnection of the safety battery terminal from the positive terminal of the 12 V battery. In the second case the voltage supply of the electromechanical switch contactors is automatically interrupted and their contacts thus open automatically.
- Overload current monitoring: Using the current sensors in each high voltage battery unit the current level in the high voltage electrical system is monitored. If too high a current level is detected, the SME control units arrange a hard opening of the electromechanical switch contactors. Heavy wear to the contacts of the switch contactors occurs as a result of this type of opening under a high current, but must be accepted to avoid damaging other components.
- Protection in the event of a short circuit: An overcurrent (over load) fuse is located in each high voltage battery, which interrupts the high voltage circuit in the event of a short circuit.
- Critical cell state: If cell monitoring electronics detect extreme undervoltage, overvoltage or excess temperature of a battery cell, this also leads to a hard opening of the electromechanical switch contactors, which are controlled by the SME control units. Although this may lead again to increased wear at the contacts, this quick shutdown is necessary in order to prevent destruction of the respective battery cells.
- Failure of the 12 V voltage supply of a high voltage battery unit: In this case the relevant SME control unit no longer works and monitoring of the battery cells is no longer possible. For this reason the contacts of the electromechanical switch contactors also open automatically here.

In addition to the open circuit of the high voltage circuit, the link capacitors are also discharged (EME, KLE) and the windings of the electrical machines (EME, EKK) short-circuited. The high voltage control units receive this request through data bus telegrams on the one hand, and detect this state on the other via the sudden drop in the current level in the high voltage circuit.

3.7.4. Charging

When charging the high voltage battery with energy from an external AC power supply the SME control unit also plays an important role. Using the state of charge and the temperature of the battery cells the SME control unit determines the maximum electrical power which the high voltage battery can currently absorb. This value is transferred in the form of a data bus telegram via the PT CAN2 to the EDME control unit. The function "high voltage power management" coordinates the individual power requirements and forwards the overall value to the electrical machine electronics (and from there to the comfort charge electronics).

During charging the SME control unit constantly calculates the state of charge already reached and monitors all sensor signals of the high voltage battery. In order to guarantee an optimal charging procedure, the SME control unit also constantly calculates current values for the maximum charge power based on these values and communicates same to the EDME control unit. The heating/cooling system of the high voltage battery is also continuously controlled by the SME control unit during the charging procedure, which contributes to a quick and efficient charging procedure.

Further details on the charging procedure, in particular the supply of power from the AC power network to the comfort charge electronics, are described in the section entitled "Power electronics".

3.7.5. Monitoring functions

- **12 V supply voltage from the safety battery terminal**
  In order to be able to quickly shut down the high voltage system in the event of an accident of relevant severity, the solenoids of all electromechanical switch contactors are supplied with 12 V from the safety battery terminal. If the safety battery terminal is blown off in the case of an accident, this cuts the voltage supply and the contacts of the switch contactors open automatically.
  In addition, the SME primary control unit electronically evaluates the voltage on this line and also initiates the shutdown of the high voltage system including the discharging of the link capacitors and the active short circuit of the electrical machine.
- **High voltage interlock loop**
  All SME control units (SME, SMES1 and SMES2) evaluate the signal of the high voltage interlock loop and check whether there is an open circuit on this circuit. In the event of an open circuit, each SME control unit can initiate a quick shutdown of the high voltage system.
- **Contacts of the switch contactors**
  After the SME control units have requested the opening of the contacts of the switch contactors during shutdown of the high voltage system, a check is carried out to see whether they have also actually opened using voltage measurement parallel to the contacts. In the highly unlikely event that the contact of a switch contactor has not opened, there is still no direct risk to the customer or Service employee. However, for safety reasons a re-start of the high voltage system is prevented. Continuation of the journey is then no longer possible.
- **Pre-charge circuit**
  If for example a fault is identified in the pre-charge circuit during start-up of the high voltage system, the start-up is immediately aborted and the high voltage system is not operated.
- **Excess temperature**
  The cooling system of the high voltage battery ensures in all driving situations that the temperatures of the battery cells are in their optimal range. If due to a fault the temperature of one or several battery cells increases so much that the optimal range is exceeded, then the power is reduced initially to protect the battery cells. If the temperature continues to increase and there is a risk of damage to the battery cells as a result, then the high voltage system is shut down in a timely manner.
- **Undervoltage**
  Undervoltage of a battery cell is avoided through constant monitoring and the adjustment of the cell voltage if required. The total voltage of all high voltage batteries is also monitored and used to determine the state of charge. If the total voltage lowers to the extent that the high voltage battery is completely empty further discharge is prevented. Continuation of the journey is then no longer possible.
- **Isolation monitoring**
  There are circuits in all three high voltage battery units to measure the insulation resistance in the high voltage circuit. The SME primary control unit evaluates the results of these measurements. If one of the measurement circuits detects the insulation resistance has fallen below a specified threshold value, then this leads to a fault entry and a Check Control message.
  As no direct danger arises for the customer or the Service employee as a result of such an isolation fault, the high voltage system remains active and the customer can continue the journey. However, the high voltage system should be checked as soon as possible by BMW Service.

In order to identify the components in the high voltage system which have caused the isolation fault, the fault must be found by the Service Technician.

3.8. Service information

3.8.1. Safe work on the high voltage system

⚠

Before working on high voltage components of the E82 E, the electrical safety rules must be followed and implemented:

1 **De-energize —** the high voltage system

2 **Secure —** the high voltage system against restart

3 **Verify —** there is NO voltage present in the high voltage system.

A brief description on how the electrical safety rules are to be implemented in the E82E is provided in the following chapters.

Preparation

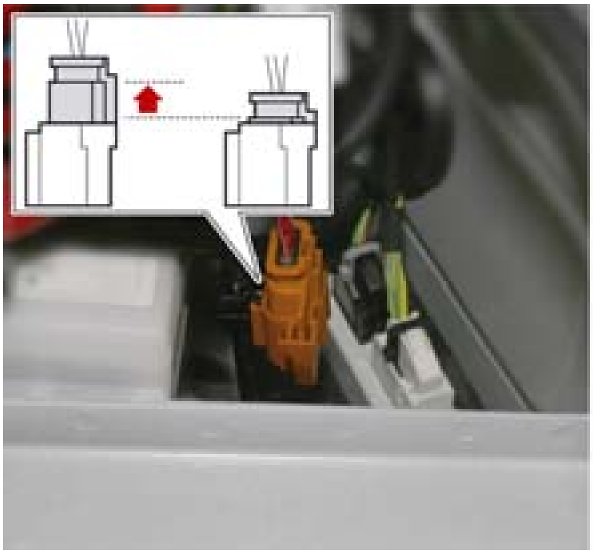
Before beginning work the vehicle must be secured against rolling (engage parking lock of the transmission and apply parking brake). Terminal 15 and terminal R must be switched off. Any connected charging cable must be disconnected.

De-energizing the high voltage system

The high voltage system in the E82E is de-energized using the high voltage safety connector. The connector must be removed from the respective plug to interrupt the high voltage interlock loop circuit and thus de-energize the high voltage system.

This image shows the high voltage safety connector in the connected state. The circuit of the high voltage interlock loop is complete.

In order to disconnect the plug from the connector, the mechanical locking tab shown in the image is released.



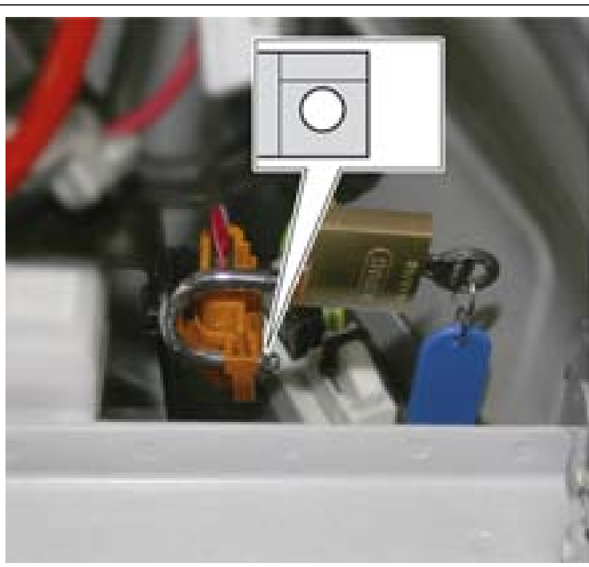
As soon as the locking tab has been released, the plug can be pulled a few millimeters out of the connector.

⚠

As soon as resistance is felt, do not pull any further or stronger! The plug and the connector of the high voltage safety connector are designed as a single component and cannot be completely disconnected from each other.

Securing the high voltage system against restart

Securing against restart is also done at the high voltage safety connector. A typical pad lock is required for this purpose.



Disconnecting the plug and connector of the high voltage safety connector reveals an opening which goes through the two parts.
The loop of a typical pad lock must be inserted in this hole.

The pad lock can now be closed.
The key must be stored in a safe place while working on the high voltage system so that no unauthorized person can unlock and remove the lock.
The high voltage safety connector can no longer be connected as long as the pad lock remains in place. This effectively prevents the high voltage system being switched on again without knowledge and approval of the Service Technician.

Verifying de-energization

De-energization is not verified in the BMW Dealer Service workshop using testing equipment or the ISTA ActiveE diagnosis system. Instead the high voltage components measure the voltage themselves and transfer the measuring result via a bus signal to the instrument panel.

Only when the instrument panel has received information from all relevant high voltage components on the de-energization state does it generate the Check Control message to display de-energization. This orange Check Control symbol shows a line through a lightning bolt symbol.

Check Control symbol "De-energized high voltage system"

To verify de-energization the Service Technician must switch on terminal 15 and wait until he sees the Check Control message with the symbol above in the instrument panel. Then and only then is it guaranteed that the high voltage system is de-energized. After verification of the de-energized state terminal 15 and terminal R must be switched off again before actual work is started.

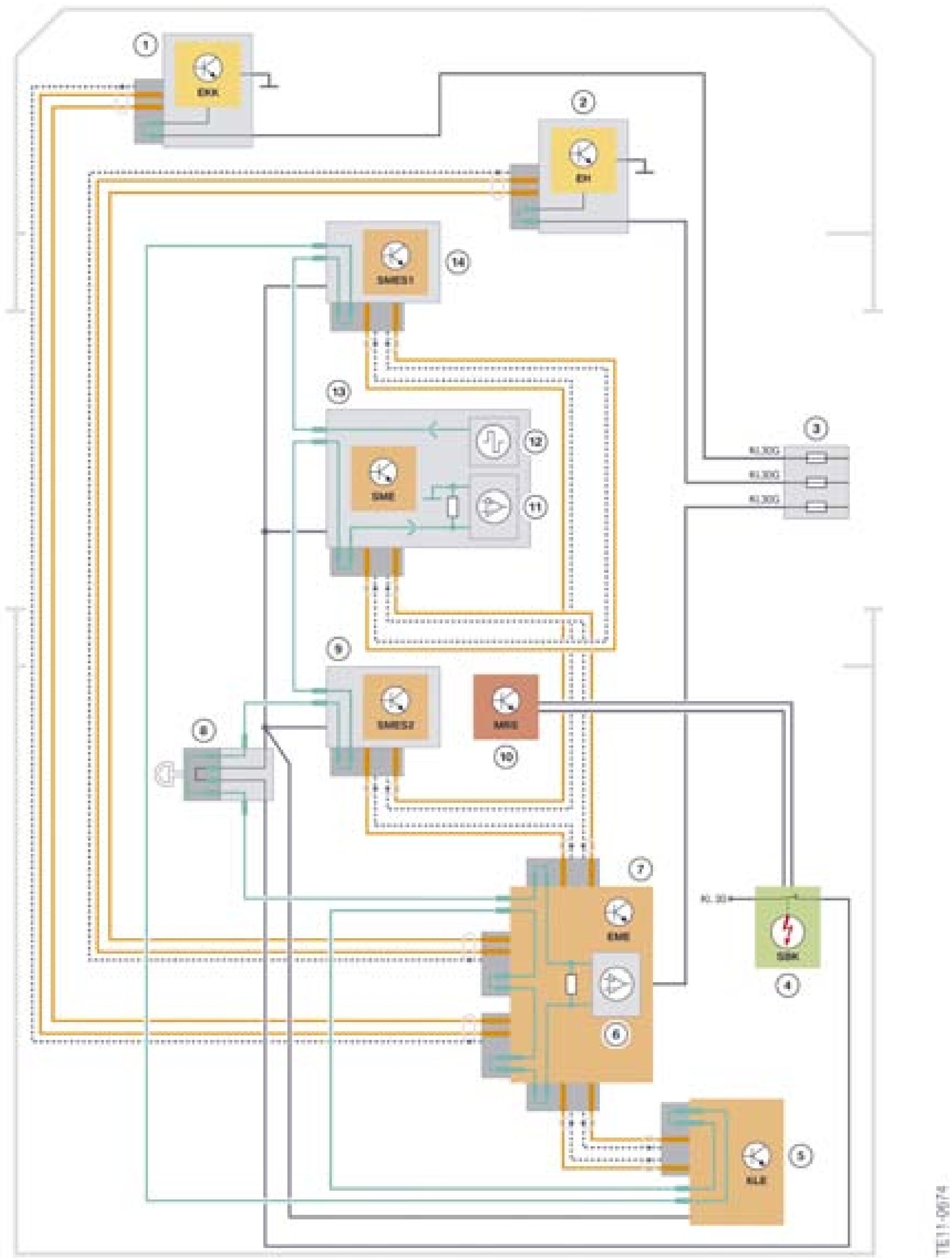
⚠

Note: If the Check Control message is not shown no work can be performed on the high voltage components!

3.8.2. High-voltage interlock loop

The conceptual current-flow diagram provided below identifies the control unit in which the test signal for high-voltage interlock loop is generated (signal source) as well as the control units in which the test signal is processed.

3. High Voltage Battery



Conceptual current-flow diagram for the high-voltage contact interlock loop

Index	Explanation
1	Electric a/c refrigerant compressor (EKK)
2	Electric heating (EH)
3	Front safety support
4	Safety battery terminal
5	Convenient-charging electronics (KLE)
6	Processing circuitry for the test signal from the high-voltage contact interlock loop in the electric motor's electronic control circuits
7	Electric motor-generator electronic control system (EME)
8	High-voltage safety plug (“Service Disconnect”)
9	Battery management electronics Slave 2 SMES2 (rear high-voltage battery unit)
10	Multiple-element restraint system
11	Processing circuitry for the test signal from the high-voltage contact interlock loop in the electric motor's electronic battery management
12	Signal generator for the test signal from the high-voltage contact interlock loop in the electric motor's electronic battery management
13	Electronic battery management circuitry master SME (high-voltage battery unit on transmission tunnel)
14	Electronic battery management slave 1 SMES1 (front high-voltage battery unit)

3.8.3. Detecting of isolation faults

The SME control units reliably detect drops in insulation resistance to below the specified levels within the high-voltage electrical system. A DTC entry in the error memory, a Check Control message, and (if required) deactivation of the high-voltage system are all automatically executed. However, the isolation monitoring cannot define the precise location of the malfunction within the high-voltage electrical system. Systematic testing is imperative in the quest to identify the components or high-voltage cables at which the isolation malfunction is originating.

3.8.4. Removal and installation

Removal and installation of the high-voltage battery units are reserved for the BMW Service Hub according to the service concept applicable in the individual market. Respond to any uncertainties by contacting the supervisor responsible for the market or getting in touch with Technical Support. Regardless of which venue assumes responsibility, a universal stipulation remains that the staff and employees assigned to perform these operations will require specialized training.

⚠

The high voltage battery must not be removed and installed in the BMW Dealer Service workshop. This work is reserved for experts in the BMW Service Hub.

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4. Power Electronics

The high voltage electrical system of the E82E contains two power electronics components:

- The electrical machine electronics (EME) required to activate the electrical machine
- The comfort charge electronics (KLE) which play a decisive role in charging the high voltage battery.

Note: For more information regarding the components required to charge the E82E and the AC power network please refer to the “General information on Charging” chapter. Details on connecting and removing the high voltage cable are provided in the chapter "Electrical machine electronics" > Connections > High voltage connections".

4.1. Electrical machine electronics (EME)

4.1.1. Introduction

The electrical machine electronics (EME) serve mainly as control electronics for the electrical machine which drives the E82E. The EME assumes the job of converting the DC voltage from the high voltage battery (up to 400 V DC) into a three-phase AC voltage (up to 360 V AC) for activating the electrical machine as a motor. The opposite applies when the electrical machine is to be operated as an generator. The electrical machine electronics converts the three-phase AC voltage of the electrical machine into DC voltage to then charge the high voltage battery (this occurs during brake energy regeneration). A bi-directional DC/AC converter is necessary for these two operating modes, which can work as both an inverter and a rectifier.

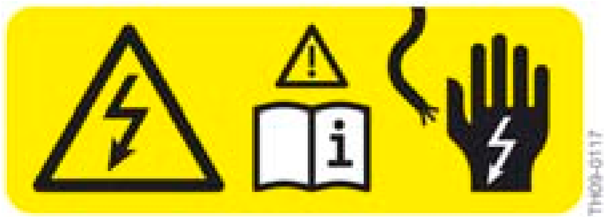
The voltage supply of the 12 V vehicle electrical system is supplied via the DC/DC converter which is also integrated in the electrical machine electronics. In addition, the electrical machine electronics also contains the EME control unit.

All of the electronic circuitry controlling the electric machine on the E82E is enclosed within an aluminum housing. The control unit, the DC/AC converter and the DC/DC converter are housed here.

Note: The housing of the electrical machine electronics may not be opened in the BMW Dealer Service workshop.

The electrical machine electronics of the E82E have been developed and supplied by BMW AG and are manufactured in the Dingolfing plant.

The electrical machine electronics (EME) is high voltage component!



Warning sticker for the high voltage component

A label is attached to the housing of each high voltage component which alerts the Service Technician as well as every other vehicle user to the possible risks associated with the use of high electrical voltage.

⚠

Only certified Service Technicians who satisfy all prerequisites may perform work on the high voltage components. Service Technician must comply with all the safety rules and always follow the proper procedure outlined in the BMW repair instructions.

4.1.2. Installation location

The electrical machine electronics (EME) is installed in the rear of the E82E, in an area separated from the luggage compartment by a cover with an access opening.

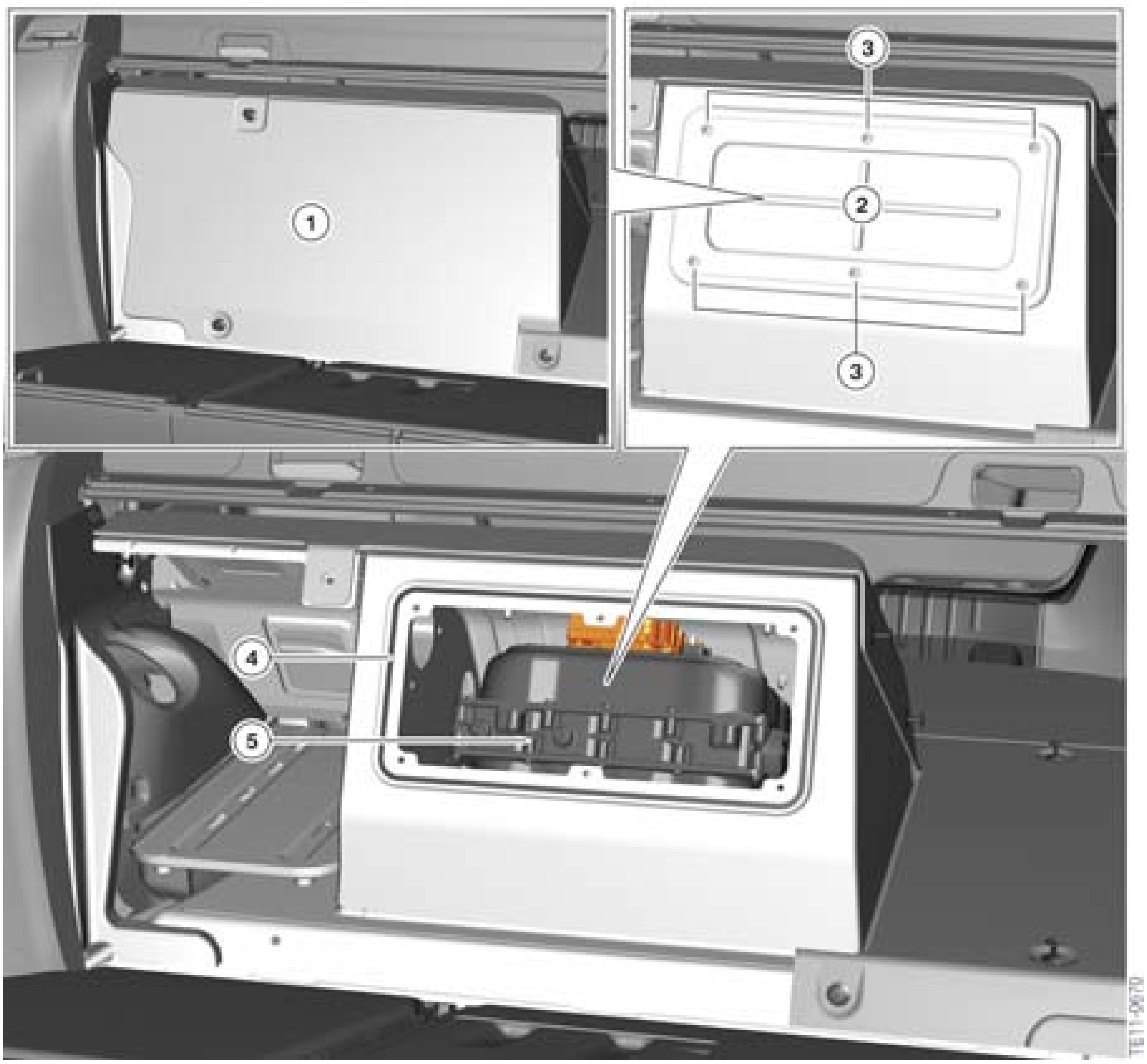
Access to the electrical machine electronics from the luggage compartment

Index	Explanation
1	Luggage compartment trim panel
2	Cover
3	Mounting bolts of the cover
4	Sealant bead
5	Electrical machine electronics

E82E Complete Vehicle
4. Power Electronics

To access the connections of the electrical machine electronics, the part of the luggage compartment covering (shown in the graphic) must first be removed. Then the cover must also be removed, whereby an opening for Service is created. The cover is secured to the body by a screws and also sealed with a bead of sealant.

There is also a second access to the electrical machine electronics behind the rear seats. When the rear seats are folded down a metal panel and the access cover can be removed. This access cover is also secured with screws and sealed. One can reach some connections of the electrical machine electronics via this opening.



Access to the electrical machine electronics from the passenger compartment

Index	Explanation
1	Cover
2	Cover
3	Mounting bolts of the Cover
4	Sealant bead
5	Electrical machine electronics

The access described here is not large enough for the removal and installation of the electrical machine electronics. Instead the complete rear axle, together with the drive unit (including the transmission, electrical machine and electrical machine electronics), must be removed.

Note: The electrical machine electronics (EME) must not be replaced in the BMW Dealer Service workshop.

⚠

In the BMW Dealer Service workshop it is only permitted to replace the **electrical machine and electrical machine electronics as one unit.** Therefore the rear axle along with the drive unit must be removed from the vehicle beforehand .

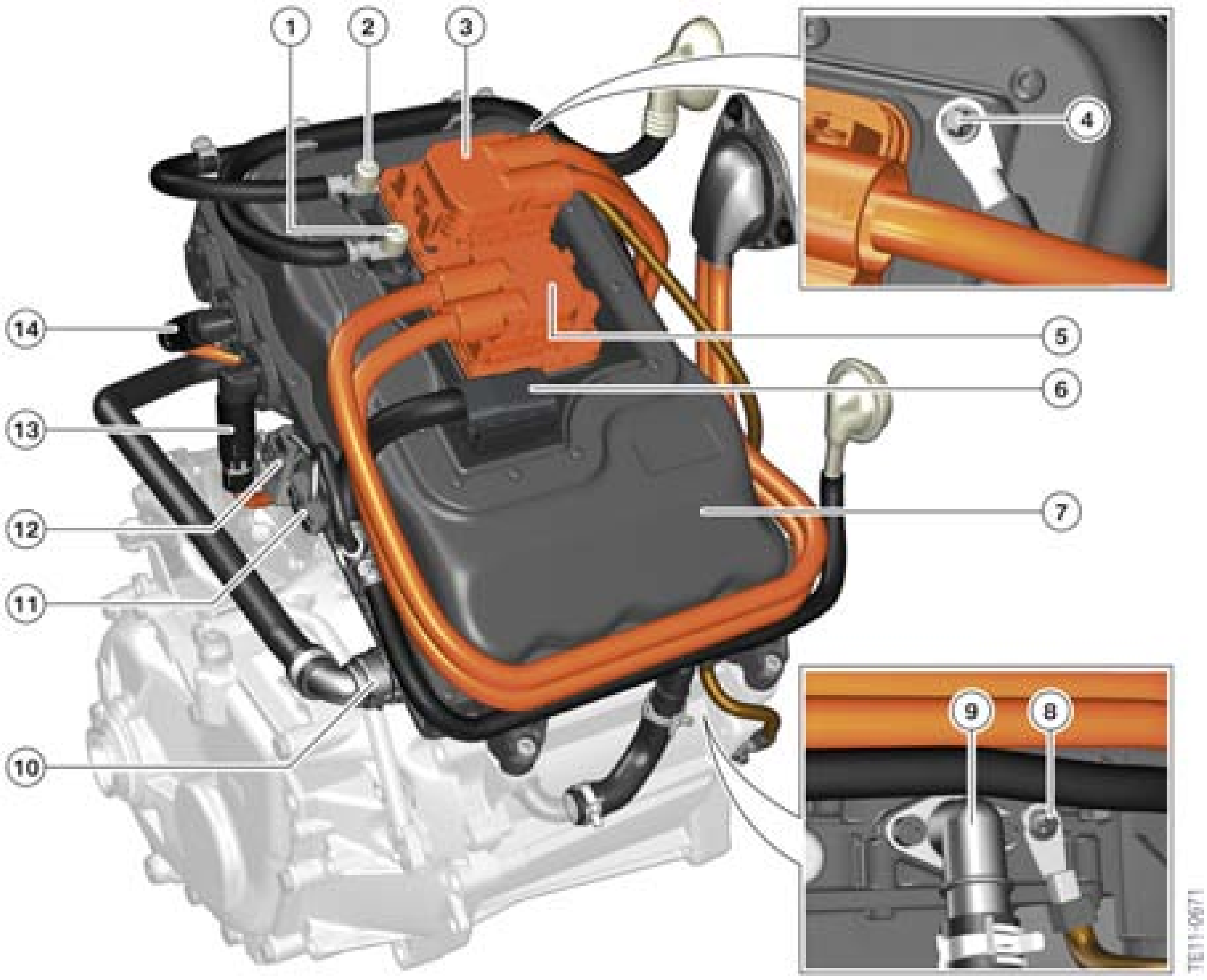
4.1.3. Connections

The connections at the electrical machine electronics can be divided into four categories:

- Low-voltage connections
- High voltage connections
- Connections for potential compensation lines
- Connections for coolant lines.

The following graphics show all connections for the electrical machine electronics. The individual categories are discussed in the following chapters.

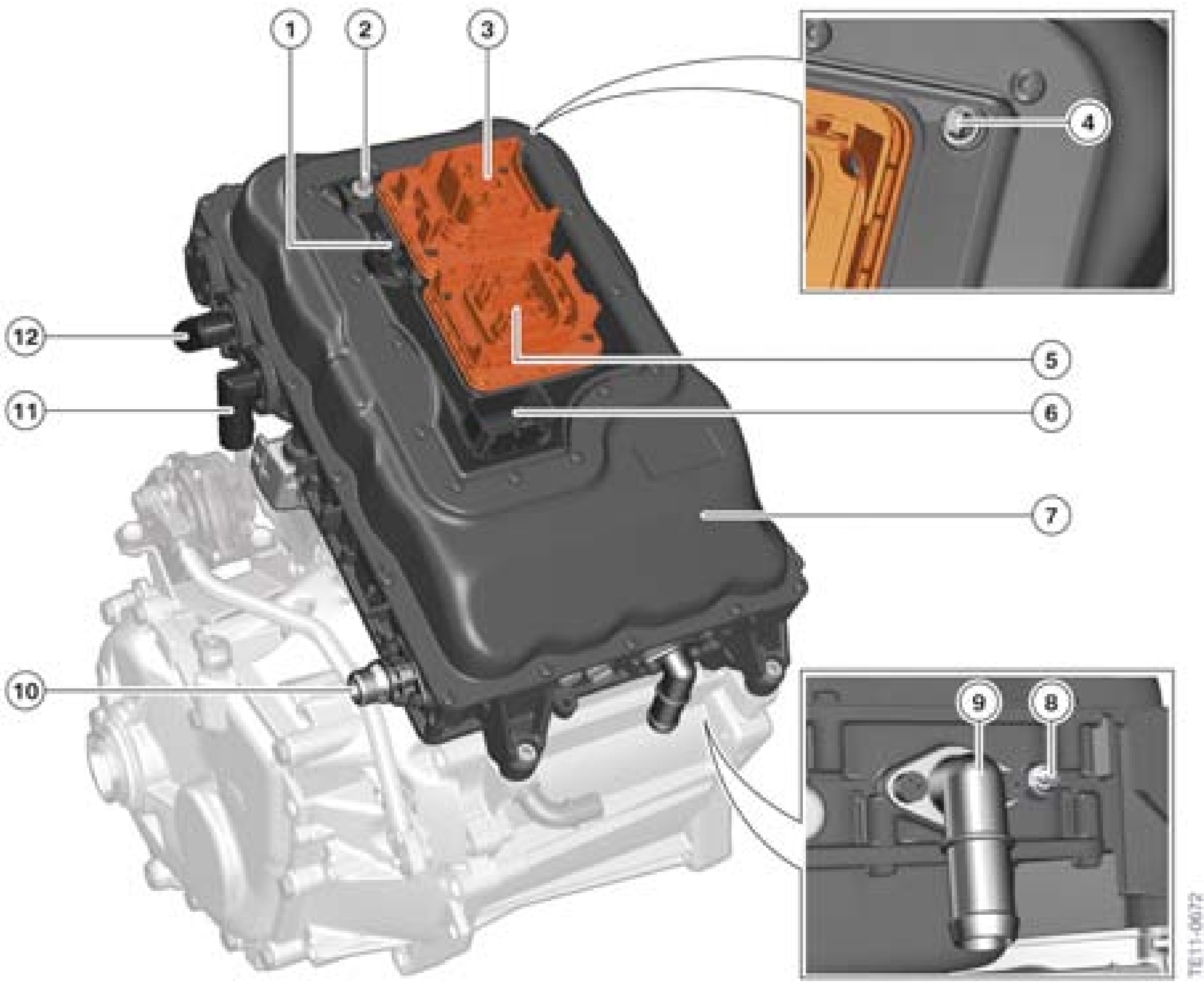
4. Power Electronics



Connections for the electrical machine electronics with lines

Index	Explanation
1	Output for DC/DC converter +12 V
2	Output for DC/DC converter, ground
3	High voltage cable (DC) to the high voltage battery
4	Potential compensation line
5	High voltage cable (DC) to the comfort charge electronics (KLE)
6	Low-voltage connector
7	Housing of the electrical machine electronics
8	Potential compensation line
9	Coolant line (return for electrical machine electronics, to the electrical machine)
10	Coolant line (supply for electrical machine electronics)

Index	Explanation
11	Signal lines from/to parking lock actuator
12	Voltage supply of the electric motor in the parking lock actuator
13	High voltage cable to the electric heating unit
14	High voltage cable to the electric A/C compressor



Connections for the electrical machine electronics without lines

Index	Explanation
1	Output for DC/DC converter +12 V
2	Output for DC/DC converter, ground
3	High voltage cable (DC) to the high voltage battery
4	Potential compensation line
5	High voltage cable (DC) to the comfort charge electronics (KLE)
6	Low-voltage connector

Index	Explanation
7	Housing of the electrical machine electronics
8	Potential compensation line
9	Coolant line (return for electrical machine electronics, to the electrical machine)
10	Coolant line (supply for electrical machine electronics)
11	High voltage cable to the electric heating unit
12	High voltage cable to the electric A/C compressor

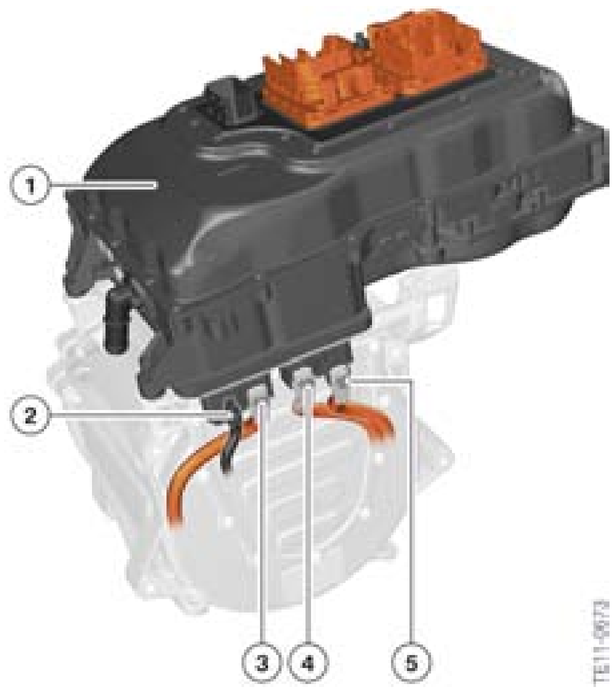
Low-voltage connections

The following lines and signals are integrated in the multi-pin low-voltage connector in the electrical machine electronics which is visible from the outside:

- Voltage supply for the EME control unit (terminal 30g from the power distribution box at front and ground)
- Terminal 30 of the safety battery terminal (can be evaluated by the EME control unit to detect an accident)
- Bus system PT CAN2 (a terminating resistor of 120 Ω is located in the EME control unit for the PT CAN2)
- Wake-up line
- Control line to the comfort charge electronics to enable the charging procedure
- Input and output of the circuit of the high voltage interlock loop (EME control unit evaluates the signal and initiates a shutdown of the high voltage system in the event of an open circuit of the circuit)
- Electromechanical parking lock: Voltage supply and signal of the path sensors, voltage supply of the solenoid and the electric motor
- Brake vacuum sensor (supply and evaluation of a pressure-dependent resistor)
- Voltage supply of the electrical vacuum pump.

All these wires and signals have low current levels. The electrical machine electronics is connected to the 12 V vehicle electrical system (terminal 30 and 31) via two separate low voltage connections and large gauge wires. The DC/DC converter in the electrical machine electronics supplies the entire 12 V vehicle electrical system with energy via this connection. The contact of these two wires with the electrical machine electronics is a bolted connection.

The connections of the electrical machine electronics to the electrical machine are not visible from the outside. They are located under a cover on the right side of the electrical machine.



Electrical connection of the electrical machine electronics to the electrical machine

Index	Explanation
1	Electrical machine electronics
2	Low-voltage connector
3	Screw connection for high voltage connection, stator winding 1
4	Screw connection for high voltage connection, stator winding 2
5	Screw connection for high voltage connection, stator winding 3

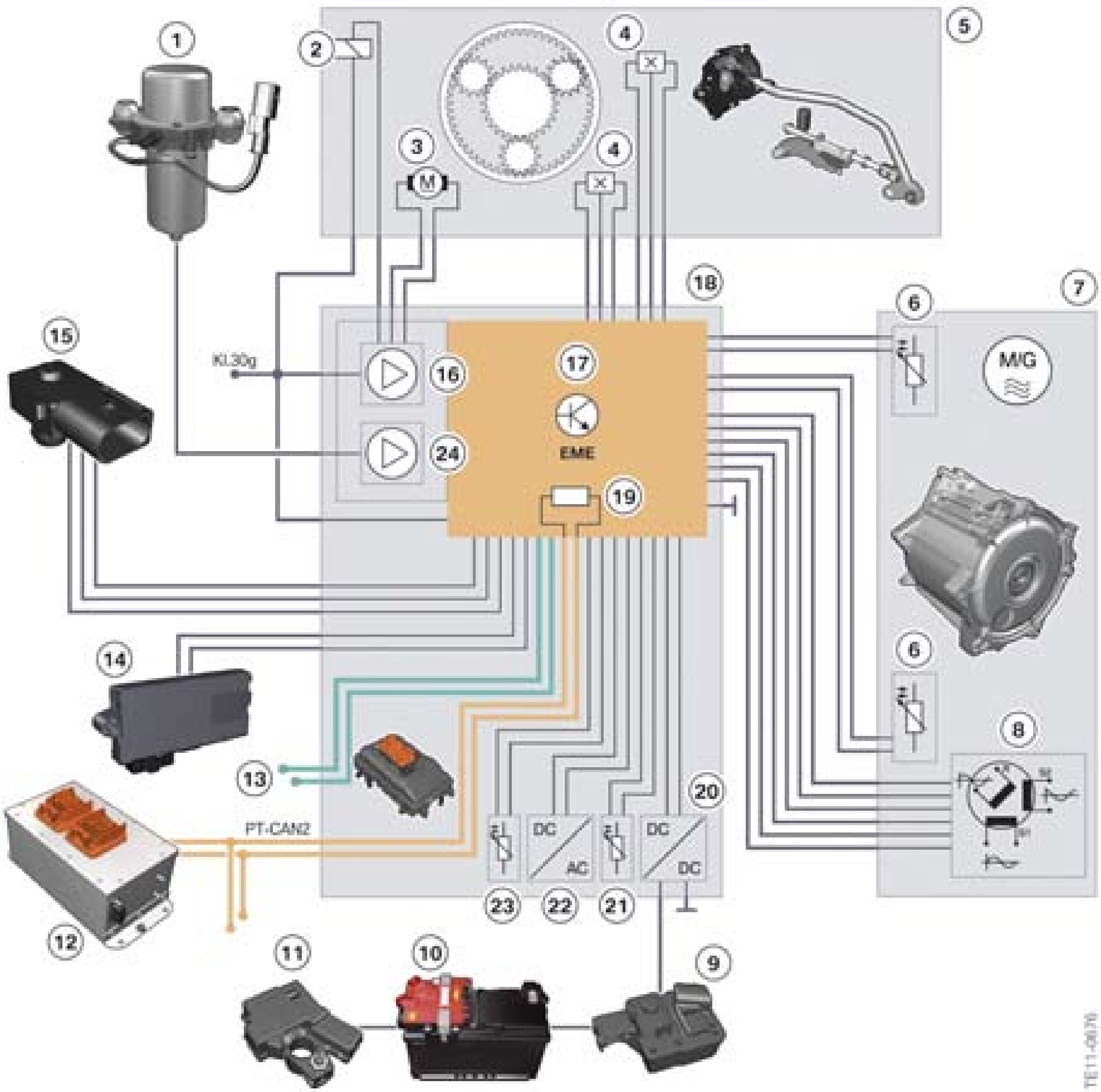
⚠

The cover on the electrical machine must not be opened in the BMW dealer Service workshop. The electrical (and mechanical) connection between the electrical machine electronics and electrical machine cannot be separated.

The high voltage connections for the supply of the stator windings and a connector via which the following signals are transmitted are located under the cover:

- Rotor position sensor of the electrical machine (supply and sensor signals)
- Signals of both temperature sensors in the electrical machine.

The following schematic diagram outlines the low voltage connections of the electrical machine electronics (in a simplified wiring diagram).



Low-voltage connections of the electrical machine electronics

Index	Explanation
1	Electric vacuum pump
2	Solenoid
3	Electric motor
4	Path sensors (Hall-effect sensors)
5	Parking lock actuator
6	Temperature sensor (NTC resistor)
7	Electrical machine (complete unit)

Index	Explanation
8	Rotor position sensor
9	Safety battery terminal
10	12 V battery
11	Intelligent battery sensor (IBS)
12	Comfort charge electronics (KLE)
13	Signal lines of the high voltage interlock loop
14	Car Access System (CAS)
15	Brake vacuum pressure sensor
16	Output stage for activating the parking lock actuator
17	EME control unit
18	Electrical machine electronics (EME) (complete unit)
19	Terminating resistor
20	DC/DC converter
21	Temperature sensor (NTC resistor) at the DC/DC converter
22	Bi-directional DC/AC converter
23	Temperature sensor (NTC resistor) at the DC/AC converter
24	Output stage for activating the electric vaccum pump

High voltage connection

There is a total of five high voltage connections on the electrical machine electronics to contact the lines to other high voltage components.

1 Connection to electrical machine:
3-phase AC voltage, 1 shield for all three cables, busbars (screwed on), the cover on the electrical machine serves as contact protection

2 Connection to the high-voltage battery:
2-pin, DC voltage, 1 shield on each cable, flat high-voltage plug with mechanical locking mechanism, contact protection provided by the covers above the contact prongs and a bridge circuit from the high-voltage contact interlock loop

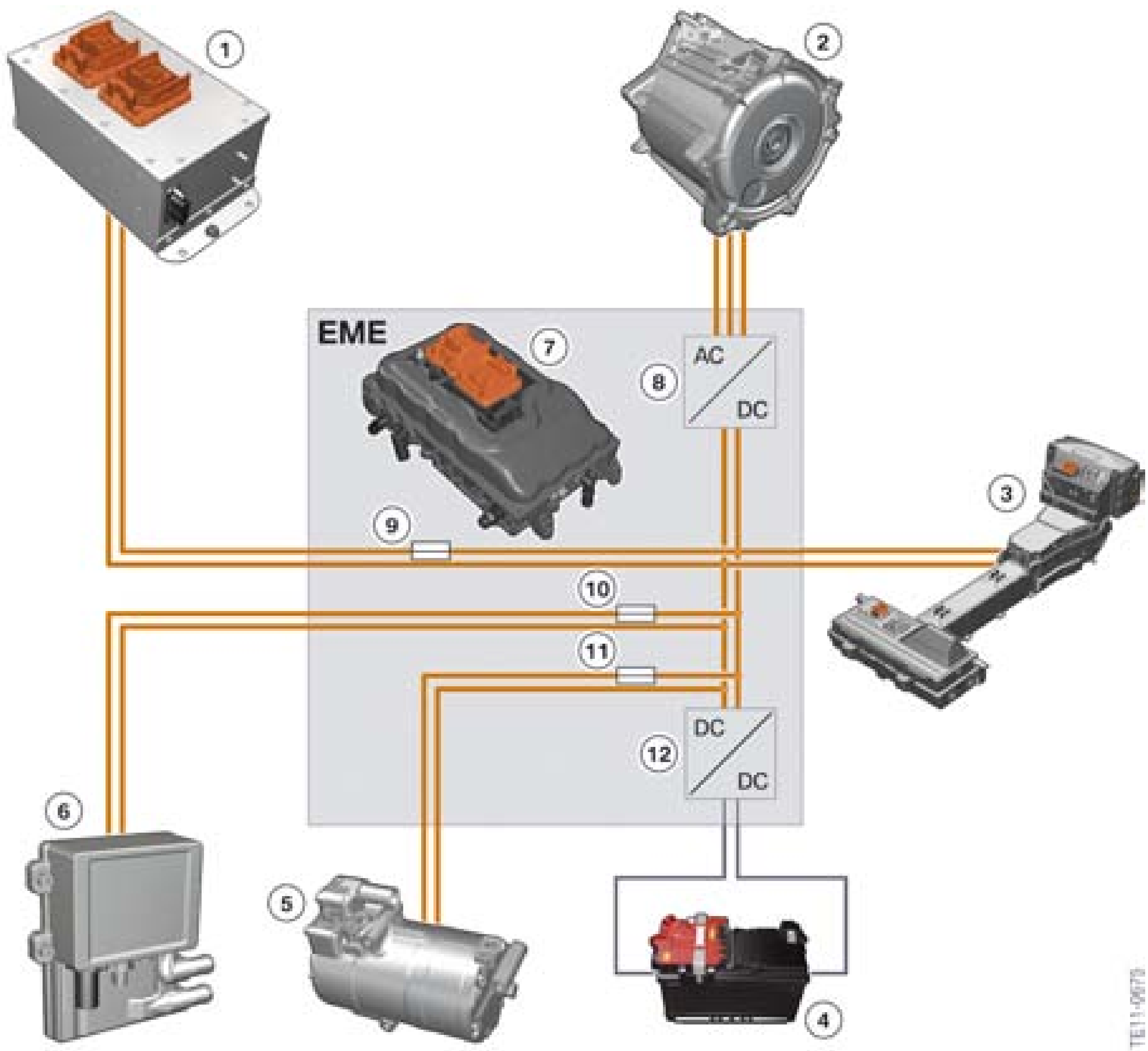
3 Connection to comfort charge electronics:
2-pin, DC voltage, 1 shield on each cable, flat high-voltage plug with mechanical lock, contact protection provided by the covers on the contact prongs as a bridge circuit from the high-voltage contact interlock loop

4 Connection to electric a/c compressor:
2-pin, DC voltage, 1 shield for both cables, round high-voltage plug with mechanical lock, contact protection from the covers above the contact prongs and through interruption of the power-supply voltage for the EKK control unit

5 Connection to electric heater:

2-pin, DC voltage, 1 shield for both cables, round high-voltage plug with mechanical lock, contact protection from the covers above the contact prongs and through interruption of the power-supply voltage for the EH control unit

The following simplified wiring diagram shows the high voltage connections between the electrical machine electronics and the other high voltage components.



High voltage connections of the electrical machine electronics

Index	Explanation
1	Comfort charge electronics (KLE)
2	Electric machine
3	High-voltage battery
4	12 V battery
5	Electric A/C refrigerant compressor

Index	Explanation
6	Electric heating unit
7	Electric motor electronics (complete unit)
8	Bi-directional DC/AC converter in the electrical machine electronics
9	Overcurrent fuse in the cable to the comfort charge electronics (current rating 150 A)
10	Overcurrent fuse in the supply line to the electric heating (current rating 40 amps)
11	Overcurrent fuse in the supply cable to the electric A/C compressor (current rating 40 A)
12	DC/DC converter in the electrical machine electronics

A certain sequence must be precisely followed during removal or attachment of the flat high voltage connectors and round high voltage connectors. The individual steps are described below.

