Reference Manual

F30 PHEV
COMPLETE VEHICLE

Technical Training

Reference Manual

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The Ultimate Driving Machine®

BMW
Technical Training

F30 PHEV Complete Vehicle

BMW of North America, LLC
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ST1600
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For changes/additions to the technical data, repair procedures, please refer to the current information issued by BMW of North America, LLC, Technical Service Department.

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Safety Notice!!!

The diagnosis and replacement of the high-voltage components and high-voltage battery unit is only allowed in a retail service center that has qualified and certified service technicians. These technicians must have completed the ST1507 F15 PHEV Complete Vehicle instructor led course and successfully passed the written certification.

Technical training.

Product information.

F30 PHEV High-voltage Components

BMW Service

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Technical Training
ST1600 1/1/2016

General information

Symbols used

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

⚠

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

Information status and national-market versions

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

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

Additional sources of information

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

- Owner's Handbook
- Integrated Service Technical Application.

Contact: conceptinfo@bmw.de

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

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F30 PHEV High-voltage Components

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1. Introduction

1.1. Positioning

With the new BMW 330e, BMW is adding another innovative variant to The Ultimate Driving Machine. With its plug-in hybrid drive, the latest BMW 3 Series variant combines brand-typical driving dynamics with the option of driving electrically and emissions-free during shorter local trips, while also offering maximum efficiency over long distances. The BMW 330e combines high dynamics with extremely low fuel consumption. Thanks to the combination of the BMW EfficientDynamics technology BMW eDrive with the BMW TwinPower Turbo gasoline engine, it has been possible to achieve an efficient and dynamic plug-in hybrid drive that perfectly matches the BMW brand: dynamic driving, electrical and emissions-free efficient driving on short trips.

Looking further ahead, the BMW Group plans to offer plug-in hybrid vehicles in all core brand models. All Group models benefit from BMW i, with the fundamental technologies of the battery cells and electrical machines as well as the power electronics making their way into future plug-in hybrid models. Purely electrical driving is possible on both short city trips and commutes. On longer trips, the vehicles are usually driven through "mixed operation". The new BMW 3 Series plug-in hybrid prototype combines the B48 4-cylinder gasoline engine and an electric drive.

The further development of hybrid drive systems as part of Efficient Dynamics is aimed at increasing the share of electrical power used in driving. In order to guarantee the brand-typical dynamics, unrestricted everyday practicality and the greatest possible long-distance capability, the BMW Group relies on so-called high electrification. Special features of the future Power eDrive technology include significantly more powerful electrical machines as well as a doubled capacity of the high-voltage battery. Here the drive components developed for future hybrid systems can achieve a system power of more than 500 kW. The lithium ion batteries also go far beyond those of current hybrid systems, with a storage capacity of up to 20 kilowatt hours (kWh).

The BMW 330e, with the development code F30 PHEV, is based on the F30. The hybrid technology is based on the consistent further development of the drive technology used in the series models BMW ActiveHybrid 5 and BMW ActiveHybrid 7. The BMW 330e is a full hybrid vehicle with a lithium-ion high-voltage battery unit that can be charged using a domestic power socket, for example.

The abbreviation PHEV in the development code stands for **P**lug-in **H**ybrid **E**lectric **V**ehicle.

The drive system of the BMW 330e consists of a 4-cylinder gasoline engine with TwinPower turbo technology (B48), an 8-speed automatic transmission (GA8P75HZ) and an electrical machine. The main advantage of the hybrid technology used in the F30 PHEV is of course the further increase in driving power compared with the conventionally powered BMW 3 Series, together with lower fuel consumption.

The electrical drive of the BMW 330e enables purely electrical and thus emissions-free driving with speeds up to 120 km/h / 75 mph. The maximum electrical range is 40 kilometers / 25 miles. Furthermore, a start/stop engine function specific to a hybrid opens up additional potential in terms of efficiency by switching off the combustion engine each time the car is stopped at traffic lights or in traffic.

With the standard driving experience switch, the driving modes SPORT, COMFORT and ECO PRO can also be selected in the BMW 330e. Using an additional button (eDrive button), the F30 PHEV can drive up to 120 km/h / 75 mph by purely electrical means, without starting the combustion engine.

F30 PHEV High-voltage Components

1. Introduction

Generations of the BMW hybrid cars

Index	Explanation
1	The E72 was launched on the market at the end of 2009 as the first BMW hybrid car. The technology used here (so-called generation 1.0) was a product created from the cooperation venture between General Motors, Daimler Chrysler and BMW. A nickel metal hydrid battery was used as an electric energy storage device.
2	The second hybrid car from BMW came on the market in 2010 under the name active hybrid 7. It is a mild hybrid car with 1.5 generation technology. This technology was developed together with Mercedes Benz. The highly efficient lithium-ion battery was used in the high-voltage electrical system.
3	The active hybrid 5, the third BMW hybrid car, has been built since the end of 2011. The F10H is the first vehicle with second generation hybrid technology. A lithium-ion battery is used as an electrical energy storage device.
4	In 2012 the production of further BMW hybrid cars with generation 2.0 technology began: The second BMW active hybrid 7 is produced under the development code F01H/F02H and replaced the F04. At the same time the BMW active hybrid 3 (development code F30H) came on the market.
5	The BMW 530Le (development code F18 PHEV), as the first BMW hybrid car with generation 3.0 technology, is being built especially for the Chinese market from the end of 2014. It is a Plug-in Hybrid Electric Vehicle. A lithium-ion battery is used as an electrical energy storage device.
6	The BMW X5 xDrive40e (development code F15 PHEV) is another BMW hybrid vehicle of generation 3.0. The F15 PHEV is also a plug-in hybrid vehicle with a lithium ion battery. This vehicle is available from the end of 2015.

F30 PHEV High-voltage Components

1. Introduction

1.2. Identifying features

1.2.1. Exterior

The BMW 330e distinguishes itself from the conventional F30 through a range of special features. The "eDRIVE" inscription on the C-pillars and on the acoustic cover of the combustion engine indicate that it is a hybrid vehicle. The 330e is available with a range of wheel rims as standard. The wheels can be optionally equipped with sporty 19" aero wheel rims in five-spoke design, which reduce the drag of the vehicle. The charging socket cover on the left side of the front side panel indicates that the BMW 330e is a Plug-in Hybrid Electric Vehicle. Lastly, the model designation 330e on the tailgate of the vehicle rounds off the differences compared with the conventional 3 Series.

F30 PHEV exterior identifying features

Index	Explanation
1	Charging socket cover
2	Inscription "eDrive" on both C-pillars
3	Acoustic cover with "eDrive" inscription
4	Model designation "330e" on the tailgate
5	19" aero wheel rims

1.2.2. Interior

F30 PHEV interior identifying features

Index	Explanation
1	eDrive button
2	Hybrid-specific displays in the instrument cluster
3	Door sill cover strip with “eDrive” inscription
4	eDrive menus in the CID

Some features of the interior of the BMW 330e are also different to the conventional F30.
The refuelling button is located beneath the light switch. The next special feature can be found below the keypad in the center console: the eDrive button. Using this button, the driver can select different functions by means of a toggle function and can drive up to 120 km/h by purely electrical means.

The inscription "eDRIVE" can also be found on the front door sill cover strips.

The hybrid-specific operating conditions and the state of charge of the high-voltage battery unit are displayed in the instrument cluster and if desired in the Central Information Display. Both the display in the CID and in the instrument cluster are activated upon start-up.

F30 PHEV High-voltage Components

1. Introduction

The interior space of the F30 PHEV remains unchanged compared with the F30. The placement of the high-voltage battery unit in the luggage compartment means that the luggage compartment capacity in the F30 PHEV is slightly smaller.

1.3. Technical data

Combustion engine and transmission	Unit	BMW 328i	BMW ActiveHybrid 3	BMW 330e
Design		R4	R6	R4
Number of valves per cylinder		4	4	4
Displacement	[cm^3]	1997	2979	1998
Transmission		8HP45	GA8P70HZ	GA8P75HZ
Drive		Rear	Rear	Rear
Maximum power, combustion engine	[kW (HP)] [rpm]	185 (240) 5200	225 (306) 5800 - 6400	135 (184) 5000 - 6500
Maximum torque of combustion engine	[Nm (lb-ft)] [rpm]	305 (225) 1250 - 4800	400 (295) 1200 - 5000	290 (215) 1350 - 4250
Complete system power	[kW (HP)] [rpm]	-	250 (340)	185 (252)
High-voltage battery unit		-	Lithium-ion	Lithium-ion
Power of electrical machine	kW	-	40	65
Maximum torque, electrical machine	[Nm]	-	210	250

Vehicle performances	Unit	BMW 328i	BMW ActiveHybrid 3	BMW 330e
Acceleration 0 – 100 km/h (0 – 60 mph)	[s]	6.3 (5.9)	5.5 (5.2)	6.2 (5.9)
Maximum speed	[km/h (mph)]	210 (130)	210 (130)	210 (130)

1. Introduction

Consumption and emissions	Unit	BMW 328i	BMW ActiveHybrid 3	BMW 330e
Consumption (EEC cycle urban)	[l/100 km]	10.8	11.3	-
Fuel consumption EEC cycle extra-urban	[l/100 km]	9.4	6.9	-
Fuel consumption combined (NEDC)	[l/100 km]	6.1	5.9	1.9
CO_2 emissions	[grams per kilometer]	143	139	44

Dimensions and weights	Unit	BMW 328i	BMW ActiveHybrid 3	BMW 330e
US Vehicle curb weight	[kg(lbs)]	1570 (3641)	1730 (3813)	1775 (3915)
US Payload	[kg(lbs)]	410 (904)	408 (900)	353 (780)
Fuel tank capacity	[liters (gallons)]	60 (15.8)	57 (15)	41 (10.8)
Luggage compartment volume	[liters]	480	390	370

1.4. Equipment

The F30 PHEV and F30 differ not only in the technical data but also in the range of optional equipment offered. Below is a list of the key optional equipment that is **not** offered in the F30 PHEV:

- Trailer tow hitch
- xDrive
- Dynamic Drive
- Adaptive chassis and suspension

F30 PHEV High-voltage Components

2. Drive Components

2.1. Introduction

In the F30 PHEV, the B48B20M0 is an element of the BMW hybrid drive. The 2.0 liter engine, which in the F30 PHEV generates a power of 135 kW/184 hp and a maximum torque of 290 Nm, ensures increased sustainability and efficiency.

2.2. Modified B48 engine

The B48 engine and its periphery were modified for use in the BMW 330e. Details of the individual modifications are provided in the following.

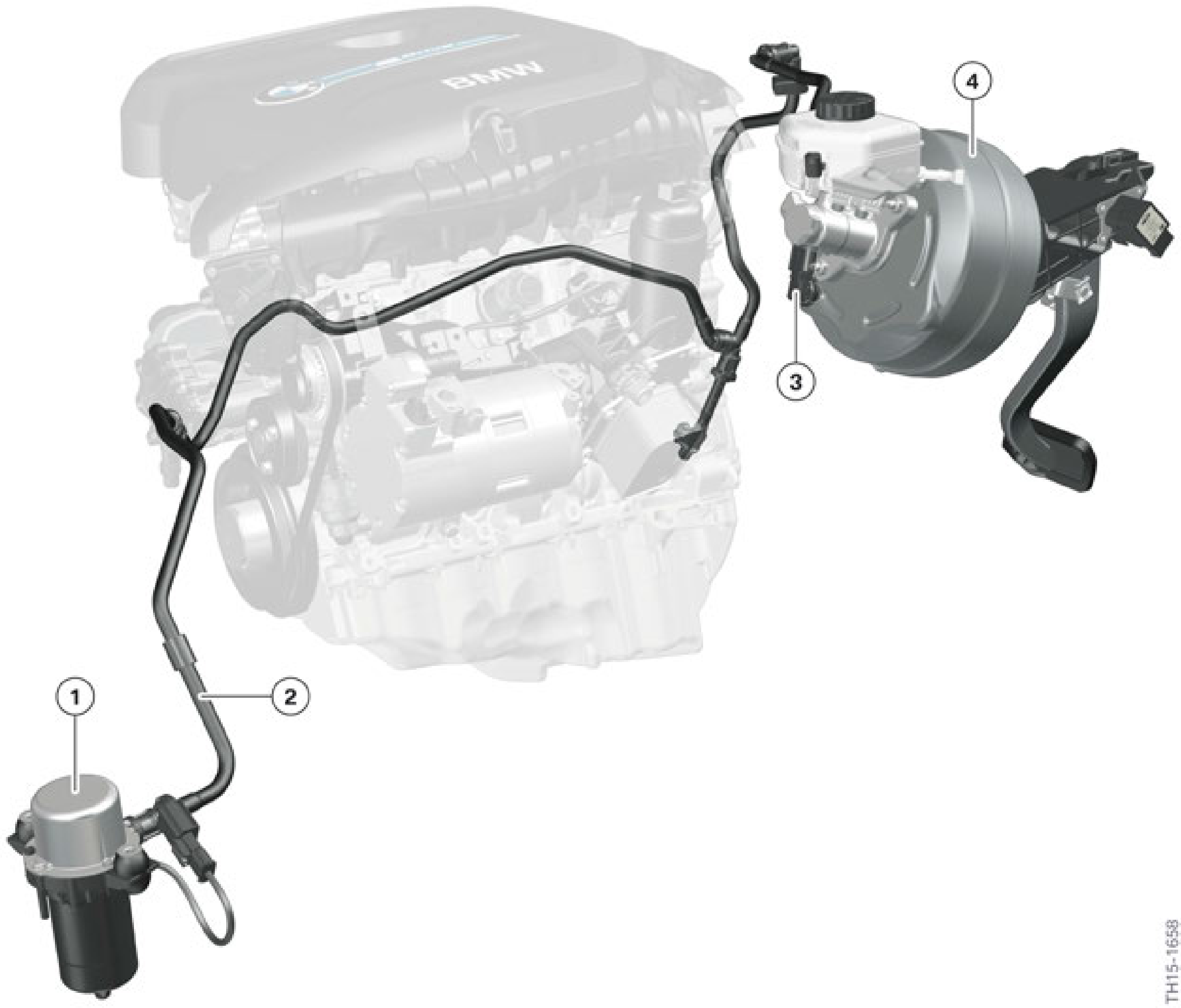
Components from belt drive	Replaced by	Background
Power steering pump	Electronic Power Steering (EPS)	With the Electronic Power Steering both the steering assistance and the self-aligning forces can be freely defined. This means the steering behavior and vehicle behavior can be adapted optimally to the corresponding driving situation.
A/C compressor	Electric A/C compressor (EKK)	As the combustion engine is at a standstill during an electric trip, it cannot power the A/C compressor. This is why an electrically operated A/C compressor is used.
Alternator	Electric Motor Electronics (EME)	The electrical machine electronics converts the high voltage to 12 V voltage using the integrated DC/DC converter and supplies the 12 V vehicle electrical system.
Vacuum pump	Electrical vacuum pump	As the combustion engine is at a standstill during an electric trip, it cannot power the mechanical vacuum pump. This is why an electrical vacuum pump is also used in addition to the mechanical vacuum pump.

2.2.1. Vacuum system

Various components of the F30 PHEV are shown with a vacuum supply. The B48 engine generates the required vacuum using a mechanical vacuum pump. As the vacuum supply must also be guaranteed in phases in which the B48 engine is switched off, the vacuum system has been enhanced with an electrical vacuum pump. As soon as the value in the vacuum system drops below a certain threshold, the electrical vacuum pump is activated. The vacuum is recorded by a pressure sensor in the brake servo, which is already known from vehicles with an automatic engine start-stop function.

2. Drive Components

The following graphic provides an overview of the respective components.



F30 PHEV vacuum system

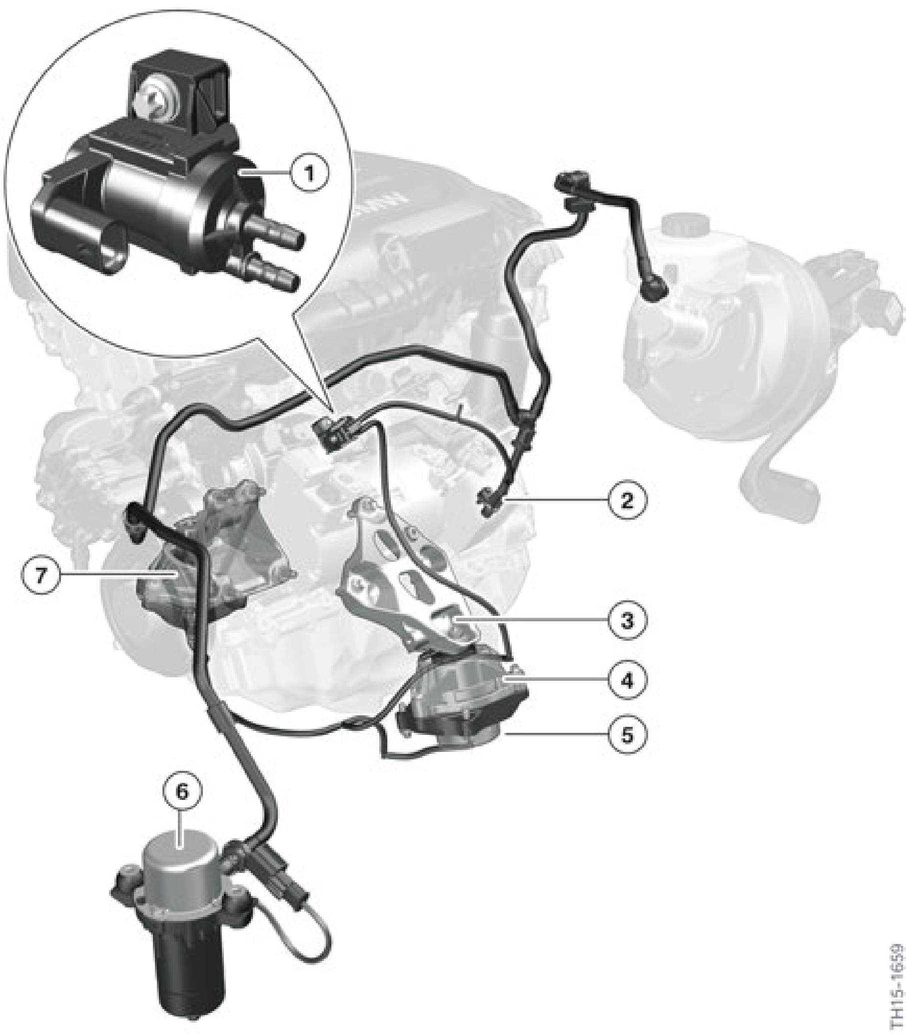
Index	Explanation
1	Electrical vacuum pump
2	Vacuum line to electrical vacuum pump
3	Pressure sensor
4	Brake servo

2.2.2. Engine mounting

In the F30 PHEV the engine mounting is effected using the controlled variable-motor mounts known from vehicles with diesel engines. These are adjusted to hard or soft by means of a vacuum in order to guarantee a comfortable start and idle state of the combustion engine. The engine mounting has been raised on the left and right using spacer sleeves and the engine support arms shortened to improve the oscillation comfort during start-up of the combustion engine.

The valve for activating the controlled variable-motor mounts of the combustion engine is activated by the Digital Motor Electronics (DME). The behavior of the controlled variable- motor mounts of the F30 PHEV is similar to the controlled variable-motor mounts in vehicles with diesel engines. If a vacuum is applied to these, they are soft. This corresponds to the setting for idle state and start-up of the combustion engine and ensures comfortable damping action. As soon as the vacuum is no longer applied to the motor mounts and an ambient pressure is established, the motor mounts become hard. This setting is activated when driving the F30 PHEV.

The vacuum supply of the controlled variable-motor mounts are effected by the vacuum system of the F30 PHEV described above.