⚠

Before any work is performed on the high voltage system, the electric safety rules must be observed, this also applies before removing the high voltage connectors:

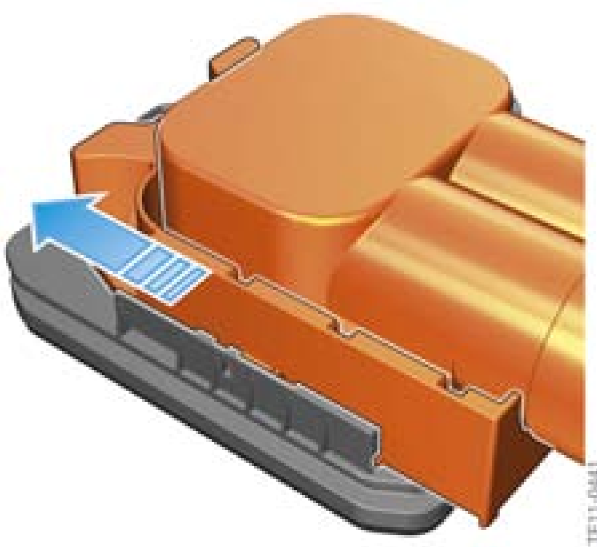
1 **De-energizing** the high voltage system
2 **Secure** the high voltage system against restart
3 **Verify** there is NO voltage present in the high voltage system.

The application of the electric safety rules in the E82E is described in the "high voltage battery" section in the chapter entitled "Service information".

Removal of the flat high voltage connector

This procedure applies not only to the high voltage connector at the electrical machine electronics, but also to the high voltage connectors at the comfort charge electronics and at the high voltage battery units.

Bridge of the high voltage interlock loop
Before the high voltage connector can be removed, the bridge of the high voltage interlock loop must first be removed. The bridge closes the circuit of the high voltage interlock loop when connected. The high voltage control units permanently monitor the circuit of the high voltage interlock loop and the high voltage system is only active when the circuit is closed.
If the circuit of the high voltage interlock loop is interrupted during removal of the bridge, the high voltage system automatically shuts down. This represents an additional safety precaution as the Service Technician has already placed the high voltage system in a de-energized state before starting the work.



Removing the mechanical lock
After the high voltage interlock loop bridge has been removed move the mechanical lock in the direction of the arrow. The mechanical lock is integrated into the high voltage connectors of the high voltage components (e.g. electrical machine electronics).
By moving the connector lock in the direction of the arrow the mechanical guide of the high voltage connector/cable is released, which allows its removal.

Removing the high voltage cable connector
The high voltage cable connector must now be removed in the direction of the arrow. After the connector has been removed a few millimeters (A), a counter force is felt. The connector must then be pulled further in the same direction (B). Note: In no circumstances can the connector plug be pushed back onto the connector of the high voltage component after reaching position (A). This could result in damage to the high voltage component connector.

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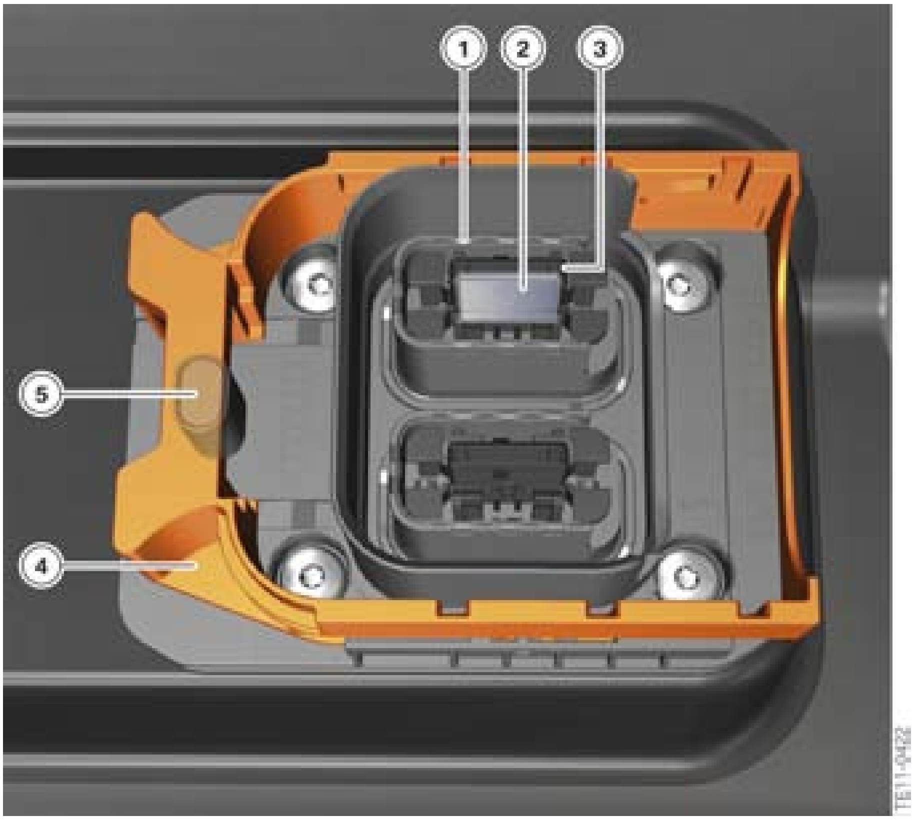
The high voltage cables connectors must be removed in a horizontal direction in two steps. A change of the direction during removal is not permitted and will result in damage to the HV component connection.

When re-attaching the high voltage cable proceed in reverse order. The following graphic shows the complex structure of the high voltage connector on the high voltage component and clarifies why one must proceed carefully when removing and attaching the high voltage cables.

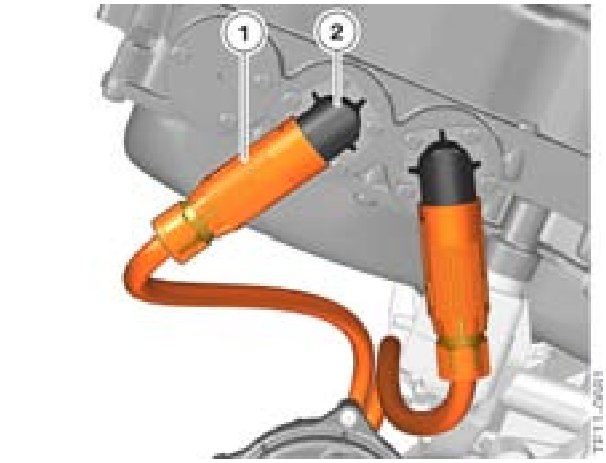


High voltage connector of high voltage component

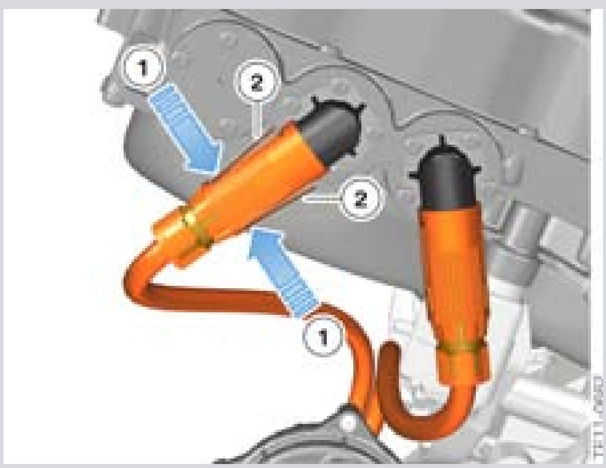
Index	Explanation
1	Electrical contact for shielding
2	Electrical contact for high voltage cable
3	Shock protection
4	Mechanical lock
5	Plug connection for bridge of the high voltage interlock loop circuit

Removal of the round high voltage connector

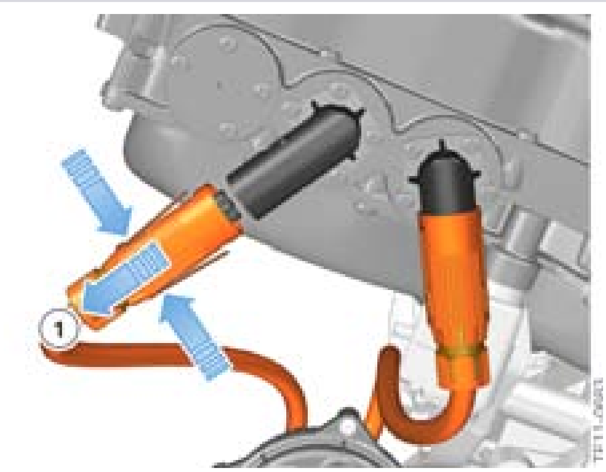
The procedure described here applies to the high voltage connector at the electrical machine electronics, the electric A/C compressor and the electric heating unit. The following images show the procedure using the example of the high voltage electric heating unit connection at the electrical machine electronics.



The connector of the high voltage cable (1) is located at the high voltage connection of the component (2) and is locked.



The two locking tabs (2) must be pressed together in the direction of the arrow (1). The mechanical lock of the connector is thus released.



While the locking tabs continue to be pressed together, the connector must be pulled out in the direction of the arrow (1).

When re-connecting the high voltage cable the locking tabs must not be pressed together. Instead just push the connector onto the high voltage connection of the component. A “Click” sound ensures that the locking tabs have engaged. In addition, the locking tab engagement should be checked by lightly pulling on the connector.

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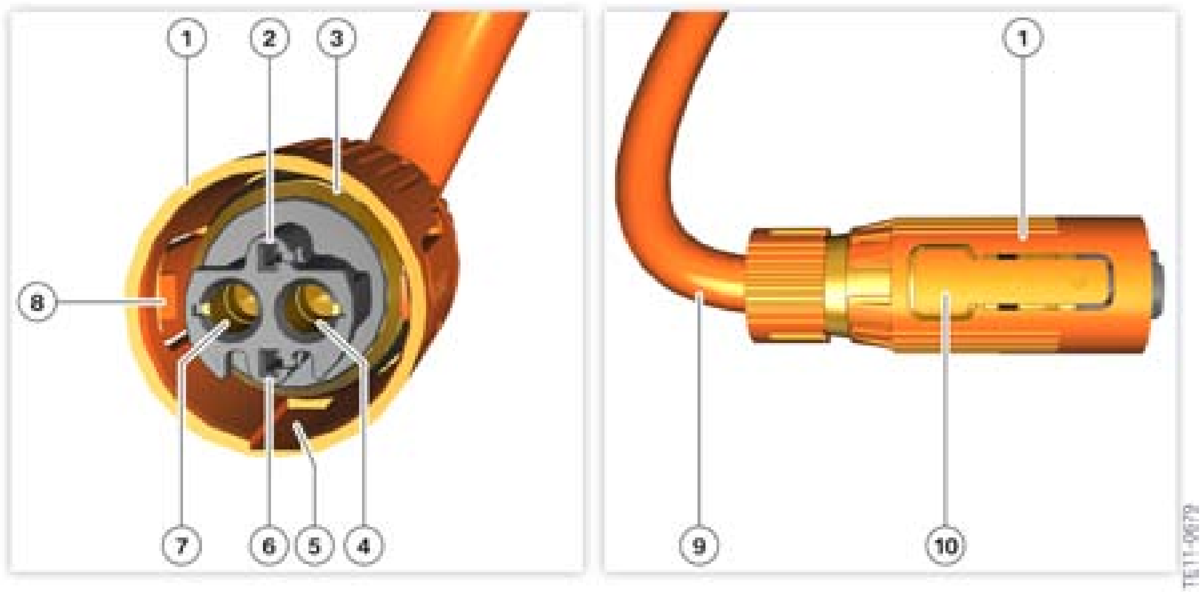
The following graphic shows the structure of the round high voltage connector on the high voltage cable.



Structure of the round high voltage connector at the EME

Index	Explanation
1	Housing
2	Connection 1 for bridge in the connector
3	Connection for shielding
4	High voltage connection pin 2 (DC, minus)
5	Mechanical encoding
6	Connection 2 for bridge in the connector
7	High voltage connection pin 1 (DC, plus)
8	Locking tab
9	High voltage cable
10	Actuation points of locking tabs

The bridge/jumper in the high voltage connector is for electrical safety. The signal of the high voltage interlock loop runs via this bridge if the high voltage cable is connected to the electrical machine electronics. If one of these circuits is interrupted the current flow in the respective high voltage cable automatically drops to zero. As the two contacts of the bridge (2, 6) are located opposite the high voltage contacts, this measure offers protection against electric arching when removing the high voltage connector.

However, there is no high voltage interlock loop integrated into the HV line connections at the EKK nor at the EH, just at the EME connector. For the high voltage cable connection at the electric A/C compressor and the electric heating unit the 12 V supply (of both control unit) runs via the bridge within the high voltage connector. If one of these circuits is interrupted (e.g. as the component is being disconnected) the 12 V supply (for the integrated control unit) will be disconnected first and thus the load on the HV circuit will drop before the HV line is disconnected. Although the HV power supply should be disconnected before we start work on the HV system this measure offers added protection against electric arching when removing the high voltage connector.

Connections for potential compensation lines

To ensure galvanic separation (isolation) from the 12V system the safety concept of the high voltage system includes the measurement and monitoring of the insulation resistance of the high voltage cables to each other and to ground. This safety function is performed in the E82E by the control units in the high voltage battery units (SME, SMES1, SMES2). It is designed to detect isolation faults in the entire high voltage circuit. Therefore it is necessary that the housing of all high voltage components are galvanically connected to the ground.

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Note: The high voltage system must not be operated if the ground wires/straps (for potential compensation) are not connected properly to the high voltage components.

To guarantee the galvanic connection with ground the drive unit has two (potential compensation) ground straps. One is located at the rear of the drive unit and connects the housing of the electrical machine and the electrical machine electronics. The second is located at the right side of the electrical machine electronics and connects the housing of the electrical machine electronics to the vehicle body ground. The ground straps are attached to the housing and/or the body via bolted connections.

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If the high voltage components or the body component need to be replaced in the event of repair, then proceed as follows for the assembly: The galvanic connection between the housing and the body must be reestablished properly. The repair instructions must be followed precisely with regard to the ground straps tightening torque and self-tapping screws.

Connections for coolant lines

The electrical machine electronics (EME) is integrated in the cooling circuit of the electric motor. This cooling circuit is described in detail in the chapter entitled "Electric motor > Electrical machine > Cooling".

On the left side of the electrical machine electronics there is a connection for the coolant input (supply), which is connected via a quick-release coupling to the coolant line. The coolant line branches out from the radiator: One branch flows into the electrical machine electronics, the other into the comfort charge electronics. The coolant output (return) of the electrical machine electronics is located at the rear of the drive unit. A short hose sends the coolant from the electrical machine electronics to the electrical machine. This coolant hose is fixed to the connections of the electrical machine electronics and the electrical machine using clamps.

4.1.4. Structure and functions

The internal structure of the electrical machine electronics incorporates three subcomponents: The bidirectional DC/AC converter, the DC/DC converter and the EME control unit. The link capacitor is also part of the power electronics circuits. It is used to equalize the voltage and filter high-frequency. However reverse polarity protection is not integrated in the electrical machine electronics of the E82E. Reverse polarity protection is done by a totally separate component. For more information see section entitled "12 V voltage supply".

The subcomponents of the EME perform the following functions:

- Control of the internal subcomponents by the EME control unit
- Supply of the 12 V vehicle electrical system via the DC/DC converter
- Control of the electrical machine (speed, torque) using the DC/AC converter
- Contact of the electrical machine via busbars
- Contact of the high voltage battery
- Contact of the comfort charge electronics
- Contact of the electric A/C compressor
- Contact of the electric heating unit
- Communication with other control units, in particular the EDME
- Cooling of the electrical machine electronics
- Activation of the electromechanical parking lock
- Activation of the vacuum pump
- Active and passive discharging of the link capacitors to voltages below 60 V
- Active evaluation of the signal for the high voltage interlock loop (high voltage interlock)
- Self-test and diagnostic functions.

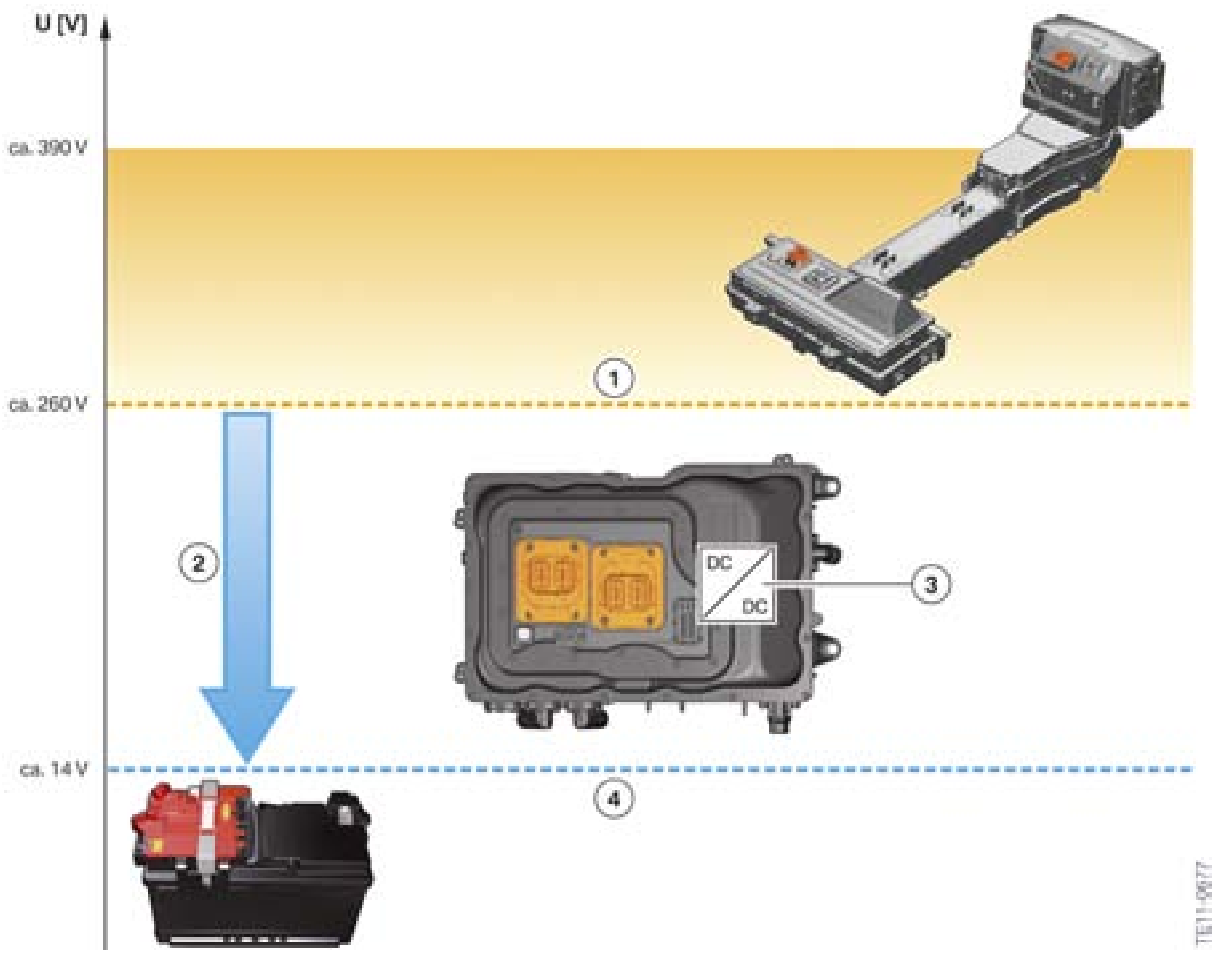
DC/DC converter

The DC/DC converter in the electrical machine electronics of the E82E must be able to perform the following operating modes:

- Standby (also in the event of component faults or short circuit, power electronics failure)
- Downward conversion (“Buck mode,” energy flows to the low-voltage 12 V side. The converter controls the voltage on the low-voltage side)
- Upward conversion (“Boost mode,” energy flows to the high-voltage side, only potential function at this stage)
- Discharge of the high voltage DC link. (interlock fault, accident, request from the primary control unit)

The DC/DC converter is in "Standby" operating mode if the electrical machine electronics is not operating. This is the case if the EME control unit has not been supplied with voltage for example due to the state of the terminal. But also when there is a fault the EME control unit decides that the DC/DC converter assumes the operating mode "Standby". In this operating mode there is no energy transfer between the two vehicle electrical systems and they remain galvanically disconnected.

The "downward conversion" or "Buck" mode is the standard operating mode for use when the high-voltage system is active. The DC/DC converter then transfers the electrical energy from the high-voltage electrical system to the 12 V vehicle electrical system and assumes the function of the alternator in a conventional vehicle. For this the DC/DC converter must lower the variable voltage from the high-voltage electrical system to the voltage in the low-voltage electrical system. The charge status of the high-voltage battery (roughly 260 V to 390 V) is among the factors determining the voltage in the high-voltage electrical system. The DC/DC converter regulates the voltage in the low-voltage electrical system for ideal charging of the 12 V battery while also dialing in a voltage of about 14 V, with precise figures varying according to charge status and battery temperature. The EME control unit thus communicates with the EDME control unit, in which the power management functions are performed. The set-point value specification for the voltage is obtained from this, which the DC/DC converter should adjust in the low-voltage electrical system. The maximum power rating of the DC/DC converter in continuous operation is 2500 W.



Operating principle of the DC/DC converter

Index	Explanation
1	Voltage level of the high voltage electrical system, from 260 V to about 390 V
2	Buck mode
3	DC/DC converter in the electrical machine electronics
4	Voltage level of the low-voltage electrical system, about 14 V

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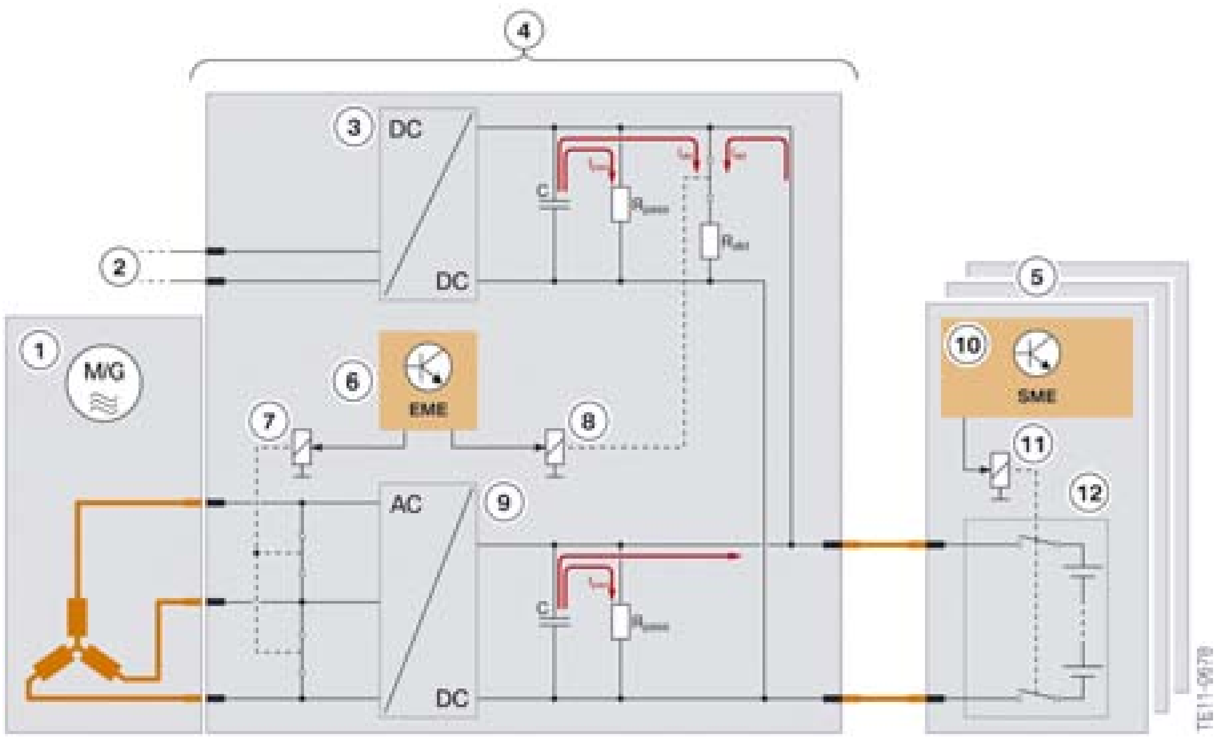
In contrast with the "Boost mode" of the DC/DC converter used in the F04 (which charges the HV battery via the 12 V system) and although the same technology is used, this operating mode is not implemented in the E82E . **Charging of the high voltage battery of the E82E is not possible using energy from the 12 V vehicle electrical system.**

The last operating mode of the DC/DC converter is thus assumed for the (regular or quick) shutdown of the high-voltage system. For the shutdown of the high-voltage system the system must discharge to a safe voltage of less than 60 V within a specified period. The high-voltage power management system in the EDME control unit responds to this requirement by requesting active discharge. For this purpose the EME and the SME incorporate a discharge circuit for the DC link capacitors. A switch contact connects a low-resistance resistor R_{akt} in parallel to allow a higher discharge current I_{akt} to flow. This arrangement discharges the high-voltage electrical system/the DC link capacitors in less than 5 sec. In the interests of safety a permanent passive discharge resistor R_{pass} is also connected in parallel. This passive discharge resistor has a higher rating than the active discharge resistor. Should a malfunction prevent the active discharge system from operating, the passive discharge resistor will still allow reliable discharge of the high-voltage electrical system. The period required to discharge down to a voltage below 60 V is then longer, and can extend to a maximum of 120 sec.



Discharge of the high voltage DC link

Index	Explanation
1	Electrical machine
2	Connection to the 12 V vehicle electrical system
3	DC/DC converter in the electrical machine electronics
4	Electrical machine electronics (complete unit)
5	High voltage battery units

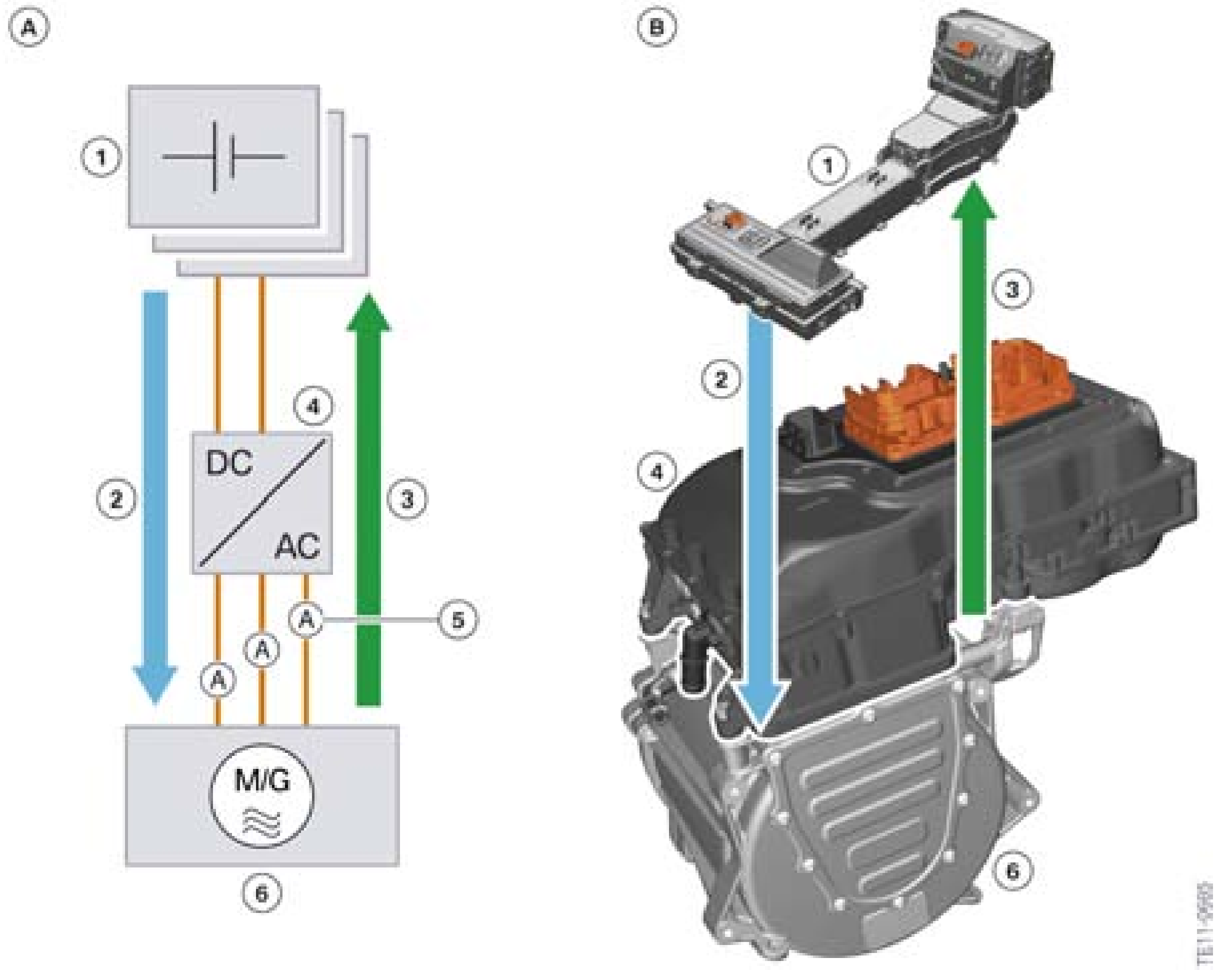
Index	Explanation
6	EME control unit
7	Relay for short-circuit of the windings of the electrical machine
8	Relay for the active discharge of the capacitors
9	Bi-directional DC/AC converter in the electrical machine electronics
10	SME control unit
11	Electromechanical switch contactor in the high voltage battery units
12	High voltage battery
C	Link capacitors
R_{pass}	Passive discharge resistance
R_{act}	Active discharge resistance

The illustration highlights the relays (7 and 8) to show the concept for discharging the DC link capacitors and shorting the windings in the electric motor-generator. In actual fact, transistors are installed to serve as switching elements in the place of relays.

The temperature of the DC/DC converter is measured using a temperature sensor and monitored by the EME control unit. If the temperature exceeds the permissible range despite cooling with coolant, the EME control unit reduces the power of the DC/DC converter to protect the components.

Power electronics for activating the electrical machine

The power electronics for activating the electrical machine is comprised of mainly the bi-directional DC/AC converter. This is a pulse converter, or inverter, with a 2-pin DC voltage connection and a 3-phase AC voltage connection. This DC/AC converter functions as an inverter and sends the electrical energy from the high voltage battery to the electrical machine when it works as a motor. It also functions as a rectifier and transfers electrical energy from the electrical machine to the high voltage battery. This operating mode is only active for brake energy regeneration where the electrical machine functions as an generator and "generates" electrical energy.



Operating modes of the bi-directional DC/AC converter

Index	Explanation
1	High voltage battery
2	Operating mode as an inverter - electrical machine works as a motor
3	Operating mode as a rectifier - electrical machine works as an alternator
4	DC/AC converter
5	Current sensors
6	Electrical machine

The operating mode of the DC/AC converter is determined by the EME control unit. For this the EME control unit receives an important input variable from the EDME control unit - the set-point value for what torque (amount) the electrical machine should deliver. The EME control unit determines the operating mode of the DC/AC converter, as well as the amplitude and frequency of the phase voltages for the electrical machine, from this set-point value and the current operating mode of the electrical machine (speed and torque). The power semiconductors of the DC/AC converter are activated in cycles in accordance with these specifications.

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4. Power Electronics

In addition to the DC/AC converter, the power electronics contains current sensors in all three phases on the AC voltage side of the DC/AC converter. Using the signals of the current sensors the EME control unit monitors the electrical line which is implemented in the power electronics and electrical machine and what torque the electrical machine generates. The control loop of the electrical machine electronics is closed by the signals of the current sensors and rotor position sensor in the electrical machine.

The electrical machine electronics circuitry can provide a continuous electric power output of 60 kW while also delivering a transient peak power of 125 kW.

In order to avoid overloading the power electronics, there is also an additional temperature sensor at the DC/AC converter. If a high temperature is detected at the power semiconductor using this signal, the EME control unit reduces the power supplied to the electrical machine to protect the power electronics. The customer is informed via a Check Control message of a significantly noticeable power reduction. The customer receives the same fault response (power reduction) and the same Check Control message if the temperature of the electrical machine falls below the permissible range.

Check Control symbol in the event of power reduction due to high temperature of the motor components

Voltage supply for additional high voltage consumers

The high voltage "Electric A/C compressor" and "electric heating unit" also receive their voltage supply from the electrical machine electronics.

The EME serves as a distributor of the high (DC) voltage, which is provided by the high voltage battery. In order to protect the high voltage cable of the EKK and the EH against overloading in the event of a short circuit, the electrical machine electronics contains a high voltage fuse for the electric A/C compressor and one for the electric heating unit. **Both high voltage fuses have a nominal current level of 40 A.**

The distribution and the electrical connection of the fuses have already been shown in graphics in the chapter entitled "high voltage connections".

Activation of the parking lock

The electromechanical parking lock of the E82E including its operating principle and activation are described in detail in the section entitled "Electric motor".

The electrical machine electronics contains the following components necessary for activation of the parking lock:

- Output stage for activating the electric motor of the parking lock actuator
- Current sensor for monitoring the electric motor
- Output stage for activating the solenoid
- Evaluation electronics for sensor signals.

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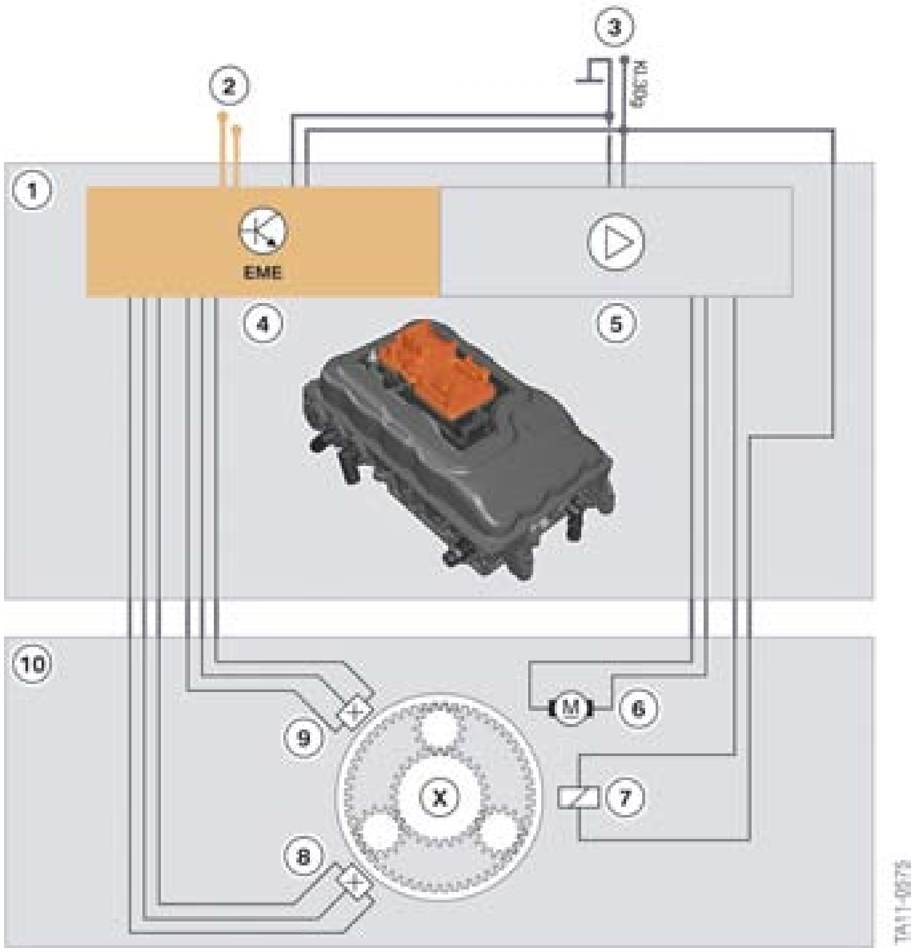
4. Power Electronics

The output stage for activation of the electric motor incorporates a bridge circuit made from power transistors. It is able to supply the electric motor with the necessary power of about 3 A to 4 A during operation, but also supply the high starting current of the electric motor of up to 10 A. The bridge circuit itself is designed in such a way that it cannot be damaged in the event of a short-circuit at the output (current limitation). In order to protect the electric motor and the line against overloading, the EME control unit monitors the current level of the output stage and also restricts it if required. For this purpose the output stage includes a current sensor whose signal is evaluated by the EME control unit.

The solenoid in the parking lock actuator must only be supplied with current if the parking lock actuator is to be electrically activated for diagnosis purposes without the parking lock mechanics being activated. A second reason for the current supply of the solenoid is if the outer lever on the parking lock sensor is to be manually operated. To operate the solenoid, the output stage of the electrical machine electronics contains an additional power transistor that connects the negative connection of the solenoid to ground while the positive connection of the solenoids is permanently connected to terminal 30 g.

The two redundant path sensors in the parking lock actuator are Hall-effect sensors. The EME control unit provides the voltage supply for the sensors. In addition, it reads the PWM signals from the path sensors, verifies them and evaluates them. The EME control unit determines the state of the parking lock (engaged/released) from the signals of the path sensors and makes the state available as a data bus signal. This is read in by the EDME control unit for example, where the transmission functions, e.g. engaging the drive positions, are calculated.

The following graphic, already familiar from the chapter "Electric drive > Transmission > Parking lock", shows the electrical interface between the parking lock actuator and the electrical machine electronics.



Electrical interfaces between the parking lock actuator and electrical machine electronics

Index	Explanation
1	Electrical machine electronics EME (complete unit)
2	PT CAN2 connection
3	Voltage supply
4	EME control unit
5	Output stage for the parking lock actuator
6	Electric motor
7	Solenoid
8	First path Hall sensor
9	Second path Hall sensor, operates in the opposite direction to the first
10	Parking lock actuator (complete unit)

Activation of the vacuum pump

The electrical machine electronics provides the hardware for the evaluation of the signals of the brake vacuum sensor and for activation of the vacuum pump. The logic function for activation of the vacuum pump is located in the DSC control unit. The EME and DSC control units exchange sensor signals and the switch-on request for the vacuum pump through data bus signals via the PT CAN and PT CAN2.

The brake vacuum sensor is installed at the housing of the brake booster and is the same one used in the conventional 1-Series with automatic engine start-stop function.

The sensor is supplied with voltage by the electrical machine electronics and sends back a voltage signal dependent on the vacuum in the brake booster. This same sensor signal is converted by the EME control unit to the actual brake vacuum and sent as a data bus signal to the DSC control unit.

The DSC control unit evaluates the brake vacuum signals which includes driving dynamic variables (.e.g. the vehicle speed) and the brake pedal operation and from this determines whether the vacuum pump should be switched on. The logic function in the DSC control unit also takes into consideration a hysteresis (extended operation) so that the vacuum pump is not constantly switched on and off. Instead it remains on (for an extended period) until a required minimum level of the brake vacuum is generated. The switch-on request for the vacuum pump is sent back by the DSC control unit as a data bus signal to the EME control unit.

The electrical machine electronics contains an output stage (semiconductor relay), that switches on and off the voltage supply of the vacuum pump. Upon request the output voltage of the DC/DC converter is connected directly to the vacuum pump. Switch-on currents of up to 30 A may occur at this component. To protect the output stage and the line the current level is restricted electronically. There is no power or speed control of the vacuum pump – instead it is only switched on or off.

4.2. Charging the HV battery

4.2.1. Introduction

"Charging" corresponds to "fueling" in conventional vehicles.

The following chapter will discuss the charging of the high voltage battery in the vehicle at standstill (not by brake energy regeneration) through supply of electrical energy, which is provided by an AC power network grid and fed to the vehicle via a charging cable.

A charging socket and power electronics are required in the vehicle for voltage conversion. In the E82E this power electronics is referred to as comfort charge electronics. In addition to the AC power grid and a charging cable, a device which performs the protective and control functions is also required outside the vehicle. This device is referred to as "Electric Vehicle Supply Equipment (EVSE)". The following table lists the components inside and outside the electric vehicle and compares them with those of a conventional vehicle.

Designation inside/outside the E82E	Designation inside/outside a conventional vehicle
High voltage battery	Fuel tank
Comfort charge electronics	-
Charging socket	Fuel filler neck

Designation inside/outside the E82E	Designation inside/outside a conventional vehicle
Vehicle connector at the charging cable	Fuel pump nozzle
Charging cable	Fuel line between fuel pump nozzle and gasoline pump
Electric Vehicle Supply Equipment	Fuel pump
AC power network	Filling station

The Electric Vehicle Supply Equipment can either be integrated in the charging cable or be an element of a fixed charging station (also called "wall box"). The EVSE establishes the connection to the AC power grid and satisfies the requirements for electrical safety when charging the vehicle. In addition, communication to the vehicle is done via the “pilot line”. This enables the safe start of the charging procedure and the exchange of the charging parameters (e.g. maximum current level) between the vehicle and EVSE. Details on the two versions, on the design and on the operating principle of the EVSE are described in one of the chapters to follow.

The voltage of the AC power grid can be between 110 V and 240 V. It is supplied to the vehicle via a single-phase load. With the AC power grid a maximum charging power of $P_{max} = U_{max} * I_{max} = 240 V * 32 A = 7.7 kW$ is theoretically possible.

Many of the above mentioned components for charging the E82E are standardized in terms of their design and functions. In European countries IEC 61851 is the applicable standard. The components for charging the E82E satisfy charge level 2 described here (connection to a standard household outlet with an additional pilot line) and charge level 3 (connection to a fixed wall box with a pilot line). The applicable standard on the American continent is SAE J1772. Charge level 1 and 2 described there are comparable with charge levels 2 and 3. Most components for charging the E82E satisfy both standards in their technical version. Only one country or standard specific version is required for Europe and America for the "Electric Vehicle Supply Equipment" component.

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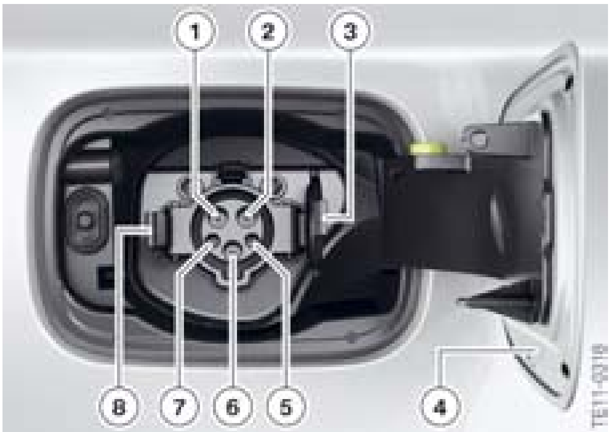
For Technicians in the BMW Dealer Service workshop the following important safety rules must be observed in relation to charging:

While the E82E is connected to the AC power grid for charging, no work can be performed on the high voltage system.

Work on the charging cable, Electric Vehicle Supply Equipment, household outlets or charging stations can only be performed by suitably qualified electricians and **not** by BMW Service Technicians/employees.

4.2.2. Vehicle charging socket

The E82E charging socket is located exactly where the fuel filler neck is located in a conventional E82. Just like in a conventional vehicle a flap/door must also be opened to gain access to the charging socket. The actual charging socket is additionally protected against moisture and dirt contamination by a cover. The charging socket thus satisfies the requirements of protection class IP5K5. The cover can be opened by pressing the release button. The state of the cover is not evaluated electronically. The flap, cover and connector assignment are shown in the following graphic.



Charging socket

Index	Explanation
1	Connection for neutral line N
2	Connection for phase L1
3	Cover
4	Flap
5	Connection for proximity line
6	Connection for grounding conductor (PE)
7	Connection for pilot line
8	Release button

The charging socket is connected to the comfort charge electronics in the vehicle. Phase L1 and neutral line N are also designed as shielded high voltage cables and end with a flat high voltage connector at the AC connection of the comfort charge electronics. The pilot line and the proximity line are realized as single signal lines. This signal line ends at a connector in the comfort charge electronics, which mechanically locks the AC connection at the comfort charge electronics. The grounding cable is connected to the body near the charging socket. The body of the vehicle and thus the ground of the high voltage connection are thus grounded.

The charge cable is mechanically locked on the charging connection of the E82E. The mechanical locking serves as protection against unintentional removal of the charging cable. To remove the charging cable the customer must actuate a mechanical release button at the connector of the charging cable. This also interrupts the proximity line and the charging process is immediately suspended.

4.2.3. Charging cable

The charging cable for the E82E is compatible with the charging socket at the vehicle and is always designed as a single-phase line (phase L1 and neutral line N). It also contains the grounding conductor PE and the pilot line. The body/ground is grounded using the grounding terminal.

The pilot line is used to detect the correct connection to the AC power grid so that the maximum available charge current level can be transmitted. An ohmic resistor is also switched in the connector of each charging cable between the proximity connection and the grounding terminal.

Using the pilot line a correct connection to the AC power grid can be detected and its maximum available charge current level transmitted. The plug on each charge cable also incorporates a circuit with two resistors and a switch contact (activated by the release button) between the proximity connection and the equipment grounding conductor. This proximity line circuit allows the vehicle's KLE to confirm that the charge cable is attached correctly. Here the KLE applies a measurement voltage and determine what value the resistor has in the proximity line. Depending upon the version of the charge cable and the applicable national standards the current capacity of the charge cable may be encoded with the resistance of the proximity wire and assessed by the KLE. When the charge cables are permanently attached to the charging station the maximum current is transmitted only through the signal on the pilot wire.