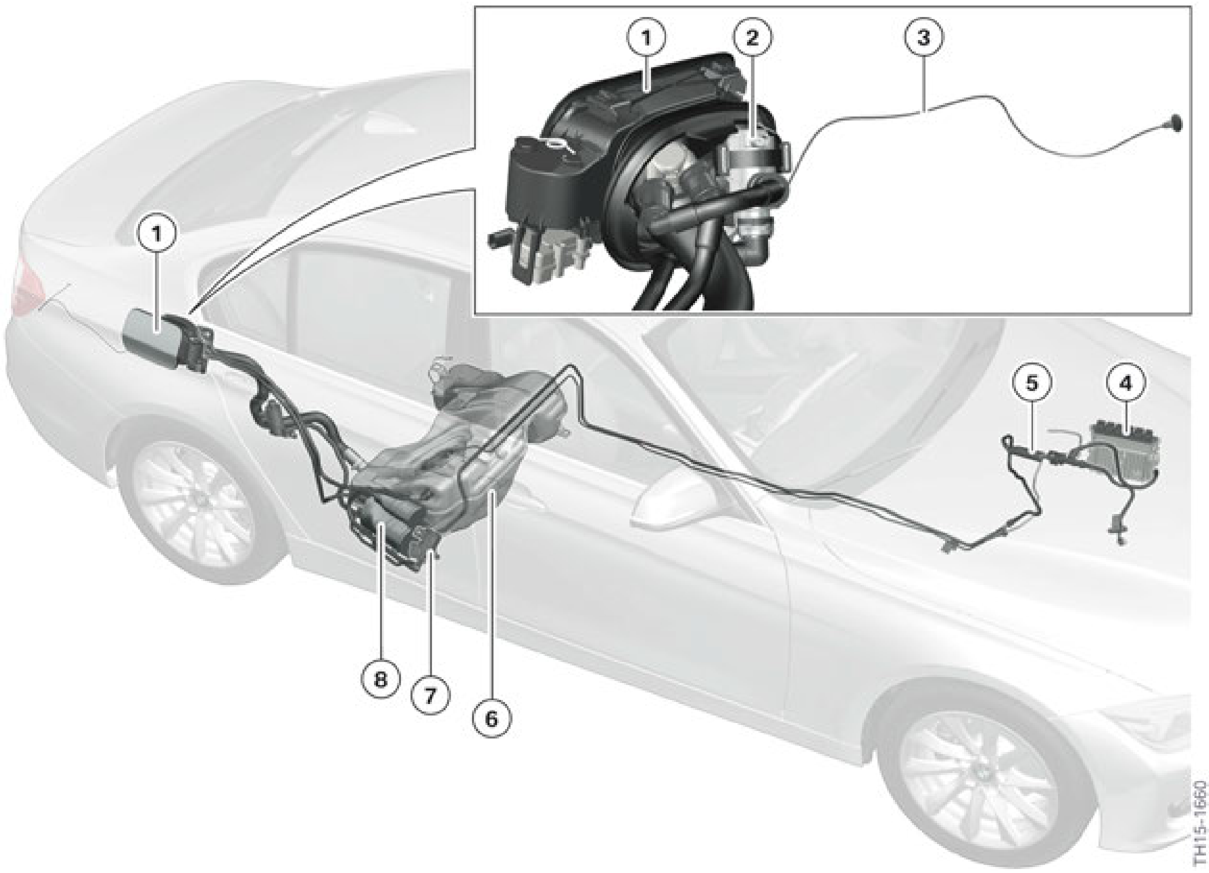
F30 PHEV engine mounting

Index	Explanation
1	Valve for activating the controlled variable-motor mounts
2	Connection for vacuum line
3	Engine support arm, left
4	Spacer sleeve, left
5	Controlled variable-motor mounts, left
6	Electrical vacuum pump
7	Mechanical vacuum pump

2.3. Fuel supply

For the operation of the combustion engine, the F30 PHEV is equipped with a pressurized fuel tank made from stainless steel. As a result during purely electric driving it is guaranteed that the gasoline fumes remain in the pressurized fuel tank. Only with the operation of the combustion engine is fresh air drawn in by the carbon canister for purging and the gasoline fumes are directed to the combustion chamber. The pressurized fuel tank remains in its original installation space since the high-voltage battery unit is accommodated in the luggage compartment. Its usable volume is 41 liters / 10.8 gallons.

2.3.1. Components and their installation locations

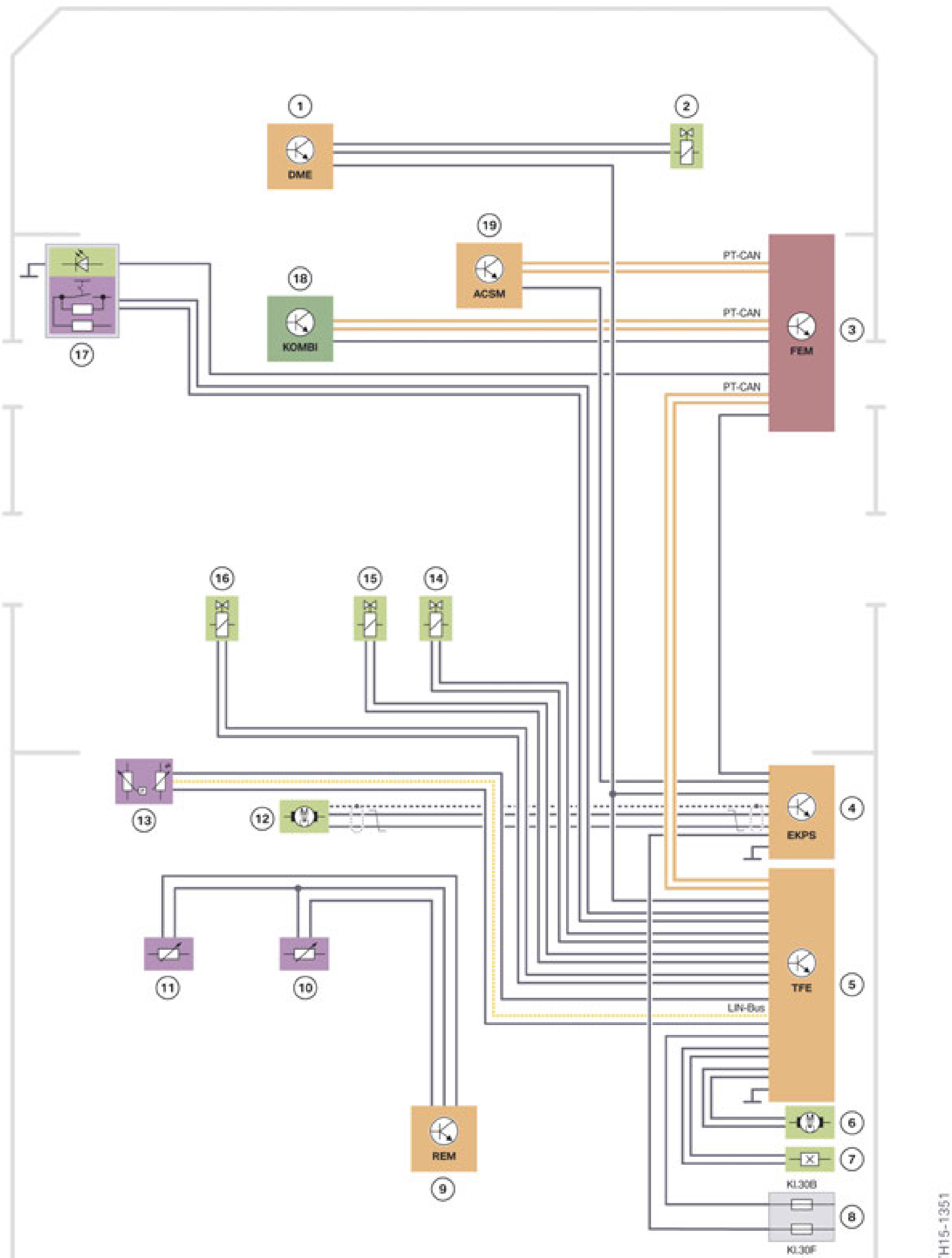


F30 PHEV components of the fuel supply in European version

Index	Explanation
1	Fuel filler flap with cover
2	Fuel tank non-return valve
3	Cable for emergency release of the fuel filler flap
4	Digital Motor Electronics (DME)
5	pressurized fuel tank
6	Fuel tank isolation valve
7	Carbon canister

The pressurized fuel tank is secured directly at the body using a tensioning strap.

2.3.2. System wiring diagram



F30 PHEV, system wiring diagram for fuel supply

2. Drive Components

Index	Explanation
1	Digital Motor Electronics (DME)
2	Tank vent valve
3	Front Electronic Module (FEM)
4	Fuel pump control electronics (EKPS)
5	Hybrid pressure refuelling electronic control unit (TFE)
6	Actuator drive for locking the fuel filler flap
7	Sensor for the position of the fuel filler flap
8	Power distribution box, luggage compartment
9	Rear Electronic Module (REM)
10	Lever sensor for fuel level, right
11	Lever sensor for fuel level, left
12	Electric fuel pump
13	Pressure/Temperature sensor
14	Fuel tank non-return valve
15	Fuel tank isolation valve (ECE only)
16	Atmosphere Isolation Valve (AIV) (US only)
17	Button with lighting for refuelling
18	Instrument panel (KOMBI)
19	Advanced Crash Safety Module (ASCM)

In the event of a crash, the fuel pump control electronics (EKPS) immediately disconnect the power supply for the fuel pump drive. The EKPS receives the information from the Advanced Crash Safety Module via the PT-CAN.

The fuel tank isolation valve is opened during current supply. It is closed when there is no current supply. In the event of a crash with the F30 PHEV, there is no active power supply of the fuel tank isolation valve (it remains closed) and a fault code entry is also not set by the TFE. Subsequent refuelling of the vehicle, as well as other functions (purging, etc.) are thus not blocked, as long as the components involved (e.g. pressure temperature sensor) are not damaged.

F30 PHEV High-voltage Components

2. Drive Components

2.3.3. Refuelling

The pressurized fuel tank must be vented before refuelling. In order to implement the refuelling procedure, first of all the "Refuelling" button must be pressed. The refuelling button is found in the area beneath the light switch. The button functions only when the vehicle is awake. The status of the button is evaluated by the hybrid pressure refuelling electronic control unit.

F30 PHEV, refuelling button

The hybrid pressure refuelling electronic control unit (TFE) monitors the current operating condition via a pressure/temperature sensor in the fuel tank and then controls the pressure reduction by opening the valves in the tank ventilation path. The fuel tank isolation valve or the fuel tank non-return valve must be opened, depending on the vehicle condition. The fuel vapors are temporarily stored in the carbon canister during refuelling. The stored vapors are routed into the engine only when the combustion engine is running and with activated purging. The fuel filler flap is released after pressure reduction from the fuel tank. The actuator drive for locking the fuel filler flap is activated and the fuel filler flap with fuel filler cap can be opened manually. The fuel filler flap release is not enabled as long as the pressure measured in the fuel tank is above the defined threshold value. The fuel tank isolation valve is also opened to reduce the tank pressure while driving if the tank pressure reaches the system limit. In stopped condition, this is achieved by a mechanical valve which is integrated in the fuel tank isolation valve.

The fuel supply of the F30 PHEV does **not** have tank leak diagnosis on EURO vehicles.

The Atmosphere Isolation Valve (AIV) is located between the carbon canister and atmosphere and is only installed in US vehicles. There is still a fuel tank shutoff valve between the carbon canister and the fuel tank. The fuel tank, carbon canister and purge air line up to the tank vent valve form a pressure system. This is necessary in order to perform the leak diagnosis legally required for US vehicles. When the vehicle is in a stopped condition or during electric driving, the atmosphere isolation valve is closed and the fuel tank shutoff valve is open.

In EURO vehicles, there is a fuel tank shutoff valve and a fuel tank isolation valve between the fuel tank and the carbon canister. The fuel tank non-return valve is open in de-energized state. The fuel tank system is isolated from the atmosphere by means of the fuel tank isolation valve.

When the combustion engine is started, the fuel tank non-return valve is closed and the fuel tank isolation valve opened in order to purge the carbon canister with the help of the combustion engine. The fuel tank non-return valve maintains the pressure in the fuel tank during this process. The combination of fuel tank isolation valve and fuel tank non-return valve makes it possible to comply with the legally required emission limits and still drive with purely electric power. The fuel supply of the F30 PHEV **has** tank leak diagnosis in US vehicles.

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Before carrying out repair work on the fuel supply, the refuelling procedure must be started so that the pressure in the fuel tank can be released. The fuel filler flap and fuel filler cap must be left open during repair work in order to exclude the possibility of a renewed pressure build-up.

If the fuel filler flap is not opened within approx. 10 minutes, it is automatically locked again. The position of the fuel filler flap is identified using a hall effect sensor.

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

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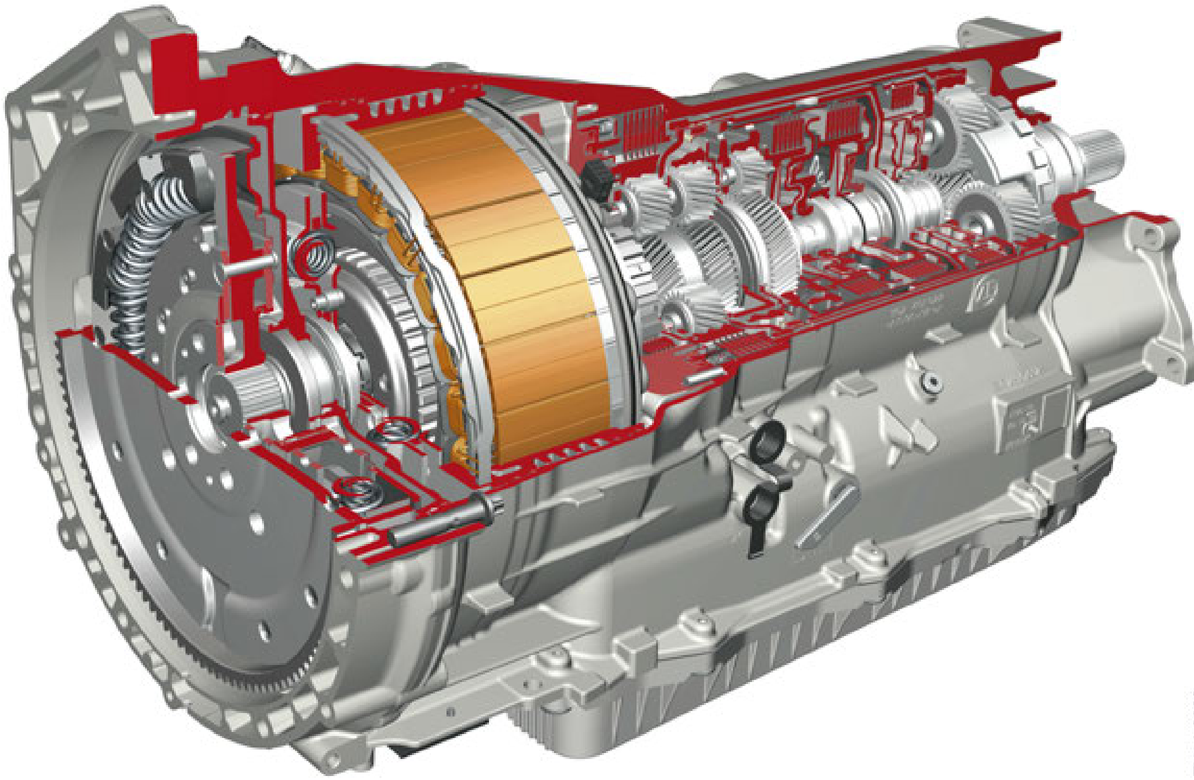
Filling the fuel tank while the high-voltage battery unit is charging is not permitted. When the charging cable is connected, ensure sufficient safety distance to highly flammable materials. Otherwise, there is a risk of personal injury or material damage in the event of improper connection or disconnection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

2.4. Automatic transmission

2.4.1. Introduction

The automatic transmission GA8P75HZ of the F30 PHEV, which is based on the transmission introduced in the F07 at the end of 2009 (GA8HP70Z), is also manufactured by ZF.

If you have already taken part in the training for the second generation of BMW active hybrid cars, you will already be familiar with the GA8P70HZ transmission used there. The structure of the automatic transmission GA8P75HZ of the F30 PHEV is similar.



F30 PHEV, GA8P75HZ transmission

2.4.2. Structure and function

Overview

In order to satisfy the requirements of a Plug-in Hybrid Electric Vehicle, the automatic transmission was adapted. For this purpose, some existing components have been modified or replaced with other components. A part of the damping system was also extracted from the transmission area and connected to the combustion engine as a dual-mass flywheel with integrated centrifugal pendulum. The connection to the transmission is effected via a spline.

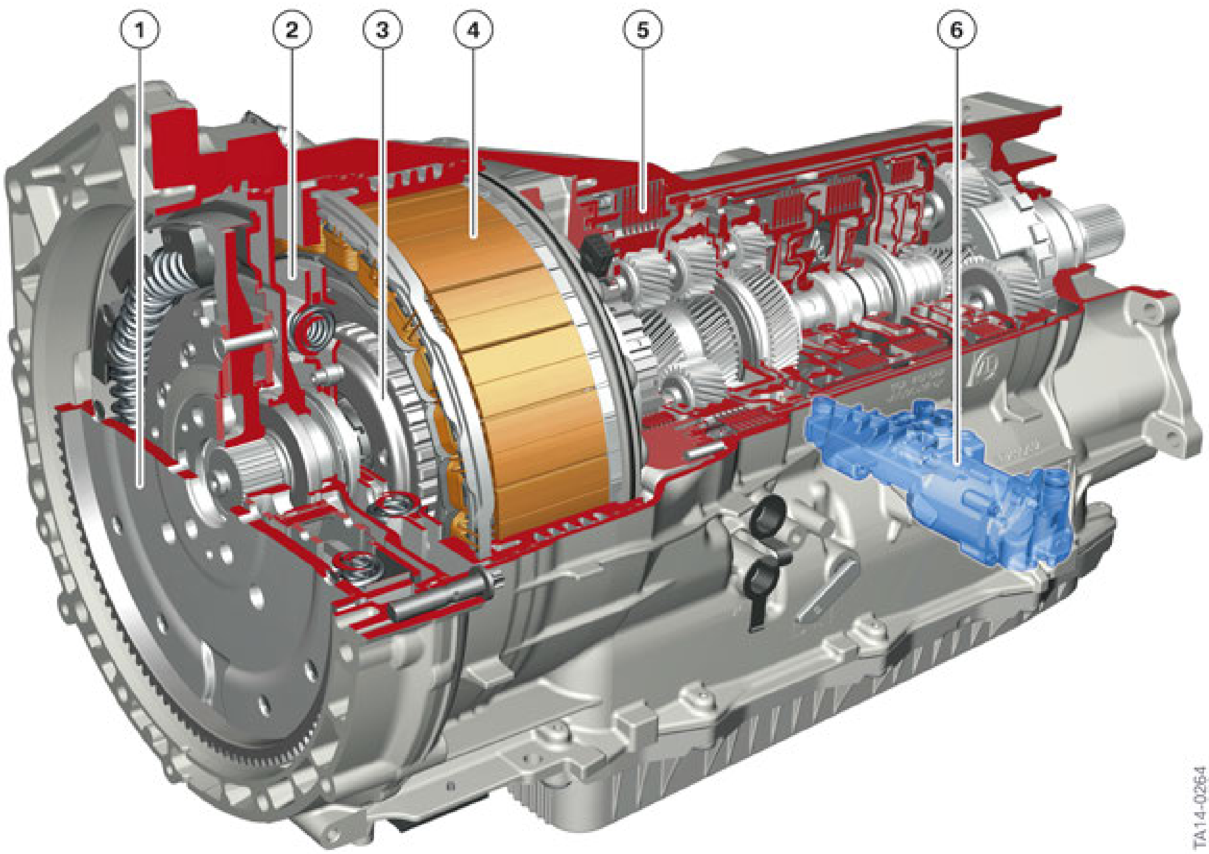
As a result of the larger electrical machine and the additional torsional vibration damper, the housing of the GA8P75HZ transmission was extended by 30 mm in comparison to the GA8P70HZ transmission.

The hybrid area in the GA8P75HZ transmission can be divided into five components:

- Dual-mass flywheel
- Additional torsional vibration damper
- Separation clutch
- Electrical machine
- Auxiliary electric oil pump (for supplying transmission oil pressure when transmission input shaft is idle, which is a modification of the GA8P70HZ).

2. Drive Components

Like on the GA8P70HZ transmission, the multidisc brake B is also reinforced in the GA8P75HZ transmission by increasing the diameter and number of discs and is equipped with actively controllable transmission oil cooling. This is necessary as, in addition to its function as a shift element, it must also enable the vehicle to start-up and crawl.



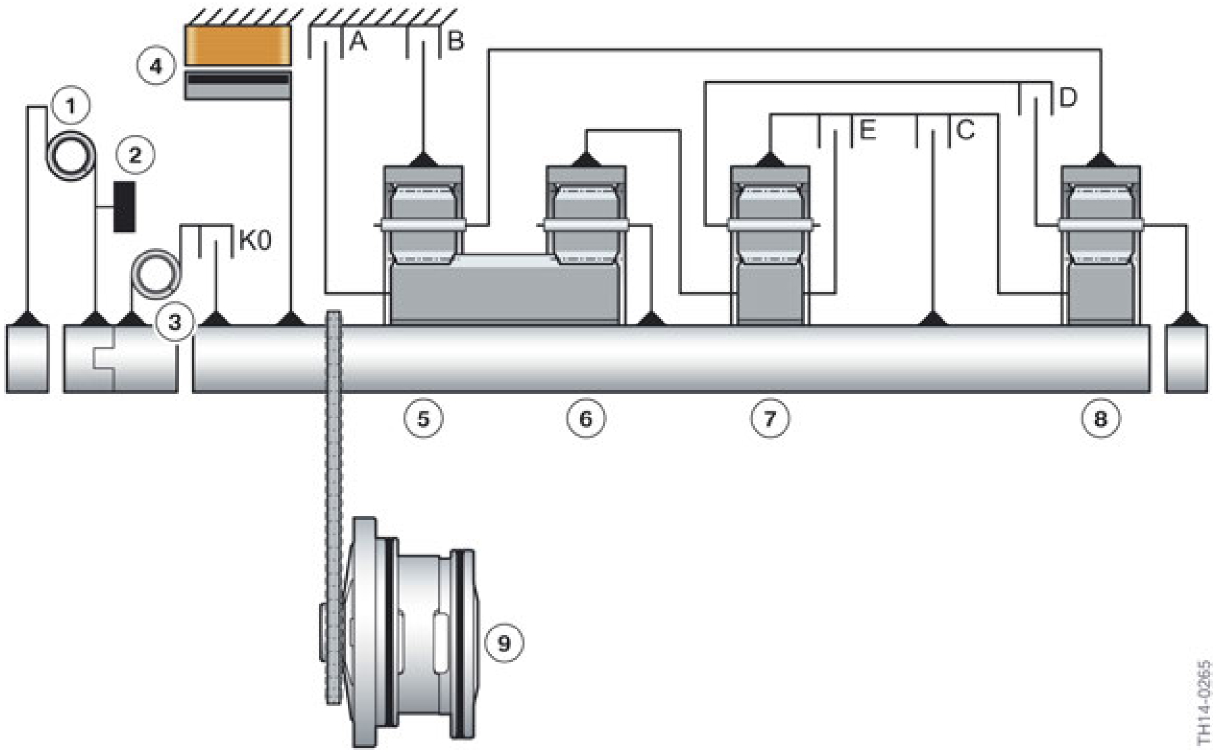
F30 PHEV, GA8P75HZ transmission

Index	Explanation
1	Dual-mass flywheel (including torsional vibration damper and centrifugal pendulum)
2	Additional torsional vibration damper
3	Separation clutch
4	Electric motor
5	Multidisc brake B
6	Auxiliary electric oil pump

The following transmission skeleton of the GA8P75HZ transmission shows how the new components have been integrated in the automatic transmission.

F30 PHEV High-voltage Components

2. Drive Components



F30 PHEV, schematic structure of the GA8P75HZ transmission

Index	Explanation
1	Torsional vibration damper
2	Centrifugal pendulum
3	Additional torsional vibration damper
4	Electric motor
5	Gear set 1
6	Gear set 2
7	Gear set 3
8	Gear set 4
9	Mechanical oil pump
A	Multidisc brake A
B	Multidisc brake B
C	Multidisc clutch C
D	Multidisc clutch D
E	Multidisc clutch E
K0	Separation clutch

F30 PHEV High-voltage Components
2. Drive Components

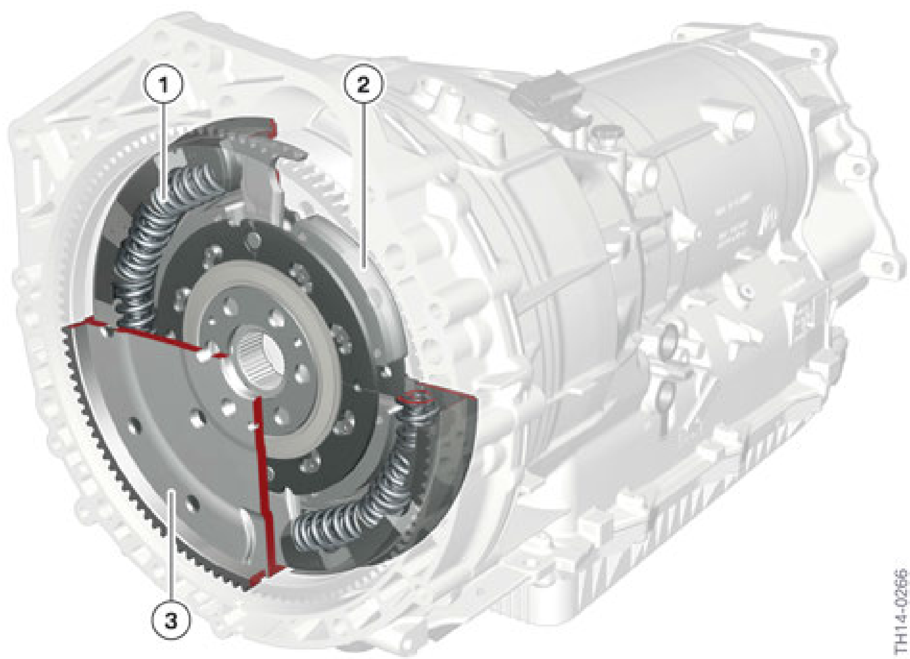
Dual-mass flywheel

In order to reduce fuel consumption and CO_2 emissions, high-charged engines are used, the number of cylinders is reduced and the drivable speeds are lowered.

However, with these measures the torsional vibrations of the crankshaft are increased as a result of the acceleration during the work cycle and deceleration during the compression cycle. This irregular rotation is the reason for torsional vibrations in the downstream drivetrain.

To isolate these torsional vibrations a dual-mass flywheel is used in the automatic transmission of the F30 PHEV. The dual-mass flywheel establishes the mechanical connection between the crankshaft of the combustion engine and the electrical machine. It consists of a torsional vibration damper and a centrifugal pendulum.

The dual-mass flywheel weighs approx. 11 kg (25 lbs) and can be replaced separately in the event of a fault.

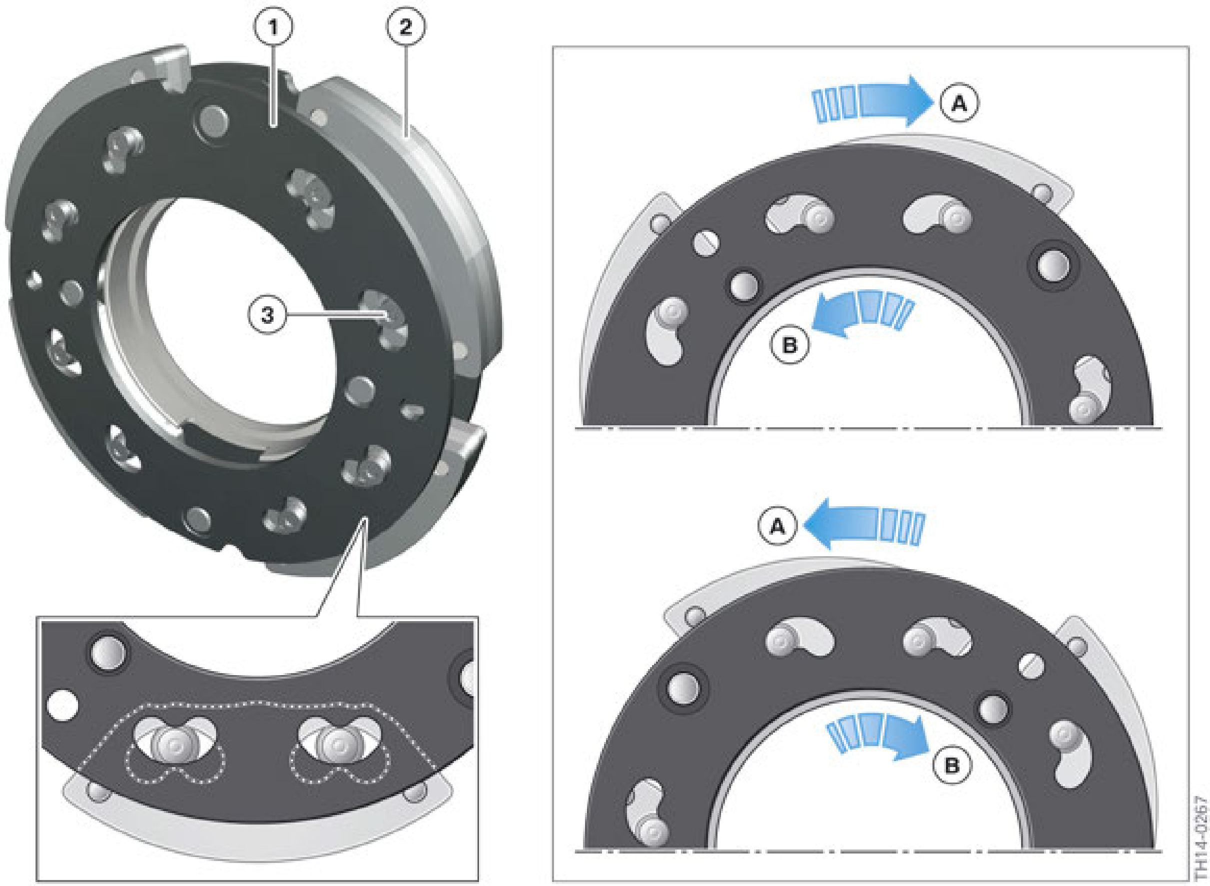


F30 PHEV, dual-mass flywheel of the GA8P75HZ transmission

Index	Explanation
1	Torsional vibration damper
2	Centrifugal pendulum
3	Dual-mass flywheel

The centrifugal pendulum is integrated in the dual-mass flywheel and can almost fully absorb the occurring torsional vibrations. It comprises a flange, on which masses can move on defined tracks. Arch-shaped curved tracks are integrated in the flange and in the masses, which serve as running tracks. The masses are connected to the flange via two rollers and can move back and forth along the curved tracks.

2. Drive Components



F30 PHEV GA8P75H, structure and operating principle of the centrifugal pendulum

Index	Explanation
1	Flange
2	Mass
3	Rollers
A	Oscillating mass
B	Torsional vibration of the engine

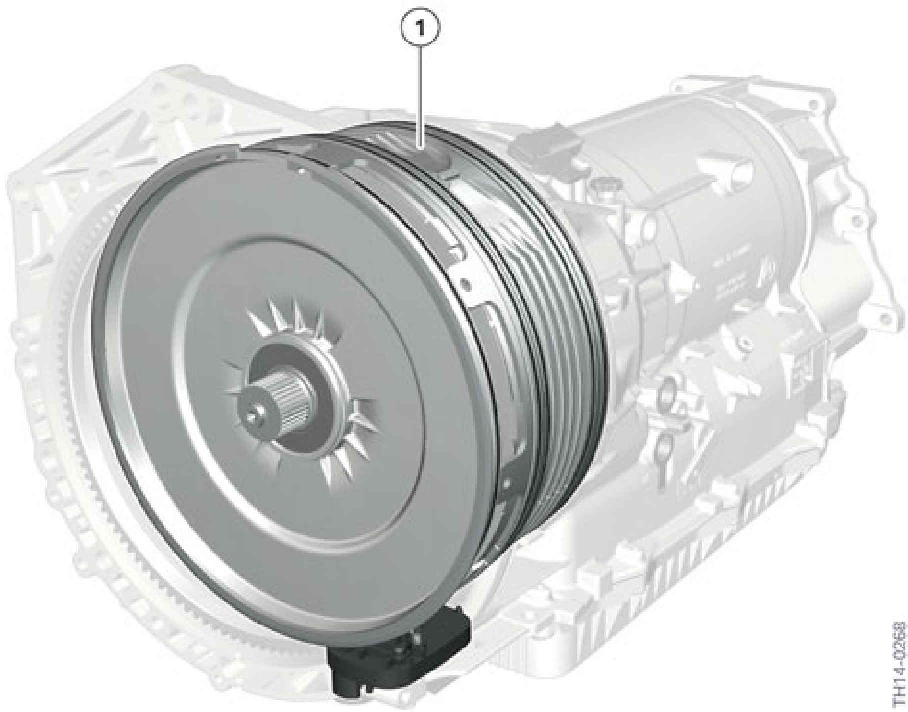
The centrifugal pendulum consists of several oscillating masses (dynamic vibration absorbers). They vibrate contrary to the torsional vibrations of the combustion engine and compensate for these. At low engine speeds, i.e. precisely when the annoying vibrations occur most, the deflection of the dynamic vibration absorbers is particularly big. This leads to improved acoustics in the passenger compartment.

F30 PHEV High-voltage Components
2. Drive Components

Electric motor

Another new feature of the GA8P75HZ transmission was the integration of the electrical machine, an additional torsional vibration damper and a separation clutch in the transmission housing of the F30 PHEV. These are located behind the dual-mass flywheel. Together with the dual-mass flywheel, the electrical machine, the torsional vibration damper and the separation clutch occupy the space of the hydraulic torque converter.

Further information on the electrical machine, the additional torsional vibration damper and the separation clutch can be found in the chapter entitled "Electrical machine".



F30 PHEV, electrical machine in the GA8P75HZ transmission

Index	Explanation
1	Electric motor

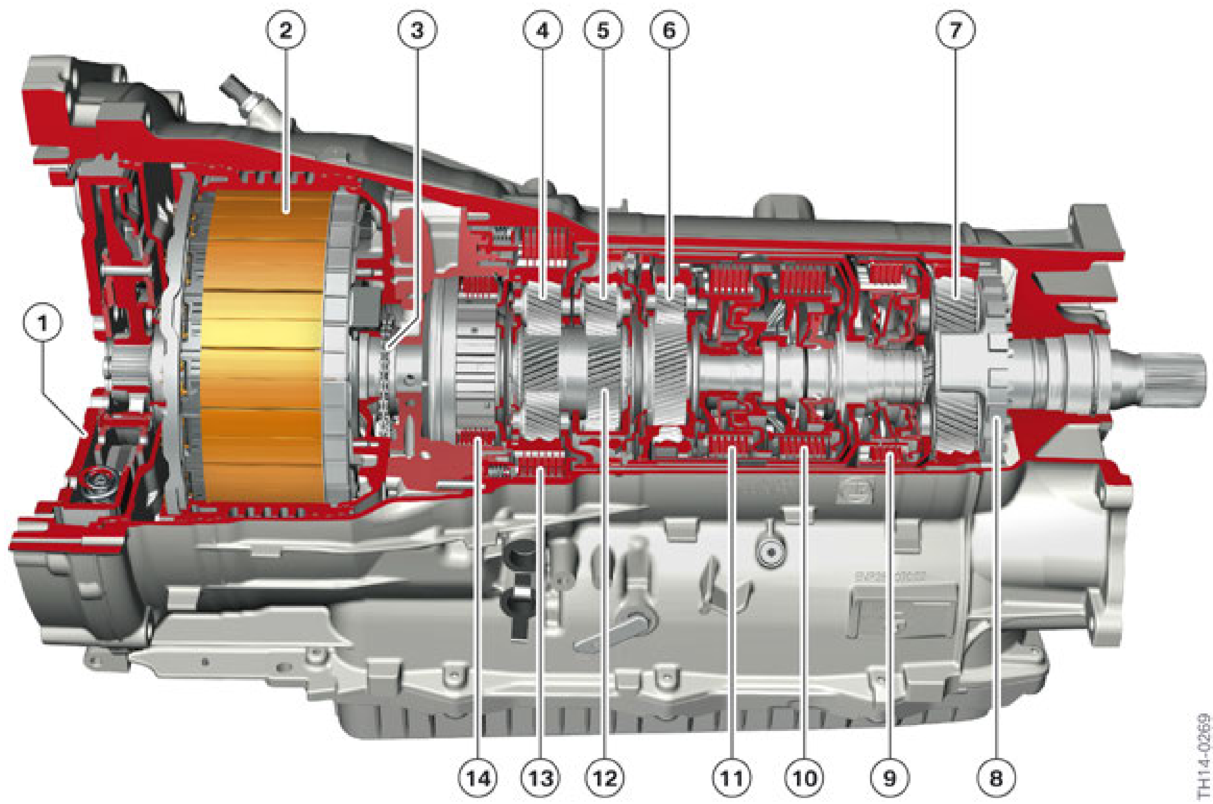
Shift elements

Brakes and clutches are described as shift elements which make possible the shifting and changing of all gears. Like in the GA8HP70Z transmission, the following shift elements are also used in the GA8P75HZ transmission:

- Two fixed multidisc brakes (brake A and B).
- Three rotary multidisc clutches (clutch C, D and E).

The multidisc clutches (C, D and E) feed the drive torque to the planetary gear. The multidisc brakes (A and B) support the torque against the transmission housing.

The clutches and brakes are closed hydraulically. For this purpose, oil pressure is applied to a piston enabling it to press the disc sets together.



F30 PHEV, overview of GA8P75HZ transmission

Index	Explanation
1	Dual-mass flywheel
2	Electric motor
3	Drive chain of the mechanical oil pump
4	Gear set 1
5	Gear set 2
6	Gear set 3
7	Gear set 4
8	Parking lock
9	Multidisc clutch D
10	Multidisc clutch C
11	Multidisc clutch E
12	Common sun gear for gear set 1 and 2
13	Multidisc brake B
14	Multidisc brake A

The shift elements of the GA8P75HZ transmission correspond in number and arrangement to those of the GA8HP70Z transmission. The eight gears are triggered in the same way.

The following table shows what shift element is closed in what gear.

gear	Brake A	Brake B	Clutch C	Clutch D	Clutch E
1	●	●	●		
2	●	●			●
3		●	●		●
4		●		●	●
5		●	●	●	
6			●	●	●
7	●		●	●	
8	●			●	●
R	●	●		●	

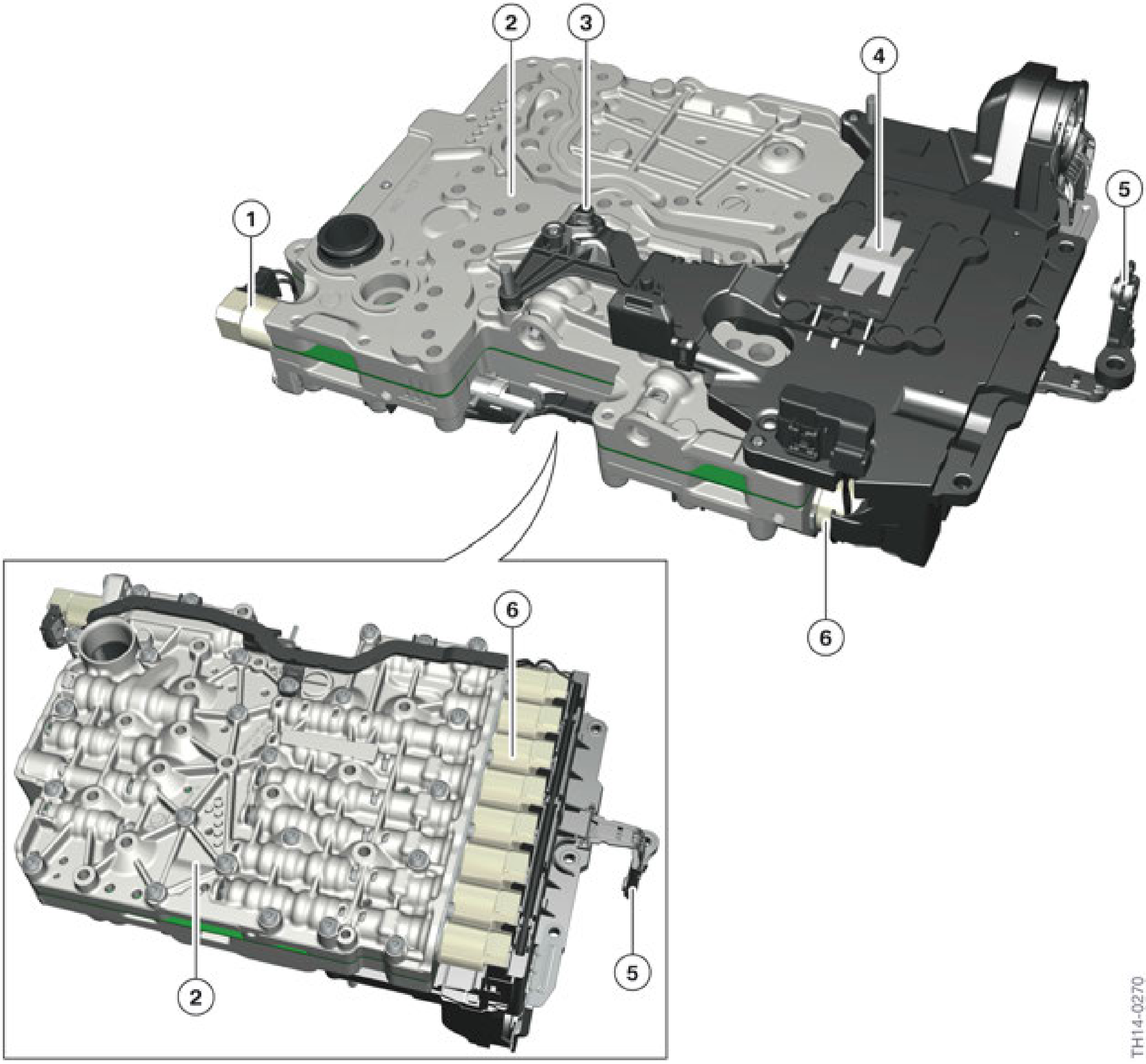
Due to the removal of the torque converter, the multidisc brake B of the automatic transmission has been modified. In the GA8P75HZ transmission of the F30 PHEV starting-up and crawling are realized via the multidisc brake B. For this the number of discs is increased and their diameter enlarged.
To guarantee sufficient cooling, transmission oil is passed through the integrated drive-off element (multidisc brake B) as required.

Mechatronics module

The mechatronics module is a combination of the hydraulic shift unit and the electronic control unit. The control unit is arranged in the lower area of the transmission and is surrounded by the oil sump. The hydraulic shift unit contains the mechanical components of the transmission control unit such as valves, dampers and actuators.