Despite these similarities with all charging cables there are two different versions which are associated directly with the Electric Vehicle Supply Equipment:

1 **Fixed version:**
The connection to the AC power grid is done via a fixed charging station (also called a wall box) which contains the Electric Vehicle Supply Equipment. The appropriate charging cable here is only the electrical connection between the charging station and the charging socket at the vehicle. It is important to note that in the US market this cable is integrated into the fixed charging station.

2 **Mobile version:**
The connection to the AC power grid is done via a typical household charging socket, which naturally contains no Electric Vehicle Supply Equipment. In this case the With “Occasional use” charging cable contains the circuits and functions of the Electric Vehicle Supply Equipment.

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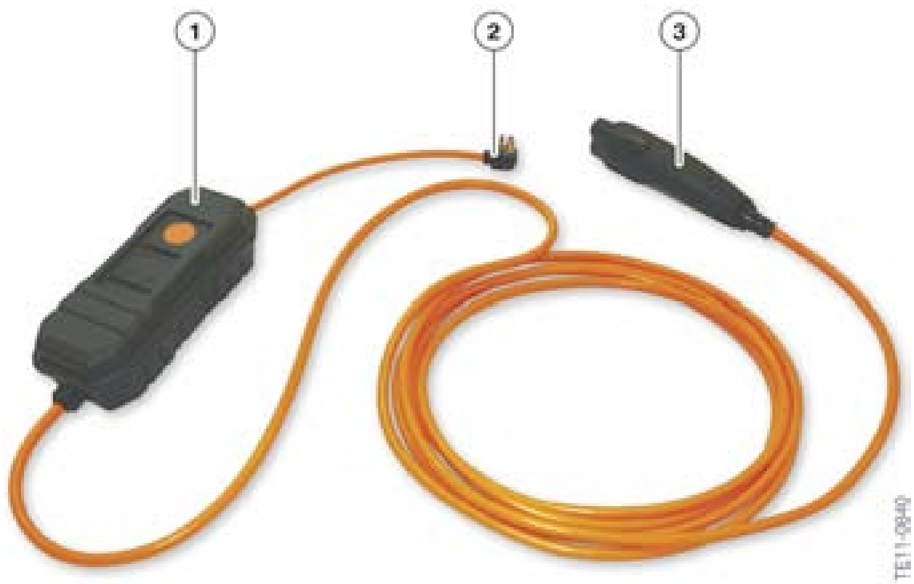
Note: The charging cable shown in the following graphic is NOT used in the US market. In the US market the charging cable is integrated into the fixed charging station and cannot be removed.

Charging cable for the connection at fixed charging station/wall box (charge level 3 IEC 61851)

Index	Explanation
1	Connector for the connection to a charging station/wall box
2	Electrical line
3	Connector for connection to the vehicle



Charging cable with integrated mobile version of the Electric Vehicle Supply Equipment (charge level 2 IEC 61851)

Index	Explanation
1	Connector for connection to a typical household charging socket
2	Electric Vehicle Supply Equipment (integrated, also called "in cable box")
3	Connector for connection to the vehicle

The two versions of the charging cable generally have the same connector for the connection to the vehicle. The following graphic shows the structure and the connections of this connector.

The cable illustrated in the graphic below is of the type currently used in the US market.

Connector of the charging cable for connection to the vehicle (standardized IEC 62196-2: Type 1)

Index	Explanation
A	General view from the side of the electrical connection
B	General view from the side of the handle
1	Mechanical lock
2	Connection for pilot line
3	Connection for grounding terminal (PE)
4	Connection for proximity line
5	Connection for phase L1
6	Connection for neutral line N
7	Mechanical guide/Connector housing
8	Button for the mechanical unlocking of the connector before removal

The connector of the charging cable and the charging socket in the vehicle are protected against direct contact. In addition, the contacts are geometrically designed in such a way that the following sequence results during connection of the connector to the charging socket:

1 Proximity line

2 Grounding terminal (PE)

3 Neutral line N, phase L1

4 Pilot line

Only when the communication between the vehicle (comfort charge electronics) and Electric Vehicle Supply Equipment has been successfully started via the pilot line is the charging voltage applied to the phase L1. This also increases the protection of customers and Service Technicians against the dangers of electricity.

4.2.4. Electric Vehicle Supply Equipment

The Electric Vehicle Supply Equipment (EVSE) establishes the connection to the AC power grid and satisfies the requirements for electric safety when charging the vehicle. In addition, communication to the vehicle is arranged via the so-called pilot line. This enables the safe start of the charging procedure and the exchange of the charging parameters (e.g. maximum current level) between the vehicle and EVSE. The EVSE can either be integrated in the charging cable (mobile cable) or be part of a fixed charging station (wall box).

In both case, the EVSE contains the following subcomponents:

- Ground fault circuit interrupter (FI)
- Display of whether the AC power grid is connected and available
- Circuit breaker for phase (L1) and neutral line (N)
- Electronic circuit for generating pilot signal
- Continuous grounding terminal (PE).

The pilot signal is a bi-polar square signal (-12 V to +12 V). The voltage level and the duty cycle are used for the communication of different states between the EVSE and electric vehicle:

- Charging cable connected at vehicle (yes/no)
- Electric vehicle is ready for charging (yes/no)
- Fault present (yes/no)
- Maximum charge current available from the AC power grid.

The pilot signal makes available a value range of 6 A to 80 A for the maximum available charge current. In the E82E a charge current of up to 32 A is used depending on the version of the EVSE.

Mobile “occasional use cable” (OUC)

The mobile charging cable version has the EVSE integrated into the charging cable and is also called the "in cable box" and is referred to as the “occasional use cable” (OUC). (It has already been shown in the chapter entitled "Charging cable"). It is designed for mobile use because of its reduced volume and weight thus the EVSE can be easily transported in the vehicle.

As a typical household charging socket is used for the connection of this EVSE to the AC power supply, the maximum current level is therefore limited for charging and the performance of the comfort charge electronics is not fully utilized. As an example, a maximum charge current of roughly 12 amps and a maximum charge power of about 2.7 kW can be attained, depending on the AC specifications in the individual country and the power grid network in the country/building. In the US the OUC cable is powered by a 110V AC household outlet and has a maximum charge current of 12 amps with a maximum charge power of about 1.6 kW it takes a minimum of 24 hours to fully charge the HV battery (it may take longer depending on initial SOC)

⚠

Please consult the Owner's Manual from the respective manufacturer for information on the operation and use of a charging cable with integrated EVSE.

Technicians in a BMW Dealer Service workshop cannot perform any maintenance or repair work on the charging cable or the EVSE. In the event of a defect or a malfunction with the charging cable or the EVSE please consult the manufacturer.

Charging station (wall mounted fast charging station)

Due to its size and electrical requirements this version of the EVSE must be installed in the customer's house or garage. This type a charging station can also be installed in public places, for example in parking garages.

⚠

The installation, maintenance and repair of charging stations can only be performed by suitably qualified electricians. The Technicians or employees of a BMW Dealer Service workshop are not authorized to perform such work as in general they lack the training and qualifications.

The connection to the AC power grid is realized via a single-phase load in the US and three-phase for Germany. However the connection to charge the E82E is always a single-phase design. In comparison to the mobile OUC cable, a maximum current level of 32 A or a maximum charging power of 7.7 kW is possible here. These maximum values are dependent, however, on the wire gauge which was used in the electrical installation of the wall charging station. The electricians configure the charging station at the installation stage in accordance with the line cross-section so that using the pilot signal the appropriate maximum current level is transmitted to the vehicle.

With this stationary charging station the full performance of the comfort charge electronics of up to 6.6 kW can be utilized. The time to fully charge of a dead high voltage battery of the E82E can then be reduced to 4 to 5 hours.

One supplier of fixed charging stations within Germany is Mennekes. The following graphics show a charging station from this manufacturer, as well as the appropriate connector at the charging cable.

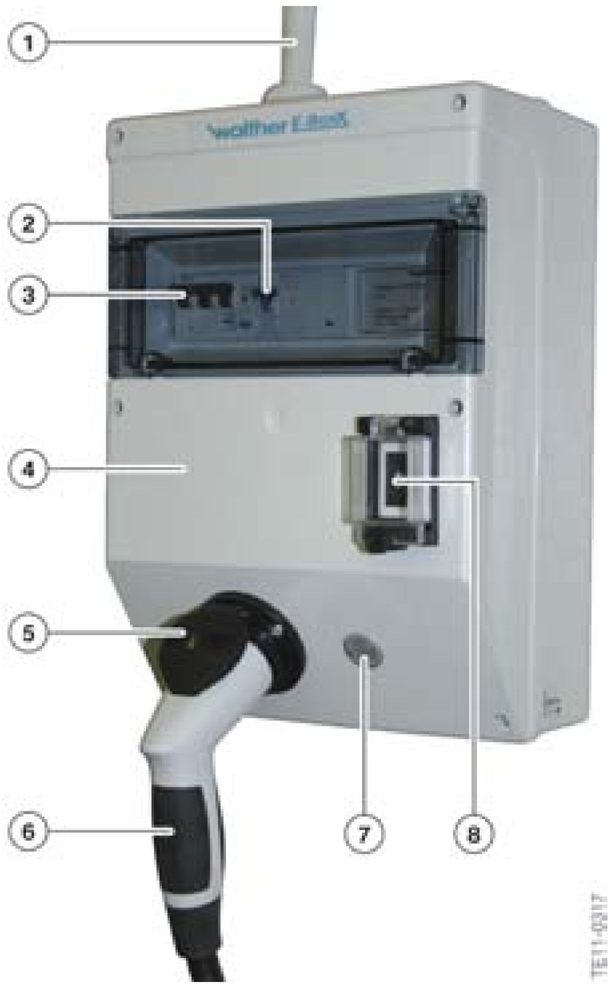
Note: This charging station is NOT currently proved for the US market.

Mennekes permanently-installed charging station

Index	Explanation
1	Automatic cutout and leakage current switch
2	Button for interrupting and continuing the charging procedure
3	Cover and socket for connecting the charge cable to the charging station

The characteristics for the charging station described here are specific to the manufacturer's version available in Germany. The following graphic illustration portrays a charging station of the type suitable for use in the BMW AG development section or, optionally, in a Service Hub.

Note: This charging station is NOT currently proved for the US market.



Fixed charging station from Walther-Werke

Index	Explanation
1	3-phase feed line of the electrical installation in the customer's house
2	Ground fault circuit interrupter (FI)
3	Line circuit breaker (overcurrent fuse)
4	Housing
5	Cover for protection of the connection against moisture and dirt contamination
6	Connector of the charging cable for the connection to a charging station/wall box
7	Button for interrupting and continuing the charging procedure
8	Switch for adjusting the maximum charge current

The features of the charging station shown here are specific to the version available in Germany from the aforementioned supplier. Charging stations from other manufacturers or the versions for other countries may differ.

Note: This charging cable is NOT currently proved for the US market.

Connector of the charging cable for the connection to the vehicle (standardized i.a.w. IEC 62196-2: Type 2)

Index	Explanation
1	Mechanical guide/Connector housing
2	Handle/Connector housing
3	Electrical line
4	Connection for neutral line N
5	Connection for phase L3 (not used for E82E)
6	Connection for grounding conductor (PE)
7	Connection for phase L2 (not used for E82E)
8	Connection for phase L1
9	Connection for proximity line
10	Connection for pilot line

Charging stations from other manufacturers and versions intended for different countries may vary from the versions illustrated here.

The following illustration shows an AeroViroment model EVSE-RS Home Charging Dock station currently installed in the US market.

EVSE-RS Home Charging Dock station for the US market manufactured by AeroVironment

Index	Explanation
1	Operating status light display
2	Charge start and interrupt buttons
3	Charge cable with plug for connection to the vehicle (stored at the charging station)

It complies with SAE J1772 with regard to the Charging Dock communication protocol and the charging connector

It has a power input of 208–240 Volt AC single-phase, 60 HZ and delivers a power output @ 30A 240V of aprox. 7.2 KW

With this stationary charging station the full performance of the comfort charge electronics of up to 6.6 kW can be utilized. The time to fully charge of a discharged high voltage battery is reduced to 4 to 5 hours.

In the US a removable charging cable between the vehicle plug connection and the charging station is not allowed. The charging cable is always connected to the charging station. The cable is rolled up and the charging plug connected and stored at the charging station.

When charging a vehicle the plug is to be removed from the charging station holder and (if all the status lights indicate it is OK to proceed) the plug may be inserted into the vehicle's charging socket.

Once inserted, the vehicle will recognize the operation, disable the drive unit and initiate the charging process. After charging is completed the customer should press the “Stop Charge” button on the wall charger and then remove the charging plug from the vehicle.

The charging cable is to be returned to the charging station when not in use.

Note: The wall mounted charging stations shown in the preceding graphics are early production models and may not resemble the actual most current charging station designs, as they vary by manufactures.

Please refer to the proper charging equipment "User Manual" for more information on the charging station you are using.

4.3. Comfort charge electronics (KLE)

4.3.1. Introduction

Although the high voltage battery of the E82E can be partially charged through brake energy regeneration, the "normal" charging procedure is then done by connecting the car to the AC power grid of the local power supply company. Energy is taken from the AC power grid and fed to the high (DC) voltage electrical system of the E82E. The comfort charge electronics (KLE) forms the link between the two networks and converts the AC voltage to DC voltage using a rectifier circuit comprising two modules. These power electronics modules are controlled by a separate control unit, which bears the same name as the complete unit: Comfort charge electronics (KLE).

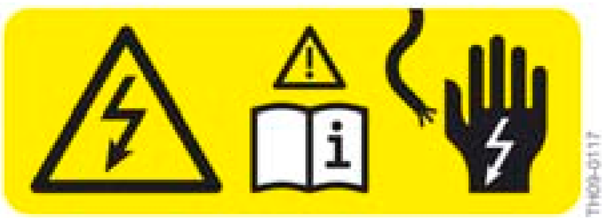
The AC voltage is fed to the vehicle or comfort charge electronics via a single-phase load connection. The input voltage which can be processed by the comfort charge electronics can be in the 100 V – 240 V, 50 Hz or 60 Hz range. The output is galvanically separated from the input and the comfort charge electronics supplies an electronically adjustable DC voltage or an electronically adjustable DC flow. The specifications for the output voltage and the output current come from the "high voltage power management" function in the EDME control unit. The values are calculated and adjusted by the KLE so that the high voltage battery is optimally charged and the other consumers in the E82E supplied with sufficient electrical energy.

The comfort charge electronics is designed so that it can provide a maximum electric power of 6.6. kW on the output side. In the E82E this is sufficient to fully charge the high voltage battery at optimal marginal conditions in four to five hours. This short loading time provides great comfort to the customer when using the vehicle. For this reason the charge electronics have been given the term "Comfort Charge Electronics" by development.

Although the KLE works at a high degree of efficiency of well over 90%, active cooling is required at full performance. This is why it is integrated in the cooling circuit of the electric motor (see section "Electric motor > Electrical machine > Cooling").

In addition to the voltage conversion and energy supply, the comfort charge electronics also assumes safety functions which protect the customer and the Service Technicians against the dangers of electricity. However, the following warnings always apply:

The comfort charge electronics is a high voltage component!



Warning sticker for the high voltage component

Only qualified Service Technicians may work at the comfort charge electronics and they must observe the repair instructions.

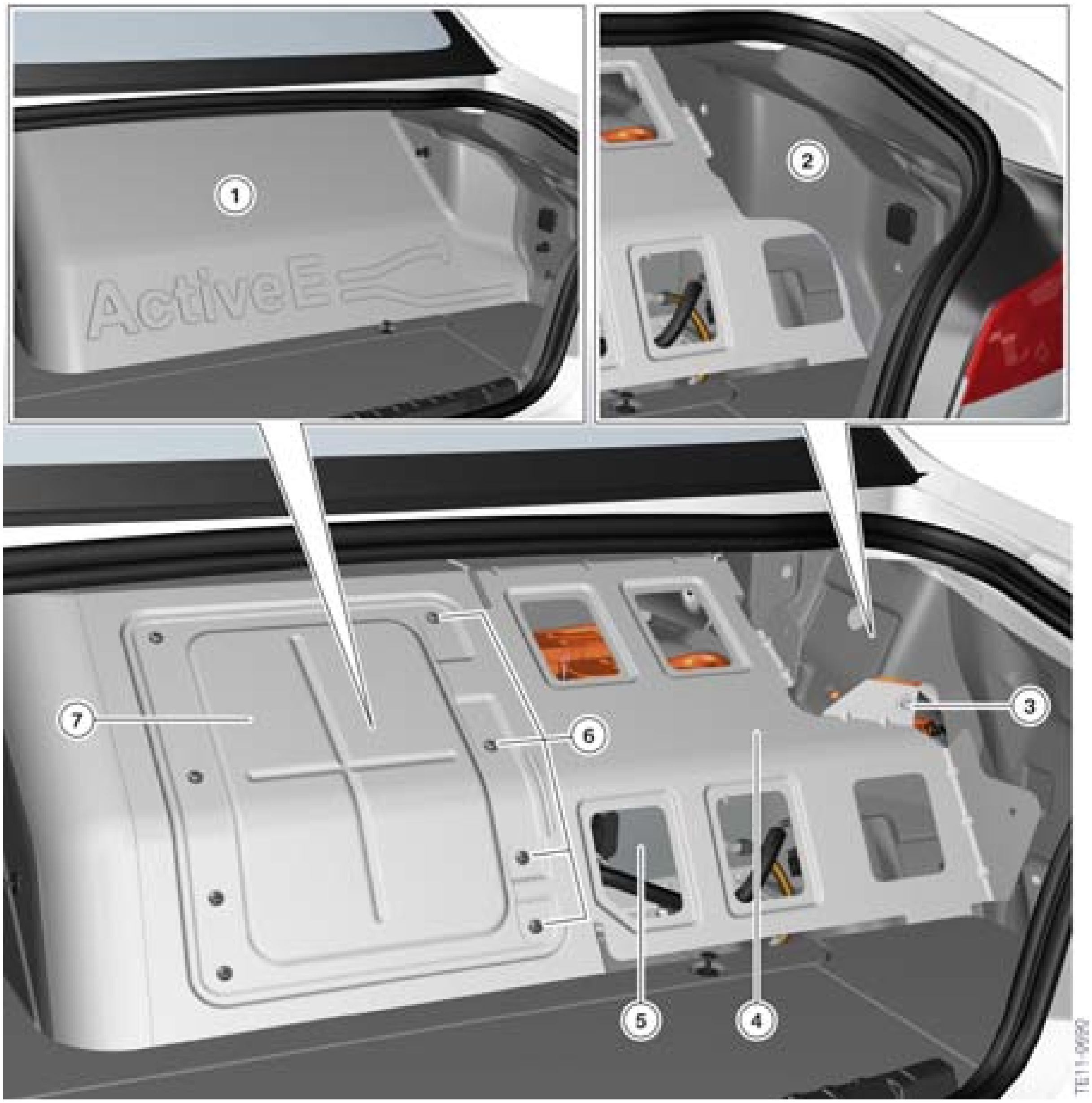
Before working on the comfort charge electronics the electrical safety rules must be followed!

As with every high voltage component, the comfort charge electronics can only be replaced in BMW Dealer Service workshop if required but never opened or repaired.

The electronic "convenient charging" system are manufactured by “Eltek Valere GmbH".

4.3.2. Installation location

The comfort charge electronics (KLE) is installed in the rear of the vehicle, in an area separated from the luggage compartment. It is located in the luggage compartment to the right of the electrical machine electronics.



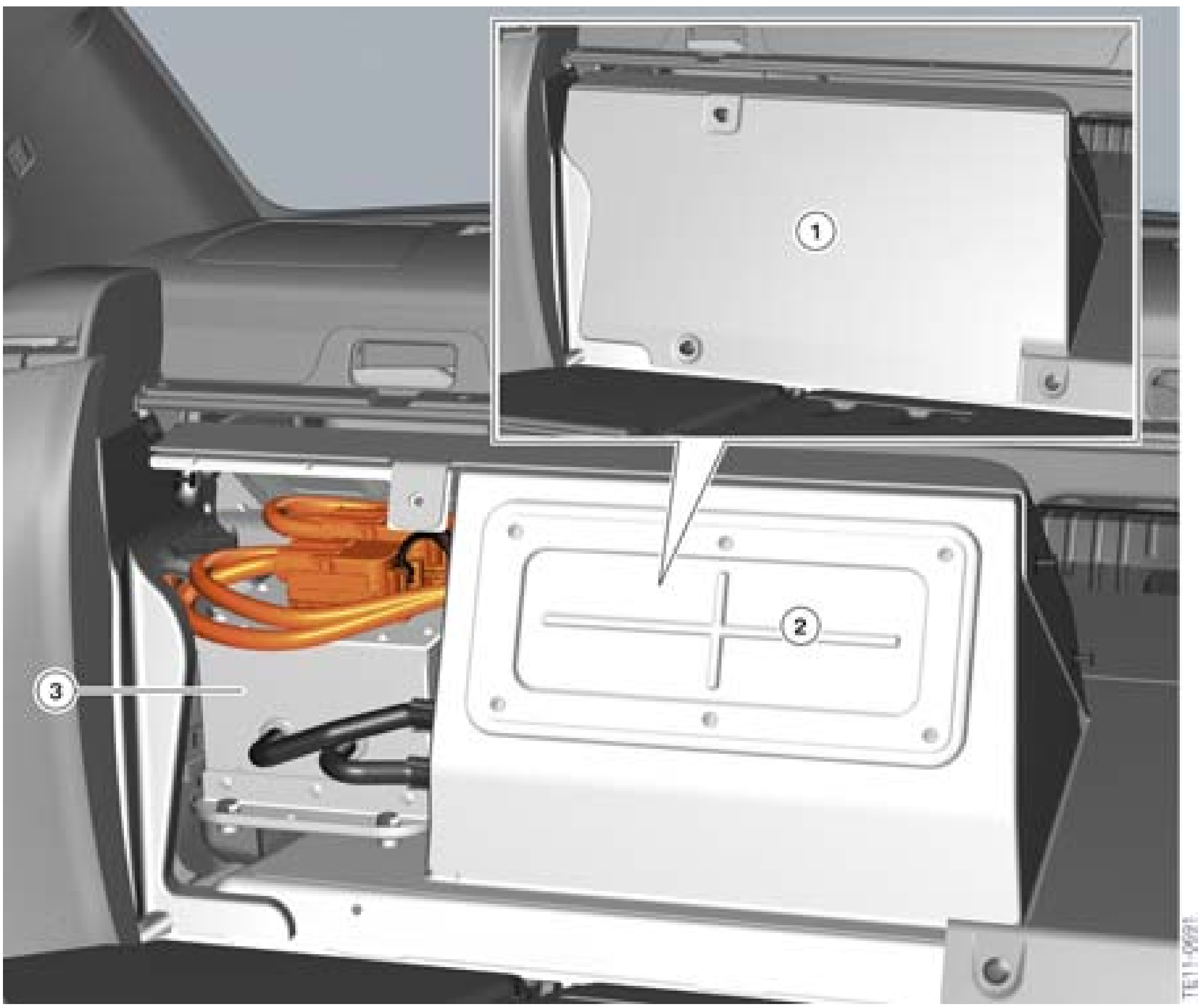
Installation location of the comfort charge electronics in the luggage compartment

Index	Explanation
1	Luggage compartment trim panel with the writing "ActiveE"
2	Luggage compartment trim panel for the side wall
3	Mounting of the cover to the body
4	Cover
5	Comfort charge electronics
6	Mounting bolts of the cover
7	Cover

E82E Complete Vehicle
4. Power Electronics

In order to access the connections of the electrical machine electronics, two luggage compartment trim panels must first be removed. Although the KLE is already visible, the metallic cover must also be removed in order to remove the connector and also of course to remove the KLE. The cover is secured with adhesive bonding to the body as well as screws on the EME (left) and body (right) covers.

Similar to the EME there is also a second access to the comfort charge electronics: A trim panel can be removed when the rear seats are folded down to access the connections for the coolant lines of the comfort charge electronics.



Access to the comfort charge electronics from the passenger compartment

Index	Explanation
1	Cover
2	Cover (access to the electrical machine electronics)
3	Comfort charge electronics

In order to be able to remove and install the comfort charge electronics, the accesses described here from the front and rear are sufficient.

Note: The screws that secure the comfort charge electronics to the body, do not have to be removed.

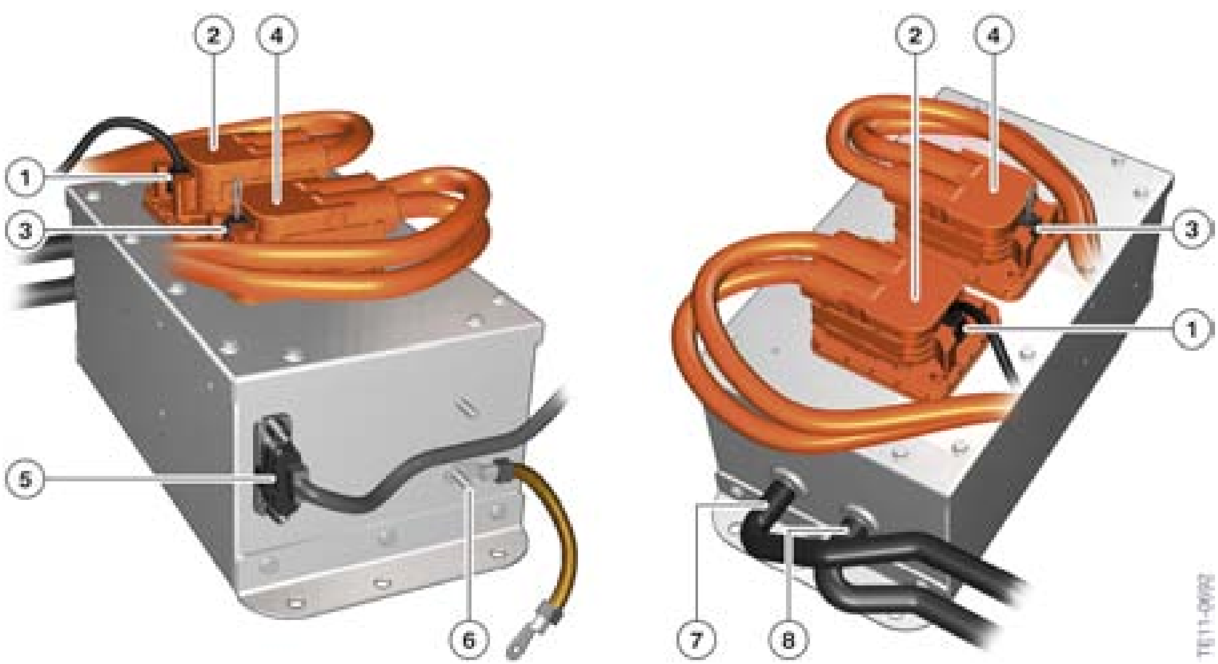
Note: The comfort charge electronics can be replaced only as a complete unit (if required).

4.3.3. Connections

The connections at the comfort charge electronics can be divided into three categories:

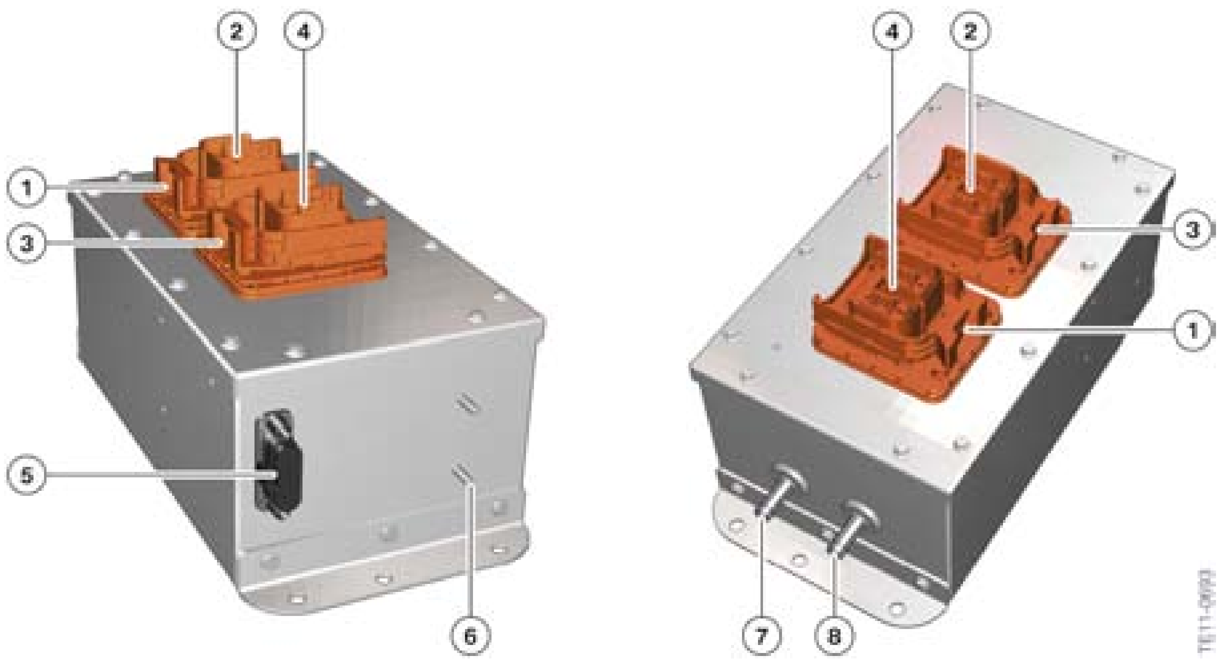
- Low-voltage connections
- High voltage connections
- Ground strap connection (potential compensation)
- Coolant line connections

The following graphics show all connections for the comfort charge electronics.



Connections of the comfort charge electronics with lines

Index	Explanation
1	Pilot and proximity line from the charging socket
2	high voltage cable (AC) from the charging socket
3	Bridge for the circuit of the high voltage interlock loop
4	High voltage cable (DC) to the electrical machine electronics
5	Low-voltage lines
6	Potential compensation line
7	Coolant line (supply)
8	Coolant line (return)



Connections of the comfort charge electronics without lines

Index	Explanation
1	Pilot and proximity line from the charging socket
2	High voltage cable (AC) from the charging socket
3	Bridge for the circuit of the high voltage interlock loop
4	High voltage cable (DC) to the electrical machine electronics
5	Low-voltage lines
6	Potential compensation line
7	Coolant line (supply)
8	Coolant line (return)

Low-voltage connections

The multi pin low voltage connector at the comfort charge electronics includes the following lines and signals:

- Voltage supply for the KLE control unit (terminal 30 g, terminal 30 from the power distribution box at front and ground)
- Bus system PT-CAN2
- Wake-up lines to the CAS control unit and to the Combox control unit
- Control line of the electrical machine electronics, with which the charging procedure is initiated
- Input and output of the circuit of the high voltage interlock loop (KLE control unit evaluates the signal)

The KLE control unit is supplied with voltage via terminal 30 and has two wake-up line outputs. The KLE can thus wake up the control units in the vehicle electrical system when the charging cable is connected.

The KLE control unit receives the request and the control signals for charging via the PT-CAN2 bus. In addition, there is a line which is wired directly from the electrical machine electronics to the comfort charge electronics. The EME must transmit an "enable" signal to release the charging process before the KLE can start to transform voltage and perform the accompanying charging process.

The KLE is also integrated in the circuit of the high voltage interlock loop. The test signal of the high voltage interlock look is supplied via the low-voltage connection and conveyed to the other high voltage components. The KLE control unit does not monitor the test signal; instead, it merely relays it.

A two pin low voltage connector is located at the two high voltage connections. The bridge for the high voltage interlock loop circuit is connected at the high voltage connection for the DC electrical system of the E82E. The bridge prevents the high voltage connector being removed when connected. a two pin line from the charging socket outlet is connected instead of a bridge at the two pin low voltage connector of the high voltage connection for the AC power grid. The connected line also functions as a mechanical protection of the high voltage connector against removal.

The following KLE information is fed via this line:

- Pilot signal from the Electric Vehicle Supply Equipment
- Electrical resistor in the proximity wiring.

Using the pilot signal the KLE identifies that the charging cable is connected to the vehicle, the AC power grid is available and there is no fault in the supply as well as the maximum current level which the AC power grid can provide. An ohmic resistor is installed in the connector of the charging cable between the proximity connection and the grounding terminal. The KLE applies a measurement voltage at the proximity connection and determines whether there is resistance and if yes what its value is. The comfort charge electronics then establishes that the charging cable is properly connected and what current level is permitted for this charging cable.

High voltage connection

There are two high voltage connections at the KLE in order to connect the high voltage lines to the charging socket and to the EME.

1 **Link to charging socket:**
1-phase (Phase L1 and neutral conductor N), AC voltage, 1 shield for both lines, flat high-voltage plug with physical lock, contact protection from cover above the flat contact prongs and through a low-voltage plug (pilot and proximity signals; locks the high-voltage plug)

2 **Connection to the electrical machine electronics:**
2-pin, DC voltage, 1 shield on each cable, flat high-voltage plug with mechanical lock, contact protection provided by the covers on the contact prongs and a bridge circuit from the high-voltage contact interlock loop.

Connection to component	No. of contacts, voltage type, shielding	Type of connection	Shock protection
Charging socket	• 1-phase (phase L1 and neutral line N) • AC voltage • 1 shielding for both lines	Flat high voltage connector with mechanical lock	• Cover over the contacts • Low-voltage connector (pilot, proximity)
Electrical machine electronics	• 2-pin • DC voltage • 1 shielding per line	Flat high voltage connector with mechanical lock	• Cover over the contacts • High voltage interlock loop

⚠

As before any work is performed on the high voltage system, the electrical safety rules must be observed even before removing the high voltage connectors:

1 **De-energize —** the high voltage system

2 **Secure —** the high voltage system against restart

3 **Verify —** there is NO voltage present in the high voltage system.

The application of the electrical safety rules in the E82E is described in the section "High voltage battery" in the chapter entitled "Service information".

The procedure for removing the flat high voltage connector is shown and described in detail in the chapter entitled "Electrical machine electronics". The procedure includes the following:

1 Remove bridge or connector at the low voltage connection

2 Remove mechanical lock of the high voltage connector

3 Remove high voltage connector by pulling upwards – as soon as a greater counterforce can be felt pull further upwards (in the same direction)
Note: Do not reverse the direction of movement!

Ground strap connection (potential compensation line)

As with all high voltage components the housing of the comfort charge electronics must be connected to the ground. The purpose of this is so the system can perform the automatic monitoring of the insulation resistance. In the case of the comfort charge electronics the grounding terminal of the AC power grid at the charging socket must also be connected to the ground. The grounding terminal and housing of the KLE must be at the same potential so that any isolation fault on the AC voltage side of the AC/DC converter can be detected. In contrast with the EME, there is only one ground strap connected to the KLE and it is attached to the rear of the housing.

⚠

Note: Charging of the E82E can only be performed if the ground strap for potential compensation is properly connected to the KLE.

⚠

If the high voltage components or the body component need to be replaced in the event of repair, please proceed as follows for the assembly: The ground strap between the housing and the body of the vehicle must be properly reestablished. Always follow the proper repair instructions with regard (tightening torque, self-tapping screws).

Connections for coolant lines

The comfort charge electronics is integrated in the cooling circuit of the electric motor. This cooling circuit is described in detail in the chapter entitled "Electric motor/Electrical machine/Cooling".

The connections for the coolant lines are located in the front of the KLE and are accessible from the passenger compartment. The coolant lines are secured to the comfort charge electronics using hose clamps. The different lengths of the coolant lines make it easy for the Service Technician to connect the lines properly at the supply and output of the comfort charge electronics.

4.3.4. Installation

The KLE incorporates the following components:

- KLE control unit
- 2 power electronics modules (AC/DC converter)
- Heat sink with coolant passages.

The KLE control unit is responsible for the communication with the partner control units, monitors the safety-relevant signals (e.g. pilot and proximity) and finally controls the power electronics modules. As the set-point values for the charging procedure come from the EME control unit, the KLE control unit does not have the primary role.

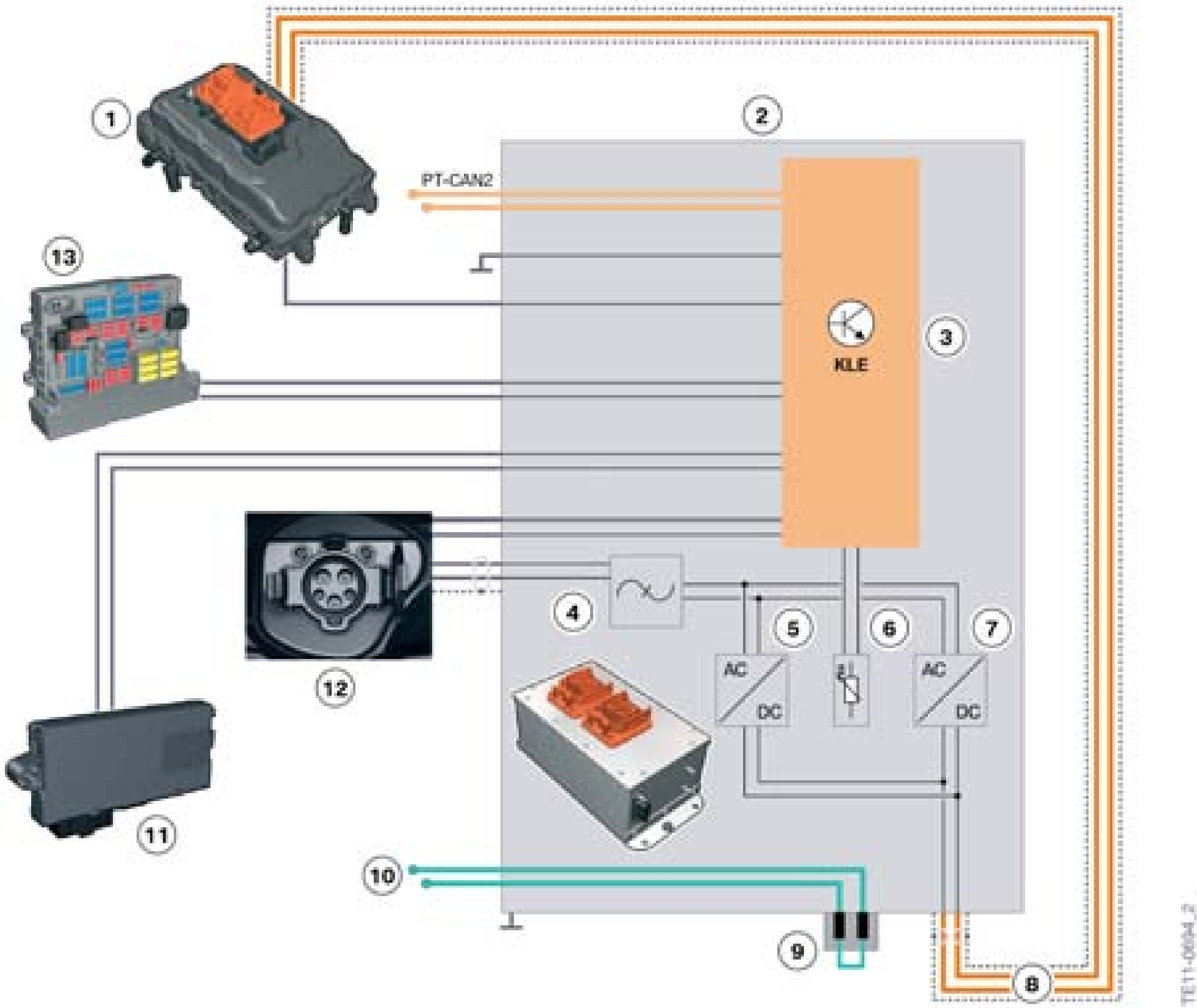
4. Power Electronics

The power electronics modules are uni-directional AC/DC converters, i.e. rectifiers. The two modules are identically installed and each provide a maximum power of 3.3 kW. The two modules are on the input side and are connected in parallel on the output side. Together the individual charging lines provide a maximum of 6.6 kW. Should a module fail this is detected by the KLE control unit and an entry made in the fault memory. The charging procedure can, however, be performed in this scenario, but at a reduced power of maximum 3.3 kW.

The AC Input and DC output of the power electronics modules are galvanically connected. The voltage level at the output is electronically controllable. On the one hand, it must be constantly adjusted by the level of the input voltage. On the other, the output voltage must be variably set according to the set-point value specification. In addition, the current level at the output can be set according to the set-point value specification. The KLE is able to provide the charging power required by the EME by changing the output voltage and current level. In each of the power electronics modules there is a temperature sensor whose signals are evaluated by the KLE control unit.

The circuit to control the output voltage in the power electronics modules also contains link capacitors. In order to quickly reduce the voltage of the capacitors to safe values (less than 60 V) when shutting down the high voltage system, a discharge circuit has also been integrated for the link capacitors. Its operating principle is the same as the one in the EME.

The following simplified wiring diagram includes the electrical structure of the comfort charge electronics and also shows their high voltage and their low-voltage connections.



Electrical structure and electrical connections of the comfort charge electronics

Index	Explanation
1	Electrical machine electronics (EME)
2	Comfort charge electronics (KLE) (complete unit)
3	KLE control unit
4	Filter for suppressing high frequency interference through the power grid (e.g. when charging several vehicles at once)
5	First power electronics module with AC/DC converter
6	Temperature sensor (1 NTC resistor per power electronics module)
7	Second power electronics module with AC/DC converter
8	High voltage cable between KLE and EME
9	Bridge for the circuit of the high voltage interlock loop

Index	Explanation
10	Input and output of the circuit of the high voltage interlock loop
11	Car Access System (CAS)
12	Charging socket
13	Power distribution box at front (in junction box)

Although the power electronics modules work at greater than 90% efficiency, the high amount of power implemented creates heat which must be dissipated to protect the internal components. For this reason a heat sink is installed between the power electronics modules. The heat sink includes a U-shaped coolant passage through which coolant is circulated. The heat energy generated during the voltage conversion is dissipated using the heat sink and the flow of coolant.

4.3.5. Functions

The function of the comfort charge electronics is mainly the controlled charging of the high voltage battery through the connection to an external AC power grid.

The following are sub-functions of the KLE:

- Protective and safety functions
- Coordination and control of the charging procedure
- Communication with partner control units in the vehicle
- Cooling.

As with all high voltage components, high voltage safety assumes top priority in the comfort charge electronics. For this reason the KLE is also integrated in the high voltage interlock loop circuit. The KLE control unit evaluates the signal and can trigger a shutdown of the high voltage system upon the occurrence of a fault in the high voltage interlock loop. In addition, the removal of the high voltage connector on the DC voltage side is only possible by an open circuit of the high voltage interlock loop circuit and leads to the shutdown of the high voltage system. Active discharge of the link capacitors during shutdown of the high voltage system is also part of the protective and safety functions, as well as the electrical check of the charging cable using the resistor in the proximity circuit. The KLE control unit evaluates the pilot signal from the Electric Vehicle Supply Equipment and permits the voltage conversion by the power electronics module only if the connection to the AC power grid is guaranteed with a grounding terminal.

At the start of the charging procedure there are two options available to the customer:

1 Set the charging start time

2 Connect the charging cable.

The customer can set the charge start time in the vehicle using the controller and the menu in the central information display. A second setting option is available to the customer via the "My BMW Remote App" for the Apple iPhone. The customer can thus select the immediate charge start time after connecting the charging cable or specify a time when the charging procedure should start.

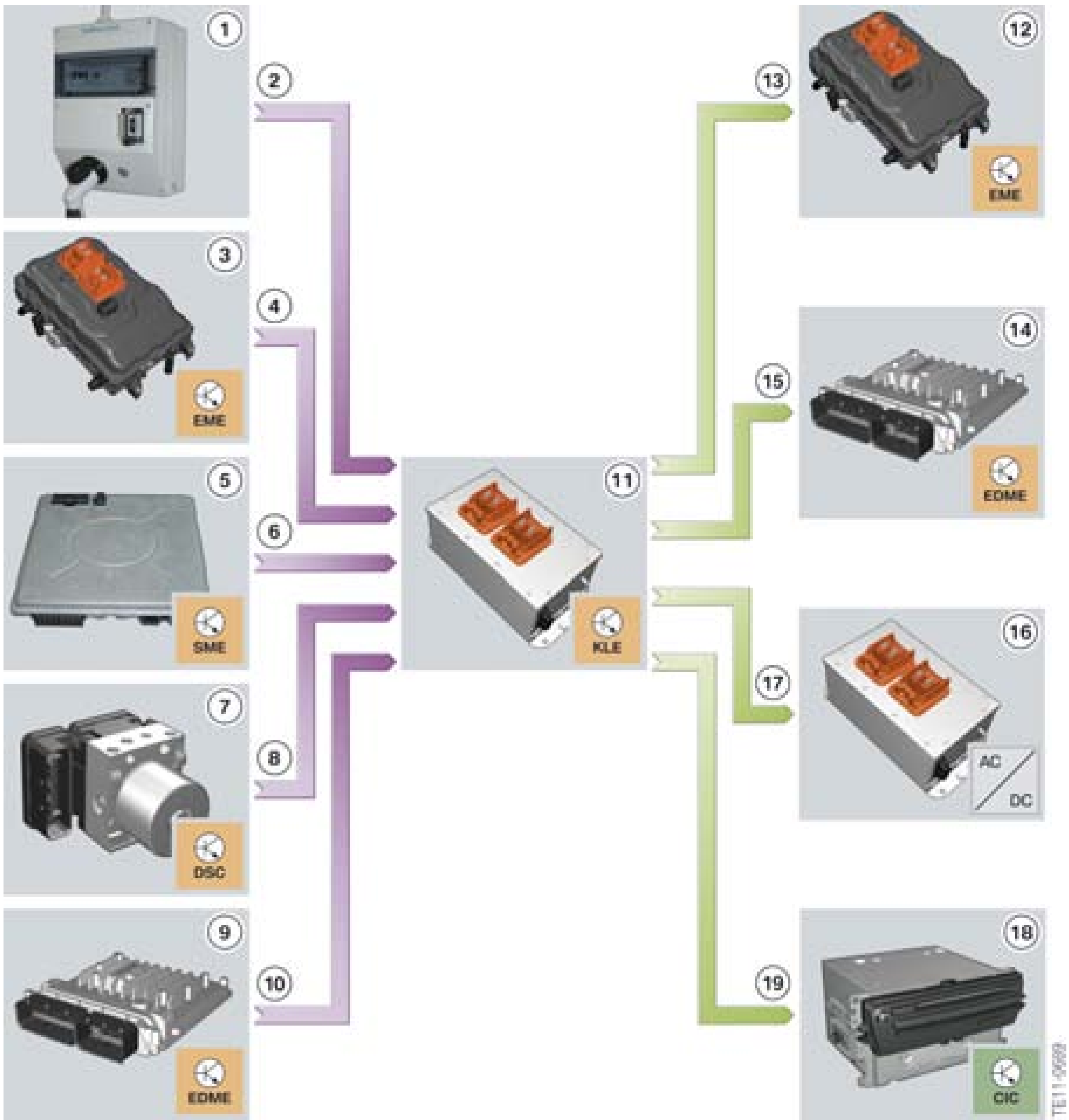
If the customer connects the charging cable, the KLE control unit wakes up the control units in the vehicle electrical system (if this has still not happened by another event). For this the KLE control unit uses a hard wired wake-up line connected to the CAS control unit. Then the KLE control unit checks both the safety-relevant preconditions, as well as the functional prerequisites, for charging.

The preconditions for charging are summarized in the following list:

- Readiness to travel OFF
- Vehicle speed at zero
- Parking lock engaged
- Charging cable connected (proximity line)
- Communication with Electric Vehicle Supply Equipment OK (pilot line)
- High voltage system started up and fault-free.

If all prerequisites are satisfied and the primary control unit for the charging procedure (EME) requests charging via the comfort charge electronics (KLE) the charging procedure is initiated. The EME control unit sends the set-point values for the charging procedure as well as the maximum charge current and specifies limit values for the maximum charge current. These values conform with the actual state (e.g. state of charge and temperature) of the high voltage battery and the power requirement of the rest of the vehicle electrical system (e.g. for climate control). The KLE control unit implements these set-point values intelligently, i.e. it takes into consideration not only the set-point value, but also other marginal conditions. These include the actual state of the comfort charge electronics (fault, temperature), as well as the current level restricted by the AC power grid and the charging cable. The following diagram includes the most important input and output variables for coordinate and control of the charging procedure.

E82E Complete Vehicle
4. Power Electronics



Input/Output variable for comfort charge electronics

Index	Explanation
1	Electric Vehicle Supply Equipment (shown here: charging station)
2	Information on whether the AC power grid is available and the charging cable is correctly connected, as well as the maximum available current level
3	Electrical machine electronics (EME)
4	Request charging power, charging voltage and charging current level (set-point value), release of the charging procedure

Index	Explanation
5	Memory management electronics (SME)
6	Information on the state of the high voltage battery, in particular the maximum absorbable charging power
7	Dynamic Stability Control (DSC)
8	Vehicle speed
9	Electrical Digital Motor Electronics (EDME)
10	State of the parking lock (engaged/released)
11	Control unit for comfort charge electronics (KLE)
12	Electrical machine electronics (EME)
13	Actual value of the set charging power, charging voltage and charging current level
14	Electrical Digital Motor Electronics (EDME)
15	Information on whether the charging cable is connected and the charging procedure is active
16	Power electronics module in the comfort charge electronics
17	Signals for controlling the power and output voltage of the power electronics module
18	Headunit of the Car Information Computer (CIC)
19	Information on whether the charging procedure is active

The cooling system of the electrical machine also cools the power electronics module of the comfort charge electronics. Accordingly the KLE must also be able to signal the cooling requirement. The KLE control unit determines the cooling requirement by using the temperature sensors integrated in the power electronics modules and the electric power currently implemented. It transmits the cooling requirements via data bus signals to the EDME control unit (where the control of the cooling system takes place). The EDME control unit then initiates the activation of the electric coolant pump and the electric fan depending on the cooling requirements. In contrast to conventional vehicles this can take place during an after-running period after parking or during the entire charging procedure. It is, however, a normal function for cooling the comfort charge electronics and is done independent of the customer control.

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The coolant pump and the electric fan can be automatically activated when Terminal 15 is at "power on" status as well as while the high-voltage battery is being charged.

The following preliminary operations must be conducted prior to conducting service work on the electric fan in order to prevent possible injuries caused by a fan that suddenly starts automatically:

1 Disconnect the charge cable (if one is connected)
2 Deactivate power at Terminal 15
3 De-energizing the high-voltage system
4 Detach the plug from the electric fan.

4. Power Electronics

The cooling system and the power electronics module are designed so that an empty high voltage battery can be fully charged at maximum charging power. If, despite this design, the temperature limit in the power electronics modules is exceeded, the charging power is reduced continuously to protect the respective components. This reduction takes place from a temperature of about 90° C/194° F in the power electronics module and can result in a longer charging time. A fault entry in the KLE control unit indicates to the Service Technician that such a power reduction has been implemented.

⚠

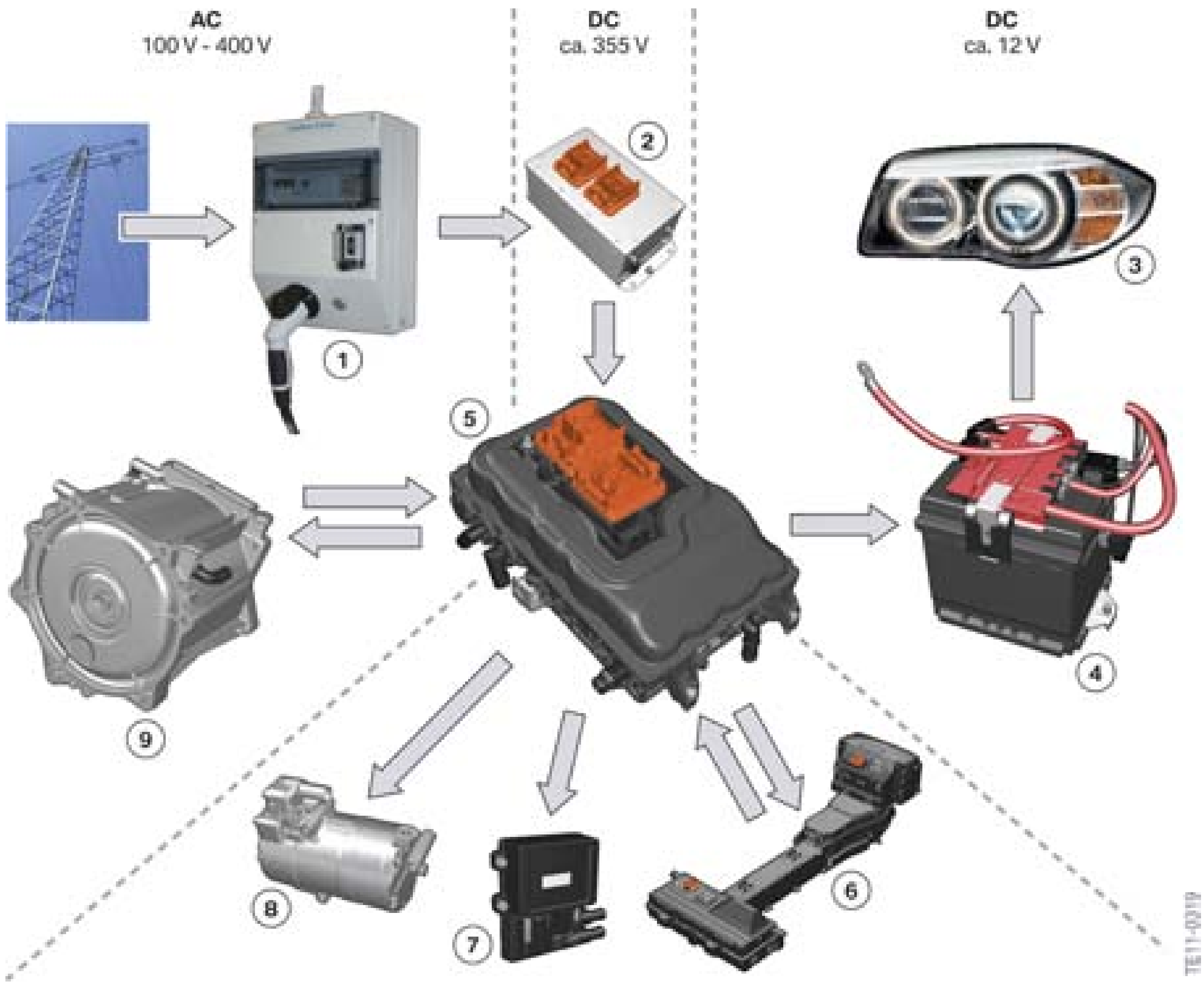
In this case the charging power is reduced to protect the comfort charge electronics against overheating. Although the charging procedure resumes, the charging time may be extended.

E82E Complete Vehicle

5. 12 V Voltage Supply

The vehicle electrical system of the E82E can be divided into three areas:

- Electrical machine (high AC voltage)
- High voltage electrical system with DC voltage
- 12 V vehicle electrical system.



Vehicle electrical systems in the E82E

Index	Explanation
1	External voltage supply (e.g. wall box)
2	Comfort charge electronics (KLE)
3	Electrical consumer in the 12 V vehicle electrical system
4	12 V battery
5	Electrical machine electronics (EME)

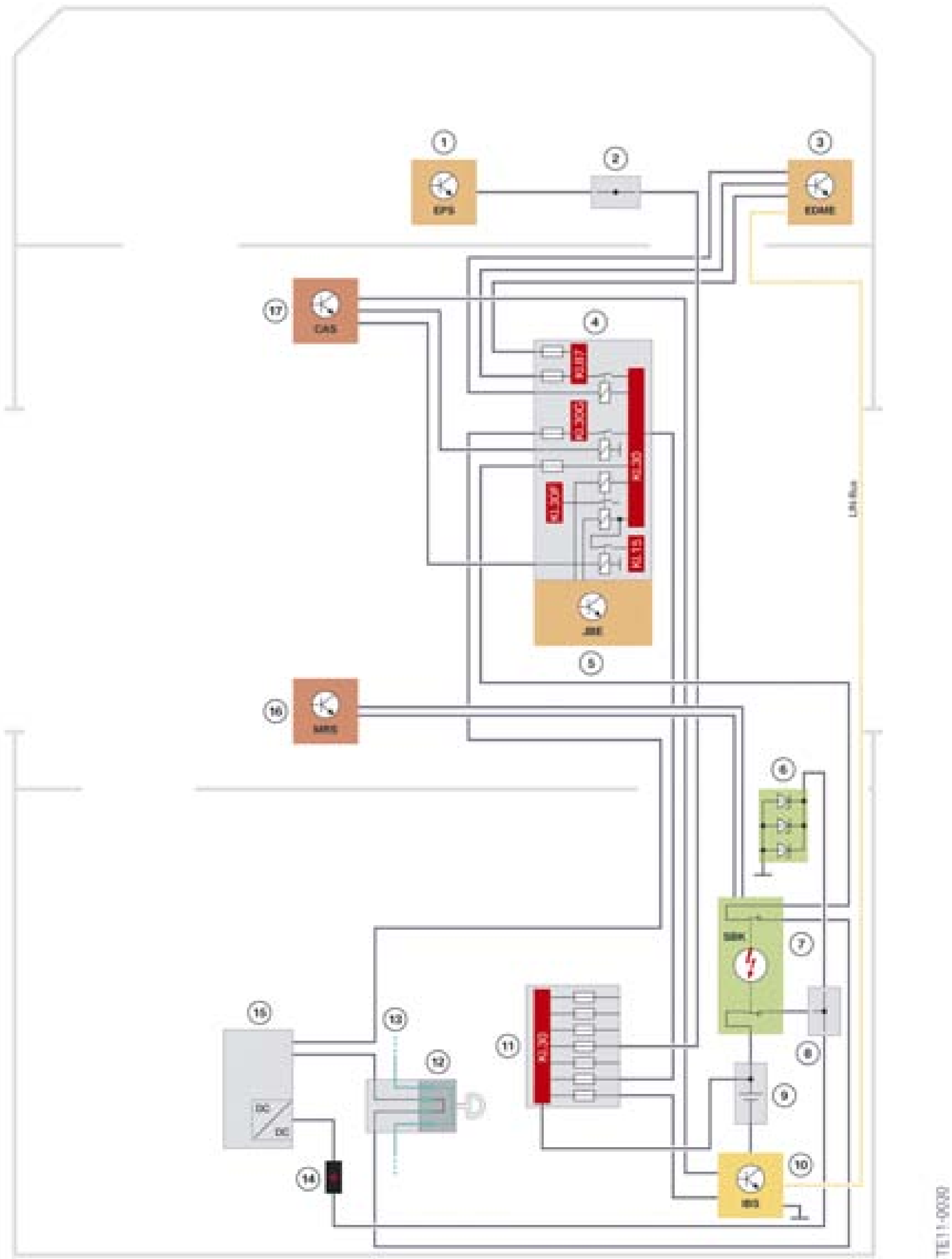
Index	Explanation
6	High voltage battery
7	Electric heating unit (EH)
8	Electric A/C compressor (EKK)
9	Electrical machine

The 12 V vehicle electrical system corresponds to the energy electrical system in previous vehicles, whereby its energy supply is the responsibility of the DC/DC converter (in the EME). The DC/DC converter replaces the alternator in a conventional vehicle. The electrical energy is only converted in one direction: from high voltage DC to low voltage DC. This means charging the high voltage battery units in the E82E (as with the previous hybrid cars E72, F04), is not possible using the 12 V charger.

E82E Complete Vehicle

5. 12 V Voltage Supply

5.1. System overview

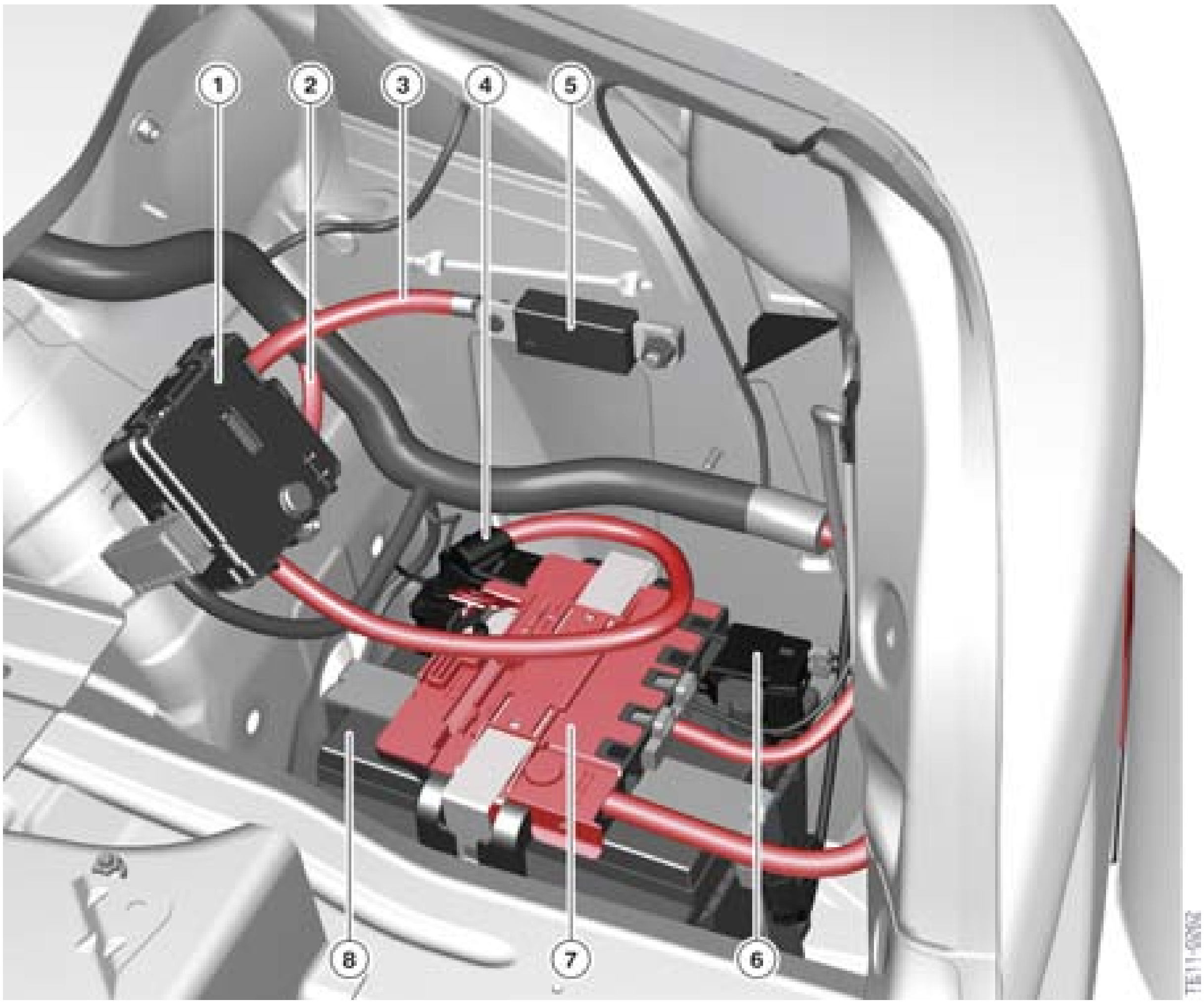


System wiring diagram for voltage supply E82E (12 V)

5. 12 V Voltage Supply

Index	Explanation
1	Electric Power Steering
2	Power distribution box, front
3	Electrical Digital Motor Electronics
4	Fuse carrier at the front behind the glove box
5	Junction box electronics
6	Reverse polarity protection
7	Safety battery terminal
8	Power distribution box, rear
9	12 V battery
10	Intelligent battery sensor
11	Power distribution box for 12 V battery
12	High-voltage safety connector
13	Signal line of the high-voltage interlock loop
14	Transfer connection point
15	DC/DC converter in the EME
16	Multiple restraint system
17	Car Access System

5.2. Components of the voltage supply



Components of the voltage supply

Index	Explanation
1	Power distribution box, rear
2	Line to the DC/DC converter in the EME
3	Line to the reverse polarity protection
4	Safety battery terminal
5	Reverse polarity protection
6	Intelligent battery sensor (IBS)
7	Power distribution box for 12 V battery
8	12 V battery

5.2.1. 12 V battery

An AGM (absorbent glass matt) battery is used as the voltage supply for the 12 V vehicle electrical system in the E82E. The battery is installed on the right side in the luggage compartment and has a capacity of 55 Ah.

In contrast to a vehicle with a combustion engine, the requirements of the 12 V battery in the E82E in relation to an engine start are quite different. The 12 V battery must only be provided in the E82E for starting-up the high voltage system. The request to the 12 V battery is no longer a minimum SoC to guarantee the motor start, but a minimum SoC to protect the 12 V battery from freezing at temperatures less than 0° C/32 °F and to start up the high voltage network.

The energy supply from the 12 V vehicle electrical system (and also charging the 12 V battery) is not supplied by the conventional alternator, but via the DC/DC converter in the EME.

A power distribution box, to which the voltage supply as terminal 30 for the junction box and the electronic power steering are connected, is mounted on the battery. The following high voltage circuit breakers are fitted in the power distribution box on the battery:

- 250 A for junction box and
- 80 A for EPS.

In addition, the voltage supply for the IBS is connected at this power distribution box.

In the event of an accident with appropriate severity the safety battery terminal is triggered by MRS. In addition to the battery positive wire to the power distribution box at the rear, the line of terminal 15C is also interrupted. Terminal 15C is read by the EME. In the event of a faulty signal from terminal 15C, the EME performs a quick shutdown of the high voltage system.

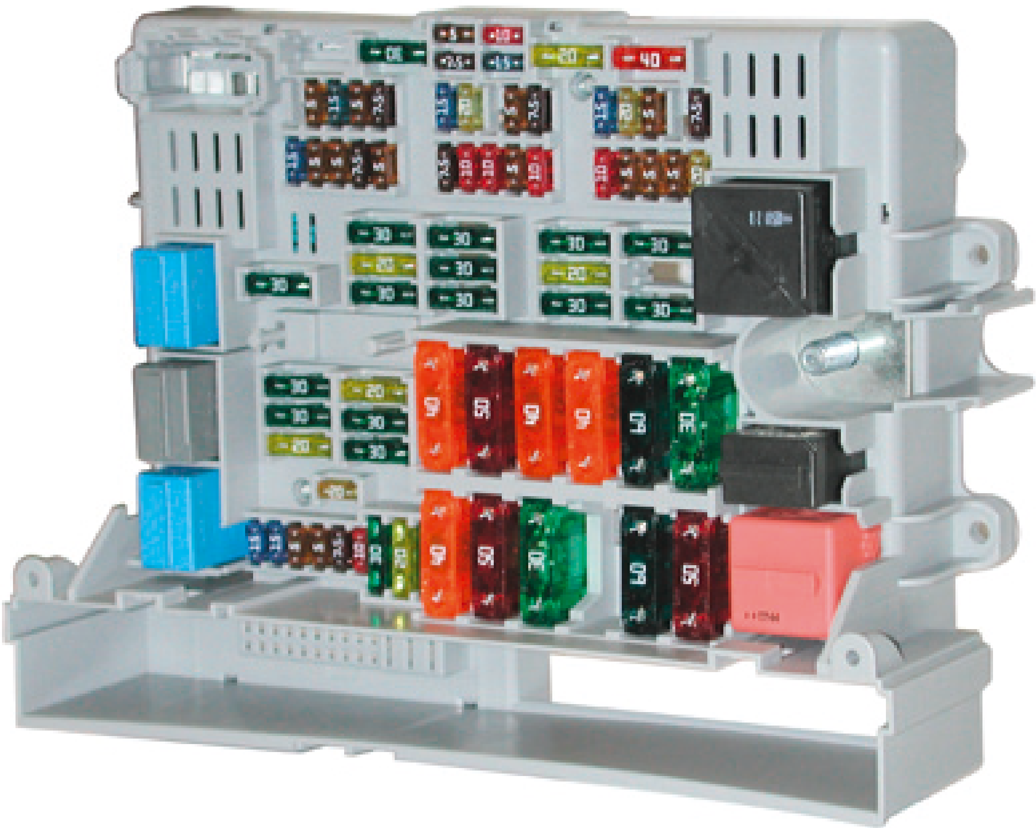
A line leads to the power distribution box at the rear from the battery positive terminal. From this power distribution box a line goes to the reverse polarity protection and the other to the DC/DC converter in the EME. There are no fuses installed in the power distribution box at the rear.

5.2.2. Reverse polarity protection

The reverse polarity protection is designed to avoid subsequent damage at the vehicle electrical system and electronic components connected thereto in the event of a polarity reversal e.g. during charging of the 12 V battery using an external charger. This task is guaranteed in conventional vehicles with a combustion engine by the diodes in the alternator.

As there is no conventional alternator in the E82E, the reverse polarity protection must be done by the reverse polarity protection module. The reverse polarity protection module is installed in the luggage compartment above the 12 V battery. It is connected on one side to the battery positive wire and on the other to the vehicle ground. There are three analog modules inside of the reverse polarity protection module, which restrict the reverse voltage for a certain period. In the case of longer polarity reversal it may suffer damage without damaging the components close-by.

5.2.3. Additional fuses



TE04-4722

Junction box

The junction box in the E82E essentially is identical to the junction box of the E82. The relay assignment, for example, remains unchanged. The fuse assignment, however, is different.

Compared with the E82, some optional equipment is not offered in the E82E. This is why there are differences in the fuse assignment. Another reason for the altered fuse assignment is the new control units in the drive train.

The following table specifies the current values for the fuses of the new components:

Component	Fuse
EDME	2 x 10 A
EKK	5 A
EKMP 1 (electric heating)	5 A
EKMP 2 (chiller)	5 A
EKMP 3 (EME)	10 A
KLE	2 x 5 A

EME	15 A
SME	5 A
Terminal 15C (safety battery terminal)	10 A
Relay for 12 V charging sockets	7.5 A
12 V charging sockets	20 A

5.2.4. 12 V charging sockets

In the E82E the customer has the option to supply electrical devices such as the flash light, car vacuum cleaner, etc. with voltage via two 12 V charging sockets. One charging socket is located in the center console, the other is in the passenger side of the luggage compartment. The two charging sockets are protected via a common 20 A fuse. In contrast to the E82, the supply line here is switched via a relay. The relay is installed in the E box beside the EDME and controlled by the EDME.

5.3. Energy management

In the E82E the Advanced Power Management is used. The power management acts by corresponding measures as soon as an operating condition has been detected which corresponds to a critical charge balance of the 12 V battery. The voltage supply of the low voltage vehicle electrical system is guaranteed by a DC/DC converter in the EME. The DC/DC converter is operated with a fixed voltage set-point value of about 14.5 V.

The power management is performed by the EDME. The EDME receives the real measured data (voltage, current, temperature and SOC) from the IBS. The IBS is installed in the E82E regardless of the equipment.

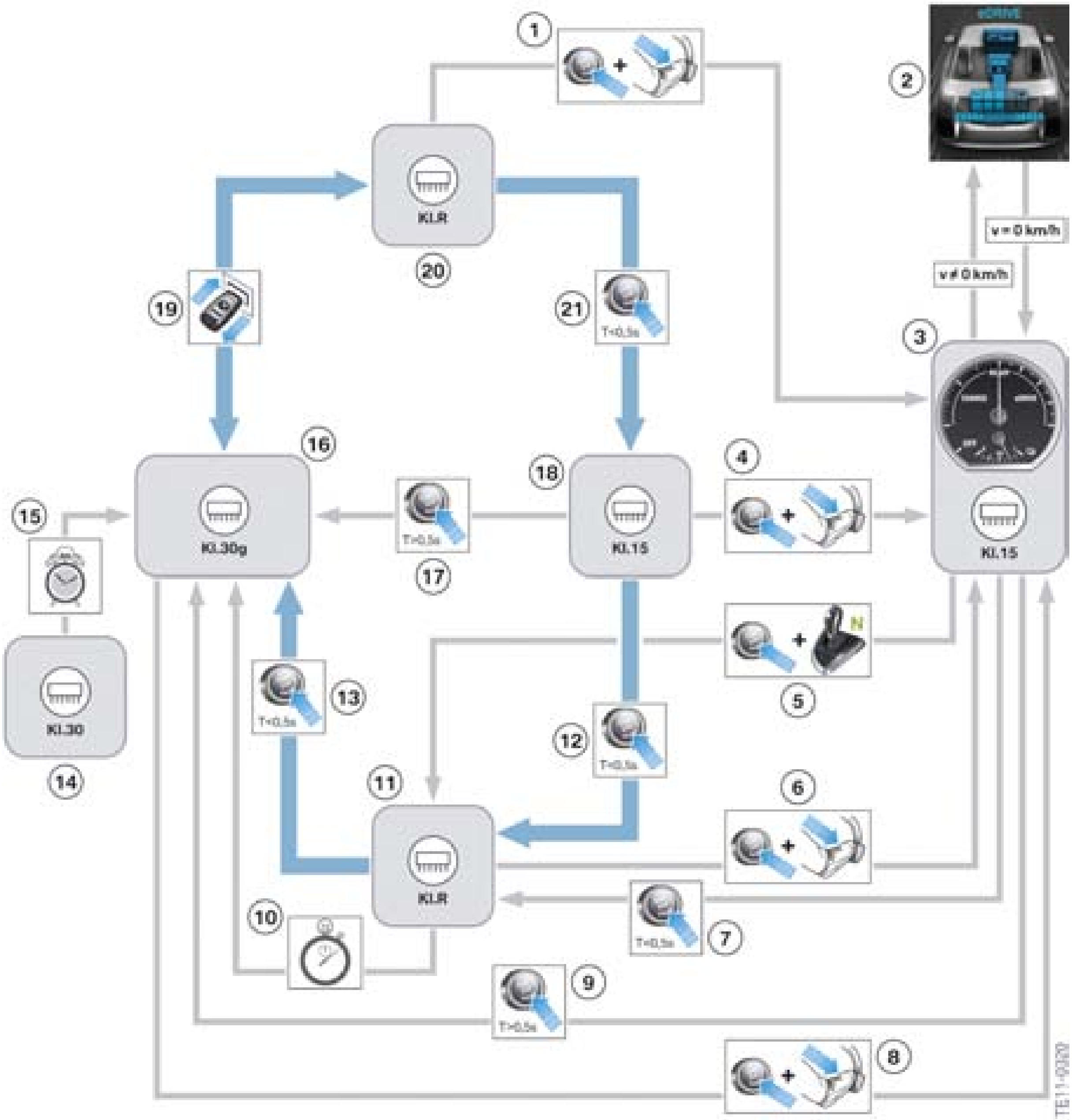
The most important power management functions in the E82E are:

- Diagnosis of the 12 V battery
- Shutdown/Reduction of electrical consumers upon detection of critical states of charge
- Recharging of the 12 V battery in the event of a low SoC value

Furthermore, the power management detects a faulty vehicle electrical system (at which too high standby currents flow) or determines an aging battery and can file information in the fault memory, which facilitates troubleshooting.

5.3.1. Terminal control

The terminal control for the E82E is shown in the following image:



Terminal control from customer's side

Index	Explanation
1	The readiness to travel is activated through simultaneous actuation of the START-STOP button and the brake pedal (from terminal R)
2	Driving with the electric drive/motor
3	Readiness to travel with terminal 15
4	The readiness to travel is activated through simultaneous actuation of the START-STOP button and the brake pedal (from terminal 15)

Index	Explanation
5	If the selector lever is in position "N" and the readiness to travel has been ended with the START-STOP button, terminal 15 remains switched on for 15 minutes (car wash function)
6	The readiness to travel is activated through simultaneous actuation of the START-STOP button and the brake pedal (from terminal R)
7	Brief press of the START-STOP button switches from readiness to travel to terminal R
8	The readiness to travel is activated through simultaneous actuation of the START-STOP button and the brake pedal (from terminal 30g)
9	Pressing the START-STOP button for longer than 0.5 s changes the terminal status from terminal 15 to terminal 30g
10	Change from terminal R to terminal 30g, if more than 8 minutes have passed
11	Terminal R
12	Brief press of the START-STOP button changes the terminal status from terminal 15 to terminal R
13	Brief press of the START-STOP button changes the terminal status from terminal R to terminal 30g
14	Terminal 30
15	Vehicle is woken up by a wake-up event
16	Terminal 30g
17	Pressing the START-STOP button for longer than 0.5 s changes the terminal status from terminal 15 to terminal 30g
18	Terminal 15
19	Terminal R is activated/deactivated by inserting/removing the remote key in/from the insertion slot
20	Terminal R
21	Brief press of the START-STOP button changes the terminal status from terminal R to terminal 15

Readiness to travel

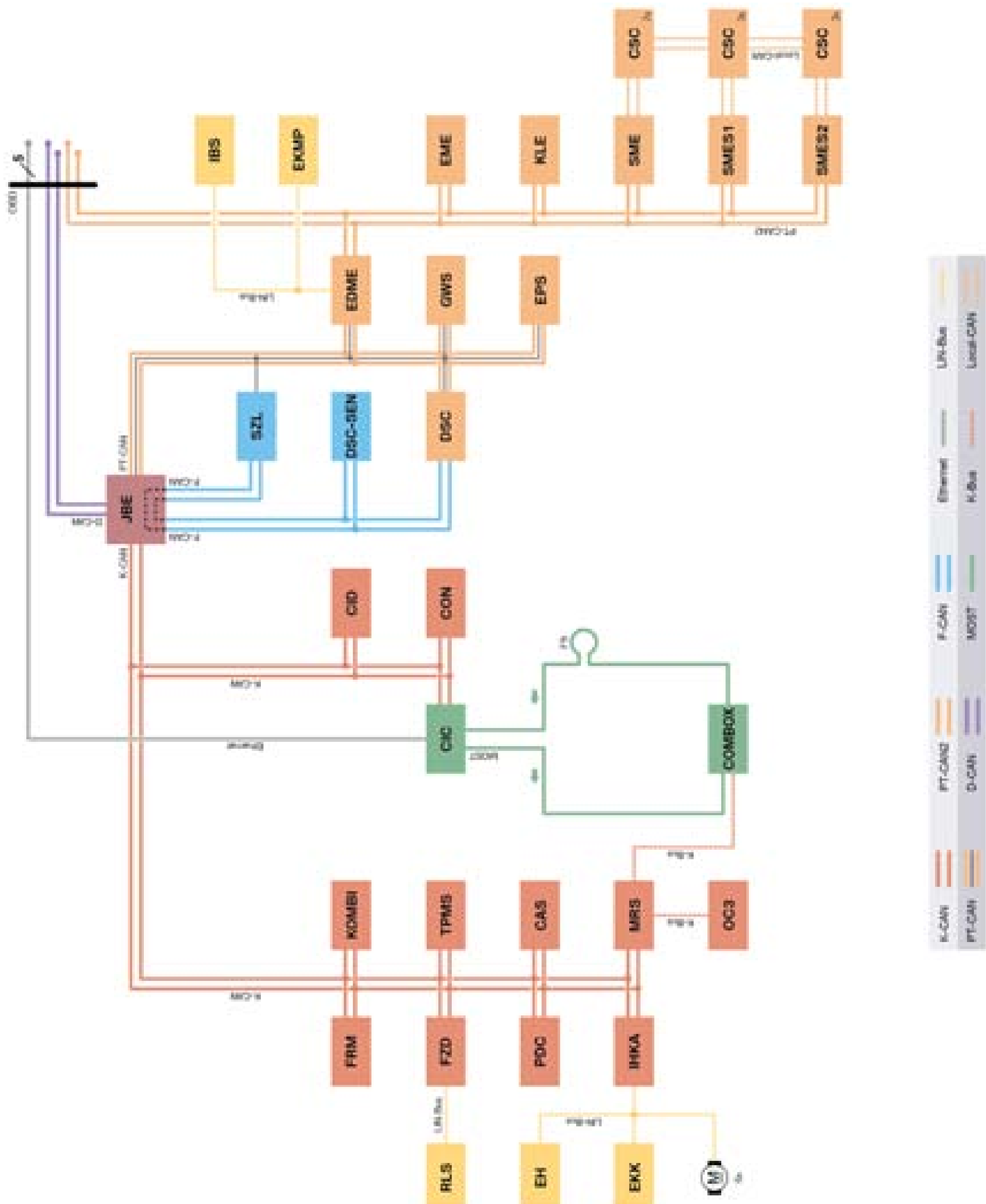
Readiness to travel is a special state of the vehicle when driving. It is always attained when the vehicle is at a standstill (e.g. in traffic or at traffic lights) but also before the initial drive-off. When “readiness to travel” is activated the indicator needle for electric driving in the instrument panel points to "READY".

Readiness to travel is activated when the remote key is in the key slot and in the case of an activated brake pedal when the START-STOP button is pressed. As soon as the accelerator pedal is pressed the vehicle drives off. Readiness to travel is the state of the vehicle between terminal 15 on and a running electrical machine. A prerequisite for activating the readiness to travel in the E82E is sufficient state of charge of the high voltage battery. In contrast to conventional vehicles (where the readiness to travel is evident by a running combustion engine) readiness to travel cannot be detected in a vehicle with an electric motor.

Readiness to travel is deactivated by pressing the START-STOP button when the vehicle is stationary. Here the drive position "P" is automatically engaged, regardless of the previously selected drive position.

6. Bus Systems

6.1. Bus overview.



Bus overview E82E

Index	Explanation
CAS	Car Access System
CIC	Car Information Computer
CID	Central Information Display
COMBOX	Combox
CON	Controller
CSC	Cell Supervisory Circuits
DSC	Dynamic Stability Control
DSC-SEN	DSC sensor
EDME	Electrical Digital Motor Electronics
EH	Electric heating unit
EKK	Electric coolant compressor
EKPM	Electric coolant pump (for the cooling circuit of the drive components)
EME	Electrical machine electronics
EPS	Electronic Power Steering
FRM	Footwell module
FZD	Roof function center
GWS	Gear selector switch
KLE	Comfort charge electronics
IBS	Intelligent battery sensor
IHKA	Integrated automatic heating / air-conditioning
JBE	Junction box electronics
KOMBI	Instrument panel
MRS	Multiple restraint system
OBD	Diagnostic socket (OBD II)
OC3	Seat occupancy mat
RLS	Rain/light sensor
SZL	Steering column switch cluster
SME	Battery management electronics
SMES1	Battery management electronics, secondary 1
SMES2	Battery management electronics, secondary 2
TPMS	Tire Pressure Monitoring System
PDC	Park Distance Control

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6. Bus Systems

6.2. Changes in comparison to E82

The bus systems of the E82E are a mix of previous bus systems (vehicle electrical system BN2000) and new control units and bus systems which already satisfy the standard for the BN2020 vehicle electrical system. Due to the reduced equipment for E82E and the altered drive (electrical machine in place of a combustion engine) some control units from the E82 have not been installed. In addition, some previous control units have been adapted for use in the electric vehicle.

6.2.1. Adapted control units

The IHKA had to be adapted to enable activation of the electric A/C compressor (EKK) in all operating conditions. In addition, the IHKA assumes control of the electric heating unit (EH). The EKK and EH control units are connected via a local interconnect network (LIN) bus to the IHKA.

The combination had to be adapted to enable representation of additional (driving-relevant) displays for readiness to travel, electric driving, brake energy regeneration and the state of charge of the high voltage battery. In addition, the Check Control messages have been enhanced with messages for the electric motor.

The CIC has been adapted to enable representation of supplemental displays in the CID and specific displays for the electric motor. By selecting "eDRIVE" in the "Vehicle information" menu, the energy and power flow, as well as the state of charge of the high voltage battery, can be visualized for each driving situation.

The software of the DSC has also been adapted for the regenerative braking process. This includes reading the brake pedal travel sensor as a hardware interface.

6.2.2. Omitted control units

Compared with the E82, some optional equipment is not offered in the E82E. For this reason some control units are no longer shown in the data bus overview. Another reason for the omission of the control units is the modified powertrain type.

The following table provides a list of the omitted control units.

Omitted control unit	Function	Reason for omission
FLA	High-beam assistant	Cost savings and weight reduction.
AHL	Adaptive headlights	Cost savings and weight reduction.
RAD1/RAD2	Radio 1 and Radio 2	CIC is offered for all vehicles standard equipment.
SINE	Siren and inclination sensor	The installation location of the indicator light for the theft warning position in the inside mirror is used to indicate that the vehicle is currently charging.
DME	Engine control unit	As the vehicle is not driven using a combustion engine, the engine control unit DME is omitted. Instead there is a new control unit for the electric drive –> EDME.

EGS/DKG	Transmission control unit	The E82E uses a fixed ratio transmission. The signals from the electronic gear selector switch are implemented by the EDME.
EKPS	Electronic fuel pump control	As the vehicle is not driven using a combustion engine, the control unit for the electric fuel pump is also omitted.
AL	Active steering	Cost savings and weight reduction.
TOP HIFI	Top HiFi amplifier	Cost savings and weight reduction.
CDC	CD changer	Cost savings and weight reduction.
SMFA/SMBF	Seat module for driver/front passenger seat	Cost savings and weight reduction.
IHKR	Integrated automatic heating / air-conditioning	Only the IHKA is offered.
ASP	Exterior mirror, high	Cost savings and weight reduction.
SBFA	Switch block, driver's door	Cost savings and weight reduction.
ZH	Auxiliary heater **(NOT for US)**	The auxiliary heater is not offered in the E82E. Instead each vehicle is equipped with an electric heater (EH).

6.2.3. New bus systems

Compared to the bus systems of the E82 only two bus systems are new in the E82E: PT CAN2 and Local Controller Area Network.

PT-CAN2

In the E82E another Controller Area Network bus is used as an additional bus system for networking the powertrain control units (EDME, EME, SME, KLE). The data transfer rate of the PT-CAN 2 is 500 kBit/s. The PT-CAN2 is already known from other vehicles (F01, F04, F25). As with previous Controller Area Network bus systems, the PT-CAN2 is also designed as a twisted two-wire line. The use of twisted two-wire lines results in enhanced electromagnetic compatibility of the bus systems.

The terminating resistors in the PT-CAN2 are located in the following control units:

- EDME (120 Ohm)
- EME (120 Ohm).

Local CAN

The Local Controller Area Network is used as a sub-bus system for the data transfer between the SME and CSC modules, as well as between the CSC module themselves. The properties of the Local Controller Area Network are already known from earlier vehicles, e.g. F01. The data transfer rate at the Local CAN is 500 kBit/s.

6.2.4. New control units

Several components (control units) are involved in the control on the electric powertrain.

EDME

Electrical Digital Motor Electronics in the E82E

The primary role for the control of the electric motor in the E82E is assumed by the motor control within the "Electrical Digital Motor Electronics" (EDME). It is similar to the DME installed in vehicles with a gasoline engine.

The EDME has the following functions:

- Evaluation of the driver's demand (accelerator pedal)
- Coordination of torque requests
- Operating strategy including behavior in emergency operation
- Activation of the electrical machine
- Heat management
- Evaluation of the electronic gear selector switch (Shift-by-Wire function)
- Power management for the high voltage vehicle electrical system
- Power management for the low voltage vehicle electrical system
- Activation of the vacuum pump.

EME

Electrical machine electronics in the E82E

As the most important partner control unit of the EDME the electrical machine electronics (EME) assumes the activation of the electrical machine and supplies the low voltage vehicle electrical system with energy.

For the activation and control of the (permanently excited) electrical machine in the high voltage electrical system a bi-directional inverter is necessary, which converts the high voltage DC of the high voltage battery to a three-phase alternating current (AC) for the electrical machine. In generator mode of the the operation of the electrical machine is reversed and the high voltage battery is recharged via the rectifier.

In addition, a unidirectional DC/DC converter is integrated in the EME which is responsible for the voltage supply of the low voltage vehicle electrical system.

SME/CSC

The electrical high voltage power supply in the E82E is comprised of a total of three high voltage battery units. Each of the three high voltage battery units contains the following electrical/electronic components, in addition to the actual battery cells:

- Control unit for battery management electronics (SME)
- Several cell monitoring electronics called Cell Supervisory Circuits (CSC)
- Interface box with switch contactors, sensors and overload fuse.

To maximize the service life of the high voltage battery units, they are operated in a precise and defined manner. This includes the following marginal conditions:

- Operating cells in the optimal temperature range (heating/cooling and limiting the current level if required)
- Adjusting the state of charge of the individual cells if required
- Use the storable energy of the battery in a certain area.

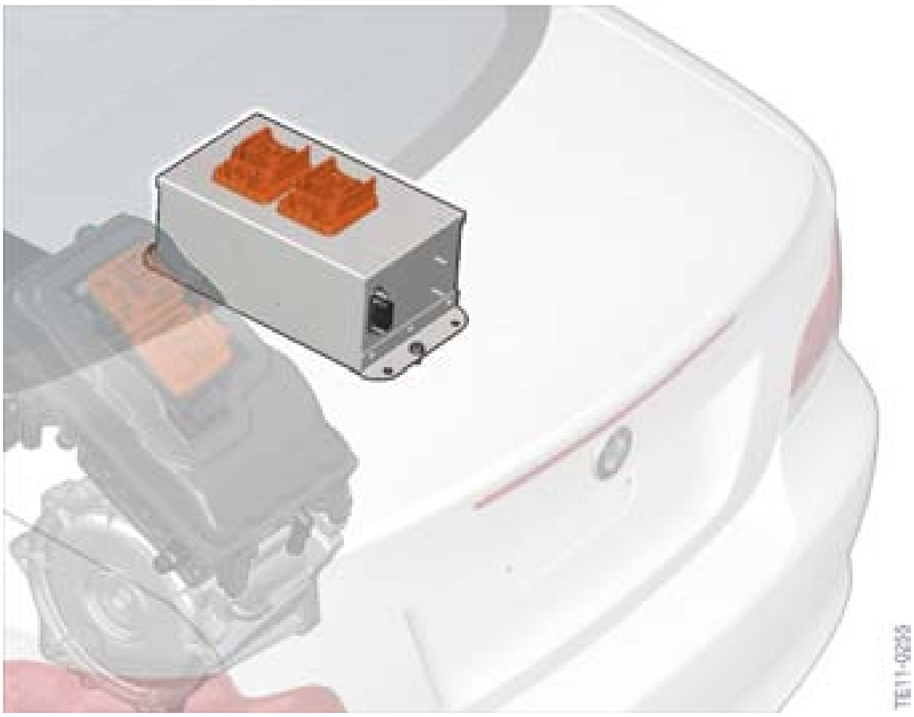
To adhere to these marginal conditions, there is a control unit (in each of the high voltage battery units) called battery management electronics (SME). These control units are differentiated by their own code designation:

High voltage battery unit	Code designation	Function
In the transmission tunnel	SME	Primary (Master)
In the front of the vehicle	SMES1	Secondary
In the rear	SMES2	Secondary

For the fault-free operation of the LMC batteries used in the E82E certain marginal conditions must be observed (as with all lithium-ion batteries). The cell voltage and the cell temperature may not fall below or exceed certain values; otherwise the battery cells may suffer permanent damage. For this reason each high voltage battery unit contains several cell monitoring electronic components referred to as "Cell Supervisory Circuits" (CSC).

The cell monitoring electronics communicate the values measured via a Local Controller Area Network. This Local CAN connects all cell monitoring electronics to each other (beyond the limits of the high voltage battery units) and to the SME control units. The measured values are evaluated in the SME “primary” control unit and a response is triggered if required (e.g. control of the cooling system).