The mechatronics module was adapted for operation in the GA8P75HZ, for example the slip at the starting clutch (multidisc brake B) is now calculated via the speed signal of the sensor (3).
The transmission input speed is determined in the GA8P75HZ transmission with help of the rotor position sensor of the electrical machine.

2. Drive Components



F30 PHEV, mechatronics module of the GA8P75HZ transmission

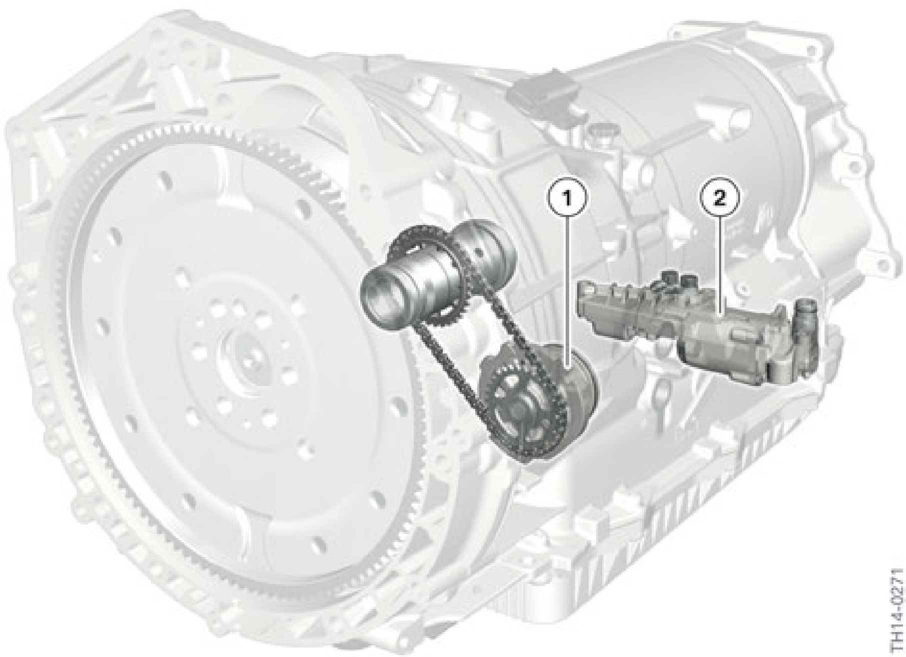
Index	Explanation
1	Parking lock magnet
2	Hydraulic shift unit
3	Speed sensor, planet spider, gear set 1
4	Electronic control unit
5	Output speed sensor
6	Electronic pressure control valves and solenoid valves

Oil supply

The basic functions of the oil circuit of the GA8P75HZ transmission correspond to those of the GA8HP70Z transmission. The oil has the following tasks:

- Lubrication
- Control of the shift elements
- Cooling

It is a conventional pressure circulating system. In addition to the mechanical oil pump known from the GA8HP70Z, an auxiliary electric oil pump has been integrated in the automatic transmission of the F30 PHEV.



F30 PHEV, oil pumps of the GA8P75HZ transmission

Index	Explanation
1	Mechanical oil pump
2	Auxiliary electric oil pump

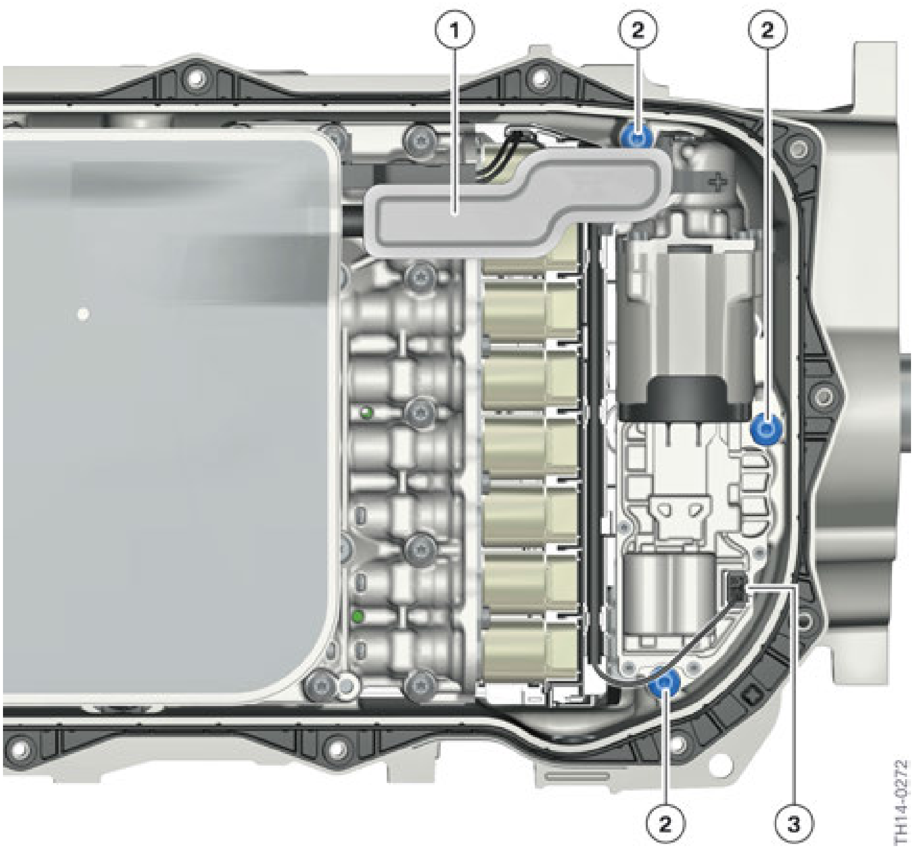
The mechanical oil pump is driven by a rolling tooth chain on the transmission input shaft. If the separation clutch is open, the drive is effected via the electrical machine; if the separation clutch is closed the drive is effected through a combination of a combustion engine and the electrical machine.

In operating phases with insufficient speed at the transmission input shaft, the auxiliary electric oil pump compensates for leakages in the hydraulic system, in order to reduce the response time of the transmission in the event of a load requirement.

2. Drive Components

The auxiliary electric oil pump is a vane-type compressor, like the mechanical oil pump. It is driven by a brushless direct current motor. The control electronics are integrated in the housing of the auxiliary electric oil pump and are activated by the electronic transmission control (EGS). The auxiliary electric oil pump can be operated from a transmission oil temperature of -5° C (23° F). In special cases, such as in the event of a failure of the electrical machine, the auxiliary electric oil pump can already be operated from a temperature of -15°C (5° F)in an emergency operation, in order to close the separation clutch. This enables the driver to continue his trip, also in the event of failure of the electrical machine.

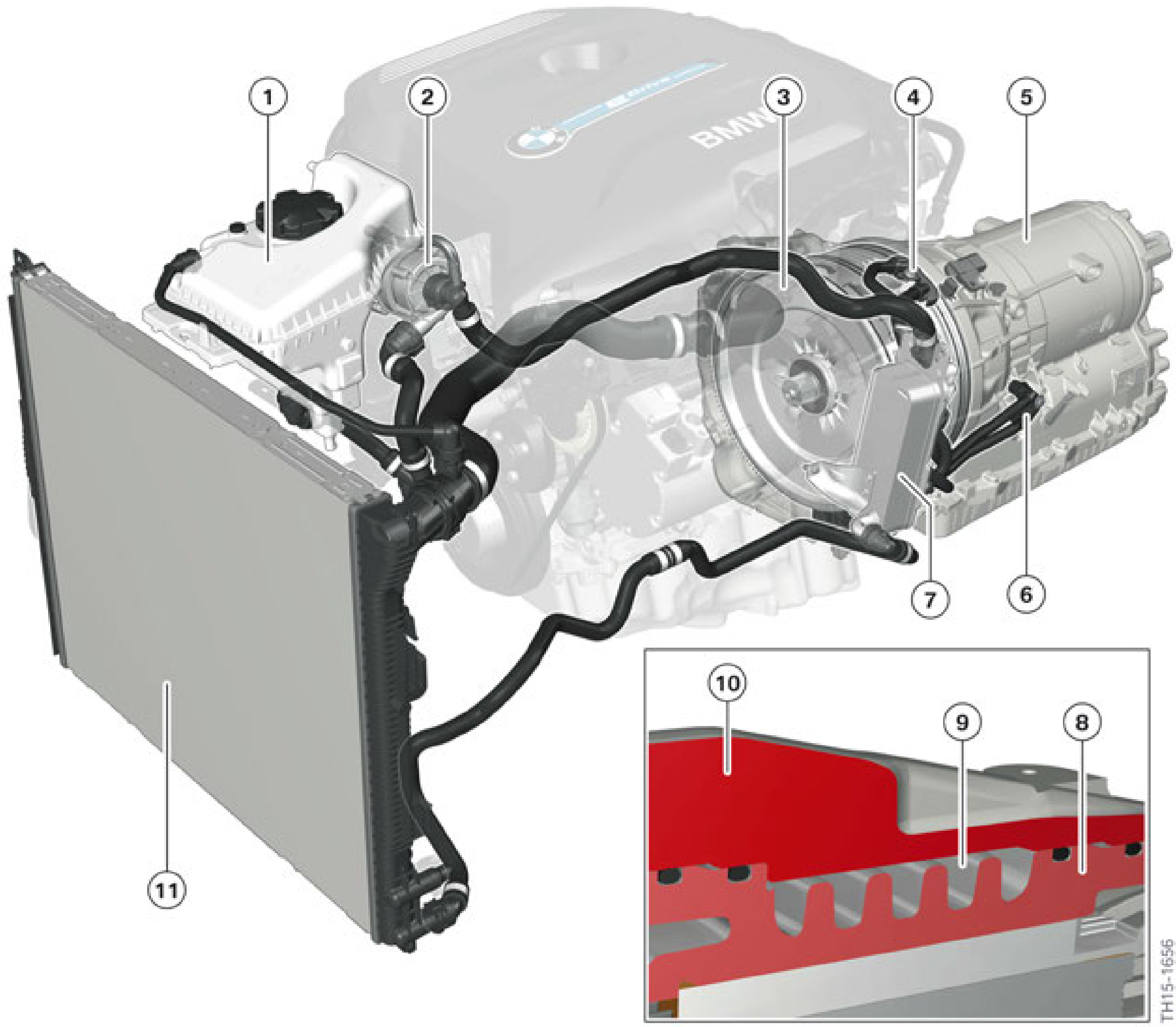
In the GA8P75HZ transmission, it occupies the space of the hydraulic impulse storage known from the GA8HP70Z. Like the hydraulic impulse storage, the auxiliary electric oil pump can also be replaced in the event of a fault.



F30 PHEV, installation location of auxiliary electric oil pump

Index	Explanation
1	Intake pipe
2	Bolting points of the auxiliary electric oil pump
3	Electrical connection

Oil cooling



F30 PHEV, oil cooling of the GA8P75HZ

Index	Explanation
1	Coolant expansion tank
2	Electric coolant pump (70 W)
3	Electric motor
4	Connection of transmission oil lines for cooling of the electrical machine
5	Transmission
6	Connection of transmission oil lines for cooling of the transmission
7	Transmission oil-coolant heat exchanger

Index	Explanation
8	Stator support
9	Coolant duct, electrical machine
10	Automatic transmission housing
11	Coolant/air heat exchanger

2.4.3. Service information

As the vehicle still has an electric drive in addition to the combustion engine, the function of the purely electric drive is available to the customer and the Service employee. During the attempt to start the engine one can engage Drive (D) or Reverse (R) gear through the usual operation of the electronic gear selector switch. After the brake pedal is released the vehicle is then moved with help of the electric drive.

Similar to the conventional 8-speed automatic gearboxes, there is also the option of an electrical emergency release for the GA8P75HZ.

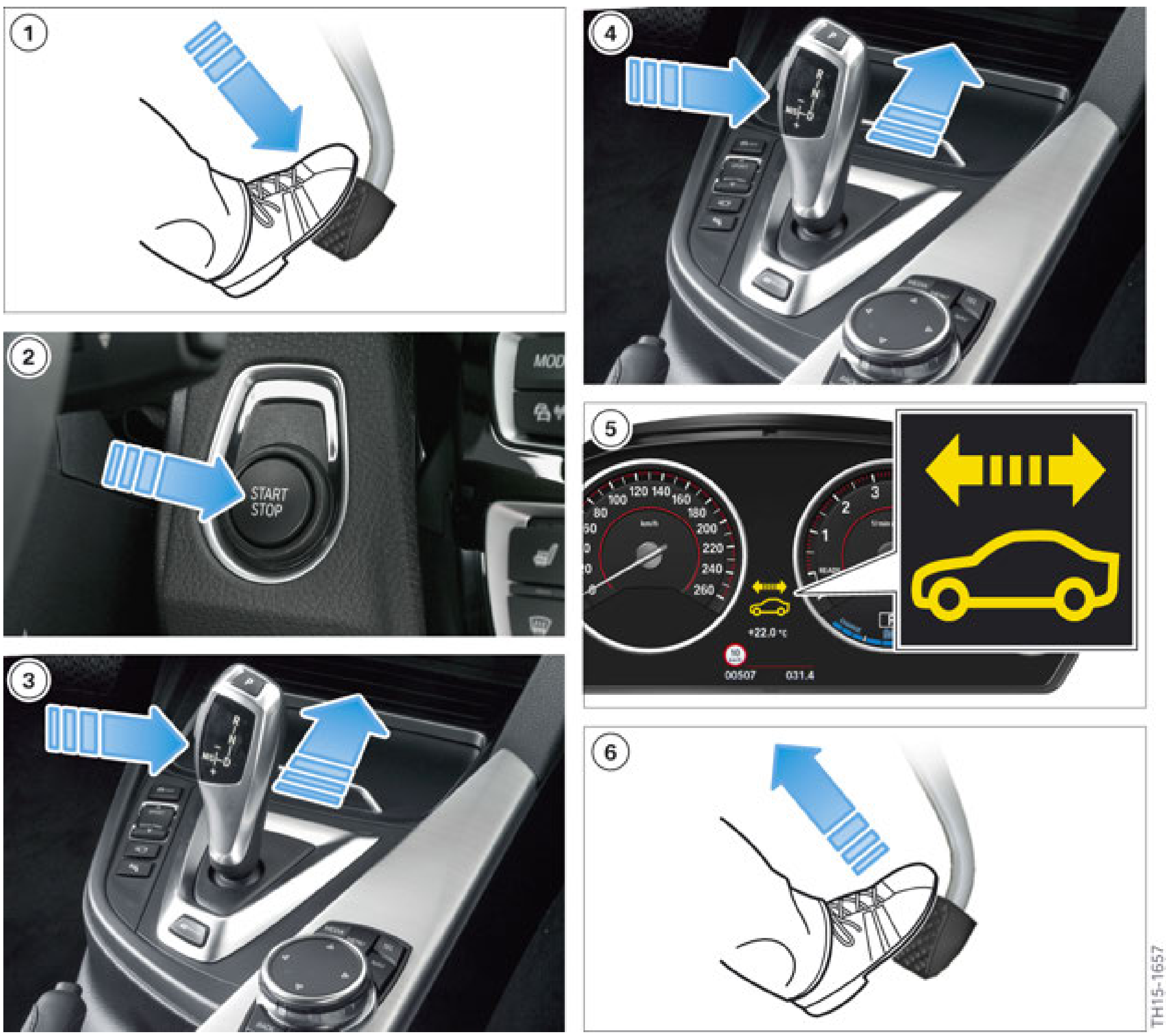
In conventional vehicles the starter motor rotates and also drives the mechanical transmission oil pump via the torque converter. With help of the built-up transmission oil pressure the parking lock can be released. In the GA8P75HZ, however, the separation clutch is open without transmission oil pressure. For this reason, the transmission oil pressure cannot be generated for releasing the parking lock in the GA8P75HZ via the rotating starter motor. Instead the transmission oil pressure can be built up via the additional electric transmission oil pump. Alternatively the electrical machine can drive the mechanical transmission oil pump and thus build up transmission oil pressure.

In general, the following applies for the electronic and mechanical emergency release of the automatic transmission:

⚠

Before performing an emergency release of the parking lock the vehicle must be secured against rolling away.

Electronic emergency release



F30 PHEV, electronic emergency release of the parking lock

Index	Explanation
1	Press brake pedal and hold down during the procedure.
2	Press start/stop button and hold down during the procedure.
3	Press release button at electronic gear selector switch.
4	Hold down release button, move the gear selector switch to N position and hold in this position until N position is illuminated.
5	As soon as the neutral gear N was engaged in the transmission, a Check Control message appears in the instrument cluster
6	The brake pedal, start/stop button, gear selector switch and release button can be released.

Conditions under which the electronic emergency release is made difficult or does not function at all:

- If the vehicle is on an incline (tensioning in the drivetrain).
- At very high or low transmission oil temperatures (modified viscosity).

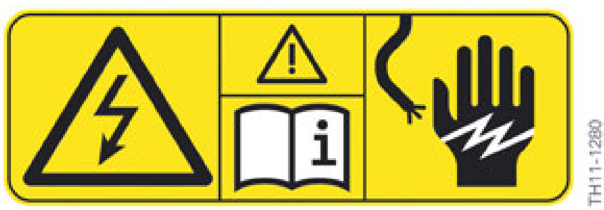
3. Electrical Machine

3.1. Introduction

The electrical machine in the F30 PHEV is a permanently excited synchronous machine. It can convert electrical energy from the high-voltage battery unit into kinetic energy, by which the vehicle is driven. Both electric driving up to approx. 120 km/h as well as support of the combustion engine are possible, for example when overtaking (boost function) or for active torque support when changing gears.

In the reverse situation, the electrical machine converts kinetic energy into electrical energy during braking and in coasting (overrun) mode and stores this in the high-voltage battery unit (energy recovery).

The electrical machine is a high-voltage component!



High-voltage component warning sticker

Each high-voltage component has on its housing or casing an identifying label that enables Service employees and vehicle users to identify intuitively the possible hazards that can result from the high electric voltages used.

Only Service employees who satisfy all the prerequisites are permitted to work on the designated high-voltage components: suitable qualifications, compliance with the safety rules, procedure following the repair instructions to the letter.

Work on live high-voltage components is expressly prohibited. Prior to every operation which involves a high-voltage component, it is essential to disconnect the high-voltage system from the voltage supply and to secure it against unauthorized return to service.

1. Switch off terminal 15.
2. Charging plug is not connected at the vehicle.
3. Wait until the vehicle is in "Sleep" mode (can be detected if writing in the START-STOP button is not illuminated).
4. Open high-voltage safety connector.
5. Secure the high-voltage safety connector against restart.
6. Switch on terminal 15.
7. Wait until the Check Control message "High-voltage system switched-off" is displayed in the instrument cluster.
8. Switch off terminal 15 and terminal R.

⚠

For reasons of high-voltage safety the electrical machine must not be opened or otherwise dismantled.

3.2. Designation and identification

3.2.1. Designation of electrical machines

The electrical machine designation is used in the technical documentation for clear identification of the electrical machine. However, the identification of the electrical machine is relevant for Service.

3.2.2. Identification of the electrical machine

The electrical machines have an identification to ensure clear identification and classification. This identification is also necessary for approval by government authorities. The identification of the electrical machines is equivalent to the identification of the combustion engines. The serial number of the electrical machine can be found under the electrical machine identification on the electrical machine. This consecutive number, in conjunction with the identification, permits unambiguous identification of each individual electrical machine.

Position	Meaning	Index	Explanation
1	Developer of electrical machine	G I J	Electrical machine in/at the transmission Electrical machine, BMW Electrical machine, external
2	Machine type (outer diameter of the stack of sheets)	A B C D E	< 200 mm > 200 mm < 250 mm > 250 mm < 300 mm > 300 mm Outer rotor with small diameter
3	Change to the basic machine concept	0 or 1 2 to 9	Basic machine Changes, e.g. variation of sheet cut (even numbers reserved for motorbikes, odd numbers for passenger cars)
4	Machine type (engine procedure)	N U O P R S T	Asynchronous machine Direct current machine Axial flow machine Permanently excited synchronous machine Switched reluctance machine Electrically excited synchronous machine Transverse flow machine
5 + 6	Torque	0 to ...	e.g. 25 = 250 Nm
7	Type test concerns (changes that require a new type test)	A B to Z	Standard Acc. to requirements, e.g. adaptations to length and coils

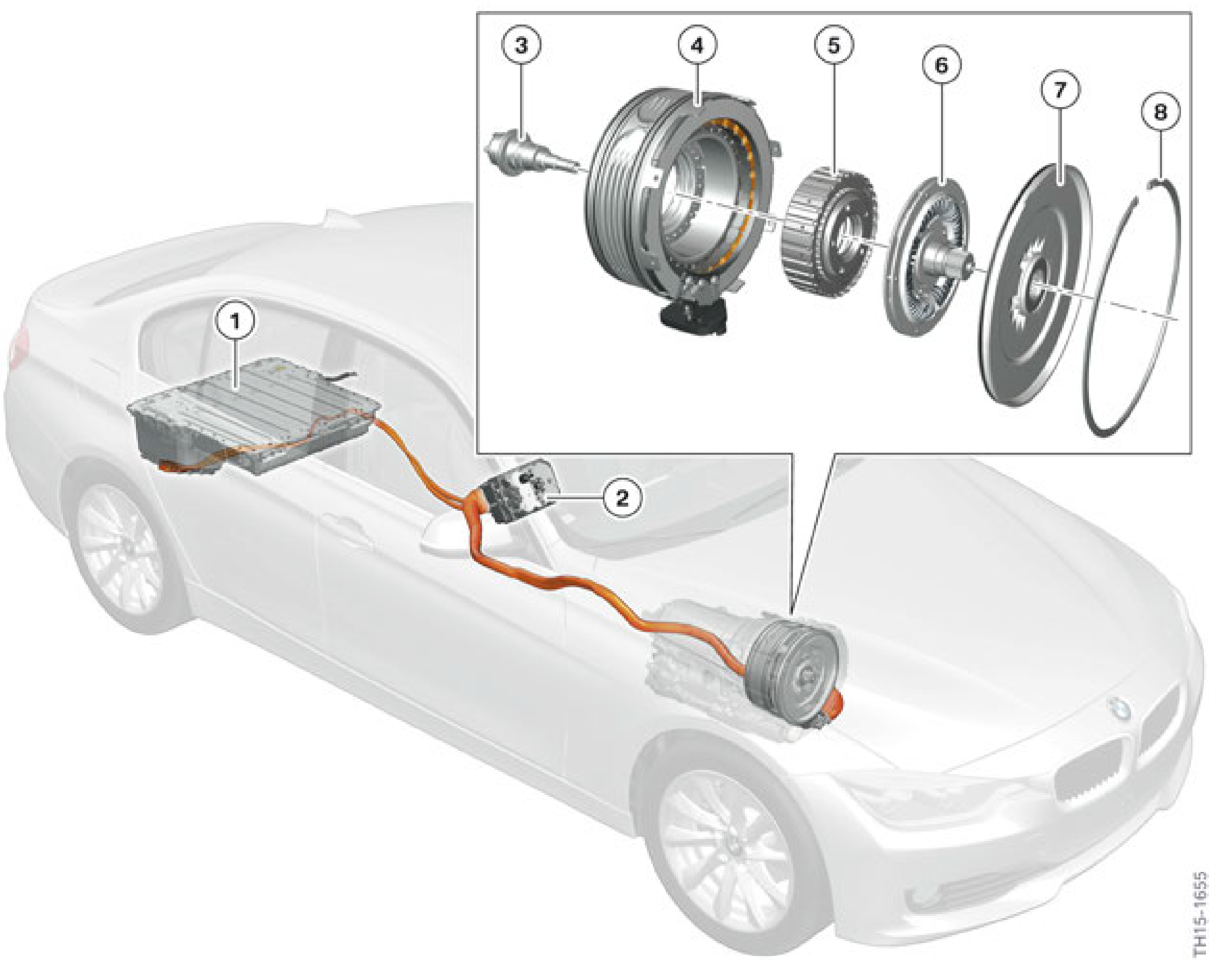
For the electrical machine, the identification looks like: GC1P25A.

3. Electrical Machine

3.3. Technical data

Supplier	ZF Friedrichshafen AG
Maximum torque	250 Nm at 0 - 2700 rpm
Maximum power in the F30 PHEV (< 10 seconds)	65 kW at 2500 rpm
Power (continuous)	45 kW from 5000 rpm
Efficiency	up to 96 %
Maximum current	450 A_{eff}
Operating speed range	0 - 7200 rpm
Weight (without torsional vibration damper)	Approx. 26 kg (57 lbs)

3.4. Installation location



F30 PHEV, installation location and secondary components of the electrical machine

Index	Explanation
1	High-voltage battery unit
2	Electric motor electronics
3	Hollow shaft
4	Electric motor
5	Separation clutch
6	Additional torsional vibration damper
7	Lid at electrical machine
8	Circlip

The hybrid components are integrated as individual components in the transmission bell housing and assume the installation space of the hydraulic torque converter in the transmission housing.

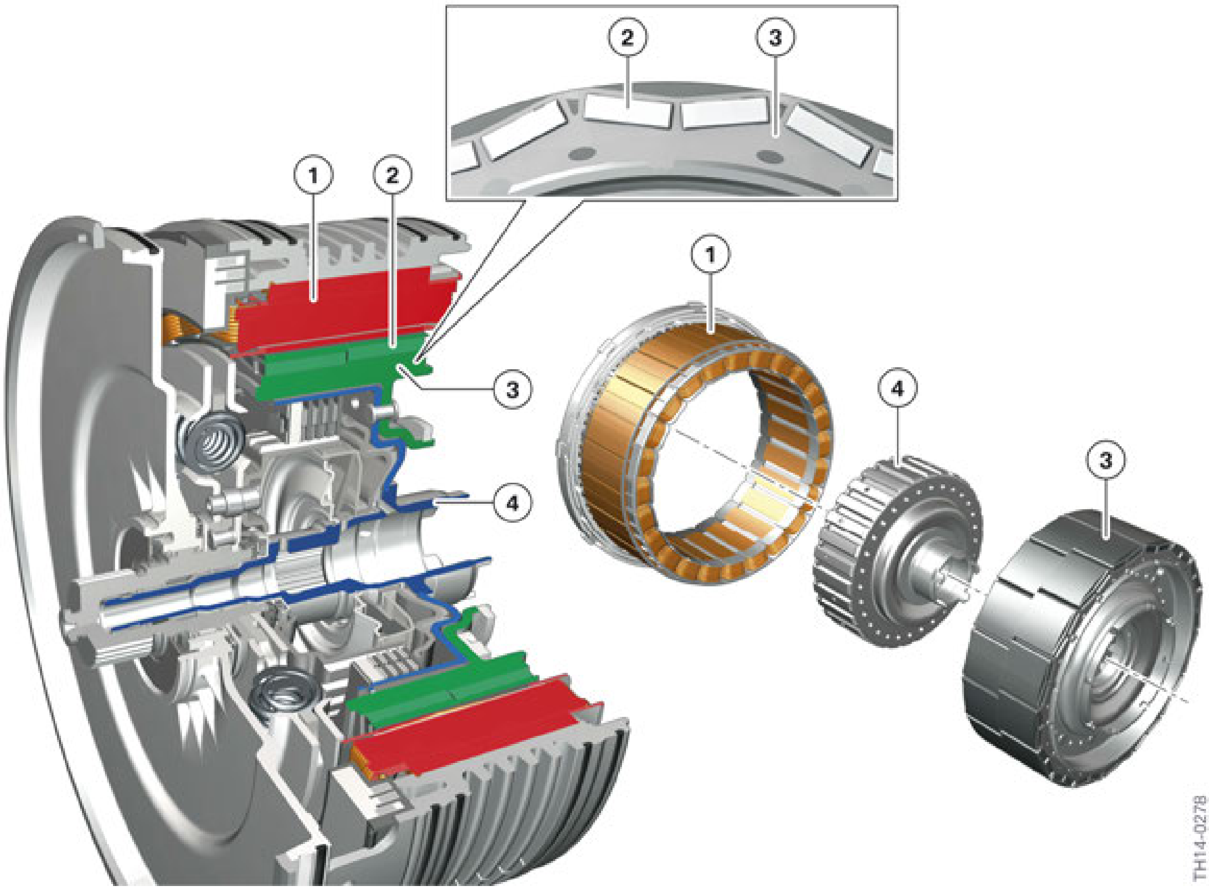
3.5. Design

The main components of the electrical machine are:

- Rotor and stator
- Connections
- Rotor position sensor
- Cooling

The hybrid system in the F30 PHEV is a so-called parallel hybrid system. Both the combustion engine and the electrical machine are mechanically coupled with the sprockets. For the vehicle drive it is possible to use both drive systems individually and at the same time.

3.5.1. Rotor and stator



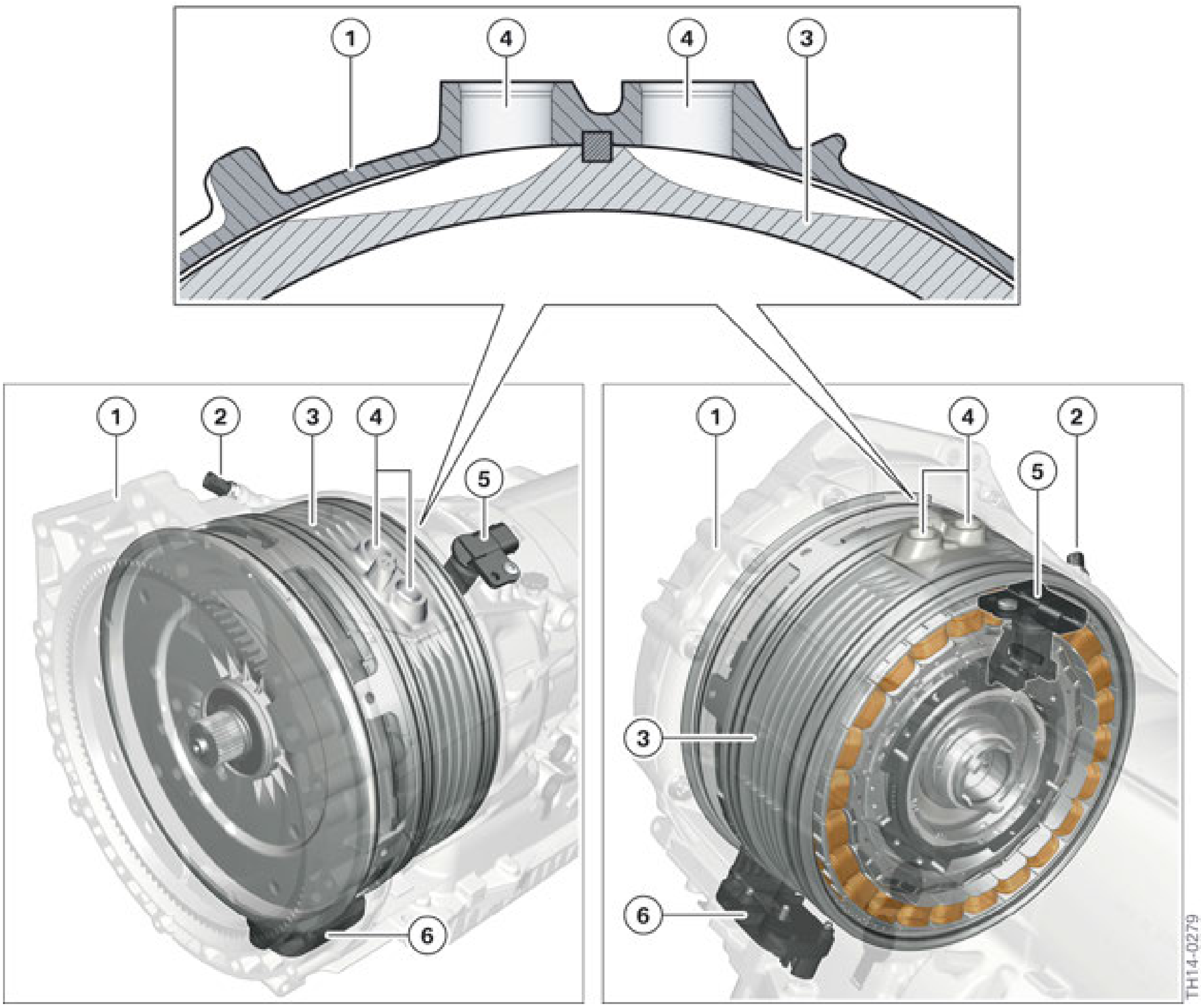
F30 PHEV, rotor and stator, electrical machine

Index	Explanation
1	Stator
2	Permanent magnets
3	Rotor
4	Hollow shaft with outer basket of separation clutch

The electrical machine (traction electrical machine) in the F30 PHEV is structured as an inner rotor. “Inner rotor” means that the rotor is arranged with the permanent magnets arranged in a ring shape on the inside. The coils for generating the rotating field are located on the outside and form the stator. The electrical machine of the F30 PHEV has pairs of poles.

The rotor is mounted above a flange on the rotor hollow shaft, which is positively connected to the transmission input shaft.

3.5.2. Connections



F30 PHEV, connections, electrical machine

Index	Explanation
1	Transmission bell housing
2	Temperature sensor
3	Coolant ducts
4	Connection for coolant (transmission oil)
5	Electrical connection, rotor position sensor
6	High-voltage connection

3. Electrical Machine

There are four connections of the electrical machine on the housing of the automatic transmission:

- Temperature sensor
- Cooling (by transmission oil)
- Rotor position sensor
- High-voltage cables

High-voltage connection

F30 PHEV, high-voltage connection, electrical machine

Index	Explanation
1	High-voltage connection
2	High-voltage connector

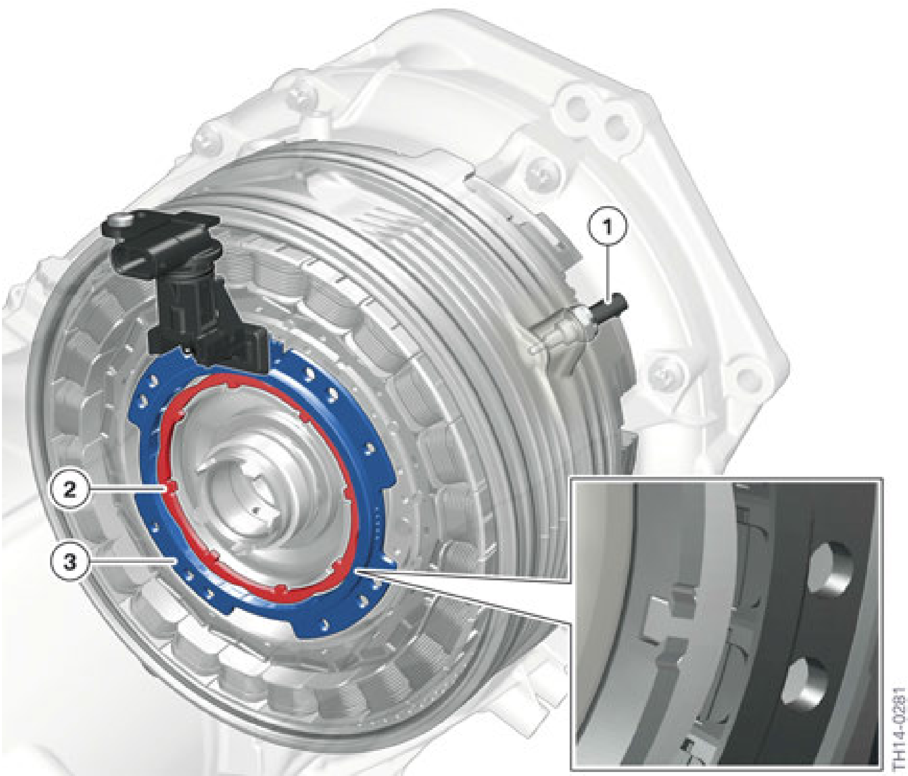
Electrical energy is fed to the coils of the electrical machine via the high-voltage connection. The high-voltage connection connects the electrical machine electronics to the electrical machine via a three-phase, shielded high-voltage cable.

The high-voltage connectors are screwed on to the electrical machine electronics and the electrical machine.

⚠

High-voltage cables must not be repaired. In the event of damage, the line must essentially be replaced!

3.5.3. Sensors



F30 PHEV, sensors, electrical machine

Index	Explanation
1	Temperature sensor
2	Rotor of the rotor position sensor
3	Stator of the rotor position sensor

So that the voltages for the coils in the stator can be correctly calculated and generated by the electrical machine electronics in terms of amplitude and phase layer, the precise position of the rotor must be known. The rotor position sensor is responsible for this task. Its structure is similar to that of a synchronous machine and has a specially shaped rotor, which is connected to the rotor of the electrical machine, as well as a stator which is connected to the stator of the electrical machine. The phase voltages induced by the rotation of the rotor in the coils of the stator are evaluated by the electrical machine electronics and thus the rotor position angle is calculated.

⚠

Upon replacement of the automatic transmission or the electrical machine electronics, the rotor position sensor must be adjusted with help of the diagnosis system.

The components of the electrical machine must not exceed a certain temperature during operation. There is a temperature model and a temperature sensor for temperature monitoring of the electrical machine. This is designed as a variable resistor with negative temperature coefficient and measures the output temperature of the coolant at the housing of the automatic transmission. The hotter the NTC, the lower its resistance.

The electrical machine electronics evaluates the signals of the temperature sensor, compares them with the calculated temperature model and reduces the power of the electrical machine if the temperature of the electrical machine approaches the maximum permissible value.

There is no longer a separate temperature sensor at one of the stator coils.

⚠

A replacement of the rotor position sensor is currently not permitted in the BMW Service workshop.

3.5.4. Separation clutch

The F30 PHEV is a "full hybrid car". In contrast to vehicles with hybrid generation 2 (F10H, F30H, F01H/F02H), electrical driving is possible in the F30 PHEV at much higher speeds.

Similar to the GA8P70HZ transmission, the combustion engine is also disconnected from the electrical machine and the rest of the drivetrain via a separation clutch. In the F30 PHEV this separation clutch is arranged between the additional torsional vibration damper and the electrical machine.

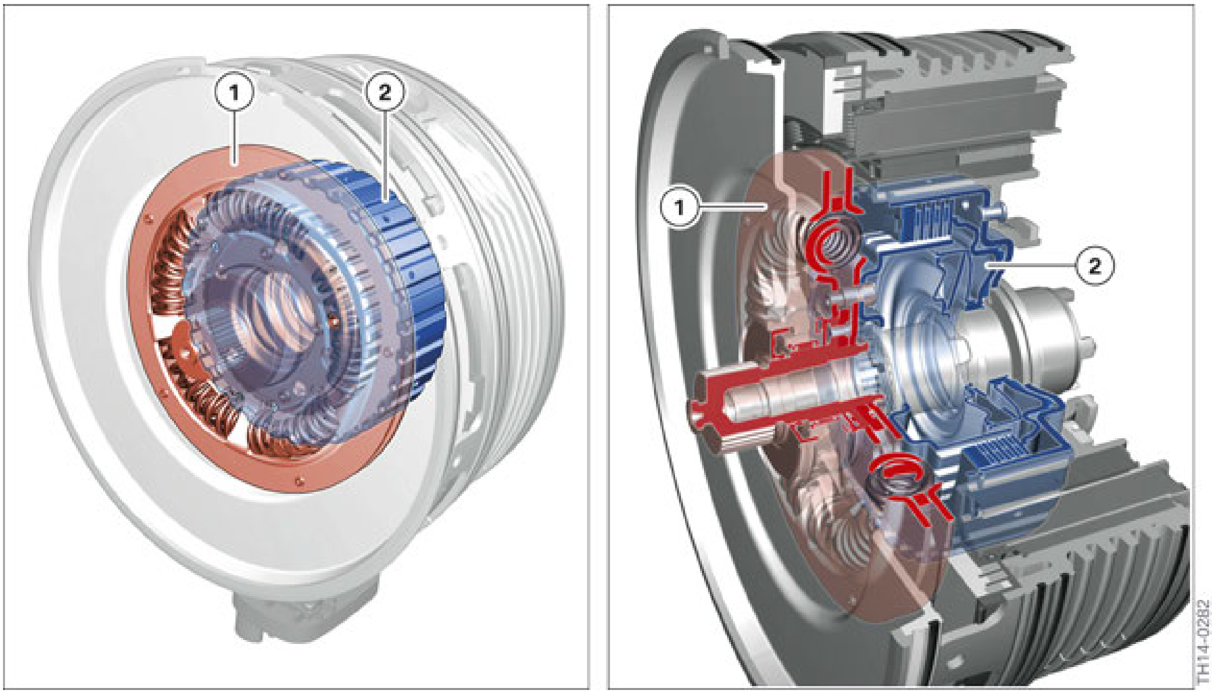
The separation clutch is integrated in the housing of the electrical machine. It is designed as a wet multidisc clutch in open version, thus optimizing the friction losses. It is used in order to disconnect the combustion engine from the electrical machine and the rest of the drivetrain in certain operating conditions. This is carried out for example in fully electric driving and when "coasting".

The separation clutch boasts extreme accuracy so as not to feel the connection and disconnection of the combustion engine. As soon as the separation clutch is closed, the electrical machine, transmission input shaft and the combustion engine rotate at the same speed.

The cooling of the separation clutch is effected via the transmission oil.

The separation clutch is, like all clutches and multidisc brakes of the automatic transmission, operated by the mechatronics module. It is opened in a depressurized state. To close the clutch, transmission oil pressure is required. This is generally provided by the mechanical oil pump. In exceptional cases, e.g. failure of the electrical machine, the separation clutch can also be closed via the auxiliary electric oil pump. However, this is effected with a loss of comfort.

As the mechanical oil pump is powered by the electrical machine when the separation clutch is open, it may not be possible to close the separation clutch in the event of a malfunction with the electrical machine and at a transmission oil temperature below -15° C (5° F) and thus no starting process may take place.



Separation clutch of the GA8P75HZ transmission

Index	Explanation
1	Additional torsional vibration damper
2	Separation clutch

Similar to torque converters in conventional transmissions, the separation clutch in the F30 PHEV is able to disconnect from the combustion engine and the rest of the drivetrain by micro-slip control of rotational irregularities. The acoustic comfort in the vehicle is thus significantly improved at very low engine speeds.