KLE



Comfort charge electronics in the E82E

The comfort charge electronics is responsible for implementing the controlled charging of the high voltage batteries when the vehicle is stationary. Although the primary charging coordinator is actually the EME. The EME can request the charging power in stages from the KLE. A unidirectional AC/DC converter is located in the KLE, which converts the high voltage AC from the electrical power grid to the high voltage direct current (DC).

EKK

As previously mentioned, the E82E uses an electrically operated A/C compressor. In order to be able to provide the necessary power, the electric A/C compressor (EKK) is operated with high voltage DC. The EKK enables the refrigerant circuit of the air-conditioning unit in all driving situations. In addition to cooling the passenger compartment, the high voltage battery units are also cooled via the refrigerant circuit. The EKK control unit is installed in the housing of the A/C compressor and connected to the IHKA via the Local Interconnect Network bus.

EH

As there is no combustion engine heat source in the E82E, an electrically operated heater has been installed to heat the interior and the high voltage battery units. This makes it possible to maintain the desired controlled air temperature in the interior of the vehicle at standstill or while driving. In addition to heating the passenger compartment, the high voltage battery units can also be brought up to operating temperature when the vehicle is connected to a charging station. The EH control unit is integrated in the housing of the electric heating unit and connected to the IHKA via the Local Interconnect Network bus.

6.3. Diagnosis

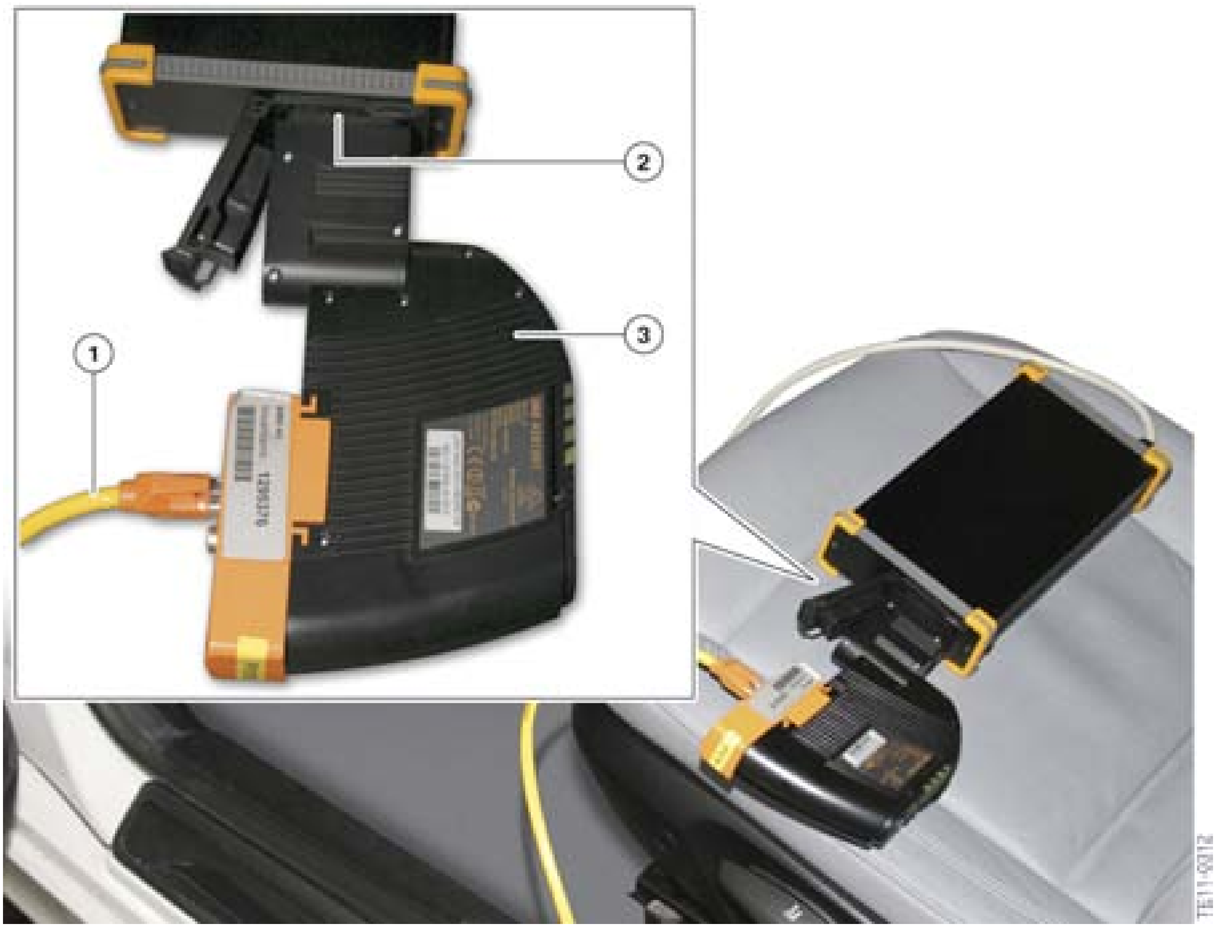
The bus systems of the E82E are a combination of two vehicle electrical system generations, vehicle electrical system BN2000 and vehicle electrical system BN2020. Because there is no central gateway module (ZGM) installed in the E82E as with BN2020, an adapter (referred to as the active gateway) is required for complete diagnosis of the system.

The ISTA/P workshop system cannot be used for the maintenance of the E82E due to the mixed installation of BN2000 and BN2020 components. This is to be achieved by using an expert tool, which, on the one hand, makes possible fault diagnosis and provides corresponding measures for fault correction, and, on the other, is in the position to program and encode vehicle components.

Connection of active gateway at diagnostic socket

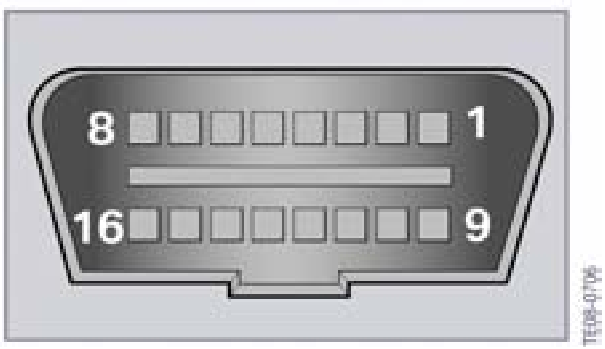
Index	Explanation
1	Button for opening the trunk lid
2	Diagnostic socket
3	Connector of active gateway
4	Active gateway

The active gateway is installed between the ICOM A and the diagnostic (OBD II) socket. The pin assignment of the diagnostic socket has also been modified for this reason.



ICOM A connection to the active gateway

Index	Explanation
1	Network cable
2	Active gateway
3	ICOM A



Diagnostic socket

Index	Explanation
1	Not assigned
2	Not assigned
3	Ethernet Rx+
4	Terminal 31
5	Terminal 31
6	D-CAN High
7	Not assigned
8	Ethernet activation
9	PT-CAN2, low
10	PT-CAN2, high
11	Ethernet Rx-
12	Ethernet Tx+
13	Ethernet Tx-
14	D-CAN Low
15	Not assigned
16	Terminal 30

The E82E diagnostic tool (known as “Expert Tool”) is a new laptop based system designed to support the E82E ActiveE vehicle platform. The Expert Tool like the car is unique and will only function in conjunction with this vehicle.

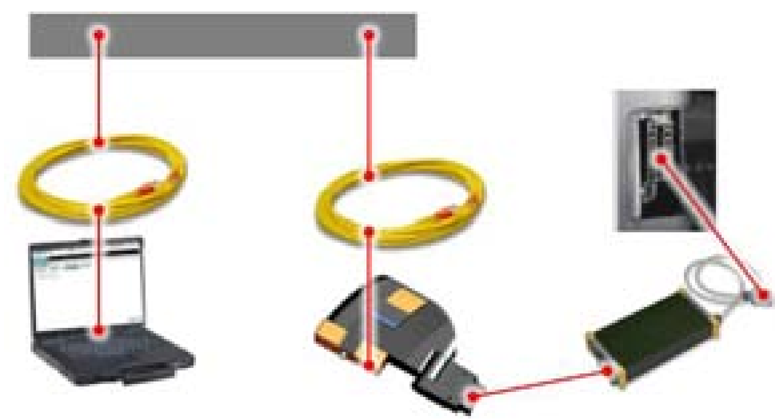
We have several possibilities to establish a connection with the vehicle.

The following process is currently recommended for connecting the Expert tool to an ActiveE vehicle. To ensure a safe and reliable connection connect to the vehicle using the laptop (CF–19) with the ActiveE Software installed and connecting the network cable, ICOM-A, Active gateway to the OBDII socket, as previously discussed.

Direct connection of the diagnostic equipment to the E82E

Another way of connecting the equipment is by connection to the ISTA network of the workshop.

This connection is helpful when the Technician is not in direct contact with the vehicle.

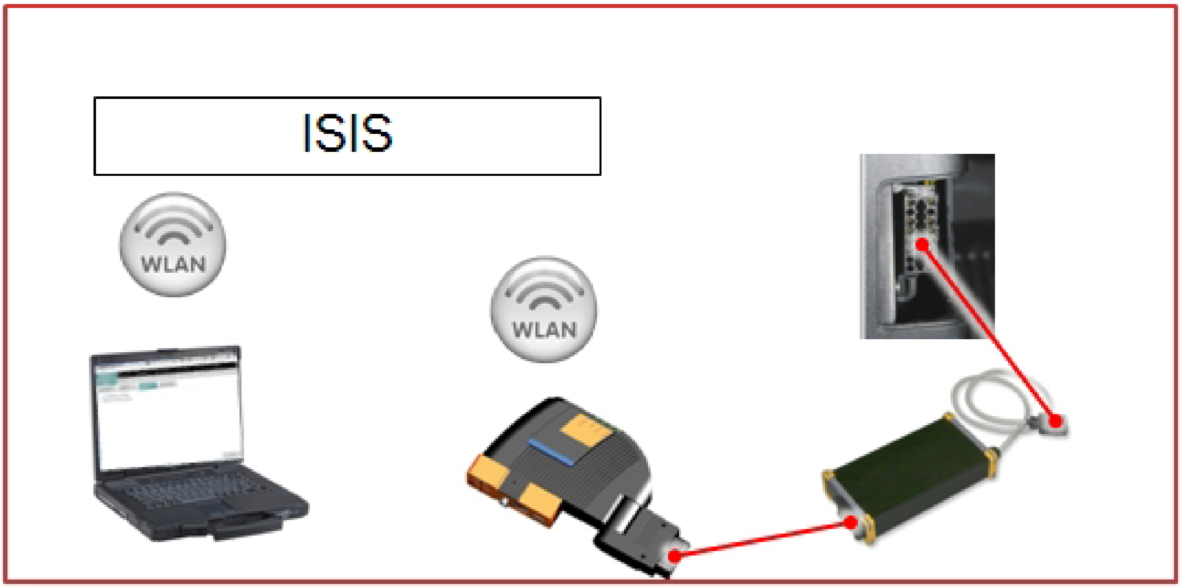


Connection of the E82E diagnostic equipment through the ISTA workshop network

The third connection choice is by using a WIFI.

This wireless connection is achieved through the workshop WLAN network and only requires the Active gateway and the ICOM A to be hard wired to the vehicle OBDII socket.

It is important to note that this connection was not fully operational at the time of the printing of this document.



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Regardless of which connection you are using, keep in mind that the correct connection configuration must be set up on the laptop in order to successfully link with the vehicle.

Configuring the laptop tool to the connection

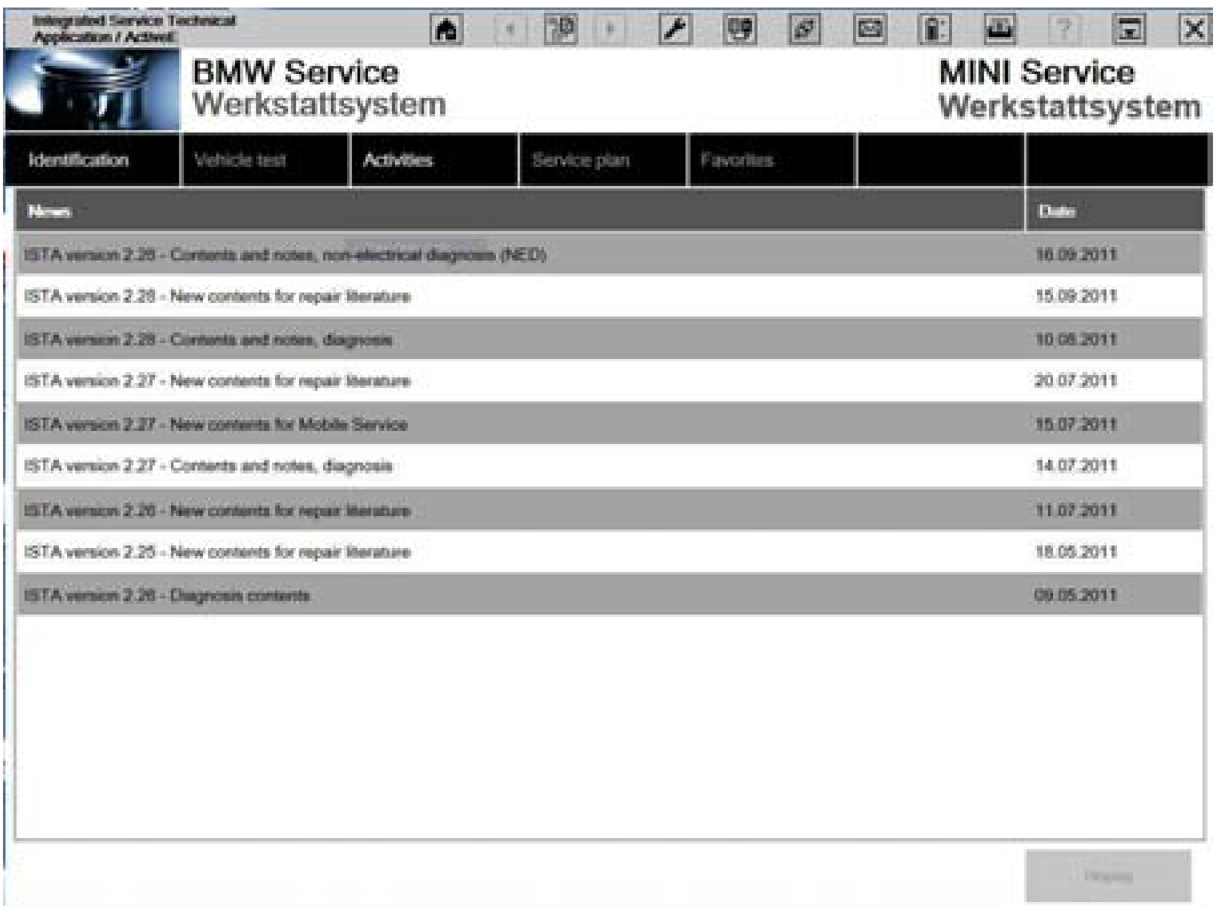
6.4. ISTA ActiveE software

The E82E is diagnosed with its own diagnostic tool called ISTA ActiceE software.

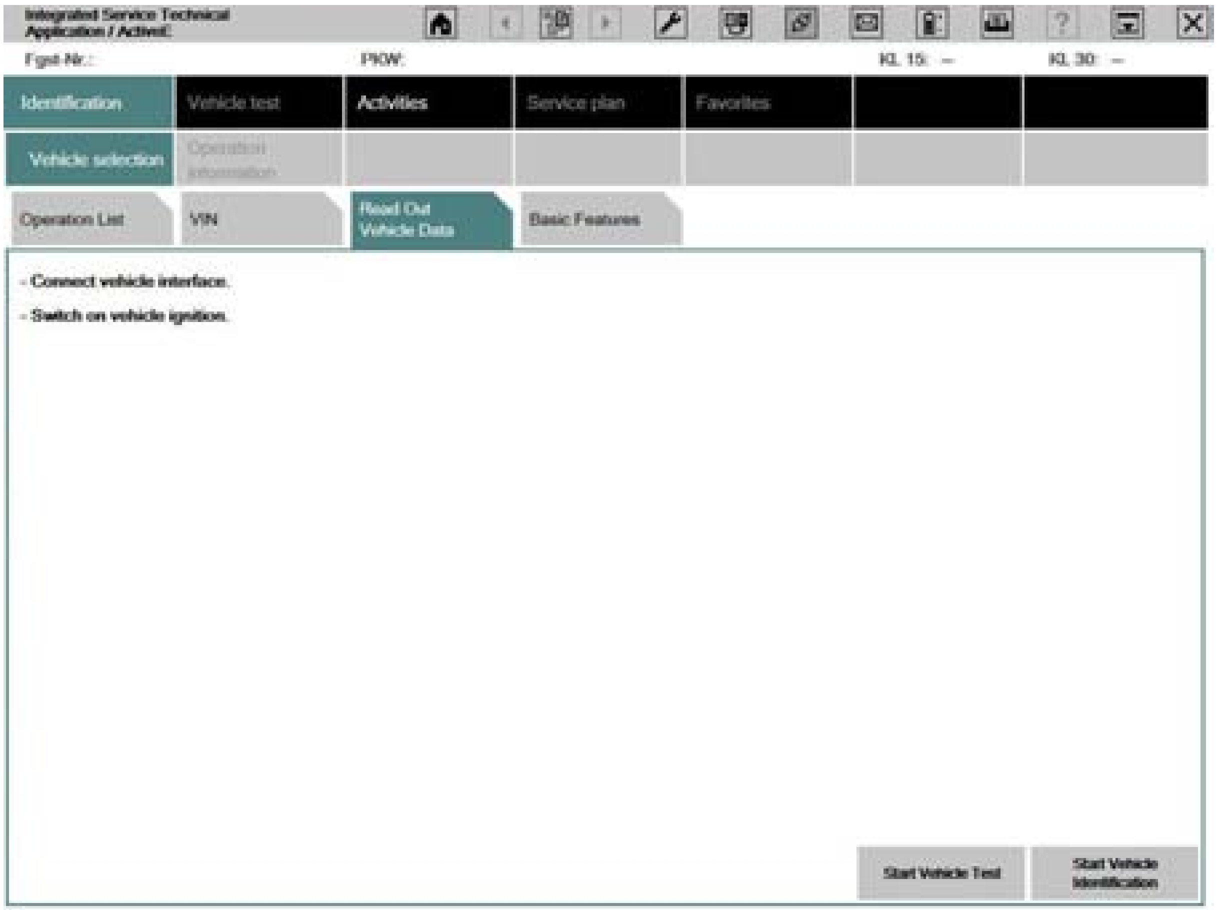
This software is installed on a laptop which is connected to the vehicle using the ICOM A and the Active gateway device previously described.

While screen look and feel is very similar to the 3g / ISPI ISTA virtual machine, connecting to an E82E vehicle is slightly different. The following process and screen shots will assist you when connecting to and E82E vehicle for the first time.

1. From the Home page, Click on “Identification”

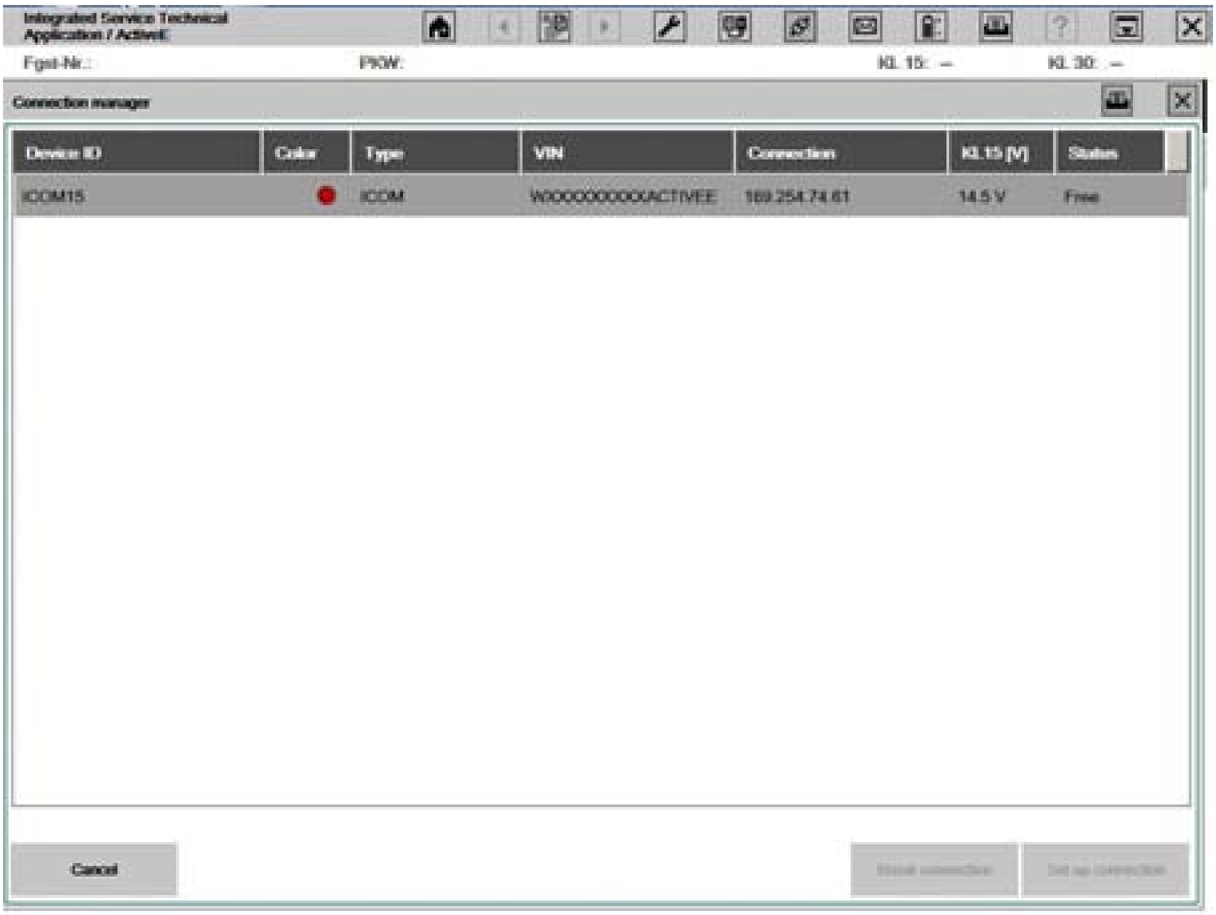


2. Click on the “Read Out Vehicle Data” tab

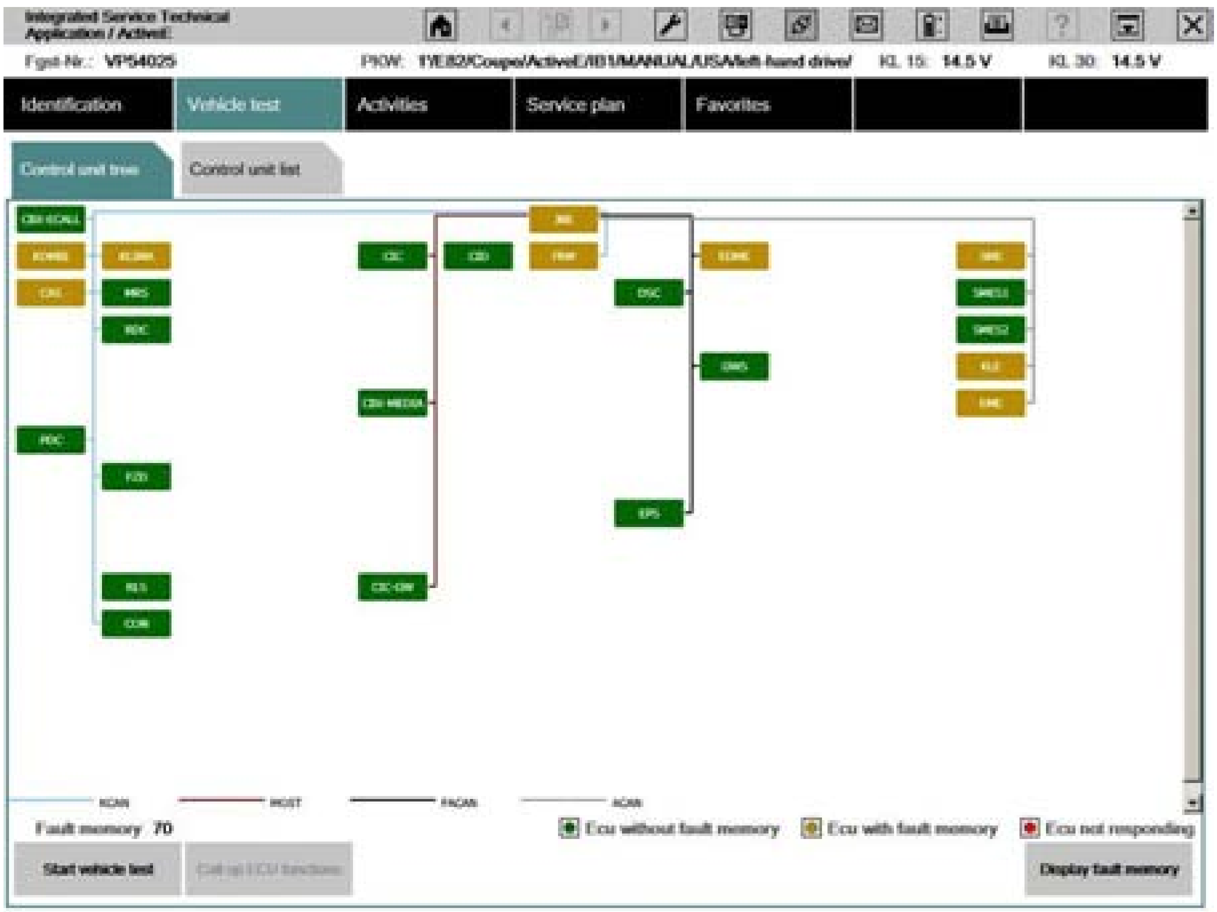


3. Click on the “Start Vehicle Identification” button

4. Click on the relevant ICOM and then click on the “Set Up Connection” button



5. Once the vehicle has been identified, click on the “Start Vehicle Test” button



On the control unit tree (Test Results) page you will be able to identify all the relevant control units associated with the vehicle as well as what the bus communication for each group of control units. With the Stylus pen touch and hold on a control unit to see relevant control unit information such as version, part number

6.5. Vehicle Programming

The E82E vehicle control units can only be programmed by using the laptop tool and ActiveE ISTA Software. The control units can only be programmed with the high voltage system disconnected. Please follow the proper safety procedures for disengaging and locking out the high voltage system. The vehicle programming process can begin once the vehicle has been identified and a test has been run.

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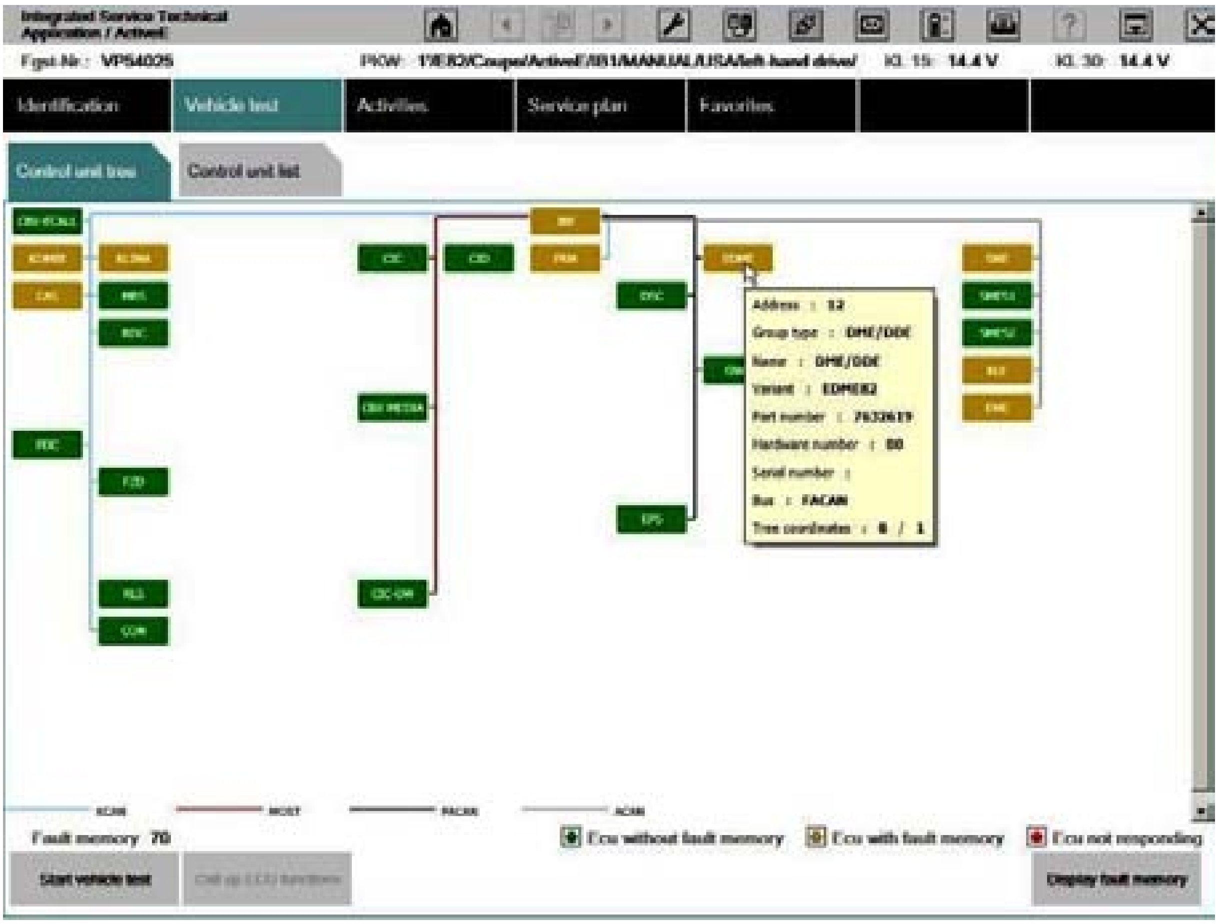
The vehicle programming process can begin once the vehicle has been identified and a test has been run.



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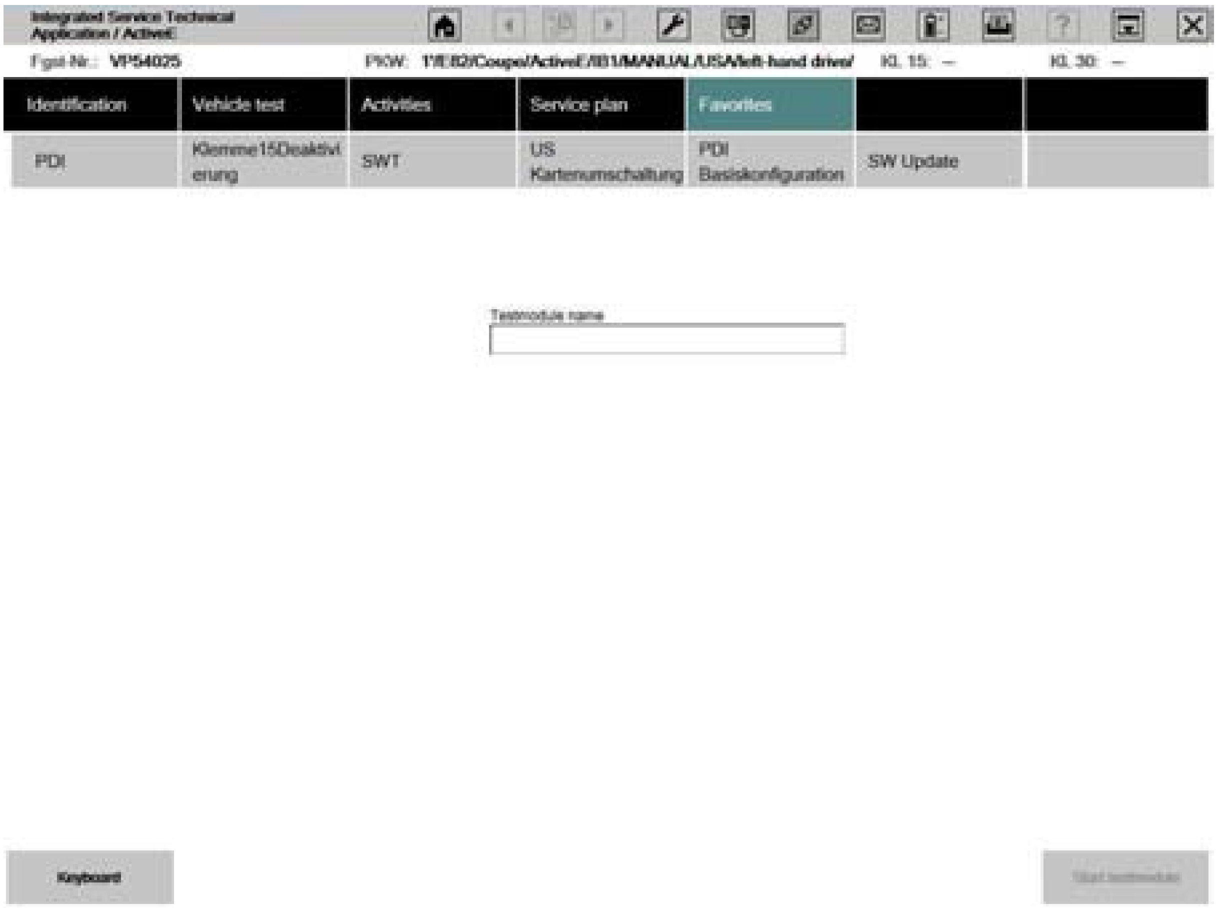
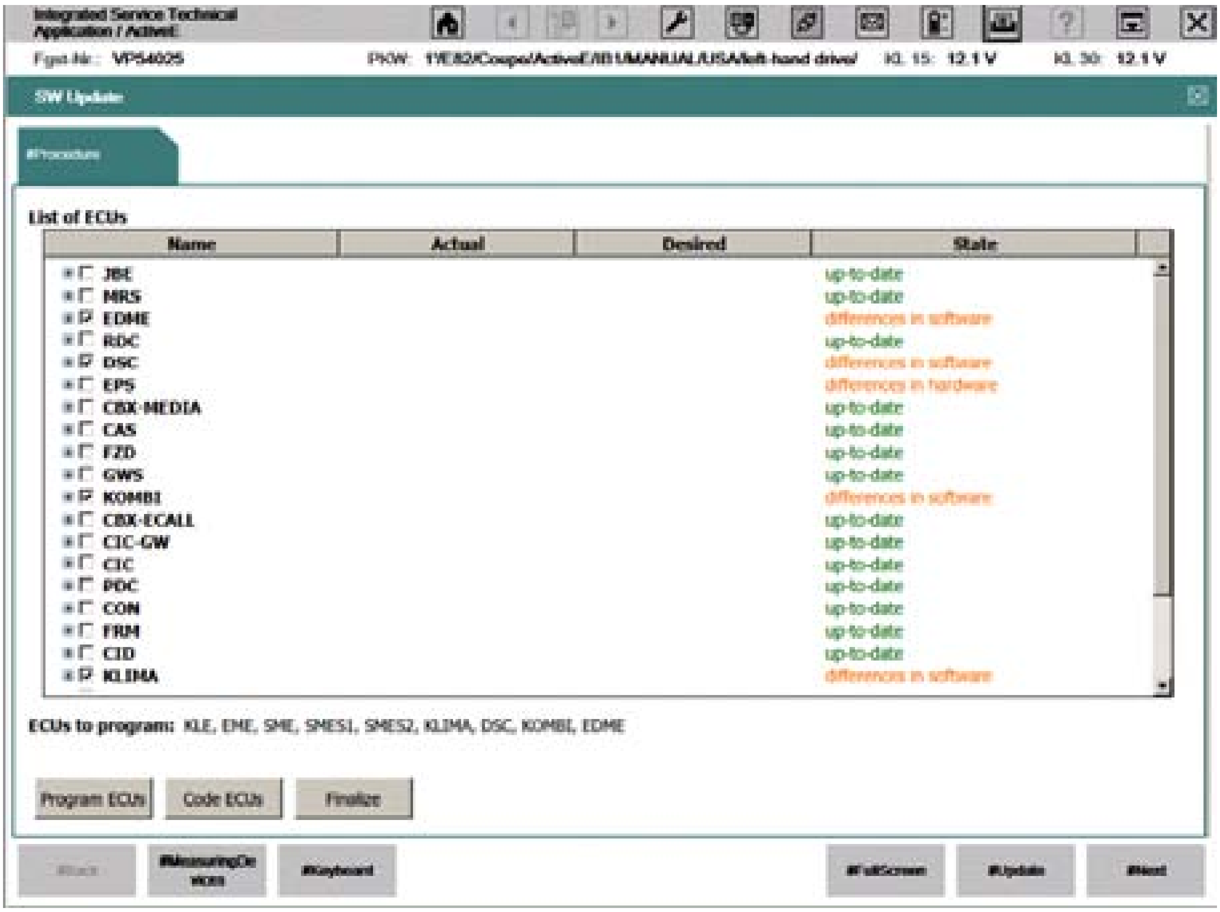
1. From the control unit tree (Test Results) page click on the “Favorites” tab



2. Click on the "SW Update" button on the "Favorites" page to see a list of control units and their software status



On the "procedure" screen you will see a control unit list advising what control units have up dated software and what control units require updating. Benefits are, you can choose what control units to update by simply clicking on the check box next to the control unit. You can also choose not to update a control unit by clicking on the check box to remove it from the update list.

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6. Bus Systems

6.6. Searching for procedures

You can search for procedures in this general view. Here text fragments which appear in SGBDs, fault code locations or in text modules are taken into account. A list of relevant procedures is displayed immediately. This can be performed by double-clicking on the relevant line. A simple mouse click on a test module lists fault memories in the bottom window, which are assigned to the procedure.

6.7. Displaying the documents

To call up information that is necessary to implement repairs, such as installation locations, wiring diagrams, etc., you can work through the respective diagnosis tree structure. Its structure is self-explanatory and it is possible to obtain desired information on all parts in the vehicle. E82E-specific ranges are also stored in this tree structure. These do not correspond to the E82 ranges, but contain the most important information.

7. Display and Operation

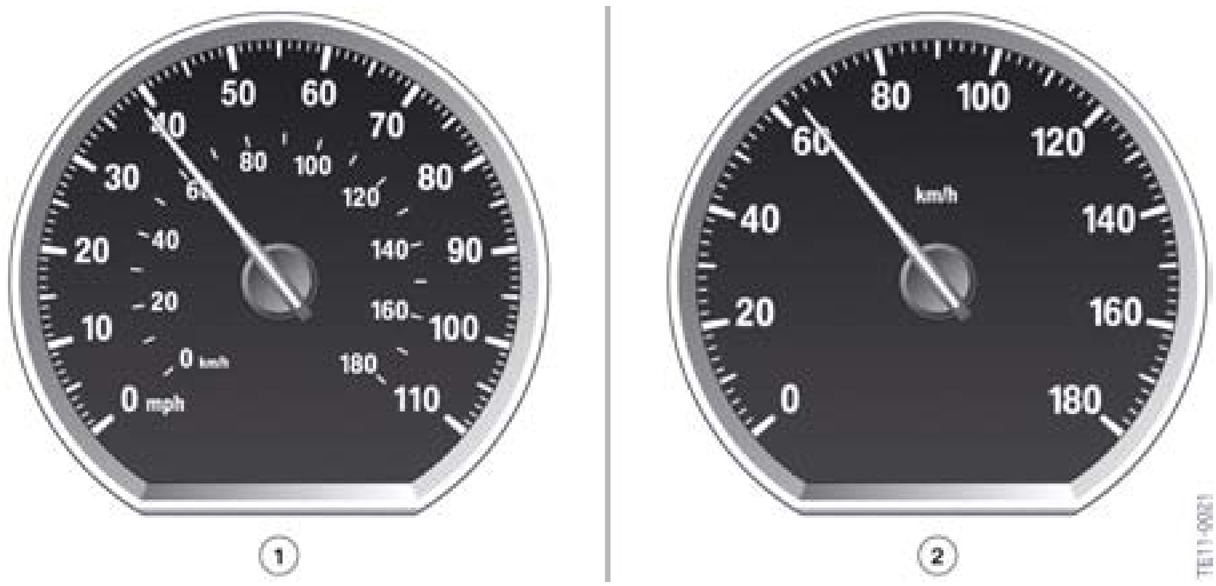
Kombi in the E82E

The driving operating conditions, as well as the charging status of the high voltage battery of the E82E are displayed in the instrument panel and upon request in the central information display. With the MyBMW Remote iPhone App, ActiveE customers are able to obtain information on the state of charge, range, remaining charge time, inside and ambient temperature of the vehicle, as well as the driving location, also outside the vehicle. The customer can directly influence the range of the vehicle using the drive experience button.

7.1. Displays in the instrument panel

7.1.1. Speed reading

The vehicle speed of the E82E is also shown in the left round instrument of the instrument panel. Depending on the national-market version there are two different scale diagrams.



Speedometer reading in US and European version

Index	Explanation
1	US version
2	European version

The speed reading has a final speed of 180 km/h. In the US version, both scales of the speed reading are shown, the outer scale shows the driving speed in mph and ends at 110 mph.

7.1.2. Display of operating conditions and charge status

The right round instrument in the instrument panel is used to display the electric driving modes. The displays are active from terminal 15. The following information is displayed on a permanent basis:

- Readiness to travel (READY / OFF)
- Electric driving (eDRIVE)
- Energy recovery (CHARGE)
- State of charge of the battery (0 to 1)

A: Display indicating readiness to travel deactivated
B: Display indicating readiness to travel activated

Index	Explanation
1	Needle for electric driving is at "OFF" —> Readiness to travel is not activated
2	Needle for state of charge of the high voltage battery is at "0" —> Display is not activated
3	Needle for electric driving is at "READY" —> Readiness to travel is activated
4	Needle for state of charge of the high voltage battery is at "3/4" –> SoC equals 75%

The driver is shown how much electrical energy is taken from the high voltage battery for electric driving (eDRIVE) or how much energy is recovered (CHARGE).

The high voltage battery is partially recharged through energy recovery. The electrical machine works here as an generator and converts the kinetic energy from the vehicle to electrical energy. In this mode the vehicle decelerates as energy regeneration takes place.

When the vehicle is at a standstill, e.g. at traffic lights, the needle is at "READY" and thus indicates to the driver the readiness to travel. The needle is at "OFF" when the readiness to travel is deactivated.

Display for electric driving (eDRIVE) and energy recovery

Index	Explanation
A	Display for electric driving
B	Display for energy recovery

7.1.3. Indicator lights

Fixed indicator lights in the instrument panel

Index	Explanation
1	Restriction of energy recovery
2	Power restriction of the electrical machine (available power falls below 70%)

There are two fixed indicator lights in the instrument panel which display any faults in the electric drive. One shows the faults of the electrical machine and the other the faults with energy recovery. The indicator lights can also light up independent of each other. For example the electrical machine can function fault-free, but energy recovery may not be possible because the high voltage battery has become too warm. In order to cool the high voltage battery, energy recovery is reduced. In this case only a yellow warning light for energy recovery lights up.

7.1.4. On-board computer displays

Display for range

Index	Explanation
1	Range in kilometer (fuel pump symbol has been replaced with an electrical plug symbol)

The following information can be shown in the on-board computer display of the instrument panel:

- Average speed
- Range or ECO PRO range potential
- Average consumption

When calculating the average speed, standstill (with deactivated readiness to travel) is not considered.

The range is projected over the last 30 km/18.6 mph taking into consideration the driving style and the current state of charge of the high voltage battery. When ECO PRO is activated the increased range potential (taking into consideration the ECO PRO functions) is shown.

⚠

If the cruising range falls to zero or the high-voltage battery's charge status falls to zero then continued vehicle operation will not be possible. In other words, the type of reserve range for charge status and cruising range that would allow additional travel over a short distance is not available.

The average consumption can be displayed in kWh/100 km, km/kWh or mls/kWh.

7.2. Displays in central information display

The energy/power flow in all operating conditions of the vehicle as well as the state of charge of the high voltage battery, can be displayed in the CID. This provides the driver with an overview of the functioning of the high voltage system during charging and different driving conditions, e.g. during energy recovery. The displays are accessed in the CID via the "Vehicle information > eDRIVE" menu selection.

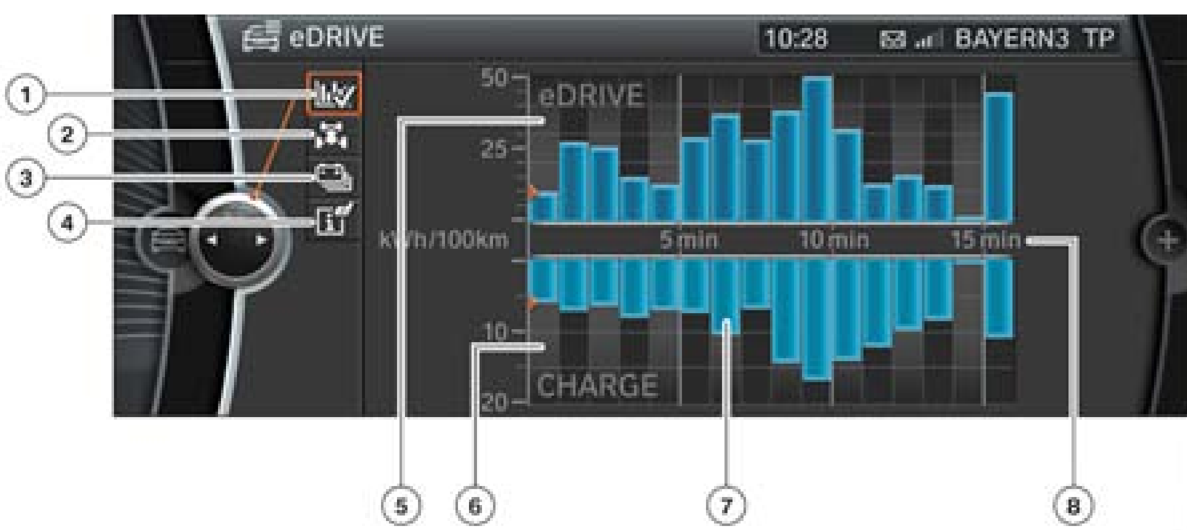
⚠

Note: The images shown here are examples of the screen content. It is possible that many of the functions in the production vehicles differ from what is shown here.

Four different categories of displays can be accessed in the CID:

- Energy consumption
- Electric driving//Energy recovery
- Information on the high voltage battery
- ECO tips

7.2.1. Energy consumption



Display for consumption history

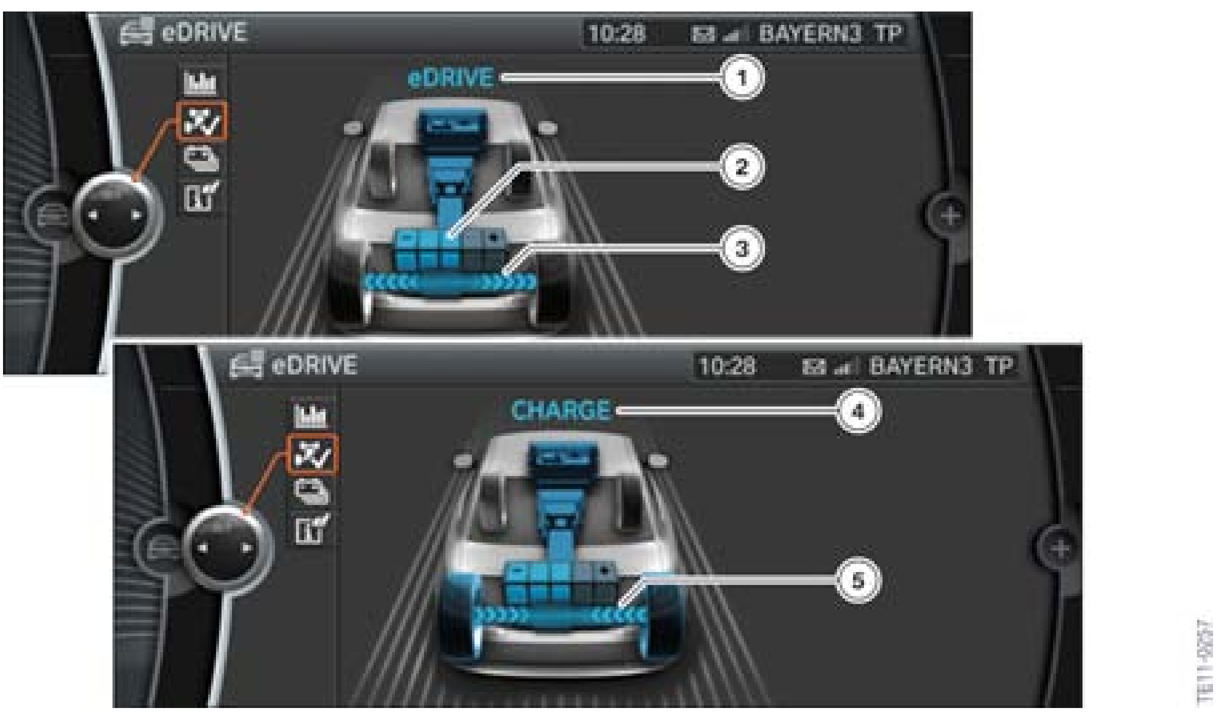
Index	Explanation
1	Selection of consumption history display
2	Selection of electric driving and energy recovery display
3	Selection of display of information on the high voltage battery
4	Selection of display for ECO tips

Index	Explanation
5	Indication range for electric driving
6	Indication range for energy recovery
7	Bars as minute display
8	Time axis (for the last 16 minutes)

Each bar shows the average energy consumed during the driving time and the energy recovered through brake energy. One bar equals one minute. The height of the bar provides information on the energy used/recovered. Depending on how the units for consumption have been selected, the specification for the Y-axis (energy axis) is also effected in kWh/100 km, mls/kWh or km/kWh. The maximum scale for the Y-axis also changes here.

Selected unit	Maximum scale for electric driving	Maximum scale for energy recovery
kWh/100 km	50	20
mls/kWh	5	20
km/kWh	10	30

7.2.2. Electric driving/Energy recovery



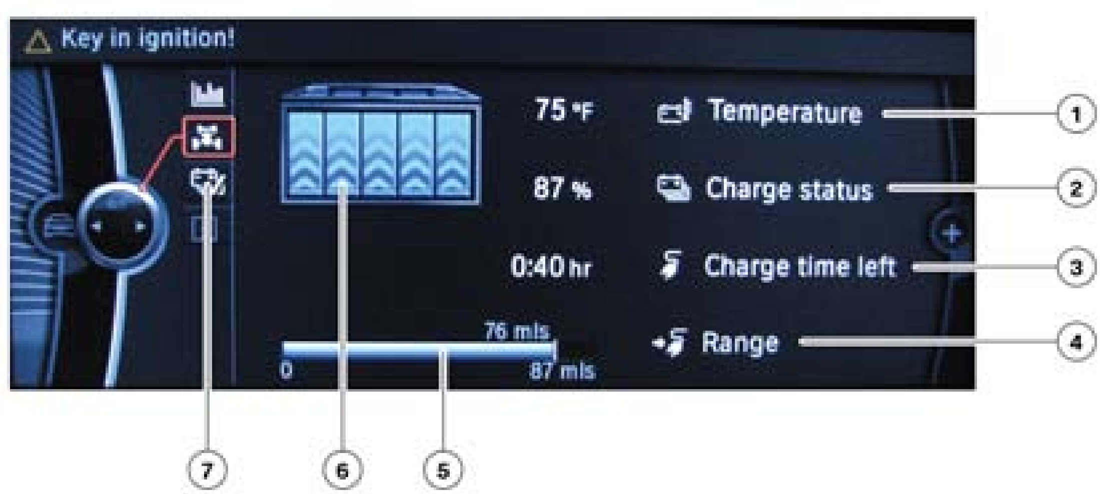
Displays for electric driving and energy recovery

Index	Explanation
1	Text message for current driving situation "eDRIVE"
2	State of charge of the high voltage battery
3	Power flow on rear axle (from the high voltage battery to the rear wheels)
4	Text message for current driving situation "CHARGE"
5	Power flow on rear axle (from the rear wheels to the high voltage battery)

When the "Electric driving/Energy recovery" menu is selected, the energy flow from the high voltage battery to the rear wheels is shown in the CIS by an animated blue arrow. In addition, the text message "eDRIVE" appears over the vehicle symbol. All three high voltage battery units are blue, whereby the third high voltage battery unit is divided into five segments. Depending on the state of charge of all three high voltage battery units the segments are highlighted in bright blue. In the example above three segments are filled which corresponds to a state of charge of 60%.

During energy recovery the direction of the animated arrow changes from the rear wheels to the high voltage battery. In addition, the text message "CHARGE" appears over the vehicle symbol.

7.2.3. Information on the high voltage battery



Display for information on the high voltage battery

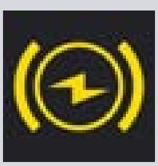
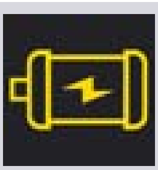
Index	Explanation
1	Current temperature of the high voltage battery
2	Current state of charge of the high voltage battery
3	Remaining charge time for the high voltage battery (only when charging plug is connected)
4	Bars for range
5	Current range
6	Symbolic representation of the high voltage battery
7	Selection of display for information on the high voltage battery

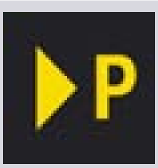
In the selection menu "Battery info" all relevant information on the high voltage battery is shown. The current temperature and the state of charge of the high voltage battery are displayed for example. If the connector for charging the high voltage battery is connected, the required time for full charging is shown. The number above the range bar displays how far the vehicle can still travel with current charging of the high voltage battery (blue). Under the range bars the values "0" and "150 km" for example mark the start and end of the bar. The end value is adjusted dynamically. This means it can also be more or less than 150 km. In the symbolic representation of the high voltage battery the five segments show the state of charge of the high voltage battery. Each segment represents 20% SoC. In the example above three segments are filled. This corresponds to a state of charge of 60%. While charging the high voltage battery the arrows in the segments are animated.

Please note that only the customer-relevant information regarding the state of charge of the high voltage battery is shown. The actual state of charge of the high voltage battery is much higher. This also means that when the value displays zero the high voltage battery is still live.

7.3. Specific Check Control messages

As with conventional vehicles, the driver is informed of any faults that occur in the E82E via Check Control messages. The following table includes the Check Control messages specific for the electric drive.

Check control message	Meaning	Possible causes
	Drive. Careful stopping	Faults in the high voltage system, functions controlling/monitoring high voltage, or safety limits of high voltage components exceeded during the journey. Available torque is set at 0 and high voltage system shuts down --> Vehicle coasts
	Drive. Moderate driving	Medium fault in the high voltage system / components or functions controlling/monitoring high voltage (temperature threshold exceeded…) --> stable reduced drive power, continuation of journey possible, HV memory fault
	Drive. Moderate driving	Speed for generator operation exceeded
	High voltage system defective	Fault in the high voltage system or functions controlling/monitoring high voltage (e.g. bus failure, interlock) at standstill --> Leads to immediate shutdown of the high voltage system
	Drive. Moderate driving	Available power below 30% Systematic occurrence with low SOC, therefore no request to visit a BMW Dealer Service workshop
	Brake pedal travel is extended	Vacuum pump is defective

Check control message	Meaning	Possible causes
	1. Inspect charge cable 2. Network/Grid power too low High-voltage system 3. No charging possible	1. Plug detected but no locking recognized –> Plug detent is not engaged. 2. Available grid power is not adequate for charging. Cause lies with the building grid/ home electrical system or the energy provider. 3. HV+ or HV- has contact resistance of < 200 kOhm relative to vehicle body –> no hazard for customer because only a conductor is damaged –> a single fault can lead to a customer hazard during charging (AC system). **--> To prevent risk to customer, the charging station automatically switches off and charging will not take place if an isolation fault (in AC or DC circuits) is detected.**
	Reserve, range Remove charging cable Check charging cable	The customer is shown the range. When the charging plug is connected active drive to readiness is prevented (risk of removing the charging cable when being supplied with voltage) Detection of fault in charging cable. Connected charging plug cannot be detected. Customer should check whether the connector is still connected before driving off.
	For charging engage P	In position N the HV battery cannot be charged for safety reasons. After engaging P, charging the HV battery is started automatically (when connector inserted)
	High voltage system is shut down	The high voltage system is de-energized using the high voltage safety connector.

7.4. ECO PRO mode

The driver of a E82E can drive his vehicle even more efficiently by activating ECO PRO mode. ECO PRO mode is activated by using the drive experience button located near the gear selector. The ECO PRO mode coordinates consistent consumption reduction for maximum range of the vehicle. The LED in the drive experience button lights up when ECO PRO mode is activated. After ECO PRO has been activated, ECO PRO is shown in the instrument panel and briefly the range potential. If the preconditions for consumption-optimized driving are no longer satisfied, e.g. maximum acceleration, ECO PRO is displayed with a shaded field.

Gear selector lever and drive experience button in the E82E

Index	Explanation
1	Drive experience button

ECO PRO mode influences the control of the electrical machine and the accelerator pedal characteristics. Here a really relaxed and, at the same time, consumption-optimized driving style is supported at low motor speeds. A specific power control for electrically operated functions such as climate control (electric heating unit and electric A/C compressor), seat and outer mirror heating, etc. ensure particularly efficient energy management in the vehicle. The displays in the instrument panel and on the Control Information Display provide the driver with information on the energy efficiency at the current time, as well as in previous stretches of the journey, and encourage him to adopt the most reasonable driving style with regard to consumption. For example the range in kilometers extended by ECO PRO is shown.

Representation of the ECO tips in the CID

Index	Explanation
1	Selection of display for ECO tips
2	Driving tips in text form using the example: Reduce speed

When the display for ECO tips and ECO PRO mode are activated the driver is given the following notes depending on the driving situation to optimize power consumption:

- Reduce speed
- Moderate acceleration
- Possible decel.

7.5. Signal paths

Signal path to the display elements

Index	Explanation
1	Display in the CID
2	Display in the instrument panel
3	Outside temperature sensor
4	Electrical Digital Motor Electronics

Index	Explanation
5	High voltage battery units with SME control units
6	SoC = State of Charger of the high voltage battery
7	Temperature sensor of the high voltage battery
8	Combox
9	iPhone
10	Car Information Computer

The image above illustrates how the signals come from the control units to the display elements. The temperature of the high voltage battery units is recorded by the temperature sensors. The temperature values of the individual high voltage battery units are included in the SME control unit and sent to other control units via PT CAN2. The CIC reads this value and edits it for the CID. The current temperature of the high voltage battery is displayed in the CID (in addition to other values) when the menu for the state of charge of the high voltage battery is accessed.

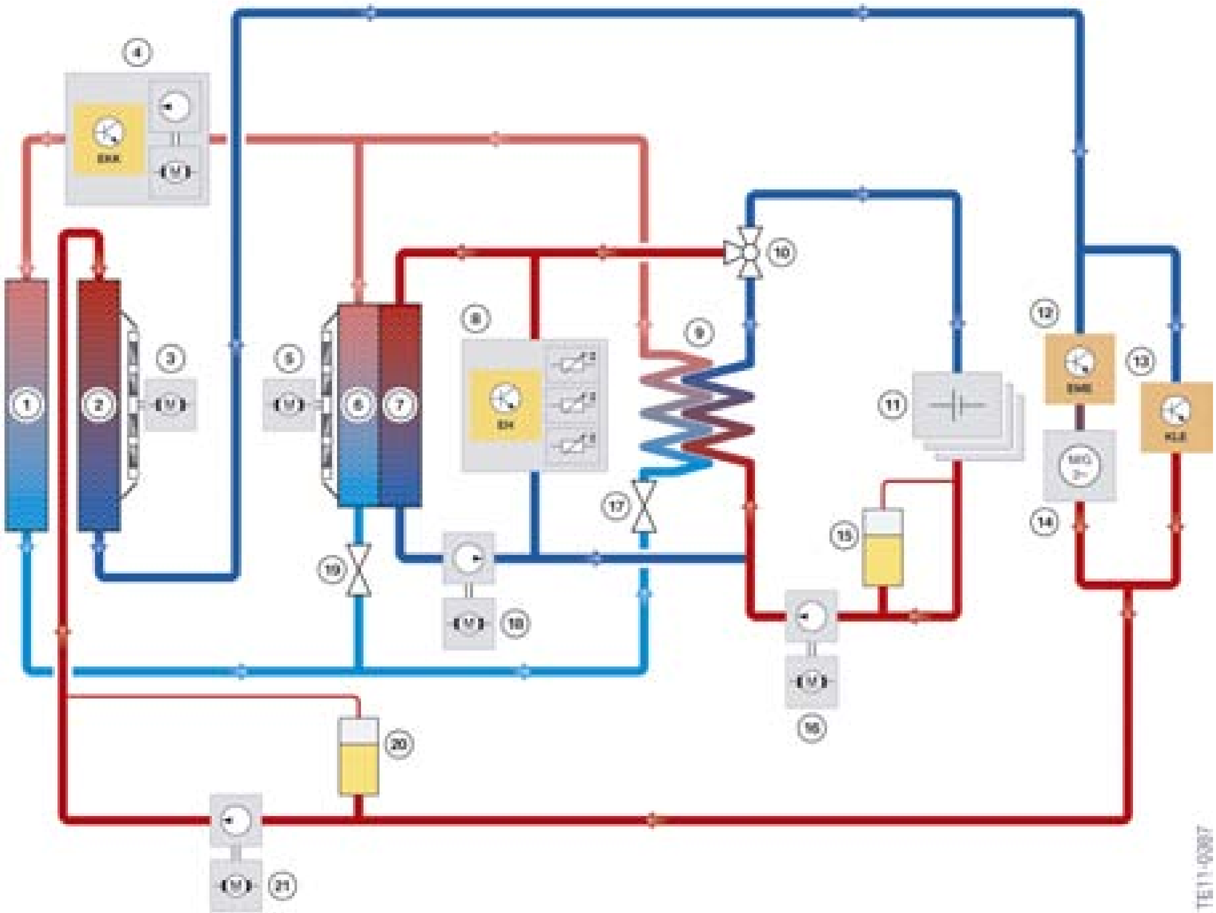
With the My BMW Remote App it is also possible to access the current status of the high voltage battery. The temperature value (and other values) is sent in this case via the Combox to the iPhone and shown in the iPhone display.

The other values such as the state of charge of the high voltage battery, the range, the remaining charge time, etc. are also sent in a similar way via bus systems, received by the CIC and then shown in the CID or via Combox in the iPhone.

8. Climate Control

Very high demands are placed on the climate control functions in the E82E. On the one hand, the passenger compartment must always be at a perfect temperature for the customer. On the other, the high voltage battery must be cooled or heated depending on the ambient temperatures in order to prolong the service life of the high voltage battery.

8.1. System overview



System overview of climate control E82E

Index	Explanation
1	Condenser (refrigerant circuit)
2	Radiator
3	Electric fan
4	Electric AC compressor
5	Blower motor
6	Evaporator (for cooling the passenger compartment)
7	Heater core (heat exchanger for the passenger compartment)
8	Electric heating unit

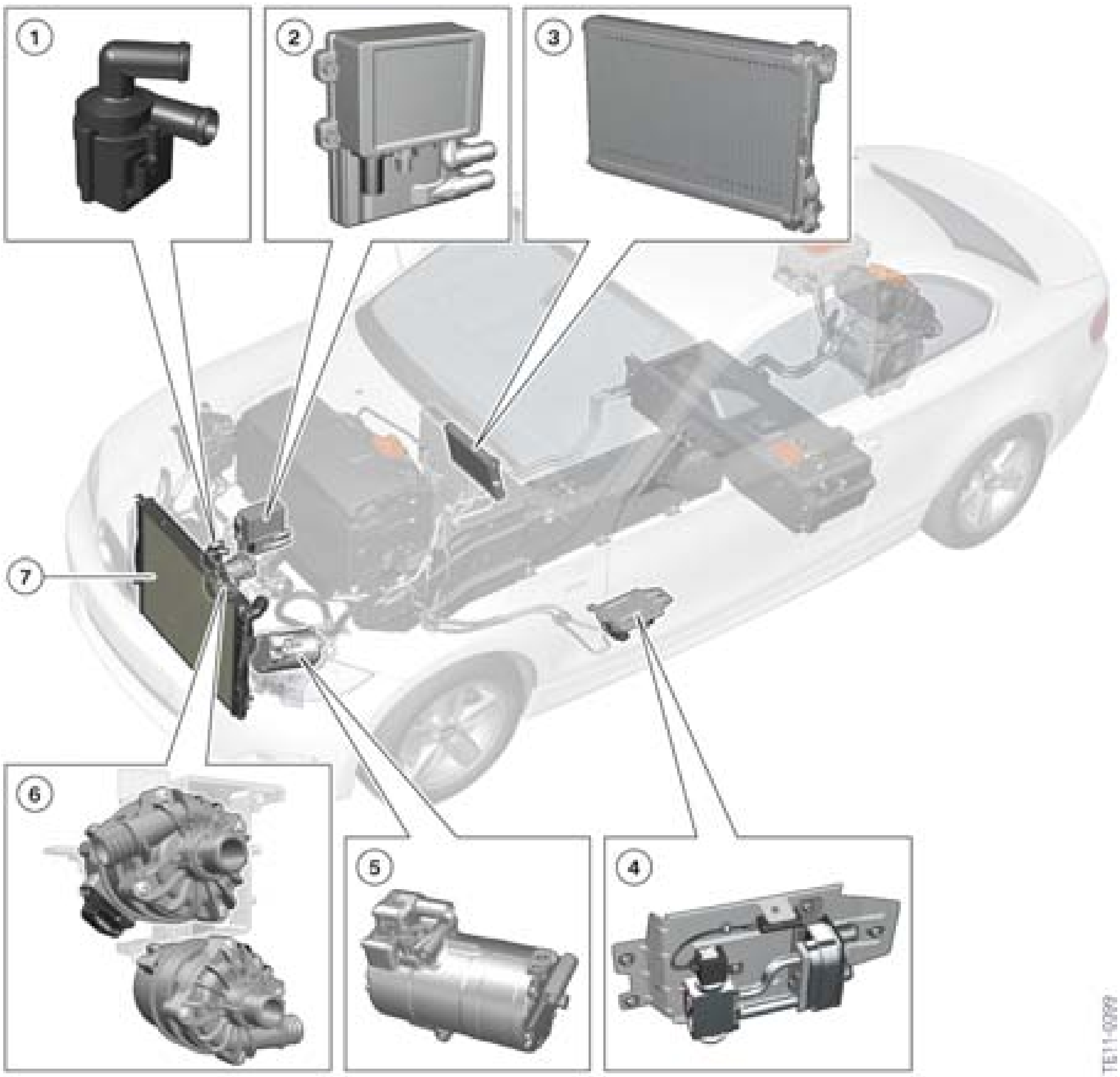
Index	Explanation
9	Chiller unit (coolant/refrigerant heat exchanger)
10	Changeover valve for heating/cooling the high voltage battery
11	High voltage battery
12	Electrical machine electronics
13	Comfort charge electronics
14	Electrical machine
15	Coolant expansion tank for the high voltage battery cooling circuit
16	Electric coolant pump (50 W) for cooling circuit of the high voltage battery
17	Combined expansion and shutoff valve in the refrigerant circuit
18	Electric coolant pump (20 W) in the electric heating circuit
19	Shutoff valve in the refrigerant circuit (for the passenger compartment)
20	Coolant expansion tank for the powertrain components cooling circuit
21	Electric coolant pump (50 W) for the powertrain components cooling circuit

The graphic above shows all coolant and refrigerant circuits in the E82E. The operating condition that all circuits are active at the same time is of course not given. All circuits are shown in color for better understanding. The blue colors indicate a lower temperature. Varying blue colors depict the different circuits. The red colors refer to a high temperature of the coolant or refrigerant. Also here the varying red colors clarify the different circuits.

Four circuits insure the cooling or heating of the components and interior:

- Powertrain components cooling circuit
- High voltage battery cooling circuit
- Heater circuit for heating the interior and the high voltage battery
- Refrigerant circuit for cooling the interior and the high voltage battery

The following image shows the most important components of climate control and their installation locations.



Installation locations of the components

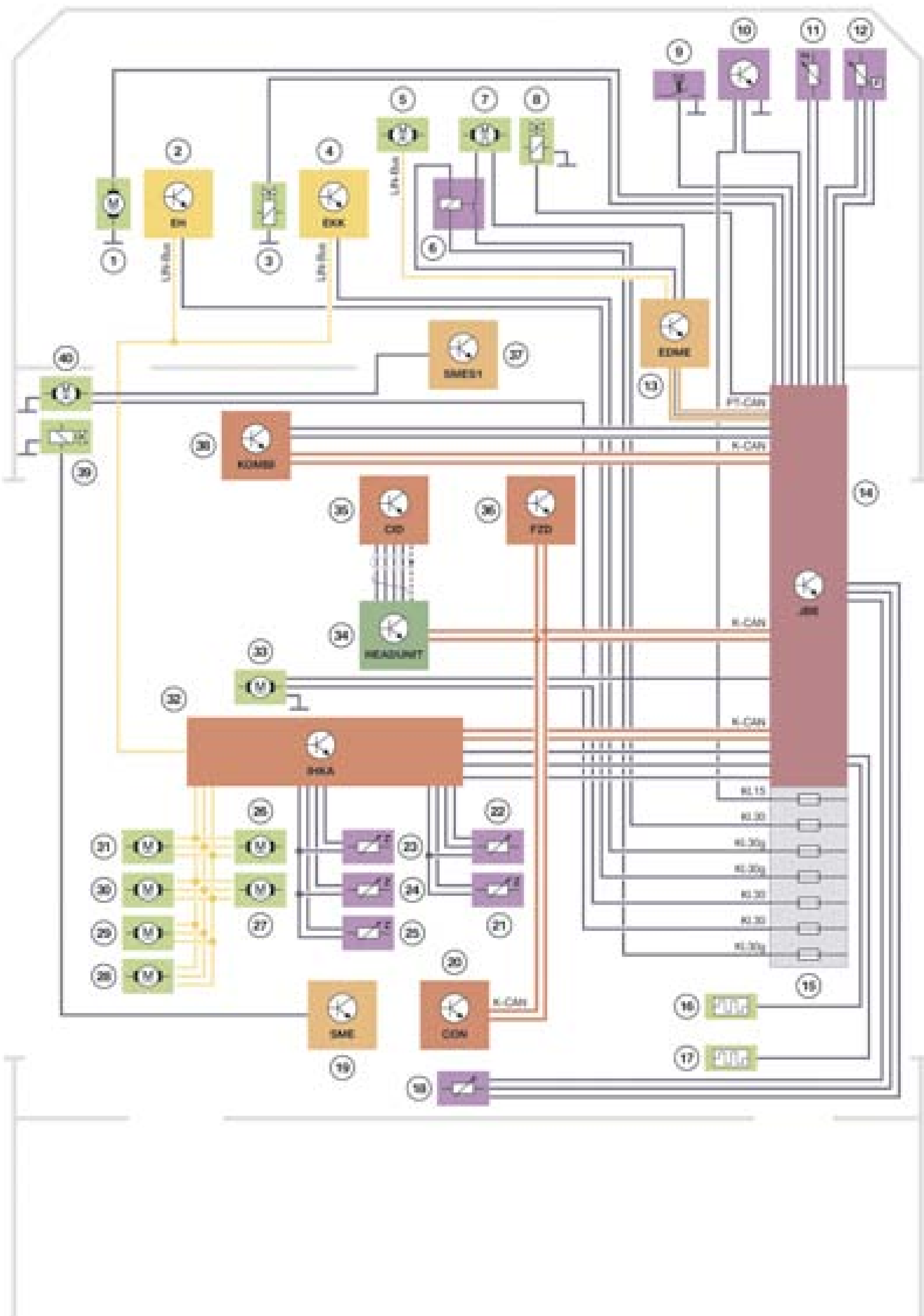
Index	Explanation
1	Electric coolant pump (20 W) in the electric heating circuit
2	Electric heating unit
3	Heat exchanger
4	Chiller unit (coolant/refrigerant heat exchanger)
5	Electric A/C compressor
6	Electric coolant pump (50 W)
7	Radiator and Condenser

E82E Complete Vehicle

8. Climate Control

In contrast to vehicles with a combustion engine, the E82E components for heating/cooling can be installed anywhere in the vehicle (depending on the available space). The only exceptions here are the radiator and condenser, which are still installed at the front of the vehicle in order to receive sufficient air flow for the cooling effect.

The components of the climate control are essentially controlled by the IHKA, SME and SMES1.



System wiring diagram for climate control E82E

Index	Explanation
1	Electric coolant pump (20 W) in the cooling circuit of the electric heating
2	Electric heating unit
3	Shutoff valve in the refrigerant circuit
4	Electric A/C compressor
5	Electric coolant pump (50 W) in the cooling circuit of the powertrain components
6	Relay for electric fan
7	Electric fan
8	Changeover valve for heating/cooling the high voltage battery
9	Coolant level switch
10	Automatic air recirculation control sensor
11	Outside temperature sensor
12	Refrigerant pressure sensor
13	Electrical Digital Motor Electronics
14	Junction box electronics
15	Power distribution box, front
16	Heating element for driver's seat
17	Heating element for front passenger seat
18	Rear stratification control
19	Battery management electronics
20	Controller
21	Solar sensor
22	Stratification control
23	Temperature sensor in the footwell
24	Evaporator temperature sensor
25	Temperature sensor in the ventilation
26	Stepper motor for defrost outlet
27	Stepper motor for blending flap on right
28	Stepper motor for footwell flap
29	Stepper motor for ventilation flap
30	Stepper motor for blending flap on left
31	Stepper motor for the central air flap
32	Integrated automatic heating / air-conditioning
33	Blower for heating and air-conditioning system
34	Head unit (Car Information Computer)

Index	Explanation
35	Central Information Display
36	Roof function center
37	Battery management electronics, secondary 1
38	Instrument panel
39	Combined expansion and shutoff valve in the refrigerant circuit
40	Electric coolant pump (50 W) in the cooling circuit of the high voltage battery

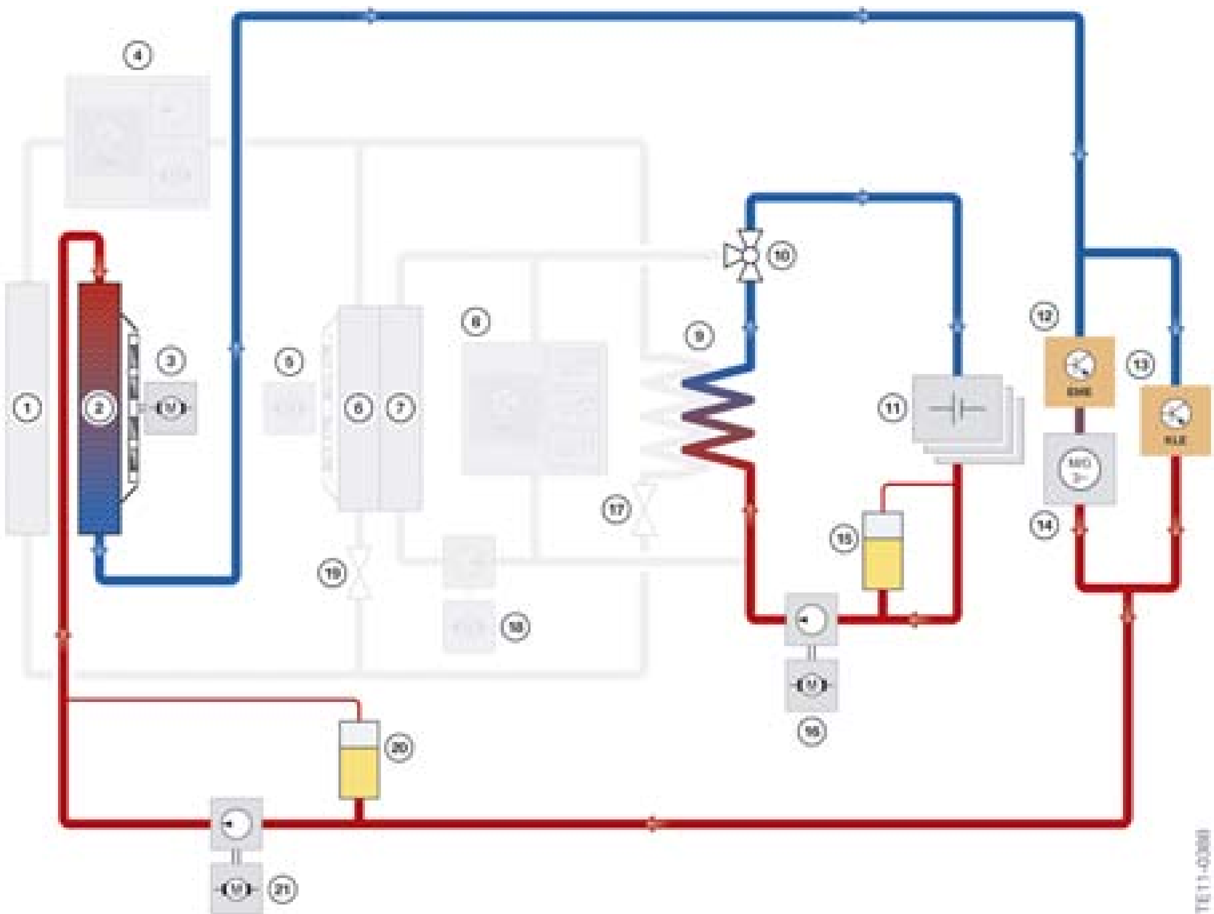
8.2. Functions

The following functions are realized in the heating/air-conditioning system:

- Cooling the powertrain components and the high voltage battery with coolant
- Cooling the passenger compartment
- Cooling the high voltage battery with refrigerant
- Heating the high voltage battery
- Heating the passenger compartment

8.2.1. Cooling the powertrain components and the high voltage battery with coolant

The cooling circuits for cooling the powertrain components and the high voltage battery are shown in color in the following graphic.



Cooling circuits for cooling the powertrain components and the high voltage battery

Index	Explanation
1	Condenser in the refrigerant circuit
2	Radiator
3	Electric fan
4	Electric A/C compressor
5	Blower motor
6	Evaporator in the refrigerant circuit for cooling the passenger compartment
7	Heat exchanger
8	Electric heating unit
9	Chiller unit (coolant/refrigerant heat exchanger)
10	Changeover valve for heating/cooling the high voltage battery
11	High voltage battery
12	Electrical machine electronics
13	Comfort charge electronics
14	Electrical machine

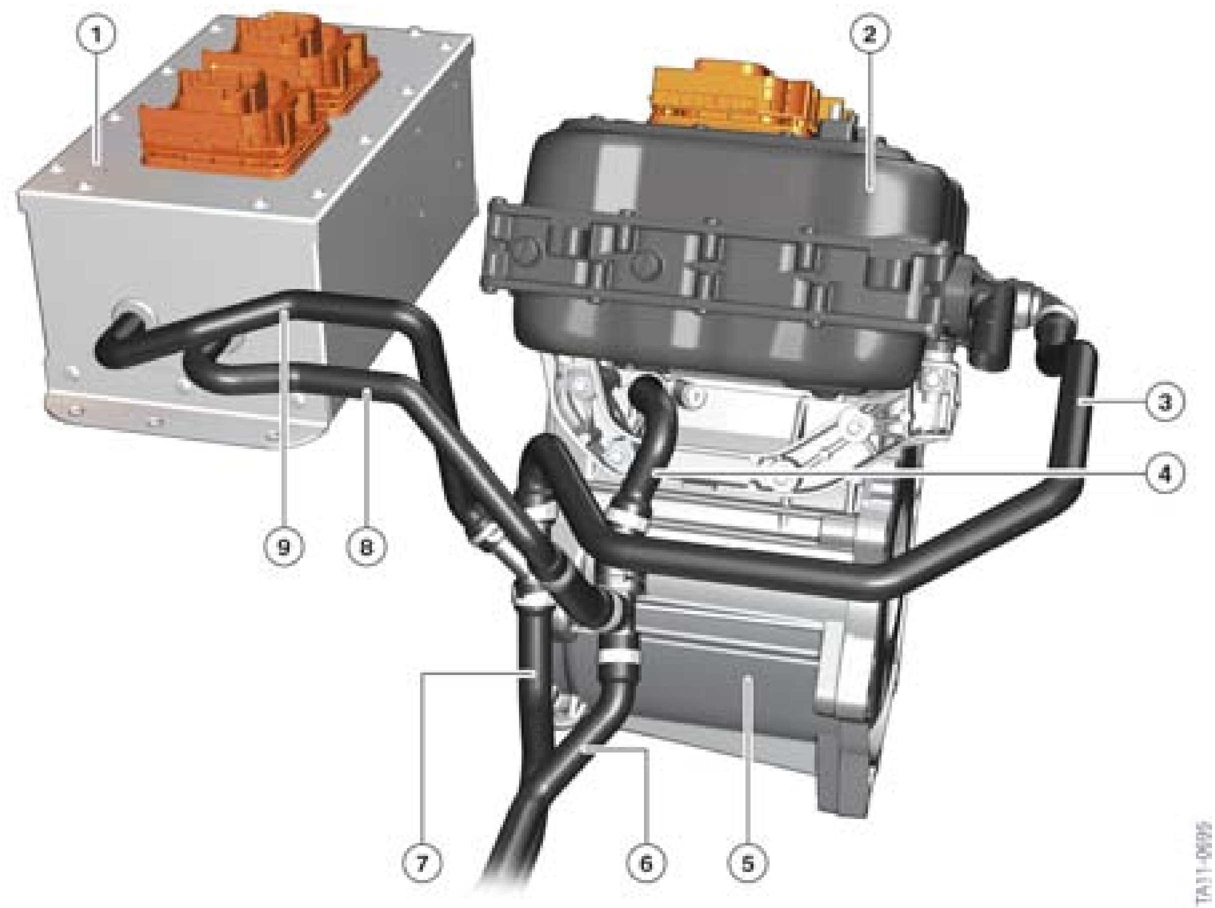
Index	Explanation
15	Coolant expansion tank in the circuit for cooling the high voltage battery
16	Electric coolant pump (50 W) for cooling circuit of the high voltage battery
17	Combined expansion and shutoff valve in the refrigerant circuit
18	Electric coolant pump (20 W) for the heating circuit of the passenger compartment
19	Shutoff valve in the refrigerant circuit (for the passenger compartment)
20	Coolant expansion tank in the circuit for cooling the powertrain components
21	Electric coolant pump (50 W) for the powertrain components cooling circuit

Temperature has a decisive influence on the service life of the high voltage battery. The cells of the high voltage battery should therefore neither emit their power nor absorb electrical energy at too high or too low a temperature. The optimal cell temperature is 20 °C/68 °F; the battery cells should not exceed a maximum temperature of 40° C/104 °F.

The coolant in the high voltage battery cooling circuit is pumped through the high voltage battery by an electric coolant pump (50 W). The heat energy generated by the battery cells is transferred to the circulating coolant. As long as the coolant is colder than the battery cells, these can be cooled solely by circulating the coolant. The changeover valve is installed so that the cooling circuit of the high voltage battery is closed. There is no connection to the cooling circuit of the electric heating. There is an expansion tank with a level sensor in the cooling circuit of the high voltage battery. The level sensor is, however, not connected and its signal is not evaluated. This means no fault is stored in the event of a loss of coolant.

A second cooling system (independent of the first described) is used to cool the powertrain components:

- Electrical machine
- Electrical machine electronics
- Comfort charge electronics



Coolant lines at powertrain components

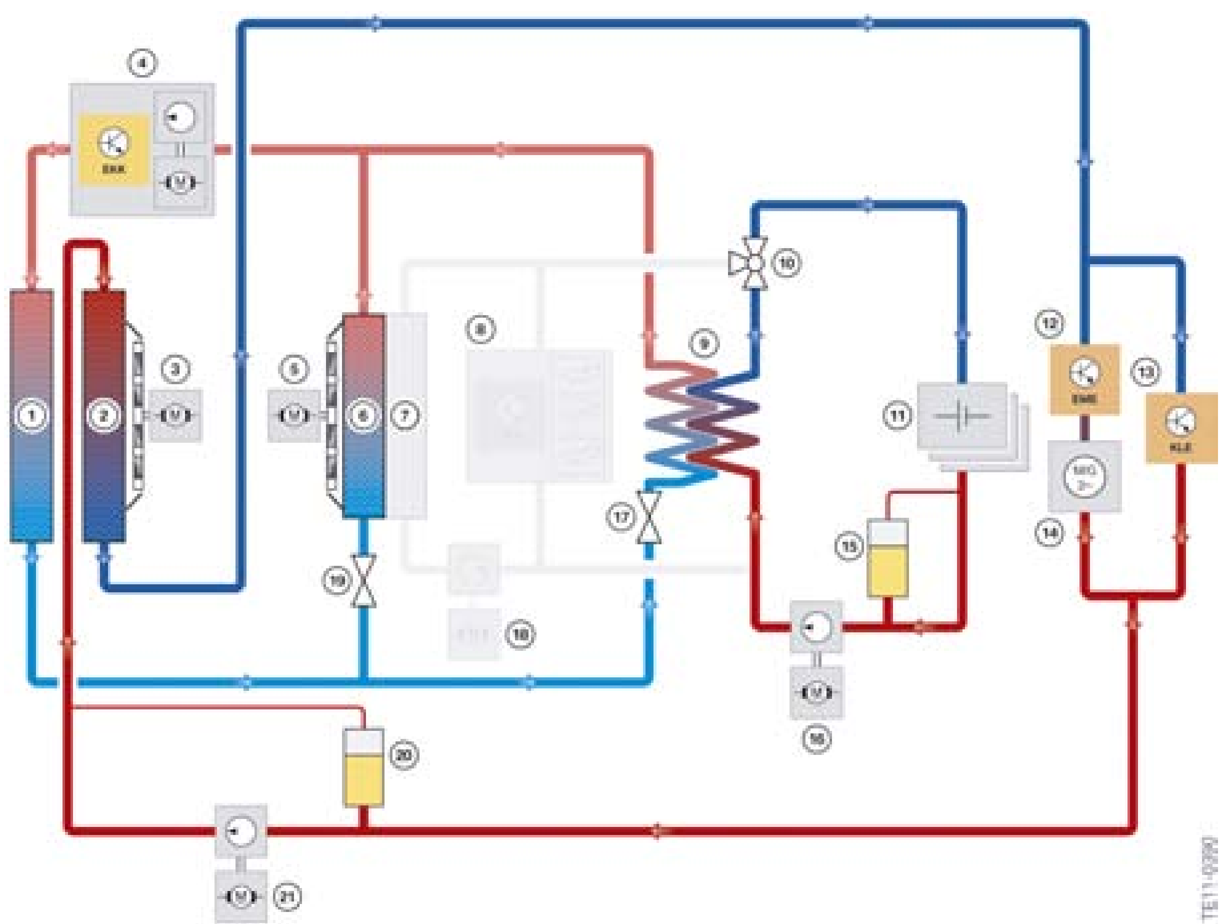
Index	Explanation
1	Comfort charge electronics (KLE)
2	Electrical machine electronics (EME)
3	Supply coolant line for EME and electrical machine
4	Return coolant line for EME and electrical machine
5	Electrical machine
6	Return coolant line for powertrain components
7	Supply coolant line for powertrain components
8	Return coolant line for KLE
9	Supply coolant line for KLE

The coolant in the powertrain components cooling circuit is pumped through the three powertrain components by another electric coolant pump (50 W). This cooling circuit connects the electrical machine and the EME in series while the KLE is cooled by a parallel branch of the same circuit. The heat energy absorbed by the coolant is carried to the radiator to be dissipated, if the air stream is not sufficient, the electric fan is also switched on by the EDME (as with conventional vehicles). The electric fan has a power rating of 400 W. An expansion tank is also installed in the cooling circuit of the powertrain components. The coolant level is recorded using a level sensor and evaluated by the JBE. In the case of loss of coolant (in the event of a leak in the system) a Check Control message is emitted and a fault stored for low coolant level.

Note: A mixture of water and antifreeze (known from conventional BMW vehicles) is used as a coolant in both cooling circuits.

8.2.2. Cooling the interior and the high voltage battery with refrigerant

We are already familiar (from the E72 and F04) with the advantages of using the refrigerant circuit with an electric A/C compressor to cool electrical components. The refrigerant circuit of the E82E essentially corresponds to that of conventional vehicles. As with conventional vehicles Tetrafluorethane (R-134a) is used as refrigerant which is pumped through the cooling circuit to absorb the heat from the passenger compartment. The system is also used to enhance the cooling efficiency of the (water cooled) electrical component coolant circuit. PAG oil (polyalkylene glycol) is used as a lubricant in the A/C refrigerant circuit.



Refrigerant circuit and the cooling circuit of the powertrain components

Index	Explanation
1	Condenser in the refrigerant circuit
2	Radiator
3	Electric fan
4	Electric A/C compressor
5	Blower motor
6	Evaporator in the refrigerant circuit of the passenger compartment
7	Heat exchanger
8	Electric heating unit
9	Chiller unit (coolant/refrigerant heat exchanger)
10	Changeover valve for heating/cooling the high voltage battery
11	High voltage battery
12	Electrical machine electronics (EME)
13	Comfort charge electronics (KLE)
14	Electrical machine
15	Coolant expansion tank in the cooling circuit for the high voltage battery
16	Electric coolant pump (50 W) for cooling circuit of the high voltage battery
17	Combined expansion and shutoff valve in the refrigerant circuit
18	Electric coolant pump (20 W) for the heating circuit of the passenger compartment
19	Shutoff valve in the refrigerant circuit (for the passenger compartment)
20	Coolant expansion tank in the cooling circuit for the powertrain components
21	Electric coolant pump (50 W) for the cooling circuit for the powertrain components

In contrast with the E82, the E82E refrigerant circuit for cooling the passenger compartment has been expanded with a parallel circuit. The chiller cooling unit is located in this parallel branch of the refrigerant circuit with the job of extracting heat energy to cool the high voltage battery. For more information regarding the chiller unit refer to the chapter entitled "high voltage battery".

The heat absorbed by the interior and/or the high voltage battery is dissipated to the ambient air in the condenser at the front of the vehicle. Upon activation of the heating and air-conditioning system for the interior or upon request for cooling the high voltage battery, the electric A/C compressor is switched on and the system supplies refrigerant flow to the respective place component. The interior cooling and the cooling of the high voltage battery are operated independently of each other. The electric A/C compressor is powered directly by the high voltage battery.

Special solenoid valves are integrated in the refrigerant circuit so the high voltage battery cooling and the interior cooling can be operated independently of each other. These only open the part of the circuit which is actually required. This guarantees high efficiency and fault-free control characteristics of the system. The following table shows how the valves and the EKK are controlled.

Cooling of	Solenoid valve for evaporator (interior)	Combined expansion and shutoff valve in the refrigerant circuit	EKK
High voltage battery	Closed	Open	Switched-on
Interior	Open	Closed	Switched-on
High voltage battery and interior	Open	Open	Switched-on
No cooling	Closed	Closed	Switched-off

The request for whether cooling power is required and if so how much, is identified and determined by the IHKA control unit. On the one hand, the request to cool the interior comes directly from the customer. On the other, the SME control unit can send a request for cooling the high voltage battery as a data bus message to the IHKA control unit. The IHKA control unit coordinates these cooling requests and controls the electric A/C compressor via a LIN-bus. As the electric coolant compressor is a high voltage consumer, the high voltage power management in the EDME control unit compares the required and available energy and only releases the electric power required for cooling when it is also currently available. The cooling requests are prioritized depending on the temperature. For example at a high ambient temperature and with a very warm interior, a higher cooling power demands a higher priority. If the desired temperature is reached, the cooling power is reduced for maintaining the temperature and the priority is set to low.