3.5.5. Additional torsional vibration damper

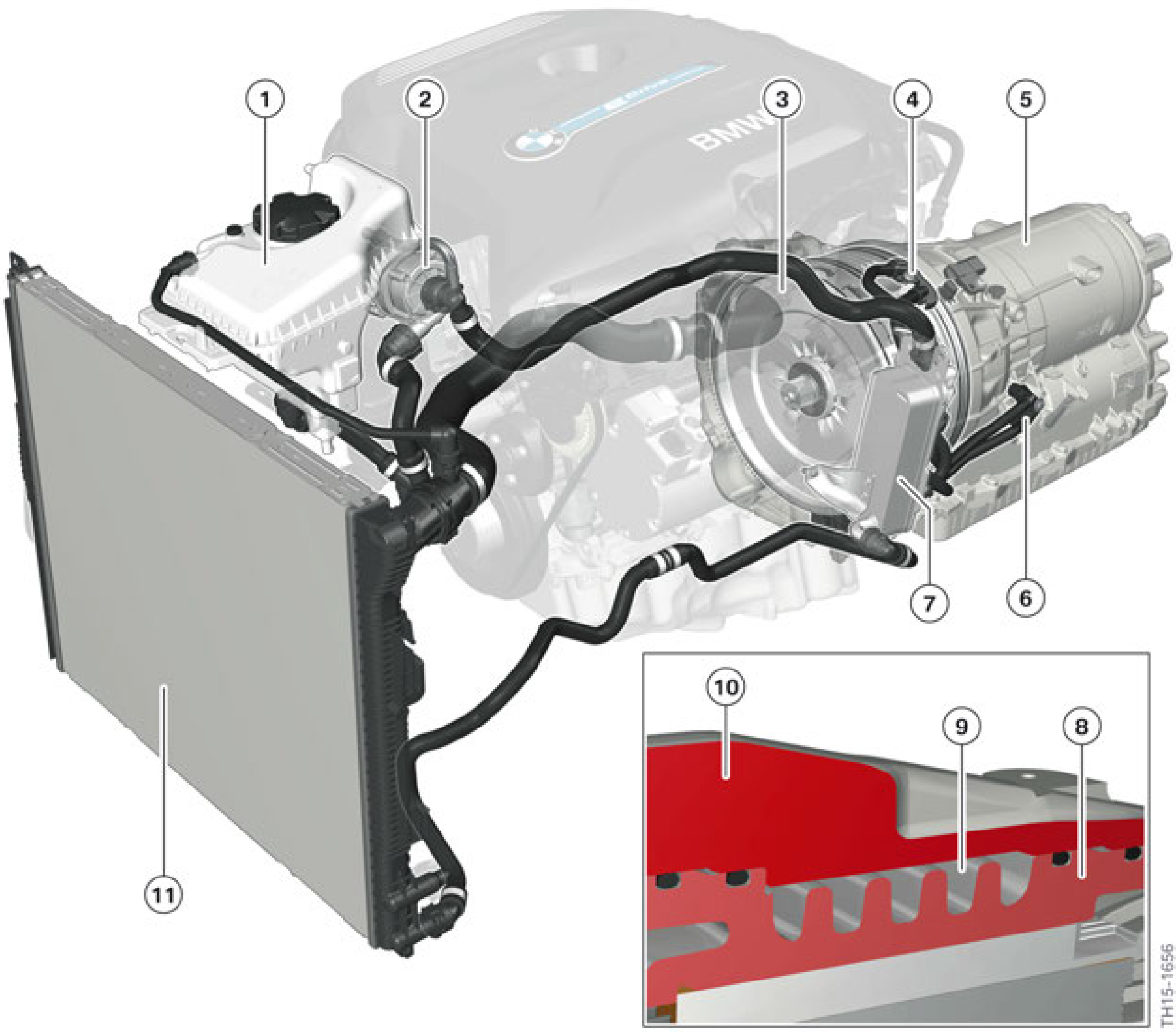
The unequal running and the resulting torsional vibrations of the 4-cylinder gasoline engine may cause strong droning or rattling noises at certain speeds and operating conditions. To isolate these torsional vibrations, a torsional vibration damper in addition to the dual-mass flywheel is used upstream of the electrical machine of the F30 PHEV. The torsional vibration damper establishes the mechanical connection between the dual-mass flywheel of the combustion engine and separation clutch.

3.6. Cooling

To guarantee the thermal operating safety of the electrical machine in every situation, it is cooled with coolant in the F30 PHEV. For this, the electrical machine is integrated in the coolant circuit of the transmission.

To cool the stator coils, the transmission oil is conducted through a coolant duct between the stator support and the housing of the automatic transmission. The coolant duct is sealed at the front and back with two sealing rings.

The rotor is also cooled by transmission oil, which absorbs heat energy in the form of oil mist and dissipates it to the ambient air at the transmission oil cooler.



F30 PHEV, cooling of the electrical machine

Index	Explanation
1	Coolant expansion tank
2	Electric coolant pump (70 W)
3	Electric motor
4	Connection of transmission oil lines for cooling of the electrical machine
5	Transmission
6	Connection of transmission oil lines for cooling of the transmission
7	Transmission oil-coolant heat exchanger

Index	Explanation
8	Stator support
9	Coolant duct, electrical machine
10	Automatic transmission housing
11	Coolant/air heat exchanger

3.7. Service information

⚠

The lid in front of the electrical machine cannot be opened in Service. All work at the electrical machine, the additional torsional vibration damper, the separation clutch, as well as at the rotor position sensor itself, is **prohibited**. In the event of a fault with one of these components, the entire automatic transmission must be replaced.

⚠

Before removing the automatic transmission, the electrical safety rules must be applied.

⚠

Upon replacement of the automatic transmission or the electrical machine electronics, the rotor position sensor must be adjusted with help of the BMW diagnosis system.

⚠

The dual-mass flywheel can be replaced separately. Always proceed in accordance with the current repair instructions.

4. Electrical Machine Electronics

4.1. Introduction

The Electrical Machine Electronics (EME) is primarily used as control electronics for the electrical machine. It is also responsible for converting the direct current voltage from the high-voltage battery unit (up to approx. 327 V DC) into a three-phase AC voltage for the actuation of the electrical machine as an engine. Conversely, when the electrical machine works as a generator, the electrical machine electronics converts the three-phase AC voltage of the electrical machine into a direct current voltage and can thus charge the high-voltage battery unit. This happens, for example, during brake energy regeneration (energy recovery). For these two operating modes a bidirectional DC/AC converter is necessary which can work as both an inverter and a rectifier.

The DC/DC converter which is also integrated in the electrical machine electronics ensures the voltage supply to the 12 V vehicle electrical system.

The entire electrical machine electronics of the F30 PHEV is located in an aluminium housing.
The control unit, the bidirectional DC/AC converter and the DC/DC converter for voltage supply of the 12 V vehicle electrical system, are located in this housing.

The EME control unit also assumes additional tasks. For example, the high-voltage power management, which manages the available high voltage from the high-voltage battery unit, is also integrated in the EME. In addition, the EME has various output stages, which are responsible for the activation of 12 V actuators.

The electrical machine electronics is a high-voltage component!

High-voltage component warning sticker

Each high-voltage component has on its housing or casing an identifying label that enables Service employees and vehicle users to identify intuitively the possible hazards that can result from the high electric voltages used.

Only Service employees who satisfy all the prerequisites are permitted to work on the designated high-voltage components: suitable qualifications, compliance with the safety rules, procedure following the repair instructions to the letter.

For reasons of high-voltage safety the electrical machine electronics must not be opened or otherwise dismantled.

In the event of a fault, the complete electrical machine electronics are always replaced.

After the electrical machine electronics have been replaced they must be put into operation with help of the BMW diagnosis system. Observe the information in the repair instructions.

4.2. Technical data

Electric motor electronics	
Supplier	Bosch
Weight	Approx. 10,8 kg / 23 lbs
Length	260 mm
Height	190 mm
Width	180 mm
Operating temperature range	-40° C to +105° C / -40° F to +221° F
Cooling	Coolant

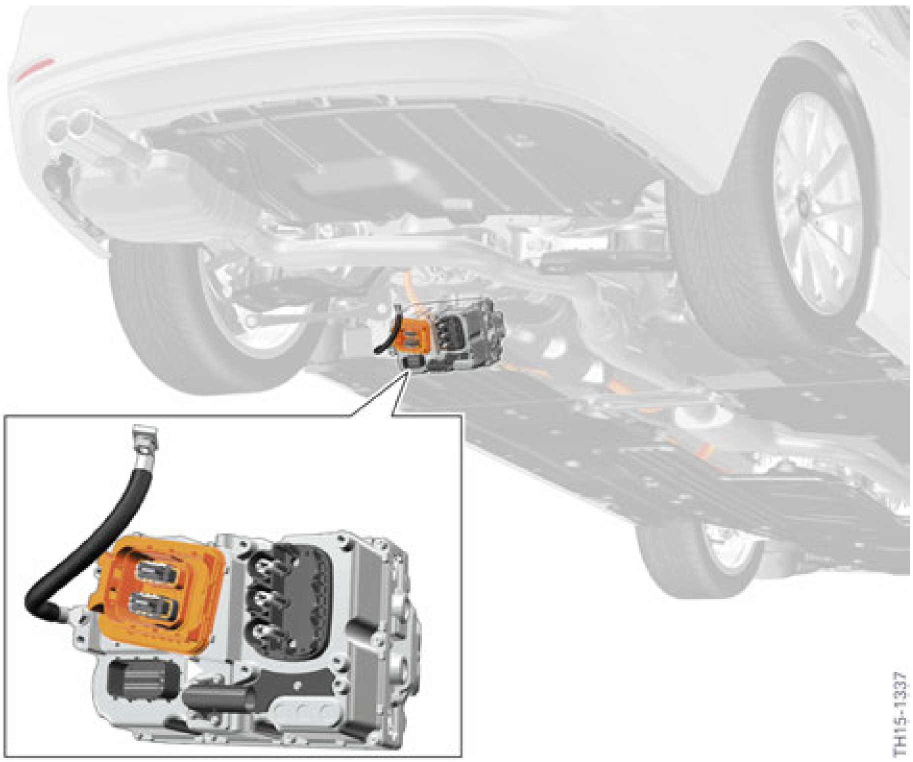
Power electronics	
Operating voltage range	180 V to 420 V DC
Output current	155 A

DC/DC converter	
Nominal output voltage	14 V DC
Output current	172 A to 200 A depending on the temperature
Output power	2.4 kW to 2.8 kW depending on the temperature

F30 PHEV High-voltage Components

4. Electrical Machine Electronics

4.3. Installation location



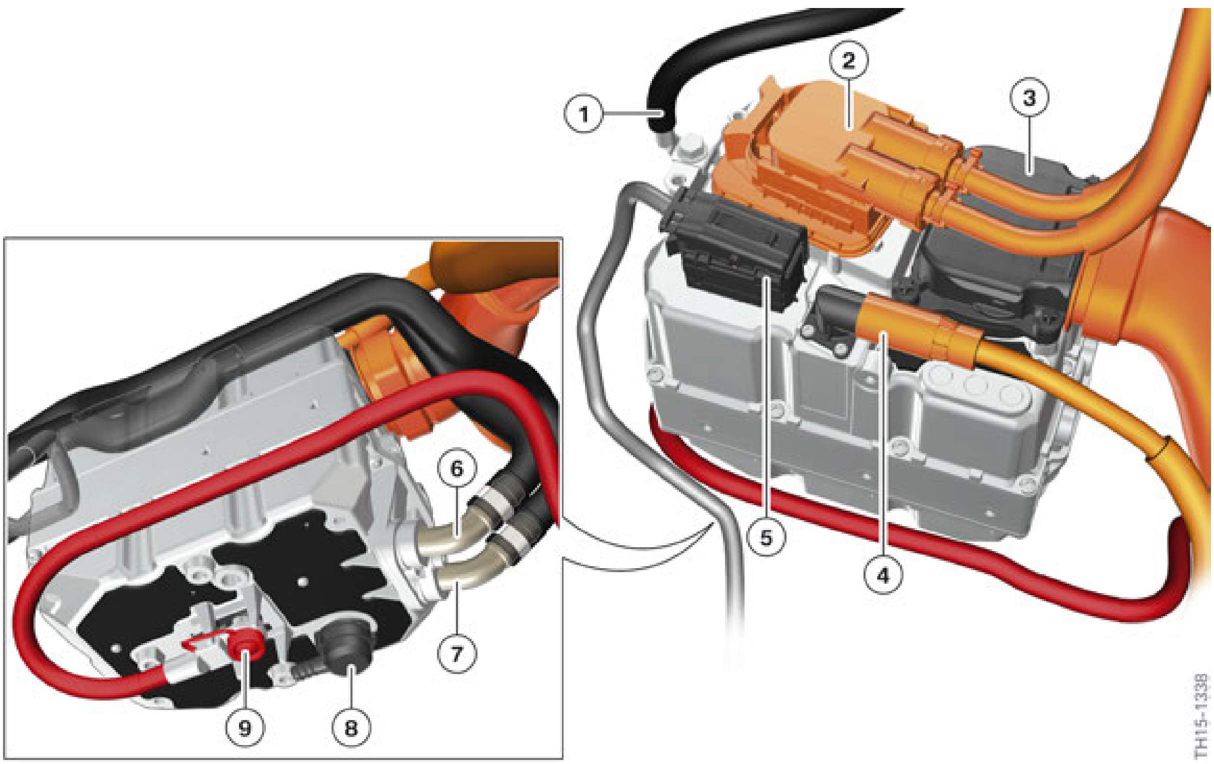
F30 PHEV, installation location of the electrical machine electronics

The electrical machine electronics are installed at the vehicle underbody to the left in front of the rear axle.

4.4. Connections

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

- Low-voltage connections
- High-voltage connections
- Connection for potential compensation line
- Connections for coolant lines



F30 PHEV, connections of the electrical machine electronics with lines

Index	Explanation
1	Connection for potential compensation line
2	High-voltage cable (DC) to the high-voltage battery unit
3	High-voltage cable (AC) to the electrical machine
4	High-voltage connection to convenience charging electronics
5	Low-voltage connector
6	Connection for coolant feed line
7	Connection for coolant return line
8	Ventilation
9	Output, DC/DC converter +12 V

4.4.1. Low-voltage connections

In the low-voltage connector at the electrical machine electronics the following lines and signals are combined:

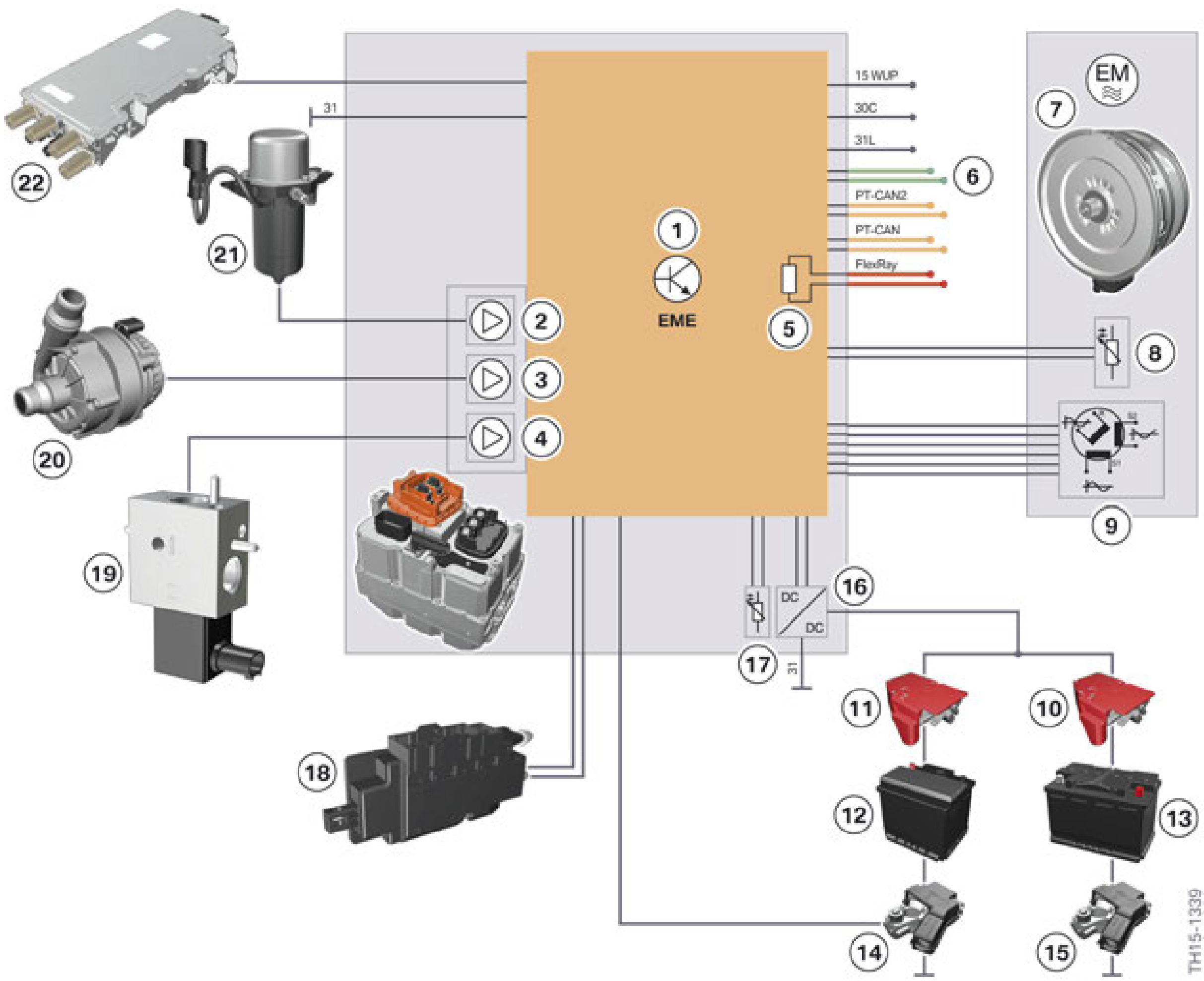
- Voltage supply for the EME control unit (terminal 30B from the power distribution box at the front and ground).
- Bus system FlexRay.
- PT-CAN bus system.
- PT-CAN2 bus system.
- Wake-up line.
- Signal lines from the ACSM for crash message.
- Actuation of the shutoff valve in the vehicle interior.
- 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 interruption to the circuit. Redundancy for SME).
- Activating the electrical vacuum pump.
- Electric coolant pump for (EME): Pulse-width modulated signal.
- Evaluation of the rotor position sensor at the electrical machine.
- Evaluation of the temperature sensor at the electrical machine.
- Intelligent battery sensor of auxiliary battery IBS2: LIN-Bus.

These lines and signals have relatively low current levels. The electrical machine electronics is connected to the 12 V vehicle electrical system (terminals 30 and 31) via two separate low-voltage connections and lines with large cross-section. Via this connection the DC/DC converter in the electrical machine electronics provides the entire 12 V vehicle electrical system with energy. The contact of these two lines with the electrical machine electronics is effected via a screw connection.

The following graphic summarizes again the low-voltage connections of the electrical machine electronics in the form of a simplified wiring diagram.

F30 PHEV High-voltage Components

4. Electrical Machine Electronics



F30 PHEV, low-voltage connections of the electrical machine electronics

Index	Explanation
1	Electric Motor Electronics (EME)
2	Output stage for the activation of the electrical vacuum pump
3	Output stage for the activation of the electric coolant pump (coolant circuit of EME)
4	Output stage for the activation of the shutoff valve
5	Terminating resistor, FlexRay
6	Signal lines of the high-voltage interlock loop
7	Electrical machine (entirety)
8	Temperature sensor (negative temperature coefficient resistor) measures coolant temperature at the output of the electrical machine
9	Rotor position sensor
10	Safety battery terminal (SBK)
11	Safety battery terminal of the auxiliary battery (SBK2)

Index	Explanation
12	Additional 12 V battery
13	12 V battery
14	Intelligent Battery Sensor 2 (IBS2)
15	Intelligent Battery Sensor (IBS)
16	Unidirectional DC/DC converter
17	Temperature sensor (negative temperature coefficient resistor) at the DC/DC converter
18	Advanced Crash Safety Module
19	Shutoff valve, vehicle interior
20	Electric coolant pump (80 W)
21	Electrical vacuum pump
22	Convenience charging electronics (KLE)

4.4.2. High-voltage connections

At the electrical machine electronics there are now only three high-voltage connections for contacting the lines to other high-voltage components. The connections for the electric A/C compressor and the electrical heating are now on the convenience charging electronics.