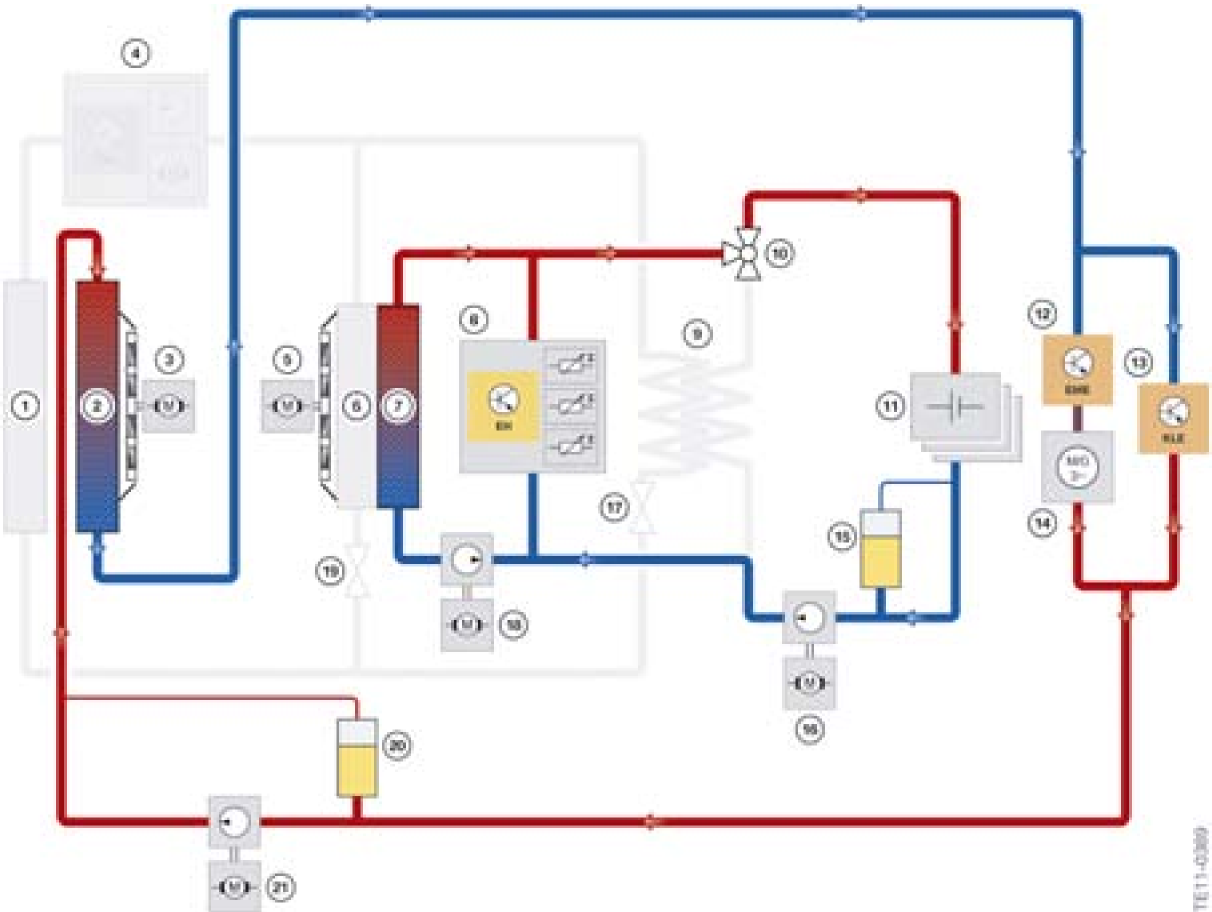
⚠

The two valves are connected in a de-energized state. This means for evacuation they have to be controlled (opened) using the ISTA ActiveE diagnosis system.

The same applies to the temperature of the battery cells. If the battery cells reach temperatures of about 30° C/86 °F, the cooling process of the high voltage battery is started. The cooling requested by the SME control unit has low priority at this point because the cell temperature is not too hot yet. Therefore it can thus be rejected by the high voltage power management in the EDME. In the event of a higher cell temperatures, the cooling request for the high voltage battery obtains top priority and is always implemented (in other words: “accepted by the high-voltage power management in the EDME”).

8.2.3. Heating the passenger compartment and the high voltage battery

Due to its higher efficiency, considerably less heat is emitted from an electrical machine than from a combustion engine. Therefore the excess (wasted) heat from the electrical machine is not enough to be used for the heating purposes. In order to be able to have a pleasant temperature in the passenger compartment or to preheat the high voltage battery, electric heating has been installed in the E82E.



Cooling circuit of the electric heating and the cooling circuit of the powertrain components

Index	Explanation
1	Condenser in the refrigerant circuit
2	Radiator
3	Electric fan
4	Electric A/C compressor
5	Blower motor
6	Evaporator in the refrigerant circuit for cooling the passenger compartment
7	Heat exchanger
8	Electric heating unit
9	Chiller unit (coolant/refrigerant heat exchanger)
10	Changeover valve for heating/cooling the high voltage battery
11	High voltage battery
12	Electrical machine electronics
13	Comfort charge electronics
14	Electrical machine

Index	Explanation
15	Coolant expansion tank for the high voltage battery cooling circuit
16	Electric coolant pump (50 W) for the high voltage battery cooling circuit
17	Combined expansion and shutoff valve in the refrigerant circuit
18	Electric coolant pump (20 W) for the passenger compartment heating circuit
19	Shutoff valve in the refrigerant circuit (for the passenger compartment)
20	Coolant expansion tank in the powertrain components cooling circuit
21	Electric coolant pump (50 W) for the powertrain components cooling circuit

The coolant is heated in the electric heating unit (8) and circulated via the 20 W electric coolant pump (18). The heated coolant flows through the heater core (water to air heat exchanger) which emits heated air into the passenger compartment with the help of a blower.

The heat from the electric heating unit is also used for heating the cells of the high voltage battery. When temperatures dip below the optimal operating temperature of 20 °C/68 °F the performance of the HV battery is restricted and its service life negatively impacted. The changeover valve for heating/cooling the battery (10) is activated so that the coolant no longer flows through the chiller unit (9) but through the electric heating unit (8). The electric heating unit heats the coolant and the heated coolant in turn preheats the battery cells to operating temperature. **The coolant is circulated via the 50 W electric coolant pump (16) and in this case the smaller 20 W coolant pump (18) is not activated. This means simultaneous operation of the passenger compartment heater and the battery heater is not possible.**

"Heating" can be implemented in practically all "active" vehicle conditions: when charging the high voltage battery, while diving in low ambient temperature, but also when the vehicle is at a standstill, if the driver "prepares" the vehicle for a pending journey.

The following conditions indicate that "Heating" is taking place:

- The electric coolant pump (16) in the high voltage battery cooling circuit or the electric coolant pump (18) in the electric heating circuit is running.
- For heating the high voltage battery, the changeover valve is switched so that the high voltage battery cooling circuit and that of the electric heating circuit are connected.
- The electric A/C compressor is not in operation.
- The combined expansion and shutoff valve in the chiller unit is closed.

The request whether heater output is required and if so how much, is identified and determined by the IHKA control unit. On the one hand, the request to heat the interior comes directly from the customer. On the other, the SME control unit can send a request for heating the high voltage battery as a data bus message to the IHKA control unit. The IHKA control unit coordinates these requests for heating and controls the electric heating via a LIN-bus. As the electric heating unit is a high voltage consumer, the high voltage power management in the EDME control unit compares the required and available energy and only releases the electric power required for heating when it is currently available.

Similar to cooling, the requests for heating are dependent upon the temperature and prioritized for the requester. For example a higher heat output with higher priority is required at a lower ambient temperature and when the cells of the high voltage battery are very cold. Once the desired temperature is reached, the heater output is reduced for maintaining the temperature and the priority is set to low.

8.2.4. Independent air-conditioning

The independent air-conditioning already known from the F04 is also offered in the E82E. If the vehicle is parked for example in direct sunlight, the rising interior temperature can be reduced within two minutes by almost half. The customer can activate the independent air-conditioning directly in the vehicle or via the My BMW Remote App on the iPhone. The vehicle cools down considerably while the customer for example is loading his shopping bags. When the vehicle is started the full cooling power is then available immediately, eliminating that initial burst of heated air coming from the air vents, as is typically the case.

The independent air-conditioning offers the added advantage in that the high voltage battery can also be cooled via the A/C refrigerant circuit if required. The energy for cooling is taken from the high voltage battery. Even if the energy has to initially be used for this, the energy consumption is considerably lower overall. The battery cells are operated in an optimal temperature range of < 30 °C/ 86 °F which increases their efficiency and service life.

The independent air-conditioning can only be operated when the following preconditions are satisfied:

- The high voltage battery is sufficiently charged.
- The vehicle is connected to the charging station
- The charging power at the charging socket must be at least 1.5 kW.

Switching ON and OFF in the vehicle

When terminal R is switched on the independent air-conditioning can be activated via the controller in the CID. A switch-on time or direct activation can be selected. The switch-on time for independent air-conditioning is only valid for the next 24 hours. Thereafter the switch-on time must be reset.

Switching ON and OFF using the My BMW Remote App

Menu for charging process and interior temperature control

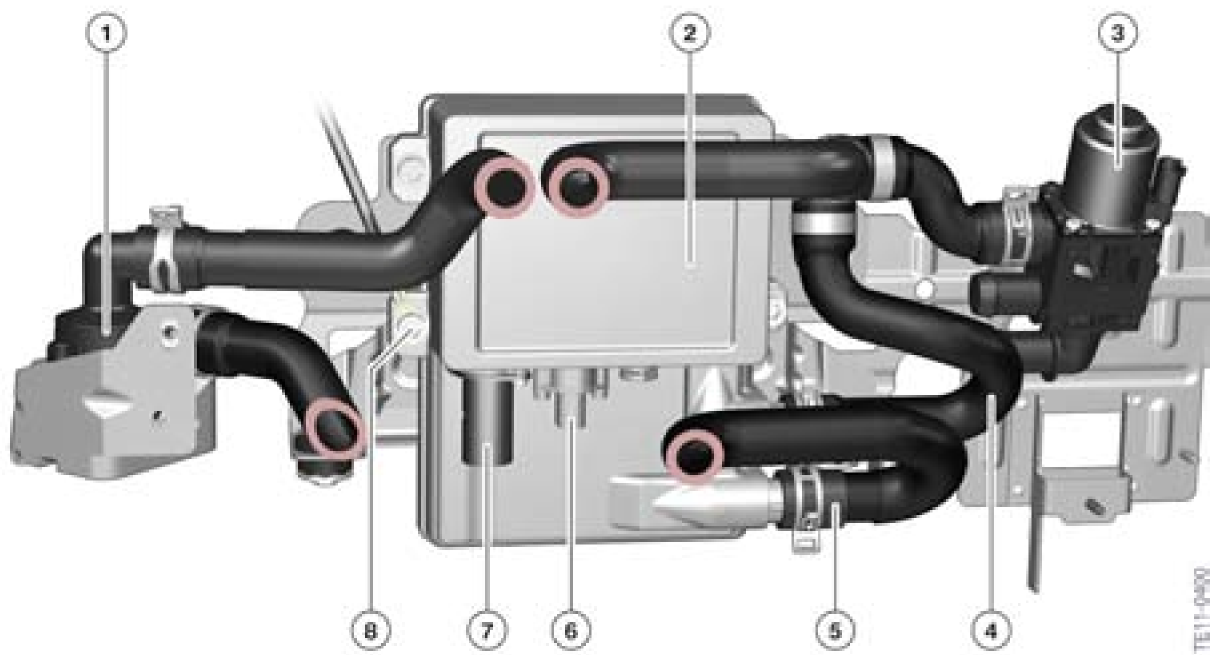
Index	Explanation
1	Menu for charging process and interior temperature control
2	Status of the charging cable (in our example: connected)
3	Control field for starting/ending the charge process or setting a switch-on time
4	Control field for starting/ending the interior temperature air or setting a switch-on time
5	Field with alternating temperature display
6	Menu selection

With the My BMW Remote App the customer can also control the independent air-conditioning when outside of or away from the vehicle. The independent air-conditioning is started and stopped and a switch-on time selected according to a similar principle as in the vehicle.

8.3. Components

8.3.1. Electric heating

Location and connections



Connections of the electric heating

Index	Explanation
1	Electric coolant pump (20 W)
2	Electric heating unit
3	Changeover valve
4	Connection for coolant return line
5	Connection for coolant supply line
6	Signal connector (low-voltage connector)
7	High voltage connector
8	Ground connection

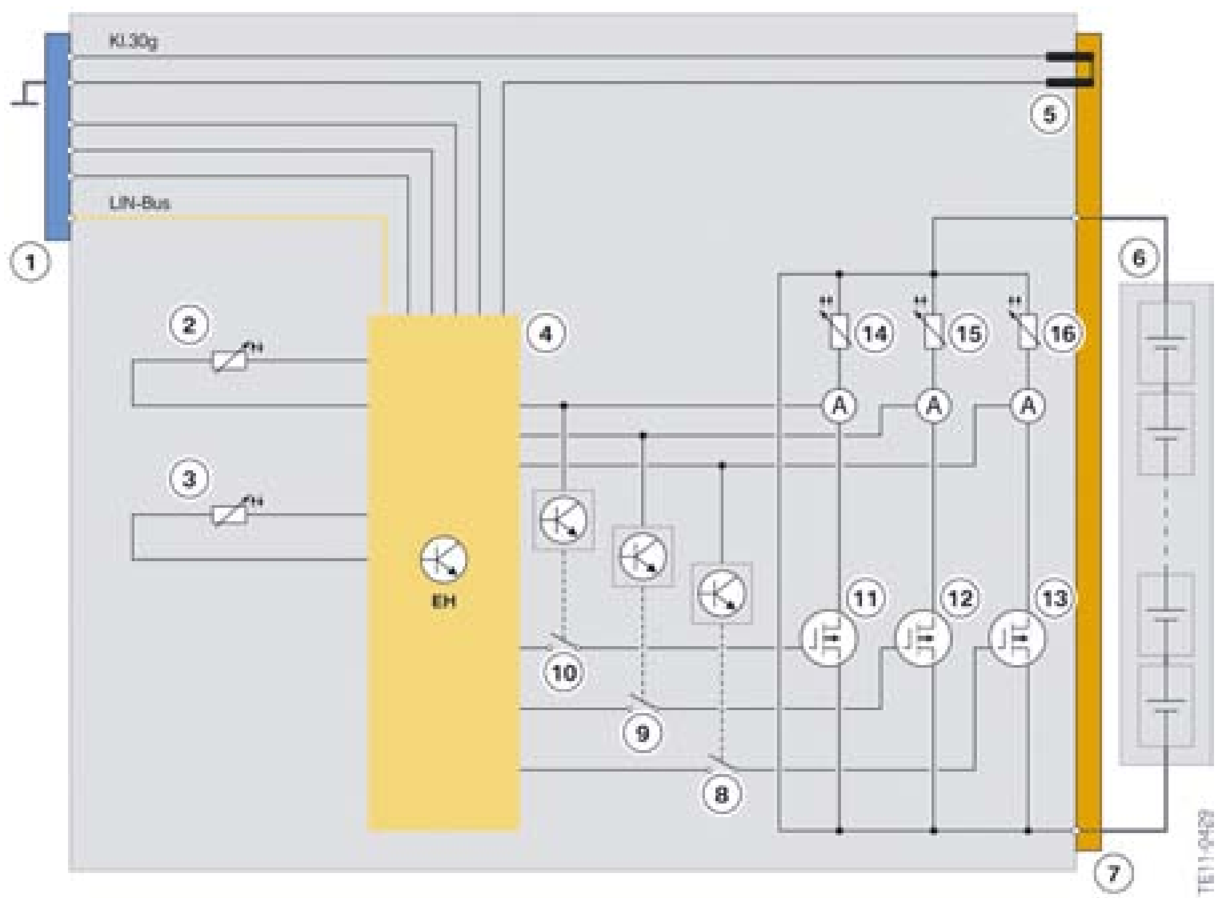
The electric heating unit is a high voltage component!

⚠

Only Service Technicians who satisfy all prerequisites may perform work on high voltage components. These technicians must be Active Hybrid certified, comply with the safety rules and always follow the proper procedures indicated in the repair instructions.

E82E Complete Vehicle
8. Climate Control

The electric heating unit is located under the hood, near the right side (passenger) inner frame rail. The changeover valve is mounted beside the electric heating unit. The changeover valve is used to feed the coolant into the required circuit branch for the respective operating condition. If the changeover valve is not supplied with current, the coolant flows through the chiller unit. When the changeover valve is energized, the branch through the chiller unit is blocked and the coolant flows through the electric heating unit instead in order to heat the high voltage battery.



Block diagram of the electric heating unit

Index	Explanation
1	Low-voltage connector
2	Temperature sensor for supply
3	Temperature sensor for return
4	Electric heating (control unit)
5	Bridge in the high voltage connector
6	High voltage battery
7	High voltage connector
8	Hardware shutdown when current is too high in heating element 3
9	Hardware shutdown when current is too high in heating element 2

Index	Explanation
10	Hardware shutdown when current is too high in heating element 1
11	Electronic switch (Power MOSFET) for heating element 1
12	Electronic switch (Power MOSFET) for heating element 2
13	Electronic switch (Power MOSFET) for heating element 3
14	Heating element 1 (PTC heat resistor)
15	Heating element 2 (PTC heat resistor)
16	Heating element 3 (PTC heat resistor)

The power rating of the electric heating unit is 4,500 W. The electric heating is realized by three heating circuits with individual heating elements, which have a power rating of 1 KW, 2 kW and 3 kW respectively. The heating circuits (individual or joint) are controlled by the electric heating unit via electronic switches (Power MOSFET).

The current through the individual circuits is measured and controlled by the electric heating control unit. A current of 11.25 A flows in a voltage range of 250 V to 400 V. The power is reduced if values fall below or exceed this voltage range. In the event of an increased power consumption the current supply is interrupted by a hardware circuit. This circuit is designed so that even in the event of a fault in the control unit current interruption is definitely implemented.

The temperature of the coolant is measured by two sensors at the input and output of the electric heating unit.

A galvanic disconnection of the high voltage circuit and the low voltage circuit is realized in the electric heating unit.

The connections for a LIN-bus, three-pin programming interface and voltage supply (terminal 30g) are located at the low voltage connector.

In addition to the contacts for the high voltage, a bridge/jumper in the KL 30g line is also integrated into the high voltage connector. The contacts of the bridge in the high voltage connector are designed as leading contacts. Therefore when the high voltage connector is removed the contacts of the high voltage bridge are disconnected first and the voltage supply of the control unit (EH) is thus interrupted. This removes the load on the HV circuit which results in an interruption of the high voltage supply (even before the high voltage connector is fully removed) eliminating electric arc at the high voltage contacts. The high voltage contacts are protected against contact. It is important to note that the high voltage connector at the electric heating unit is **NOT** part of the of the high voltage interlock loop circuit.

Control system

The request for switching on the heating comes from the IHKA control unit via a LIN-bus. The power control is realized by switching on the different heating circuits.

When the maximum temperature is reached or when the maximum allowable current level is exceeded, the heater output is automatically reduced by the electric heating control unit.

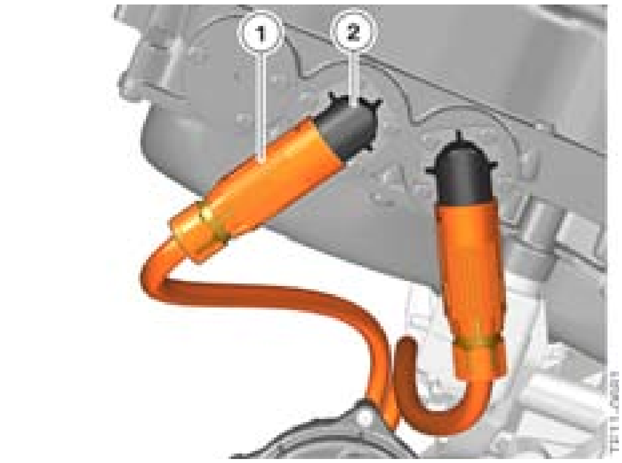
In the event of a fault in the system the electric heating is switched off.

The electric heating is designed to be maintenance-free.

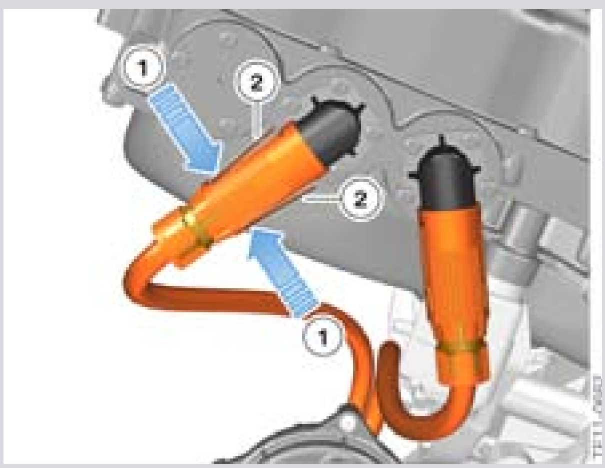
Unlocking the high voltage connector

When removing the round high voltage connectors particular attention must be paid to its unlocking. The procedure described here applies to both the high voltage connector at the EME, as well as for the high voltage connectors at the EKK and at the EH.

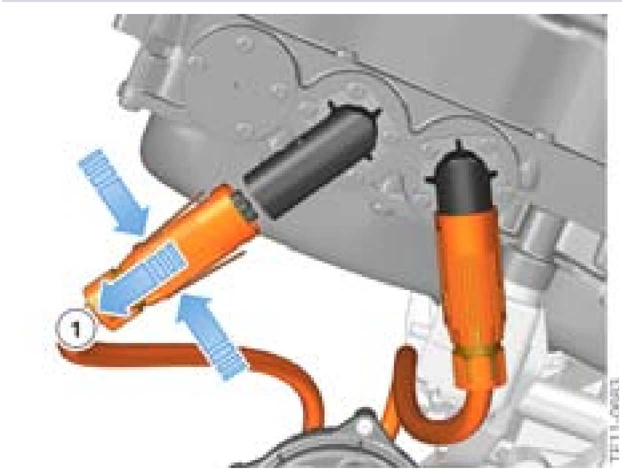
The following images show the procedure using the example of the electric heating high voltage connection at the EME.



The connector of the high voltage cable (1) is located at the high voltage connection of the EME (2) and is locked.



The two locking tabs (2) must be pressed (simultaneously) in the direction of the arrow (1). The mechanical lock of the plug connector is thus released from the high voltage component.



While the locking tabs continue to be pressed together, the connector must be removed in the direction of the arrow (1).

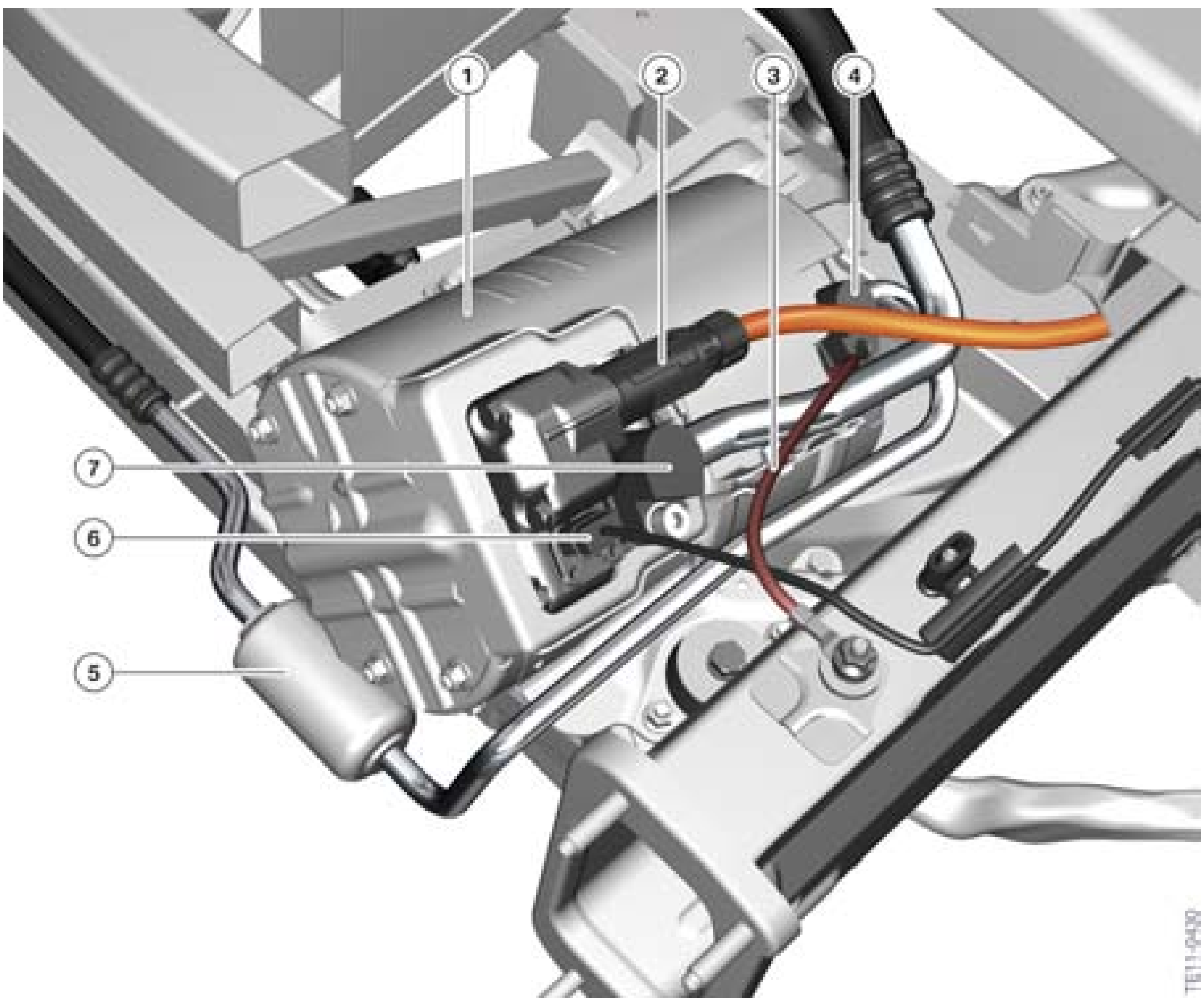
The recommended procedure is to also press together the locking mechanism detents when reconnecting the high-voltage cable. This ensures that the locking mechanism's components slide past the outside of the socket. If the locking mechanism's detents are not pressed together during connection they may be damaged.

A “click” sound ensures that the locking tabs are engaged. In addition, the locking tabs engagement should be checked by slightly pulling on the connector.

It is important to note that the round high voltage connectors of the EH and EKK at the EME **ARE** part of the of the high voltage interlock loop circuit.

8.3.2. Electric A/C compressor (EKK)

As with E72 and F04 the E82E uses an electric compressor for A/C system. In fact the operating principle of the electric compressor is identical to that of the E72 and F04. A spiral type compressor (also called scroll compressor) is used to compress the refrigerant.



Connections of the electric A/C compressor in the E82E

Index	Explanation
1	Electric A/C compressor
2	High voltage connector
3	Ground connection
4	Connection for pressure line
5	Silencer
6	Low-voltage connector
7	Connection for intake pipe

Note: The electric A/C compressor is a high voltage component!

⚠

Only Service Technicians who satisfy all prerequisites may perform work on high voltage components. These technicians must be Active Hybrid certified, comply with the safety rules and always follow the proper procedures indicated in the repair instructions.

The installation location of the electric A/C compressor is on the left cross-member under the hood.

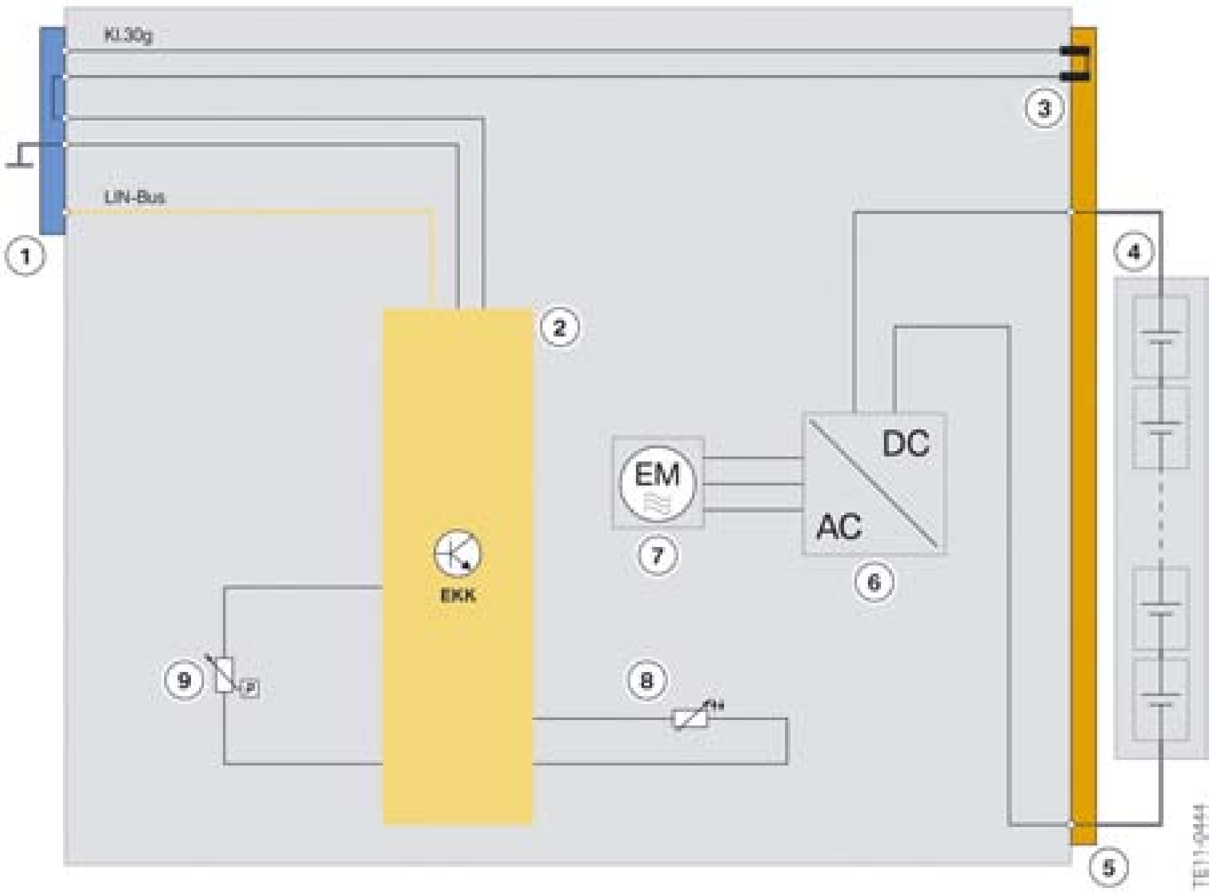
A special silencer in the pressure line is installed for noise reduction. As a result the heating and air-conditioning system is barely audible even when the vehicle is at a standstill.

The maximum electric power consumption of the electric A/C compressor is 4.5 kW. The maximum power is required for example at high ambient temperatures, high interior temperatures and low inflow of the cooling module.

The electric A/C compressor is operated at a maximum of 6,750 rpm and generates a maximum operating pressure of about 30 bar/435 psi.

The supply voltage for the EKK has a voltage range from 200 V to 420 V. The power is reduced or the EKK switched off if the voltage level falls below or exceeds this voltage range. With a temperature of the inverter in the EKK of over 115 °C / 239 °F, the EKK is also switched off. If the temperature falls below 112° C / 233.6 °F the EKK starts-up again.

Connections



Block diagram of the electric A/C compressor

Index	Explanation
1	Low-voltage connector
2	Electric A/C compressor (control unit)
3	Bridge in the high voltage connector
4	High voltage battery
5	High voltage connector
6	Inverter (DC/AC converter)
7	Three-phase AC motor
8	Temperature sensor
9	Pressure sensor

The connections for the LIN-bus, for the ground and the 12 V voltage supply (terminal 30g) are located in the 8-pin signal connector.

In addition to the contacts for the high voltage, a bridge/jumper in the KL 30g line is also integrated into the high voltage connector. The contacts of the bridge in the high voltage connector are designed as leading contacts. Therefore when the high voltage connector is removed the contacts of the high voltage bridge are disconnected first and the voltage supply of the control unit (EKK) is thus interrupted. This removes the load on the HV circuit which results in an interruption of the high voltage supply (even before the high voltage connector is fully removed) eliminating electric arc at the high voltage contacts. The high voltage contacts are protected against contact. It is important to note that the high voltage connector at the electric A/C compressor is **NOT** part of the of the high voltage interlock loop circuit.

It is important to note that the round high voltage connectors of the EH and EKK at the EME **ARE** part of the of the high voltage interlock loop circuit.

The electrical capacity in the EKK is less than 100 µF. This capacity is discharged via a passive resistor inside the EKK. After the EKK is shut down the voltage falls below 60 volt in less than 2 seconds.

The following sensors are installed in the EKK:

- Temperature sensor of the inverter
- Pressure sensor
- Current measurement in the motor winding

EKK control unit

The EKK control unit controls the speed of the three-phase AC motor in the A/C compressor subject to the requests of the IHKA. The EKK communicates with the IHKA via the LIN- bus. The IHKA is the primary control unit for the EKK.

Inverter

A three-phase synchronous motor is used to drive the electric A/C compressor. The energy here is taken from the high voltage battery. The three-phase AC current necessary for the operation of the compressor is converted using an alternating current inverter (DC/AC converter) within the compressor. The synchronous motor is operated in an (infinitely variable) 2,000 to 9,000 rpm speed range and it consumes up to 5 kW of electric power in the process.

The DC/AC converter converts the DC voltage to the three-phase AC voltage, which is necessary for the three-phase AC motor. The EKK control unit and the DC/AC converter are integrated in the aluminum housing of the compressor and are cooled by the gaseous refrigerant flow. If the temperature of the DC/AC converter rises over 110 °C / 230 °F, the high voltage supply is switched off by the EKK control unit. Different measures are adopted in an attempt not to allow the temperature rise so high through, for example, increasing its speed to cool it self. The temperature monitoring is implemented by the EKK control unit.

E82E Complete Vehicle

9. Body

9.1. Introduction

The body of the E82E is based on that of the conventional E82 LCI. To accommodate the integration of the electric propulsion unit and the high-voltage battery units, the body of the E82E features an extensive array of innovations and modifications to distinguish it from the conventional E82 LCI.

These features are listed below:

- Front bumper
- Hood with power dome
- New crash structure and support for high-voltage battery unit at front
- New crash structure in front floorpan area
- Modified 3-section floorpan
- New support structure for high-voltage battery unit on transmission tunnel
- New deformation elements in side frame
- Reinforced vertical end panel
- Revised rear floor panel
- New frame and cover for the drive unit in the luggage compartment.

At the same time, the doors, outer side frame, front and rear side panels/fenders and the roof all remain unchanged. The repair-friendly system consisting of impact absorbers on the front and rear bumpers is also implemented in the E82E. These significant and extensive innovations are described in the following chapters. A few minor revisions are briefly mentioned here:

- The front bumper in the E82E has been strengthened in relation to that in the E82
- The rear bumper carrier in the E82E is identical to that of the E82 (US)
- The trunk lid of the E82E corresponds to that of the E82 (before LCI). Thus the trunk lid of the E82E also has a lock with tumbler mechanism making it possible to open the trunk lid lock using the spare key.

⚠

The "bond and rivet" repair method is also universally approved for those body components on the E82E that are the same as on the conventional E82. Always consult the repair instructions/repair manual to determine the correct repair method and then apply the prescribed procedure.

The body of the E82E also contributes to achieving optimal levels of passive safety in this vehicle. Top priority is assigned to protecting the occupants against injuries. The body is also designed to protect the high-voltage battery units against accident damage. The body parts that provide this protection respond to accidents by deforming to absorb large amounts of kinetic energy.

E82E Complete Vehicle

9. Body

Several of the E82E's body components protect the high-voltage battery and other components against damage in the event of an accident. No attempt should ever be made to repair these body components after they are deformed in an accident. To ensure safety, vehicles must be removed from service and retired when these components are deformed.

Should doubts arise regarding a suspected component please consult the repair instructions and contact your BMW Service Hub.

9.2. Front end

9.2.1. Hood

The hood is specific to the E82E. While it is based on the hood of the E82, the following modifications have been implemented:

- The cross members on the inside have been divided into sections
- The outer panel has been enhanced with a Power Dome.

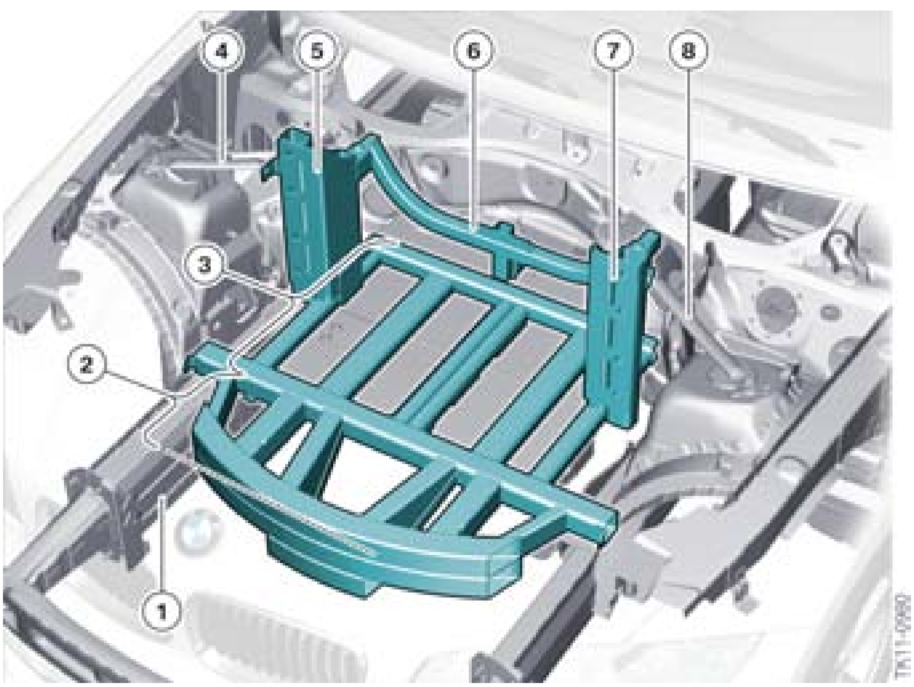
Both of these modifications were necessary to obtain adequate installation clearance for the front high-voltage battery unit.

E82E hood modifications

Index	Explanation
A	Conventional E82 hood
B	E82E hood
1	Cross members on the conventional E82 hood
2	Sectioned cross members in the E82E hood
3	Power Dome in the hood of the E82E

9.2.2. Crash structure/support for the front high-voltage battery unit

The front high-voltage battery unit is installed below the hood of the E82E. A newly-developed steel support member transfers the weight and acceleration forces generated by the high-voltage battery unit to the body shell. This support member also assumes a protective function for the high-voltage battery unit in the event of a head-on collision.



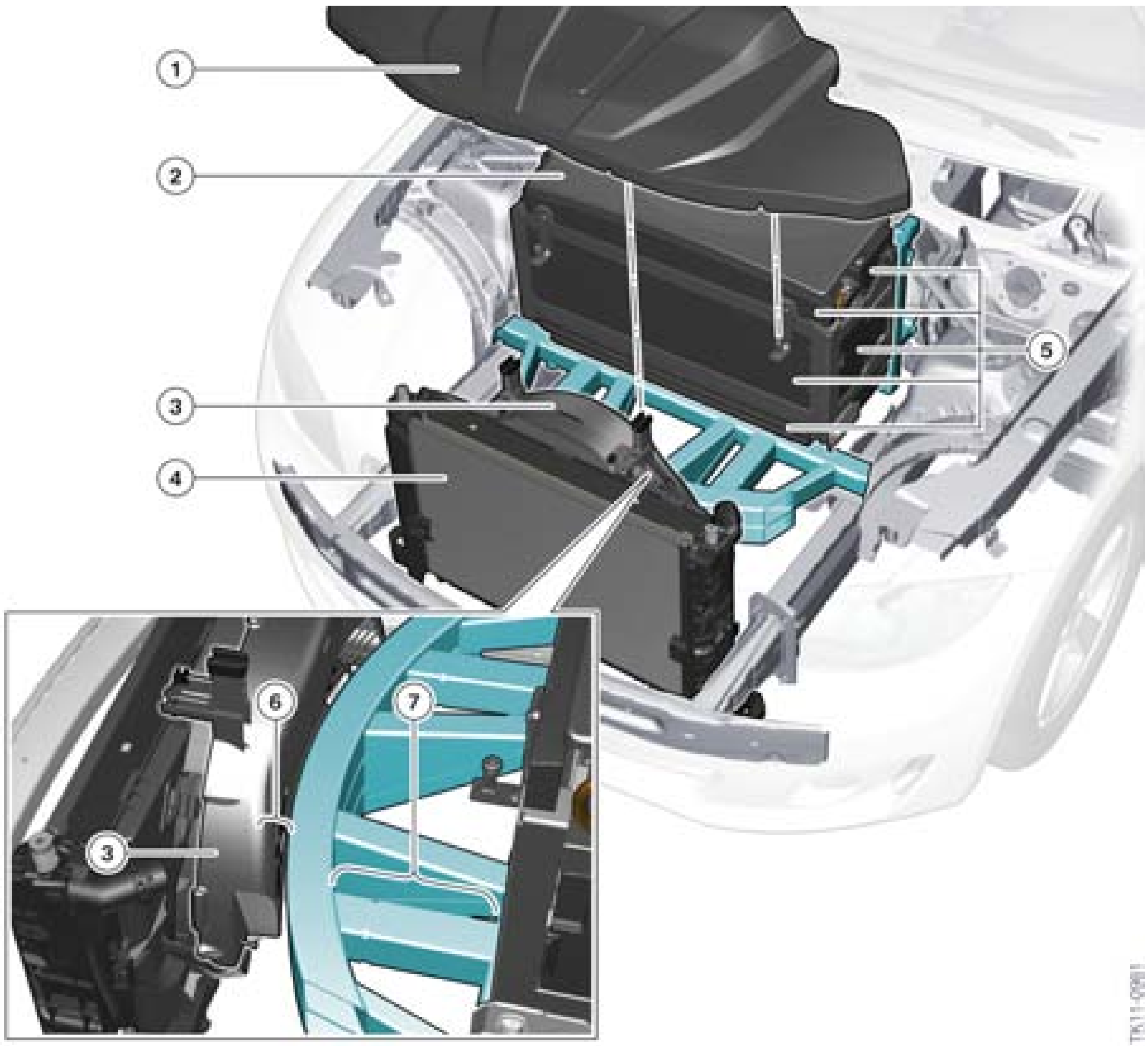
Crash structure/support for the front high-voltage battery unit

Index	Explanation
1	Body frame rail member (engine subframe in a vehicle with a conventional power plant)
2	Crash structure
3	Side member structure
4	Diagonal brace on right

Index	Explanation
5	Vertical support, right
6	Cross-member between vertical supports
7	Vertical support, left
8	Diagonal brace on left

The front high-voltage battery unit is bolted to the two vertical support members on the left and right as well as with the cross member. A forward-mounted bolted connection to the side members is also present. The two diagonal braces connect the vertical supports with the two strut domes to ensure that the entire support member remains rigidly connected to the body.

The protective function is partially realized by the crash structure at the front. Its job is to absorb energy from forces generated by a frontal impact. In the subsequent process the impact energy is transformed into permanent deformation in the deformation elements. At the same time the structure of side members behind the crash structure contributes to protecting the high-voltage battery unit. This contrasts with the crash structure in its rigid design, and it transfers any forces that may remain following the deformation elements' compression to the body shell of the E82E. In this process the structure of the side members remains stable and can shift rearward together with the high-voltage battery unit. The installation area thus remains stable for an extended period following the initial frontal impact, and the forces acting upon the high-voltage battery unit's housing remain moderate.



Front high-voltage battery unit crash structure

Index	Explanation
1	Plastic cover
2	High-voltage battery unit at the front
3	Electric fan housing
4	Cooling module
5	Foam pads
6	Gap between electric fan and crash structure
7	Deformation element in the crash structure

⚠

If the gap between the electric fan and the crash structure is closed following a frontal impact, and one of several of the deformation elements in the crash structure is deformed, the vehicle must be removed from active service.

In such a case the impact has been of such intensity that the crash structure's protective functionality came into play. Because this is a one time use component and cannot be replaced, the vehicle should not be operated further, and must be removed from active service.

Foam pads provide additional protection to guard the front high-voltage battery unit's housing against penetration from sharp objects.

The plastic cover offers a high-quality appearance for the customer while also protecting both the customer and service technicians against danger that could arise from the electric fan (when in operation).

⚠

The coolant pump and the electric fan can be automatically activated when Terminal 15 is at "power on" status as well as while the high-voltage battery is being charged.

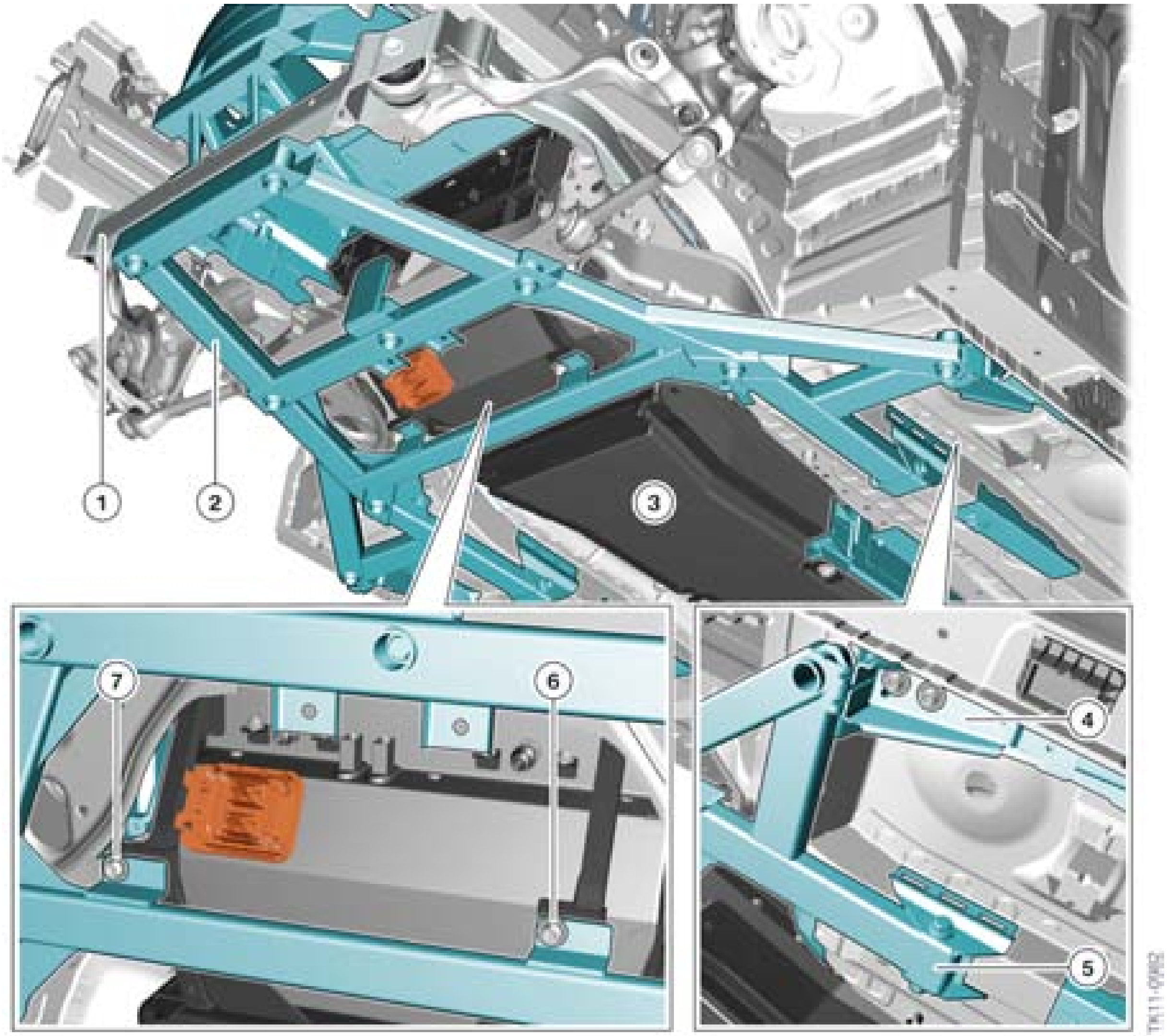
The following preliminary operations must be executed prior to conducting service work on the electric fan in order to prevent possible injuries caused by a fan that suddenly and automatically starts to rotate:

1 Disconnect the charge cable (if one is connected)
2 Deactivate power at Terminal 15
3 De-energizing the high-voltage system
4 Detach the plug from the electric fan.

9.2.3. Floorpan crash structure

Another of these crash structures is located at the front of the E82E in the floorpan area. Just as the word "crash" implies, this structure also assumes a protective function in the event of a front-end collision. The floorpan crash structure provides an additional force-transfer path and conducts the forces from a frontal impact to the side members and the body's side frame. The second main function of the floorpan crash structure is to support a portion of the weight from the transmission tunnel high-voltage battery unit and transfer the load to the body shell.

The floorpan crash structure consists of several steel members that are welded together. As the following illustration shows, the entire floorpan crash structure is bolted to the front subframe as well as the body shell adjacent to the floorpan.



Floorpan crash structure

Index	Explanation
1	Front subframe
2	Floorpan crash structure
3	High-voltage battery unit in the transmission tunnel
4	Link to floorpan/side frame
5	Link to side member in floorpan
6	Right-side link to transmission tunnel high-voltage battery unit
7	Left-side link to transmission tunnel high-voltage battery unit

Crash testing conducted in the E82E's development phase have demonstrated that the floorpan crash structure is not damaged even when the vehicle is driven over high curbs. Should the floorpan crash structure be damaged in an accident it can be replaced as a service operation.

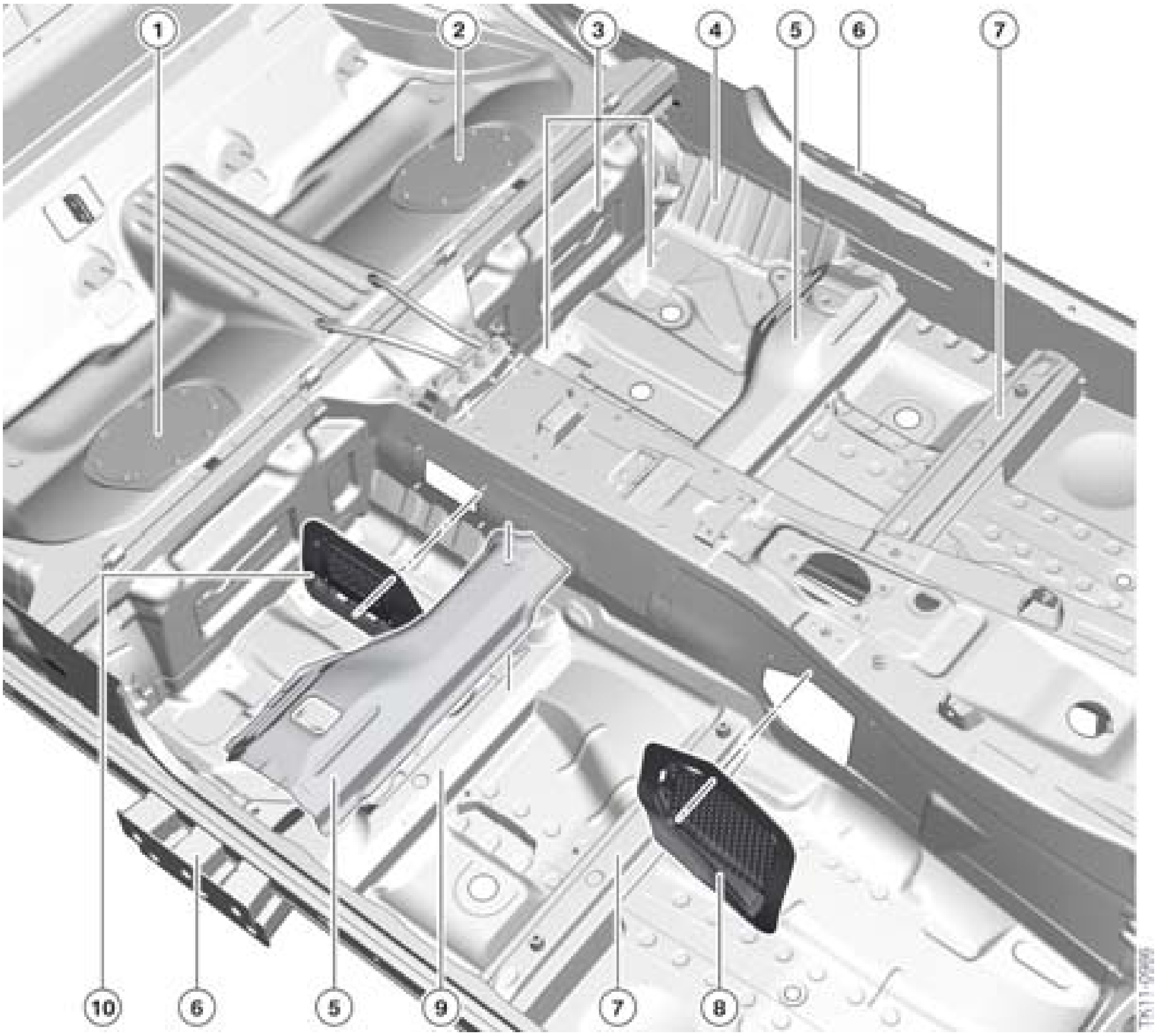
⚠

Before the transmission tunnel high-voltage battery unit can be replaced the floorpan crash structure must first be detached, while the front axle of the E82E must also be removed.

9.3. Floorpan assembly

The E82E's floorpan is based on that of the conventional E82, but the center section is removed for the transmission tunnel during manufacturing, and replaced with a center section designed specifically for the E82E. The center section for the E82E provides the greater installation space required for the transmission tunnel high-voltage battery unit. As a result this component is much more rigid than in the conventional E82. This is necessary to support the substantial weight of the transmission tunnel high-voltage battery unit. Due to the revised dimensions of the transmission tunnel all of the intermediate components joining it to the vehicle's interior have also been redesigned and are thus unique to the E82E.

The new center section and the two outer sections are joined using inert-gas welding during the manufacturing process.



Floorpan assembly, view from upper right

Index	Explanation
1	Right-side service opening for the rear high-voltage battery unit
2	Left-side service opening for the rear high-voltage battery unit
3	Front vertical panel reinforcement
4	Side frame reinforcement panel
5	Reinforcement panels on rear seat cross member
6	Deformation elements

Index	Explanation
7	Front seat cross member
8	Plastic cover for front service-access hatch for transmission tunnel high-voltage battery unit
9	Rear seat cross member
10	Plastic cover for rear service-access hatch for transmission tunnel high-voltage battery unit

Access to the electrical connections on the rear high-voltage battery unit is through the left-side service access opening located below the bench seat. A plastic cap and a cover (part of the interior trim) guard the total of three service openings in the sheet metal of the transmission tunnel. These service openings allow access to the bolts joining the transmission tunnel high-voltage battery unit to the support structure.

As shown in the illustration, the floorpan on the E82E features other reinforcement elements as well as the new, rigid center section. They are located above the rear seat cross member, at the rear of the side frame and on the vertical end panel. The illustration shows only the front reinforcements on the vertical end panel – reinforcements are also present on the rear. All of these reinforcement elements enhance the floorpan's rigidity, which is necessary due to the vehicle's higher weight and to achieve compliance with the crash requirements. In the event of a side impact supplementary deformation elements in the extension of the rear seat cross member absorb energy to reduce the forces transmitted to the vehicle's occupants.

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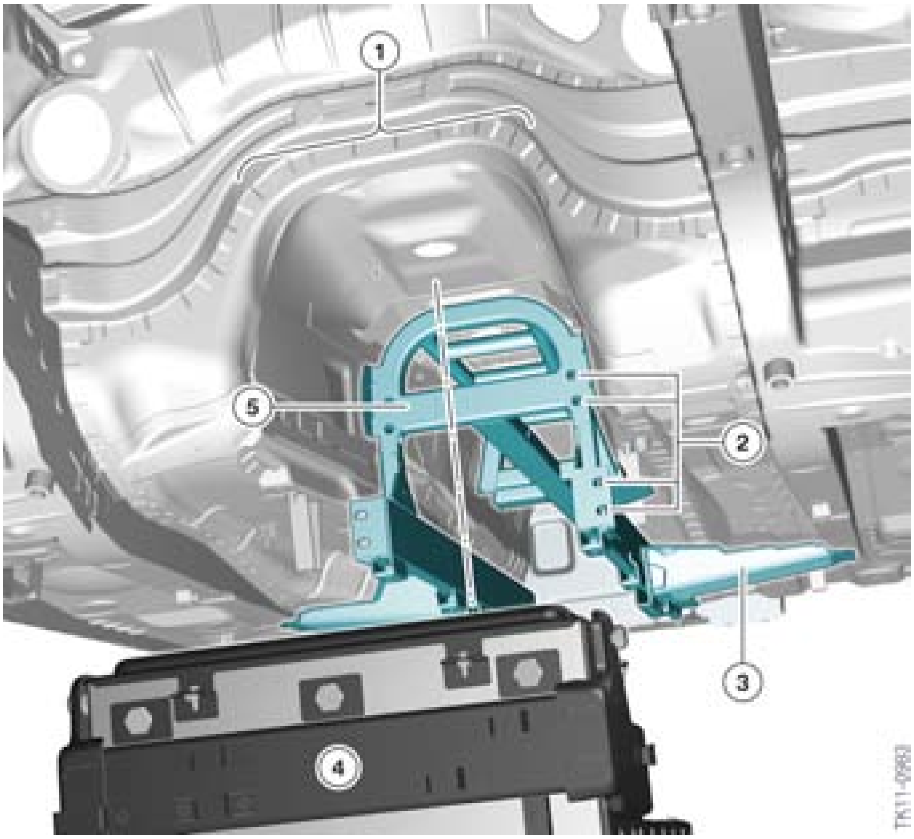
Should a deformation element in the side frame or the floorpan be deformed or damaged in response to an impact the vehicle must be removed from service.

The following illustration shows the floorpan from below and highlights the support structure for the transmission tunnel high-voltage battery unit.



Floorpan and transmission tunnel high-voltage battery unit support structure, front view from below

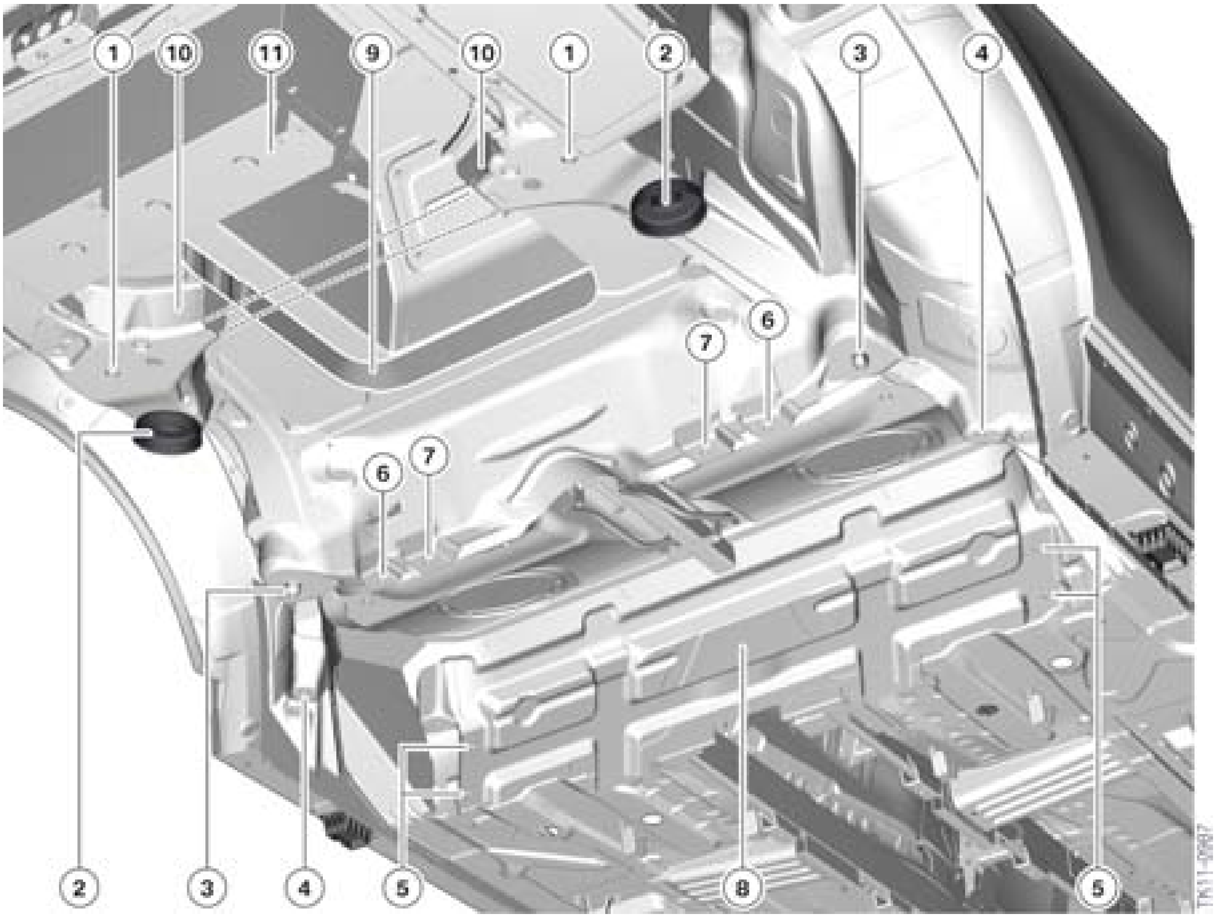
Index	Explanation
1	New transmission tunnel unique to the E82E
2	Sockets for bolted connections between the support structure and the transmission tunnel high-voltage battery unit
3	Reinforcement element
4	High-voltage battery unit in the transmission tunnel
5	Support structure

9.4. Rear end

The E82E's body shell also varies from the conventional E82 unit at the rear. These modifications are made necessary by the arrangements for attaching the rear high-voltage battery unit as well as the drive unit (located in the rear of the vehicle).

E82E Complete Vehicle

9. Body



Body shell at rear, view from lower right

Index	Explanation
1	Threaded sockets for mounting the rear subframe
2	Plate for coil springs
3	Threaded sockets for mounting the rear subframe
4	Welded nuts for mounting the radius rods
5	Welded nuts for mounting the high-voltage battery unit Rear of vehicle in the X direction
6	Welded nuts (provided for possible installation of additional braces)
7	Welded nuts for mounting the high-voltage battery unit Rear of vehicle in the Z direction
8	Vertical end panel with rear reinforcement
9	Frame
10	Open bodywork cross member
11	Luggage compartment well

The vertical end panel (8) is reinforced at the front and rear and provides the stable foundation at the rear of the E82E's body, assuming special importance in the event of an accident. For example, the vertical end panel supports the forces from the two heavy high-voltage battery units, transmission tunnel and rear.

If the vertical end panel on the E82E is damaged in an accident the vehicle must be removed from service.

The body's rear cross member on the E82E is open at the center to provide space for the drive unit. This opening represents a source of potential reductions in the body's rigidity. A frame (9) is welded to the body shell with inert-gas welding and compensates for this potential liability.

The rear high-voltage battery unit is bolted to the body shell in both X and Z planes. The E82E's body is equipped with integrated welded nuts for this purpose. Welded nuts are also used to support the mounting bolts for the radius rods.

Bodyshell luggage compartment

Index	Explanation
1	Drive unit cover
2	Cover
3	Convenient Charging System electronics cover
4	Tray for supporting the 12-V battery
5	Securing clamp for the 12-V battery
6	Frame
7	Luggage compartment well

The luggage compartment well is welded to the bodyshell's side members as well as with the frame (6). The customer can use the luggage compartment well to store luggage and cargo as well as for stowing the charge cable. The cover for the drive unit (1) is welded to the frame (6). It completely encapsulates the electric motor-generator's electronic control system and partitions its installation area from the luggage compartment. Both the cover for the electronic "convenient charging" system (3) and the cover (2) are secured with threaded connections, allowing their removal. Yet another cover on the electric motor-generator's electronic control system is located behind the rear backrests. Both covers can be removed for service access to the electric motor-generator's electronic control system.

E82E Complete Vehicle
10. Chassis Dynamics

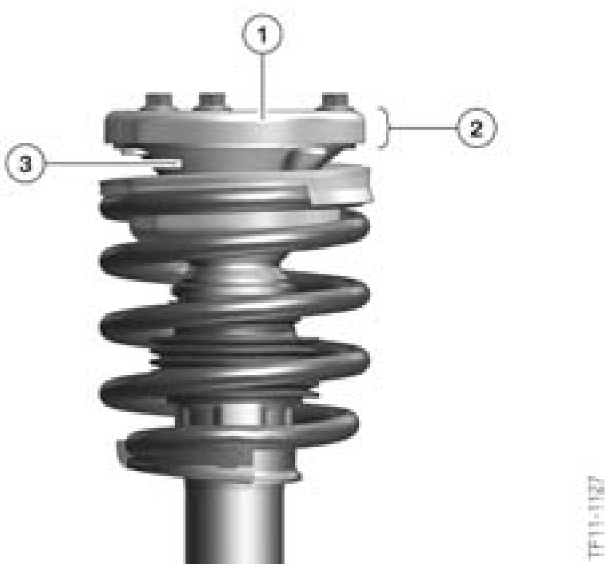
Many of E82E's suspension and dynamic-control systems have been adopted from the conventional E82. Design details have been modified to raise the vehicle/chassis, thereby obtaining the installation space required for the high-voltage battery. At the same time, vacuum generation for the braking system is completely different from the conventional E82, as it uses an electric vacuum pump. While the hardware in the E82E's DSC unit is the same as in the conventional E82, there are substantial differences in how they operate.

The modifications and differences are described in this section.

10.1. Front axle

The E82E dual-joint strut front suspension found in the conventional E82 is used. The control arms, ball joints, wheel bearings and anti-roll bar have all been adopted from the E82. The front subframe is also identical in its essential features but incorporates additional connections at the floorpan to mount the crash structure (see "Body" section). The electric A/C compressor is also mounted on the front subframe, so additional connections are also provided at this location (see “Climate control” in "Electric A/C compressor" chapter).

The front of the vehicle has been raised about 17 mm/0.67 in. by installing off-road adapter plates in the suspension (from vehicles with the off-road package). These are plates inserted at the top of the strut between the support bearing and the body shell.



Front suspension strut

Index	Explanation
1	Off-road adapter
2	Suspension raised by about 17 mm
3	Support bearing

Due to the revised vehicle height the alignment specifications for the E82E differ from those applicable to the conventional E82.

E82E Complete Vehicle
10. Chassis Dynamics

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Before a front wheel alignment is performed on the E82E the current specification data for the E82E must be loaded to the KDS suspension geometry diagnosis system. Due to the height difference the specification data for the E82E vary from those of the E82.

10.2. Steering

Both in European and US versions the E82E are equipped with **EPS (electric power steering)** featuring a parallel-mounted electric motor. This is the same steering system hardware installed on the conventional E82 (European version) which is similar to that of the F10 and F25. The control unit's software has been adjusted (with revised characteristic curves) to obtain ideal steering characteristics in the E82E.

For more information regarding electric power steering systems refer to F10 and F25 training material available on TIS and ICP.

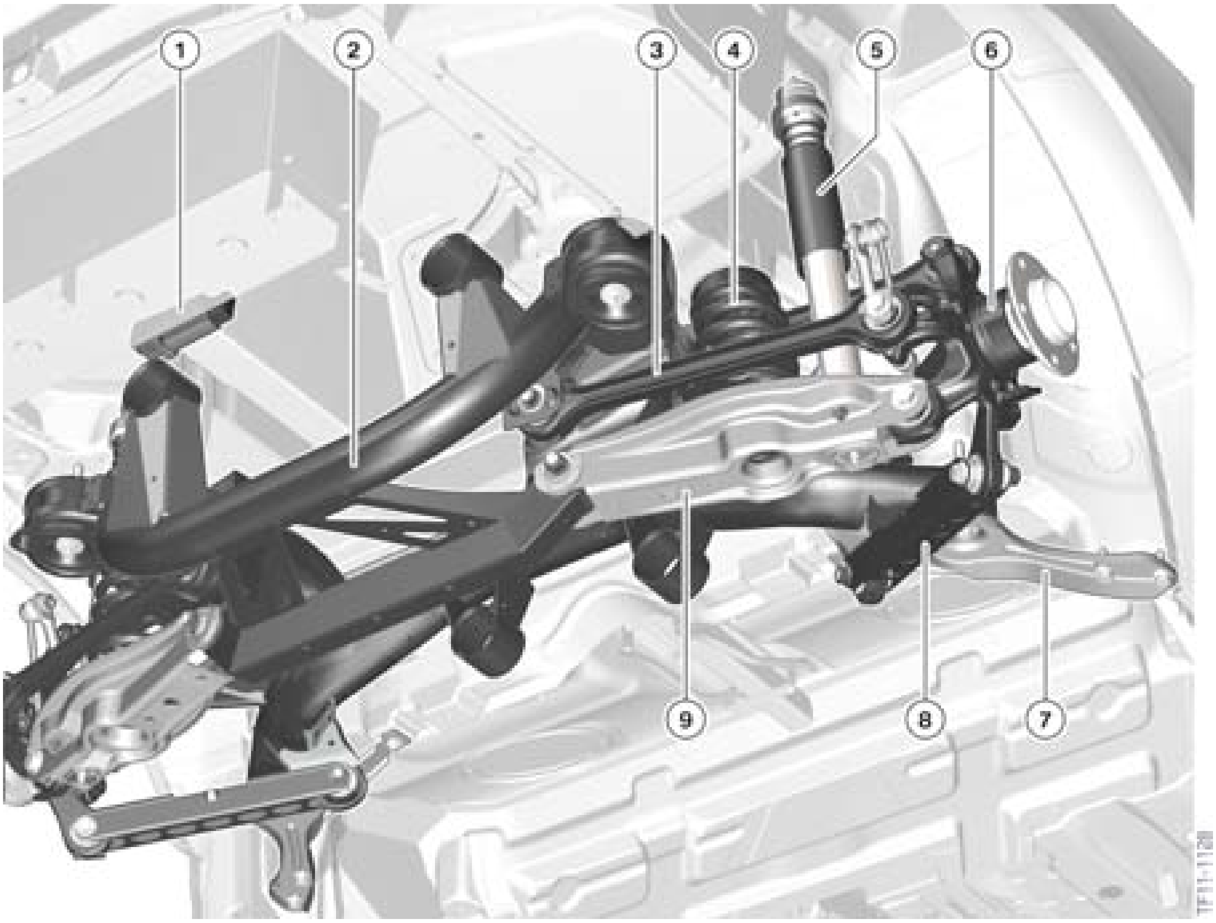
10.3. Suspension / damping

The overall package of springs and shock absorbers has been specifically designed for the E82E and varies from the conventional E82. The higher vehicle weight and the increased ground clearance and height have been considered in the selection and calibration of the components. The essential characteristics are discussed in the following.

Component	Features
Front coil springs	Stiffer than E82, and uses rough road adapters to increase ride height
Front shock absorber	Stiffer/with stronger dampening than E82
Rear coil springs	Stiffer and longer than E82 (increased height without off-road adapter)
Rear shock absorber	Stiffer/with stronger dampening than E82

10.4. Rear axle

The rear suspension of the E82E uses the same HA5 rear axle as E82. However, the modifications to the rear suspension are substantially more extensive than those implemented at the front. The rear subframe has been modified to accommodate the electric motor-generator, transmission and the E machine's electronic control system.



Rear axle

Index	Explanation
1	TPMS control unit
2	Rear axle support
3	Toe arm
4	Coil spring (unique to E82E)
5	Shock absorber
6	Wheel hub with wheel carrier
7	Radius rod
8	Trailing arm
9	Camber link

Four rubber bushings connect the drive unit to the rear subframe. The rear subframe itself is connected to the body with four additional rubber mounts and two radius rods.

The rear suspension does not use the off-road adapters (as in the front) to increase the ride height. Instead, special longer coil springs are installed. The increase in height means that the adjustment and specification data for the E82E's rear suspension also differ from those of the E82.

E82E Complete Vehicle

10. Chassis Dynamics

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Before a wheel alignment is performed on the E82E the current specification data for the E82E must be loaded to the KDS suspension geometry diagnosis system. Due to the height difference the specification data for the higher E82E vary from those of the E82.

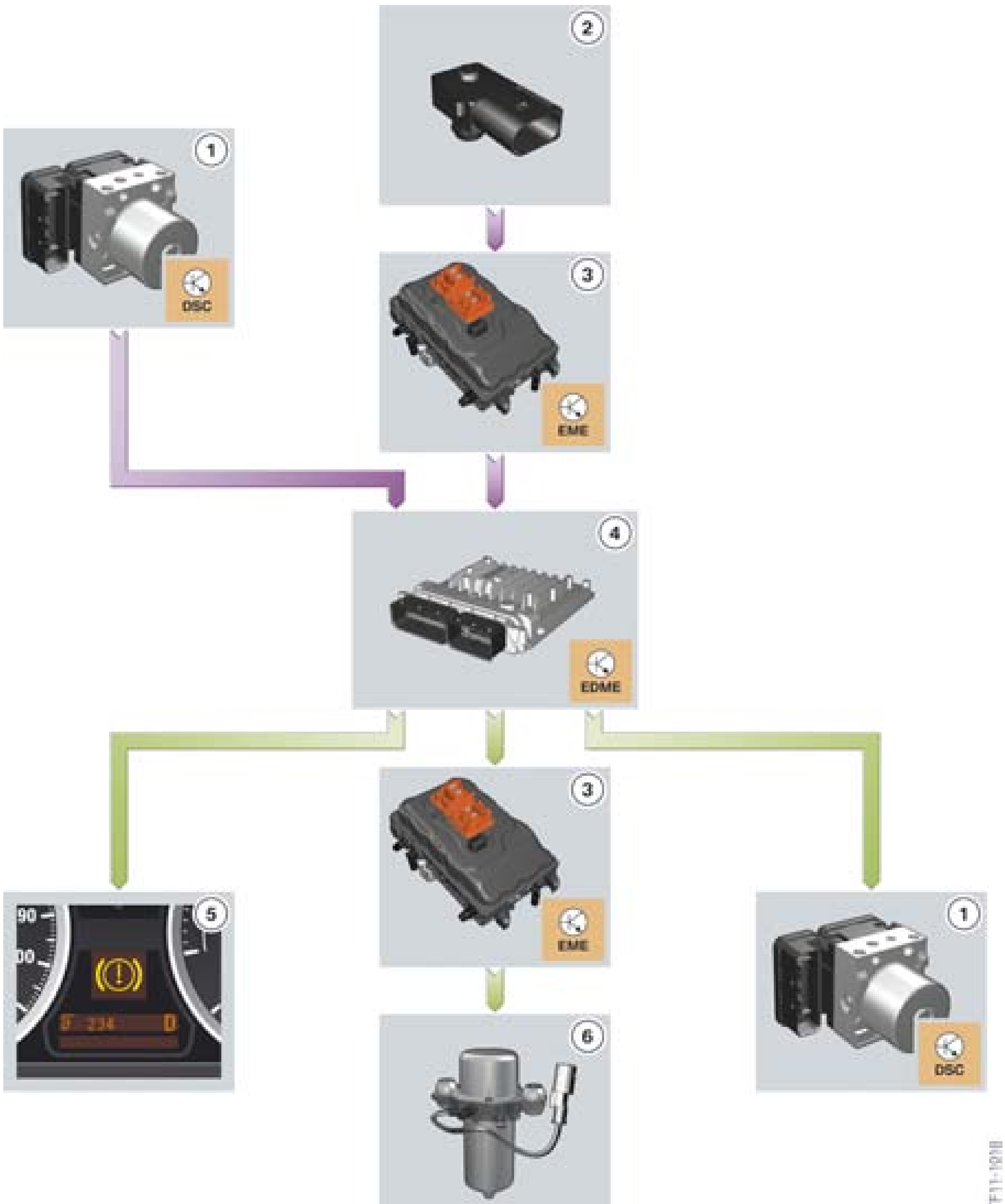
10.5. Brake system

The E82E's parking brake is identical to that used on the conventional E82 with the exception of the routing of the Bowden cables; thus the current section will restrict itself to discussing the differences in the service brakes and in the Dynamic Stability Control.

10.5.1. Service brakes

The primary difference between the service brakes on the E82E and the conventional E82 is the manner in which vacuum is produced. Instead of relying on a mechanical vacuum pump (driven by the engine) the E82E uses an ELUP (electric vacuum pump). In the E82E the distribution of the two brake circuits (front and rear) and the distribution of braking force between the two axles are identical to the E82.

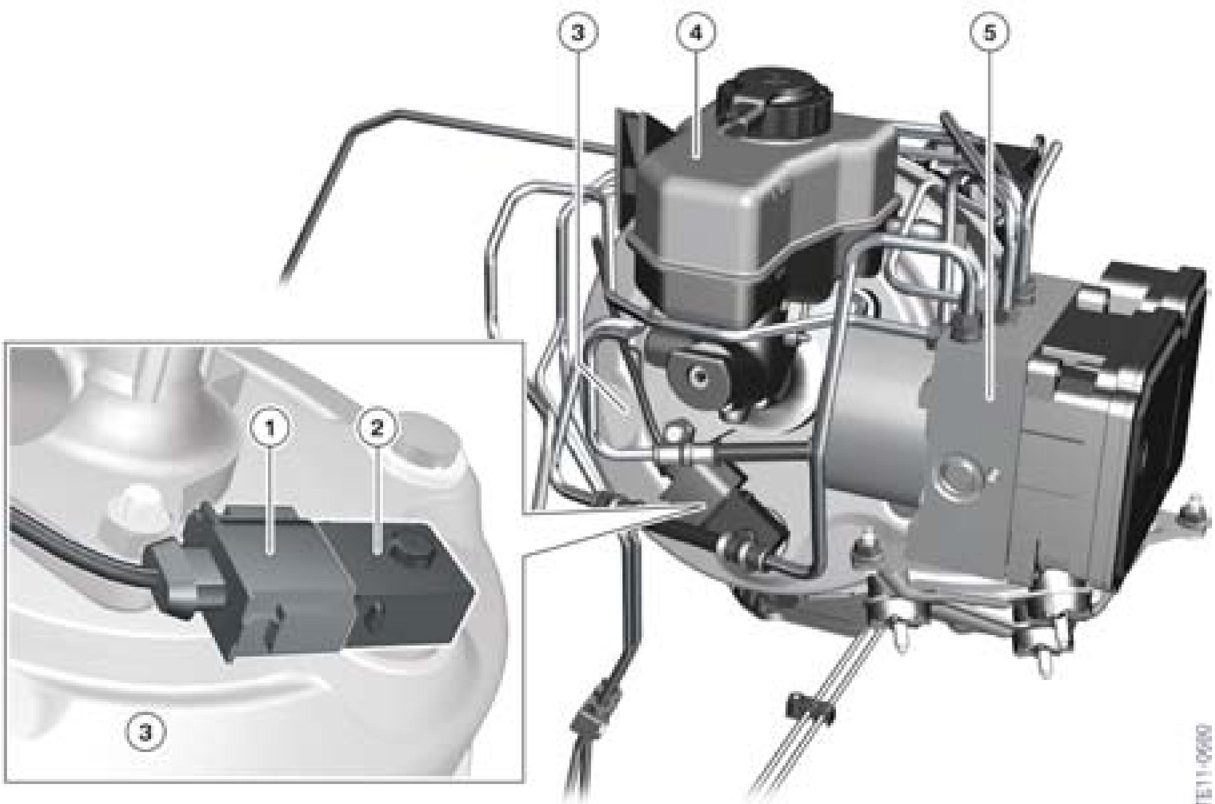
The following section describes the vacuum system, its components and their functions.



Brake system input/output

Index	Explanation
1	Dynamic Stability Control
2	Brake vacuum pressure sensor
3	Electric machine electronics (EME)
4	Electrical Digital Motor Electronics (EDME)
5	Instrument cluster
6	Electric vacuum pump

A brake vacuum sensor is installed on the brake booster. This component is known from 1-Series vehicles with the MSA automatic engine start-stop feature.



Brake vacuum sensor installation location

Index	Explanation
1	Wiring harness plug
2	Brake vacuum sensor
3	Brake booster
4	Brake fluid reservoir
5	Dynamic Stability Control

The EME control unit monitors the signal from the brake vacuum sensor and then relays it to the EDME control unit for subsequent processing in the form of a bus signal. The EDME control unit is responsible for activating the electric vacuum pump when needed to provide an adequate level of vacuum to support the brake booster. The EDME control unit's primary input is the brake vacuum signal, but it also uses other input signals transmitted from the DSC control unit in the form of bus signals, such as data on vehicle speed and hydraulic braking pressure. The EDME control unit activates the electric vacuum pump when speed drops below a specified threshold. The threshold for deactivating the electric vacuum pump does not depend on vehicle speed. Adequate hysteresis is present between the two threshold to prevent continuous alternation of activation and deactivation. If the brake vacuum sensor fails to transmit a signal the EDME reverts to utilization of a default value generated using the signal from the brake-light switch and the hydraulic brake pressure.

The EDME control unit transmits the request to activate or deactivate the electric vacuum pump to the EME control unit. An electric driver circuit in the EME is directly linked to the electric vacuum pump to allow activation and deactivation. During this process the in-rush (initial load) current is also monitored and limited as needed while the wires are also checked for shorts and open circuits.

If a malfunction is present in the vacuum system (such as failure of the electric vacuum pump) this triggers activation of a DSC function that assists in implementing the hydraulic brake boost (employed in place of vacuum booster). Activation of this DSC function is automatic and occurs whenever the DSC control unit recognizes this type of malfunction based on the brake vacuum signal. The DSC control unit also posts a Check Control message in the instrument cluster to ensure that the driver is informed of the malfunction.

Check Control symbol for failure of vacuum system

If this malfunction occurs both brake-pedal travel and the required pedal force will be greater than under normal conditions. However, the customer retains the ability to securely stop the vehicle with assisted braking and, if needed, with intervention to stabilize the vehicle from the Dynamic Stability Control.

10.5.2. Dynamic Stability Control

The Dynamic Stability Control installed in the E82E is the same hardware as in the conventional E82 (DSC Mk60E5, manufactured by Continental Teves).

The DSC in the E82E does of course adopt many functions familiar from the E82: the stabilizing functions ABS, Cornering Brake Control, ASC+T, MSR and DSC are, as would be expected, also implemented in the DSC in the E82E. Supplementary functions such as brake drying and the Hill Start Assistant are integrated in the E82E's DSC. The cruise control is also implemented within the DSC control unit. This varies from the cruise control in the 1-Series or 3-Series in that it does not incorporate a braking function (Dynamic Cruise Control DCC); instead it is merely a standard cruise-control system. In the E82E this function (usually integrated within the engine-management system) is incorporated in the DSC control unit.

The following are the major innovations and revisions in the DSC control unit's software in the E82E:

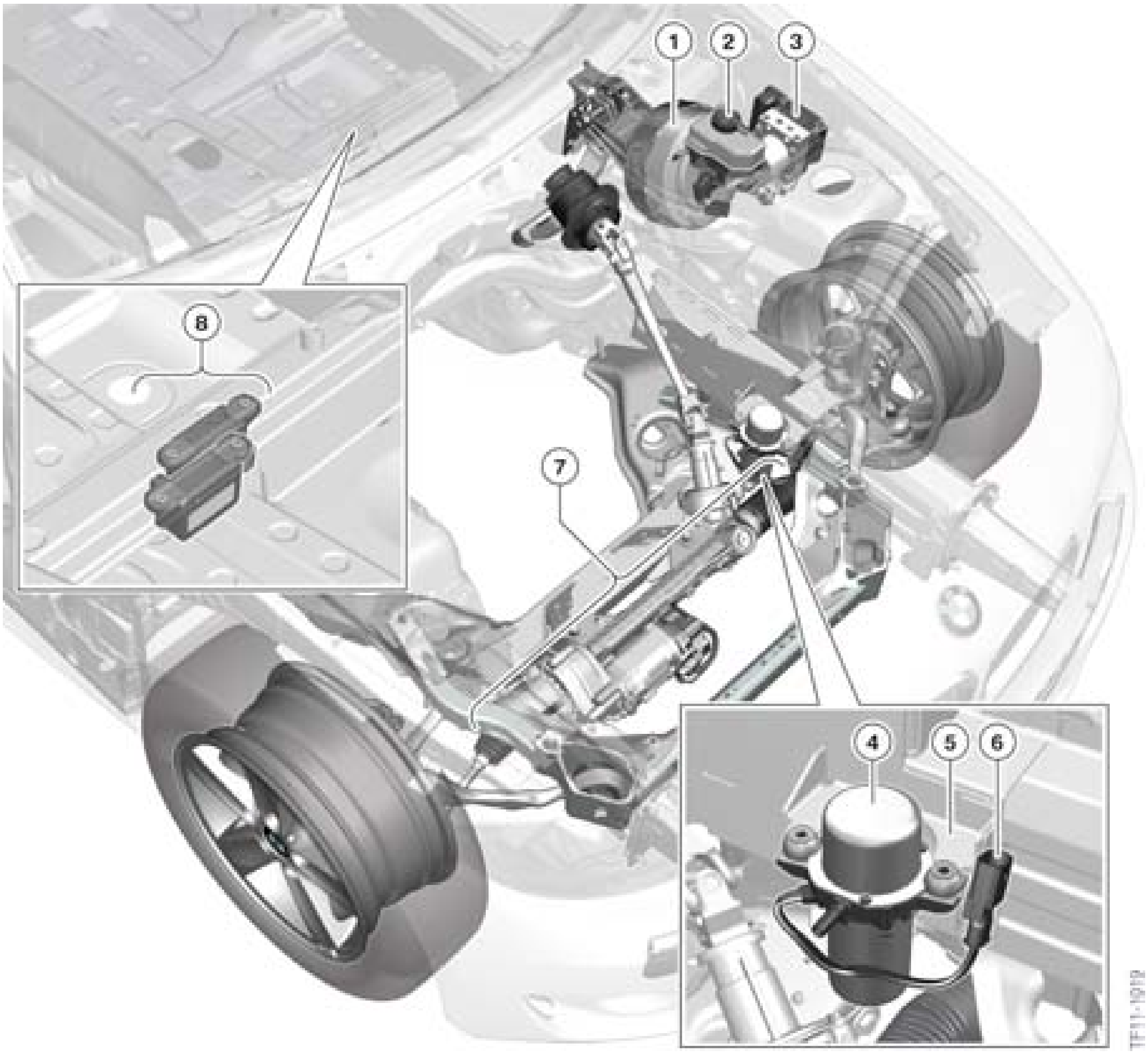
- Stability control with recognition of braking torque during energy recovery (referred to as “Hybrid Stability Management (HSM)” in development)
- Hydraulic brake booster with Hydraulic Brake Assist (referred to as "Hydraulic Brake Boost (HBB)" in development).

The braking force generated by the electric drive unit at the rear axle can be substantially greater than the engine braking from an internal-combustion engine during overrun on closed throttle. For this reason the "Hybrid Stability Management" system continuously monitors the rear wheel speed to detect slip and intervenes promptly to ensure stable vehicle response. The Dynamic Stability Control intervenes by requesting a restriction of the braking force generated by the electric drive unit. Should the vehicle assume an unstable attitude despite this effort, DSC will naturally implement supplementary intervention in the form of selective brake application at individual wheels to ensure easily controlled handling.

With “Hybrid Stability Management” the customer does not need to be concerned about vehicle stability. Even while driving on highways in winter conditions the customer can exploit the benefits of braking energy recuperation (for efficient vehicle operation) with no worries. For this reason, it is not possible to completely deactivate the DSC function in the E82E. However, a DTC mode is available as in a conventional vehicle.

The hydraulic brake assist only comes into play when the vacuum required for the brake booster is insufficient for effective servo-assistance. This is a supplementary function that only assumes active status if the electric vacuum pump ceases to operate or a leak occurs in the vacuum line, etc. Under these conditions the Dynamic Stability Control assesses the braking pressure originating with the driver and activates the DSC hydraulic pump as required. This raises the driver's braking pressure to roughly the same extent that a vacuum-based brake booster would discharge the same function. However, brake-pedal travel and brake-pedal force requirements are still different, which is why the a Check Control message appears to inform the driver of the change relative to standard conditions.

The following illustration shows the installation locations of all the major suspension components located at the front of the vehicle.



Installation locations of suspension components in the front of the vehicle

Index	Explanation
1	Brake booster
2	Brake fluid reservoir
3	Dynamic Stability Control
4	Electric vacuum pump
5	Bracket for electric vacuum pump on side member
6	Electrical connection for electric vacuum pump
7	Electric power steering (EPS)
8	DSC sensor

10.6. Wheel rims/tires

Throughout the world the E82E is available with 16-inch V-Spoke wheels, No. 360, as standard equipment. In some markets 17-inch wheel rims with different tire sizes at front and rear are available as an option. The tires installed as standard on the E82E are new-generation tires designed for ideal rolling resistance and thus make a major contribution to the extended travel range of the E82E. The dimensions of the tires offered by BMW for the E82E are listed in the following table.

Tires	European version	US version
Standard summer tires	205/55 R16 “Goodyear Efficient Grip” or “Bridgestone Ecopia”	205/55 R16 “Goodyear Efficient Grip”
Optional all-season tires	-	205/55 R16 “Bridgestone Turanza”
Optional tires with different dimensions front and rear)	205/50 R17 (front), 225/45 R17 (rear)	205/50 R17 (front), 225/45 R17 (rear)
Optional winter tires	205/55 R16 “Goodyear Ultra Grip Performance 2”	-
Optional spare tire	T125/80 R17 “Continental CST-17”	

The data provided in this table represent the status as slated for the introduction date (revisions during the E82E's model cycle remain possible).

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Note: Only tire brands and specifications approved by BMW are to be used on the E82E (mandatory agreement).

All of the summer tires, all-season tires and winter tires offered by BMW feature run-flat capabilities and are components within the “Runflat Component System” (with “RSC” designation).

The E82E uses the Tire Pressure Monitoring System (TPMS) to continuously monitor the tire inflation pressures. While the vehicle is moving the wheel's electronic systems continuously monitor the tire inflation pressures and transmit the measured data in the form of RF signals addressed directly to the TPMS control unit in which the reception antenna is also integrated. Thus the operating concept of the system used in the E82E is basically the same as that found in current-generation TPMS systems in other models, that also operate without supplementary antennas in the wheel housing. The TPMS control unit is installed in the rear of the vehicle and is also described in the "Rear axle" chapter of this training material.

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