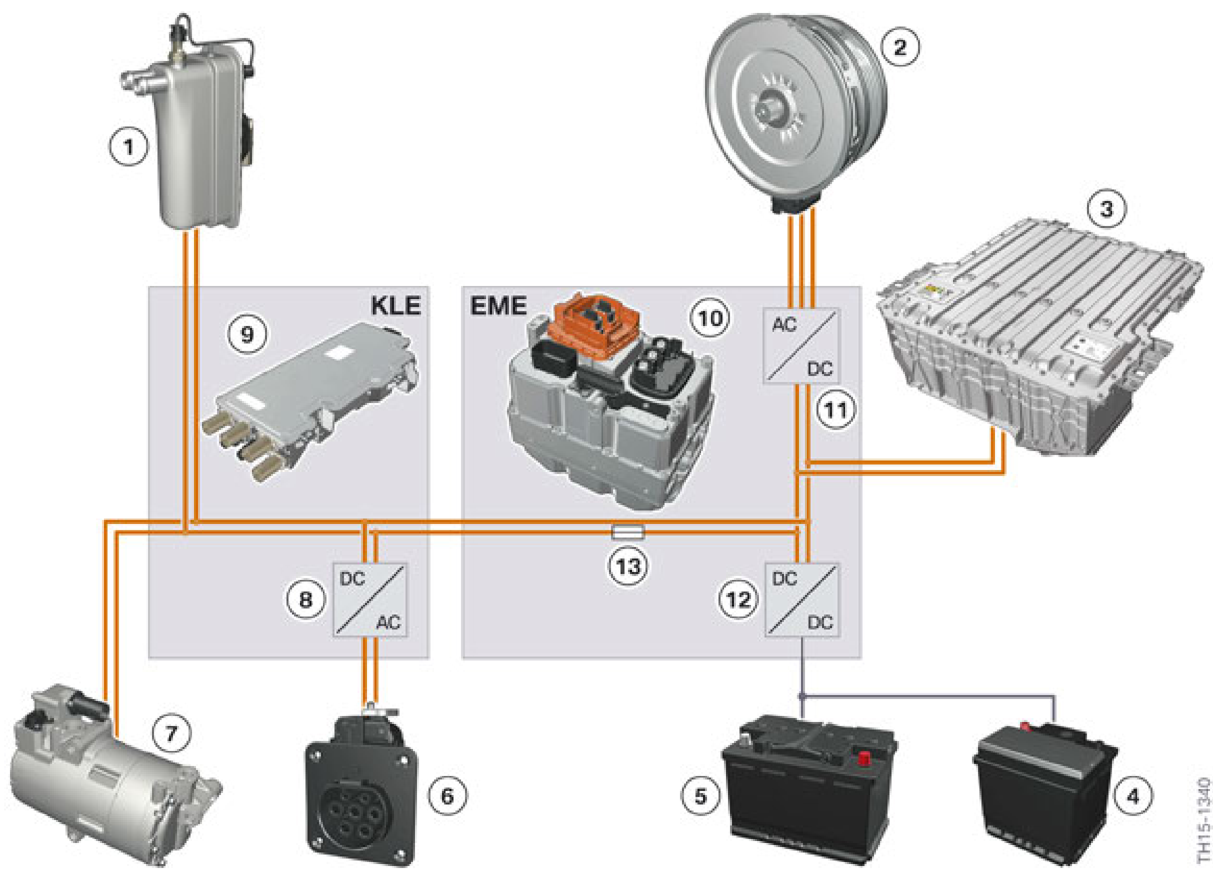
Connection to components	Number of contacts, voltage type, shielding
Electric motor	• 3-phase • AC voltage • 1 shielding for all 3 lines
High-voltage battery unit	• Two-pin • Direct current voltage • 1 shielding per line
Convenience charging electronics (AC charging)	• Two-pin • AC voltage • 1 shielding for both lines

F30 PHEV High-voltage Components

4. Electrical Machine Electronics

Connection to components	Type of connection	Contact protection
Electric motor	Screwed-on high-voltage connector	Covers over the contacts
High-voltage battery unit	Flat high-voltage connector with mechanical lock	• Cover over the contact blades • High voltage interlock loop
Charging socket (AC charging)	Round high-voltage connector	Cover over the contacts (contact protection)

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



F30 PHEV, high-voltage connections of the electrical machine electronics

Index	Explanation
1	Electrical heating
2	Electric motor
3	High-voltage battery unit
4	Auxiliary battery (12 V)

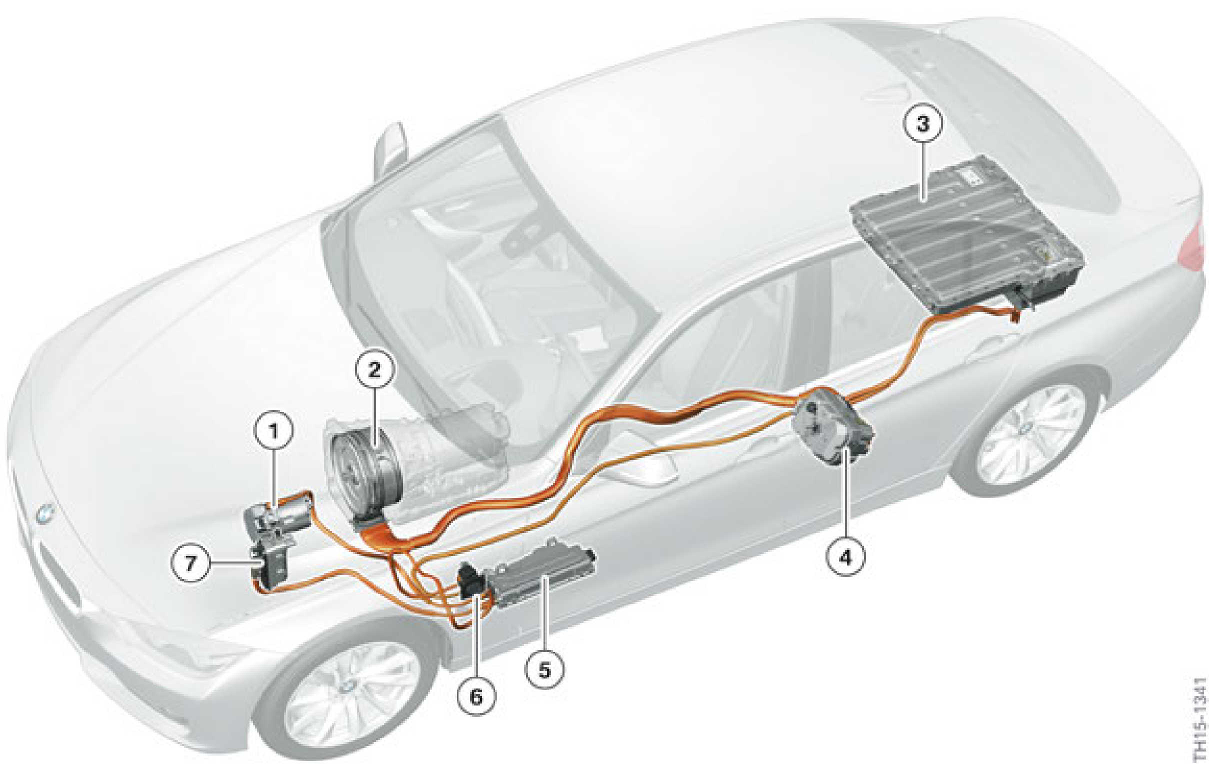
F30 PHEV High-voltage Components

4. Electrical Machine Electronics

Index	Explanation
5	Battery (12 V)
6	Charging socket
7	Electric A/C compressor (EKK)
8	Unidirectional AC/DC converter
9	Convenience charging electronics
10	Electrical machine electronics (entirety)
11	Bidirectional DC/AC converter
12	Unidirectional DC/DC converter
13	Over-current fuse (in the supply line to the electric A/C compressor (EKK) and the electrical heating (80 A))

4.4.3. High-voltage cables

The high-voltage cables connect the high-voltage components and are labelled by orange cable sleeves. The manufacturers of hybrid cars have agreed on a uniform identification of the high-voltage cable with the warning color orange. An overview of the high-voltage cables used in the F30 PHEV is provided here.

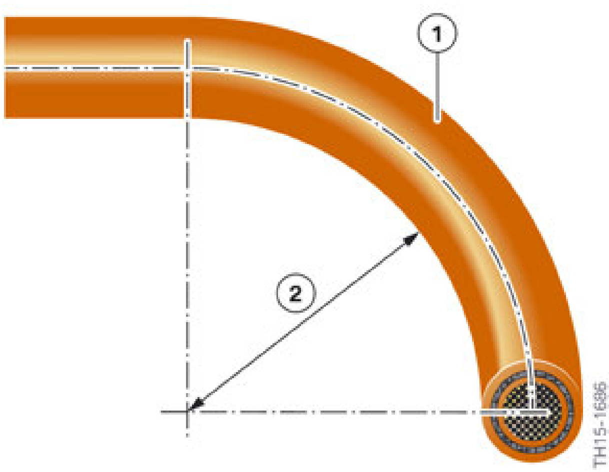


F30 PHEV, high-voltage components and high-voltage cables

Index	Explanation
1	Electric A/C compressor (EKK)
2	Electric motor
3	High-voltage battery unit
4	Electric Motor Electronics (EME)
5	Convenience charging electronics (KLE)
6	Charging socket
7	Electrical heating (EH)

⚠

High-voltage cables must not be repaired. In the event of damage, the high-voltage cable must be fully replaced!



Bending radius of a high-voltage cable

Index	Explanation
1	High-voltage cable
2	Bending radius must be greater than 70 mm

⚠

The high-voltage cables must not be excessively bent or kinked! The bending radius must not be less than 70 mm! Excessive kinking/bending of the high-voltage cable may result in damage to the cable shielding and thus to an isolation fault in the high-voltage vehicle electrical system.

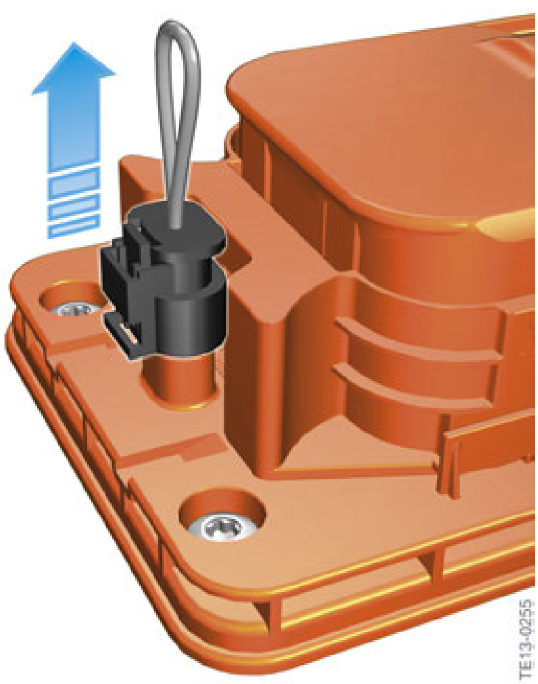
4. Electrical Machine Electronics

⚠

Work on live high-voltage components is expressly prohibited. Prior to every operation which involves a high-voltage component, it is essential to disconnect the high-voltage system from the voltage supply and to secure it against unauthorized return to service.

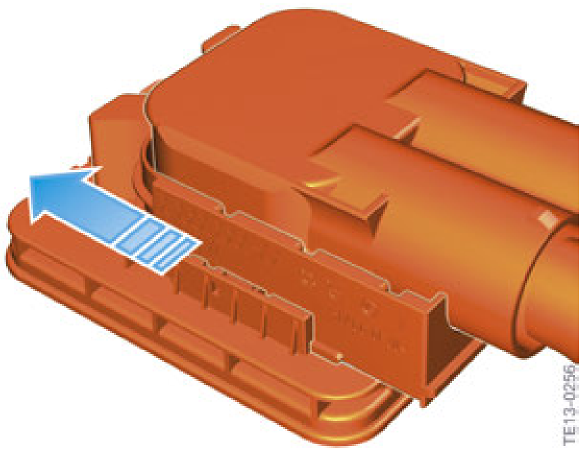
1 Switch off terminal 15.
2 Charging plug is not connected at the vehicle.
3 Wait until the vehicle is in "Sleep" mode (can be detected if writing in the START-STOP button is not illuminated).
4 Open high-voltage safety connector.
5 Secure the high-voltage safety connector against restart.
6 Switch on terminal 15.
7 Wait until the Check Control message "High-voltage system switched-off" is displayed in the instrument cluster.
8 Switch off terminal 15 and terminal R.

Removing the flat high-voltage connector

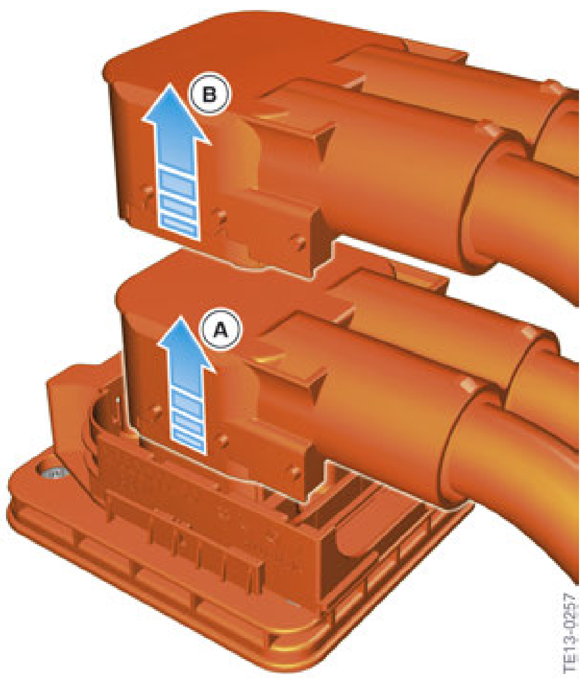


Bridge for high-voltage interlock loop
Before the high-voltage connector can be disconnected, the bridge for the high-voltage interlock loop must first be removed. The bridge closes the circuit of the high-voltage interlock loop in a connected state. The SME and EME control units continuously monitor the circuit of the high-voltage interlock loop. The high-voltage system is only active when the circuit is closed.
If the circuit of the high-voltage interlock loop is interrupted by removing the bridge, the high-voltage system shuts down automatically.
This is an additional safety precaution as the Service employee has already switched off the high-voltage system before beginning work.
If the bridge of the high-voltage interlock loop is pulled when the high-voltage system is active, this causes a "hard" opening of the safety contactors. The results may be increased wear or even damage to the contacts.

4. Electrical Machine Electronics



Removing the mechanical locking
Only after the bridge of the high-voltage interlock loop has been removed, can the mechanical locking be moved in the direction of the arrow. The mechanical locking is an element of the high-voltage connector on the high-voltage components (e.g. electrical machine electronics).
By moving the lock in the direction of the arrow the mechanical guide of the high-voltage connector on the high-voltage cable is released which permits the subsequent disconnection.



Removing the connector of the high-voltage cable
The connector of the high-voltage cable can now be pulled off in the direction of the arrow. After pulling off the connector a few millimeters (A) a higher counterforce can be felt.
The connector must then be pulled off further in the same direction (B). Under no circumstances must the connector be pressed back into the bush on the high-voltage component after reaching position (A). This may damage the protective cover at the bush of the high-voltage components.

⚠

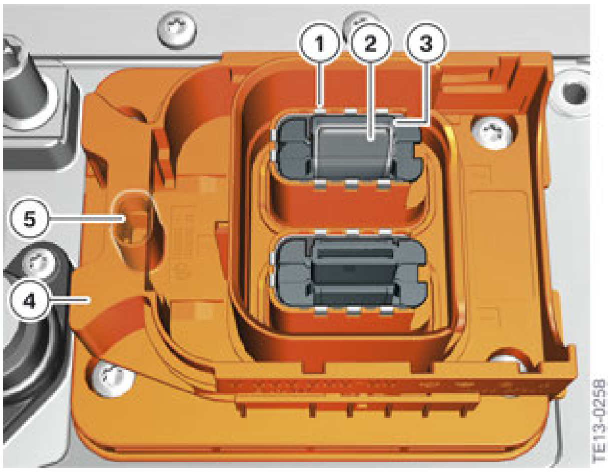
The high-voltage connector of the high-voltage cables must be pulled out at a right angle in two steps and in the same direction. Changing the direction of movement when pulling off is not permitted.

⚠

The bridge of the high-voltage interlock loop must not be pulled out when the high-voltage system is active.

Proceed in the reverse order when reattaching the high-voltage cable.

4. Electrical Machine Electronics



F30 PHEV, example of flat high-voltage connector at a high-voltage component

Index	Explanation
1	Electrical contact for shielding
2	Electrical contact for high-voltage cable
3	Contact protection
4	Mechanical locking
5	Bush with connection for bridge in the circuit of the high-voltage interlock loop

A contact is available for shielding around each of the two electrical contacts of the high-voltage cables. In addition, the high-voltage connection provides protection against contact with live parts. The actual contacts are coated in plastic so that nobody can touch them directly. Only when the high-voltage cable is connected is the coating pushed away and the contact established.

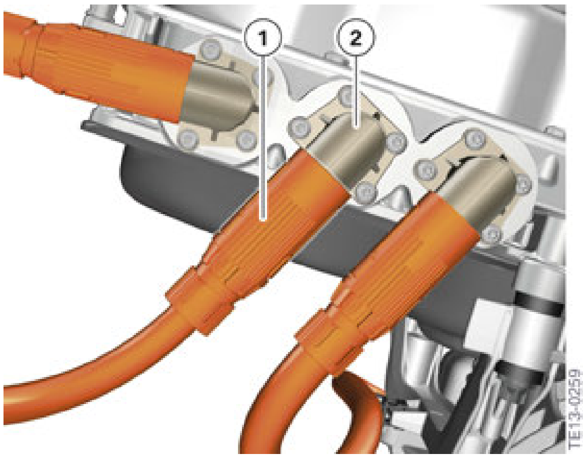
Removing the round high-voltage connector

The following graphics show the procedure for removing the round high-voltage connector using the example of the high-voltage connection at the electrical machine electronics, at which the high-voltage cable is connected for the electrical heating.

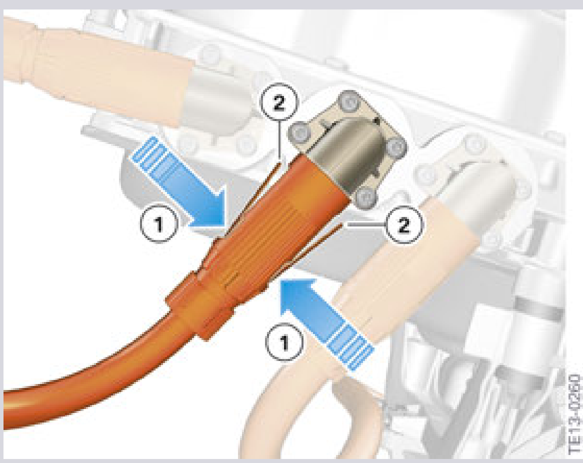
The graphics show the connections at the electrical machine electronics of the I01 and must be observed.

F30 PHEV High-voltage Components

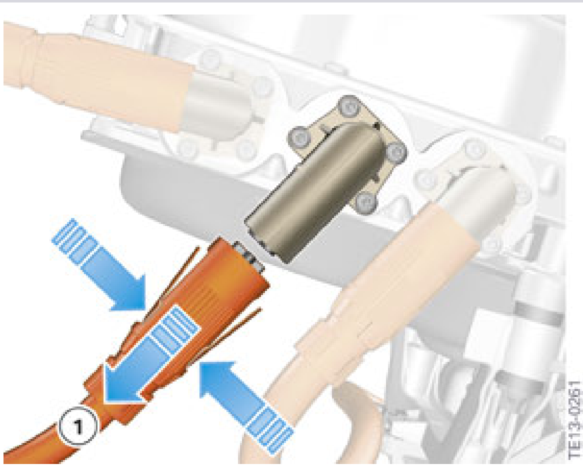
4. Electrical Machine Electronics



The round high-voltage connector (1) is connected at the high-voltage connection (2) of the corresponding high-voltage component and is locked.



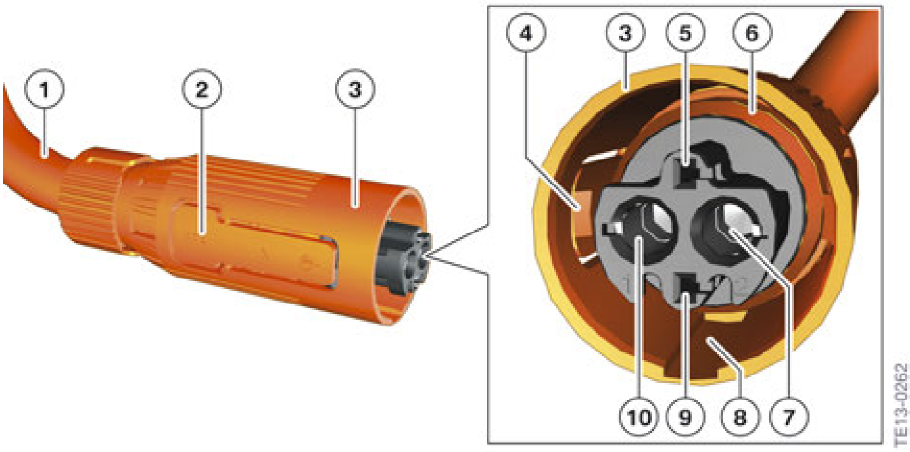
The two locking elements (2) must be pressed together in the direction of arrow (1).
The mechanical lock of the connector at the connection of the high-voltage component is thus removed.



While the locking elements are further pushed together, the connector must be removed lengthways in the direction of arrow (1).

When reconnecting the high-voltage cable the locking elements must not be pushed together. It is sufficient to slide the connector lengthways onto the high-voltage connection of the component. Ensure that the locking elements engage ("clicking" noise). In addition, the engaging of the locking elements should be checked by subsequent pulling on the connector.

4. Electrical Machine Electronics



F30 PHEV, example of structure of the round high-voltage connector

Index	Explanation
1	High-voltage cable
2	Actuation points on locking elements
3	Connector housing
4	Locking element
5	Connection 1 for bridge in the connector
6	Connection for shielding
7	High-voltage connection, pin 2
8	Mechanical encoding
9	Connection 2 for bridge in the connector
10	High-voltage connection, pin 1

The bridge in the high-voltage connector serves for electrical safety. The signal of the high-voltage interlock loop runs over this bridge when the high-voltage cable is connected to the high-voltage component. For the connection of the high-voltage cable to the EKK and to the electrical heating the voltage supply of the EKK or transmission control unit runs via the bridge. If one of the circuits is interrupted, this also results in an automatic interruption to the current flow (returns to zero) in the respective high-voltage cable. As the two contacts of the bridge opposite the high-voltage contacts advance, this measure constitutes protection against the formation of an electric arc when removing the high-voltage connector.

4.4.4. Connection for potential compensation lines

The insulation monitoring determines whether the isolation resistance between active high-voltage components (e.g. high-voltage cables) and ground is above or below a required minimum value.
If the isolation resistance falls below the minimum value, the danger exists that the vehicle parts will be energized with hazardous voltage. If a person were to touch a second active high-voltage component, he or she would be at risk of electric shock.

There is therefore fully automatic insulation monitoring for the high-voltage system of the F30 PHEV. It is performed by the battery management electronics at regular intervals while the high-voltage system is active. Earth serves as the reference potential. Without additional measures only local insulation faults in the high-voltage battery unit could be determined in this way. However, it is equally important to identify isolation faults from the high-voltage cables in the vehicle to ground.
For this reason all the electrically conductive housings of high-voltage components are conductively connected to ground. In this way isolation faults in the entire high-voltage electrical system can be identified from a central point by the insulation monitoring.

⚠

The high-voltage system must not be operated if the potential compensation cables are not properly connected to the high-voltage components.

⚠

If in the event of a repair the high-voltage components or the body components are replaced, the following must be observed during assembly: The connection between the housing and the body must be properly re-established. The repair instructions must be strictly observed (tightening torque, self-cutting screws).

4.4.5. Connections for coolant lines

The electrical machine electronics is cooled by a separate coolant circuit. The coolant connections can be seen in the graphic at the beginning of this subchapter.

4.4.6. Ventilation holes

The bottom of the housing has three ventilation holes to prevent water (resulting from temperature changes and thus possible condensation of air moisture) collecting inside the electrical machine electronics. In addition, these ventilation holes enable pressure compensation between the inside of the housing and the surrounding area. To fulfil these two tasks the ventilation holes have a permeable diaphragm for gases and an impermeable diaphragm for fluids.

F30 PHEV, ventilation of the electrical machine electronics

Index	Explanation
1	Ventilation

4.5. Tasks

The electrical machine electronics is made up internally of four subcomponents:

- Bidirectional DC/AC converter
- Unidirectional DC/DC converter
- EME control unit

The link capacitor is also an element of the power electronics gearshifts. It smooths voltages and filters high-frequency parts.

The electrical machine electronics performs the following functions using the subcomponents mentioned:

- Torque restriction of the drivetrain in the event of faults and unstable driving conditions.
- Control of the internal subcomponents by the EME control unit.
- Supply of the 12 V electrical system via the DC/DC converter.
- Control of the electrical machine (speed, torque) using DC/AC converter.
- High-voltage power management.
- Contacting the electric motor.
- Contacting the high-voltage battery unit.
- Charging the high-voltage battery unit when driving (by energy recovery).
- Communication with other control units, in particular DME, SME and DSC.
- Cooling for electrical machine electronics.
- Activation of the electric coolant pump for cooling the EME.
- Activating the electrical vacuum pump.
- Activating the shutoff valve for the vehicle interior.
- Evaluation of the second intelligent battery sensor.
- Active evaluation of the signal for the high-voltage interlock loop.
- Active and passive discharging of the link capacitor to voltages less then 60 V.
- Self-test and diagnosis.

4.6. DC/DC converter

The DC/DC converter in the electrical machine electronics of the F30 PHEV is able to adopt the following operating modes:

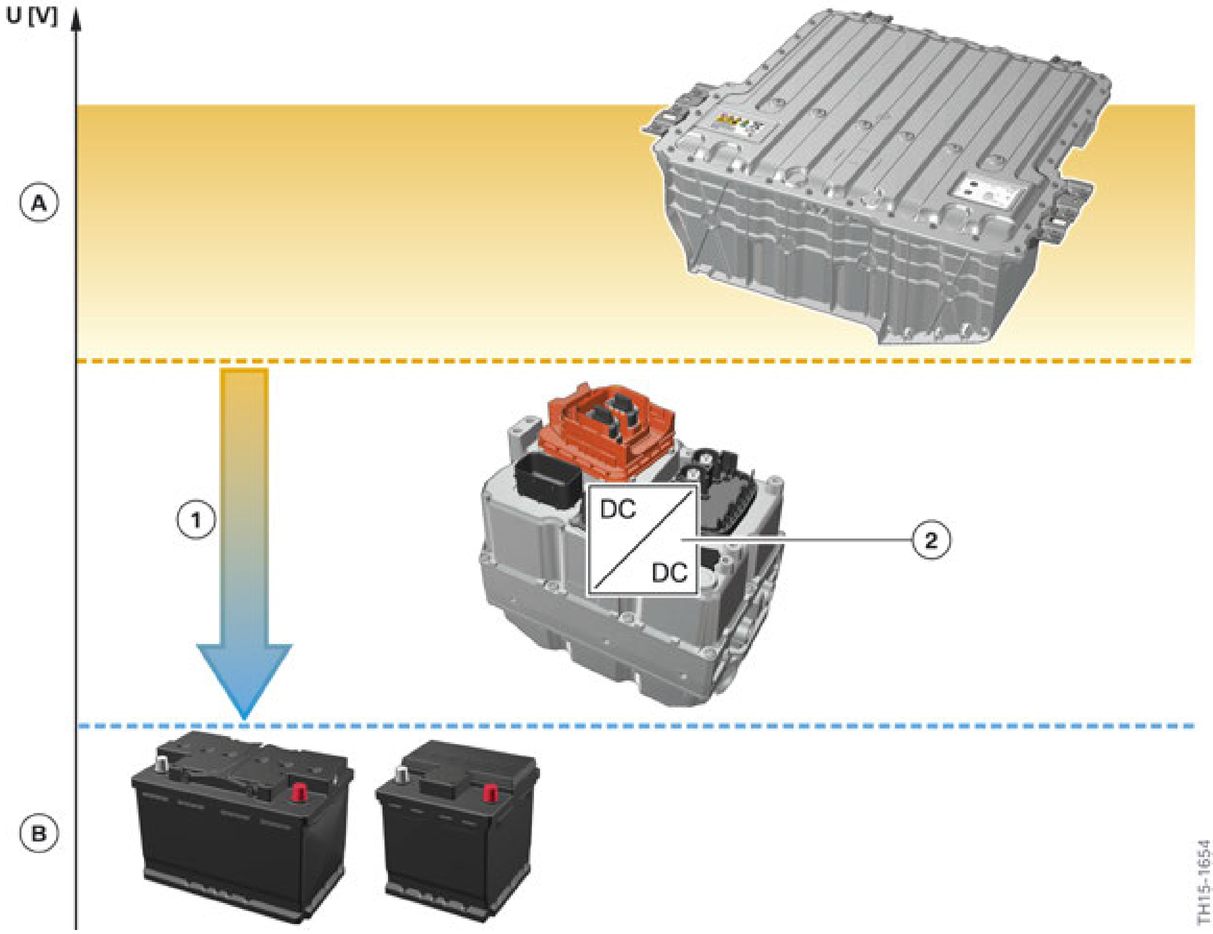
- Standby (also in the event of a component fault or short circuit, power electronics off).
- Buck mode (energy flow to the low-voltage side, converter adjusts voltage on low-voltage side).
- Discharging the high-voltage link capacitor (interlock fault, accident, request from master).

The DC/DC converter is in "Standby" mode when the electrical machine electronics is not in operation. This is the case when the EME control unit is not supplied with voltage due, for example, to a terminal status. But also if there is a fault the EME control unit prompts the DC/DC converter to assume "Standby" mode. In this operating mode there is no energy transfer between the two vehicle electrical systems and they remain galvanically separated.

Buck mode is the normal operating mode when the high-voltage system is active. The DC/DC converter transfers 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. The DC/DC converter must reduce the varying voltage from the high-voltage electrical system to the voltage in the low-voltage vehicle electrical system. Here the voltage in the high-voltage vehicle electrical system depends on the state of charge of the high-voltage battery unit, for example.

The voltage in the low-voltage vehicle electrical system controls the DC/DC converter so that the 12 V battery is optimally charged and sets a voltage of approx. 14 V depending on the state of charge and the temperature of the battery. The continuous output power of the DC/DC converter is approx. 2,400 W (temperature-dependent).

4. Electrical Machine Electronics

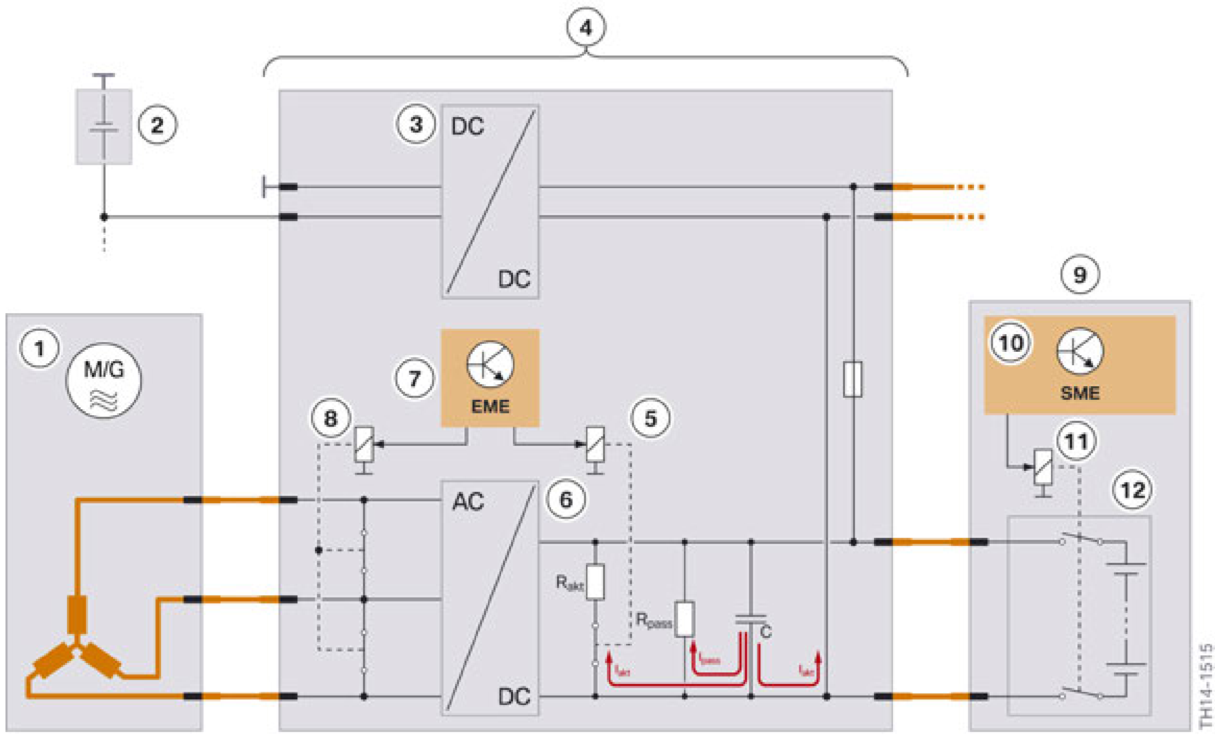


F30 PHEV, operating principle of the DC/DC converter

Index	Explanation
A	Voltage level of the high-voltage vehicle electrical system
B	Voltage of the low-voltage vehicle electrical system, approx. 14 V
1	Down conversion
2	DC/DC converter in the EME

The technology of the DC/DC converter in the F30 PHEV would also enable the operating mode "Boost mode", like the DC/DC converter in the F04. However, this operating mode is not used in the F30 PHEV. Charging of the high-voltage battery of the F30 PHEV is thus not possible using energy from the 12 V vehicle electrical system.

The last operating mode of the DC/DC converter is assumed during (regular or quick) shutdown of the high-voltage system. For the shutdown of the high-voltage system the system must be discharged to a safe voltage less than 60 V within five seconds. The DC/DC converter has a discharge circuit for the link capacitors. First of all, the discharge circuit tries to transmit the energy stored in the link capacitors to the low-voltage vehicle electrical system. If this does not lead to a sufficiently quick reduction of the voltage, the discharging is effected via an active resistor. This discharges the high-voltage vehicle electrical system in less than five seconds. For safety reasons there is also a so-called passive discharge resistor (switched in parallel). This enables a reliable discharge of the high-voltage electrical system if the first two measures do not work for discharging due to a fault. The period up until the discharge to a voltage below 60 V is longer and is maximum 120 s.



F30 PHEV, discharge of the high-voltage link capacitor

Index	Explanation
1	Electric motor
2	Connection to the 12 V vehicle electrical system
3	DC/DC converter
4	Electrical machine electronics (entirety)
5	Relay (for active discharging of the capacitors)
6	Bidirectional DC/AC converter
7	EME control unit
8	Relay (for short-circuit of the coils of the electrical machine)
9	High-voltage battery unit
10	SME control unit
11	Electromechanical switch contactor
12	High-voltage battery unit
C	Link capacitor
R_{pass}	Passive discharge resistor
R_{act}	Active discharge resistor

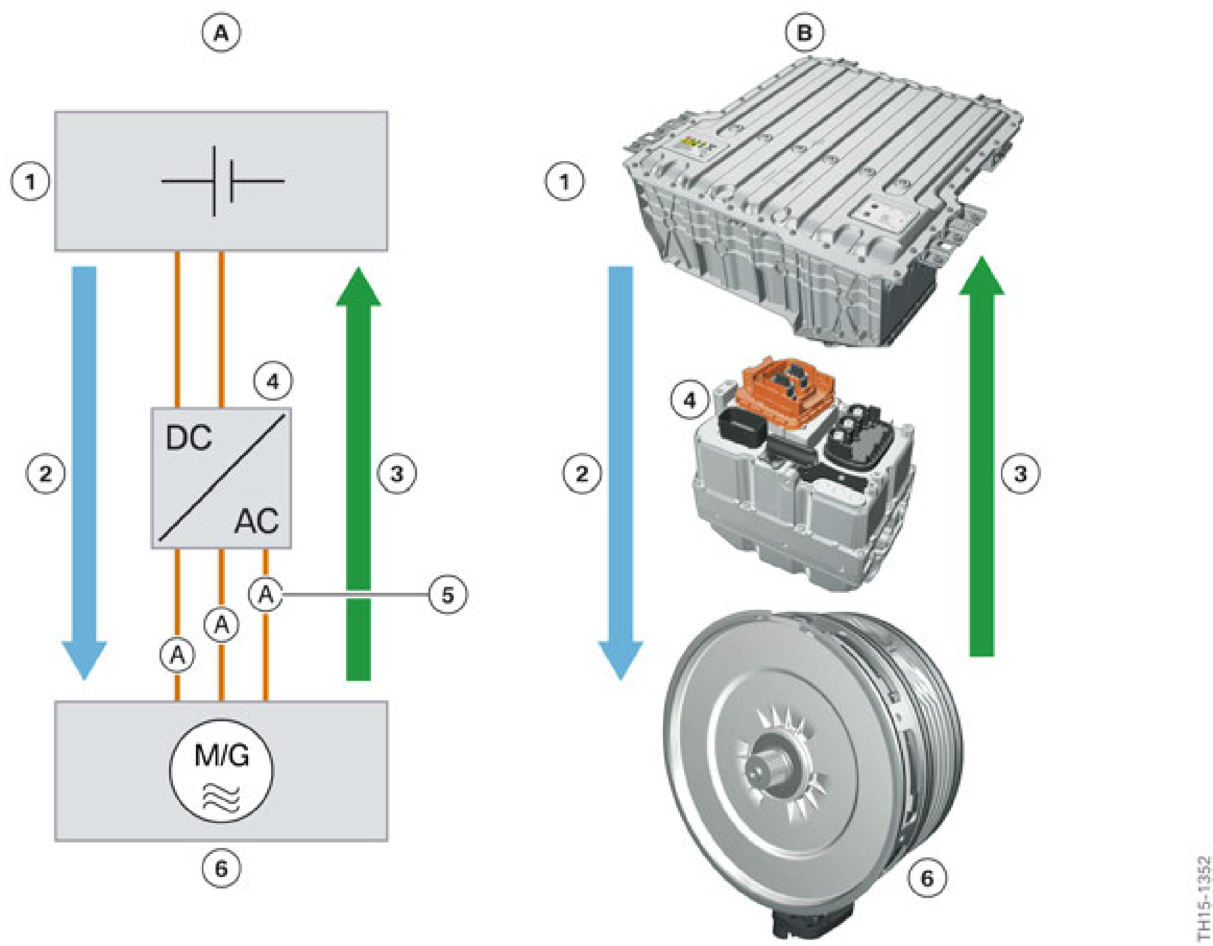
4. Electrical Machine Electronics

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 using the coolant, the EME control unit reduces the power of the DC/DC converter to protect the components.

4.7. Power electronics for activation of the electrical machine

The power electronics for the activation of the electrical machine are mainly made up of the bidirectional DC/AC converter. It is a pulse converter with a two-pin DC voltage connection and a 3-phase AC voltage connection. This DC/AC converter can work as an inverter and conduct electrical energy from the high-voltage battery unit to the electrical machine when it is to work as a motor.

However, the DC/AC converter can also work as a rectifier and transfers electrical energy from the electrical machine to the high-voltage battery unit. This operating mode occurs during brake energy regeneration in which the electrical machine works as an alternator and "generates" electrical energy.



F30 PHEV, operating modes of the bidirectional DC/AC converter

4. Electrical Machine Electronics

Index	Explanation
A	Schematic diagram
B	Schematic diagram with components
1	High-voltage battery unit
2	Operating mode as inverter, electrical machine works as an engine
3	Operating mode as rectifier, electrical machine works as an alternator
4	DC/AC converter
5	Current sensors
6	Electric motor

The operating mode of the DC/AC converter is defined by the EME control unit. The EME control unit also receives the setpoint values (essential input variables) from the DME control unit for which torque (amount and sign) the electrical machine should supply. From this setpoint value and the current operating condition of the electrical machine (engine speed and torque) 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. According to these specifications, the power semiconductors of the DC/AC converter are activated in sync.

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

The performance data of the electrical machine electronics and the electrical machine are coordinated in development. The electrical machine electronics are able to provide continuous electrical power of 45 kW and a temporary maximum power of 65 kW. In order to avoid overloading the power electronics, there is also another temperature sensor at the DC/AC converter. If an excess temperature of the power semiconductor is identified using this signal, the EME control unit reduces the power delivered to the electrical machine in order to protect the power electronics.

4.8. High-voltage power management

The power management for the high-voltage electrical system includes two subfunctions: one for driving and one for charging mode.

In driving mode, the energy flows from the high-voltage battery unit to the high-voltage consumers and the energy flows during energy recovery to the high-voltage battery unit are coordinated. The following steps are performed by the EME and repeated constantly:

1 Query of the power available from the high-voltage battery unit (Signal source: SME).
2 Query of the power which the high-voltage battery unit can use (Signal source: SME).
3 Query of the requested drive or braking power from the electric drive (Signal source: DME).
4 Query of the requested power for climate control (electrical heating, EKK, IHKA).
5 Decision on the distribution of the electrical power and communication to the control units of the consumers.

In charging mode the high-voltage power management has another task: It controls the energy flow from outside the vehicle via the EME to the high-voltage battery unit and, if required, by the convenience charging electronics to the electrical heating or to the electric A/C compressor. The procedure constantly repeated in the EME consists of the following individual steps:

1 Query of the available power from outside (Signal source: KLE).
2 Query of the power which the high-voltage battery unit can use (SME).
3 Query of the power which is required for the climate control (IHKA).
4 Requesting the necessary power from the EME.
5 Communication of the available partial powers to the receivers, the high-voltage battery unit (SME control unit) and heating and air-conditioning system (IHKA control unit).

The externally available power cannot be at a high level; it is restricted by the power network and the EME. Therefore, the available power must be queried first before it can be distributed. Depending on its state of charge, for example, the high-voltage battery unit cannot absorb an arbitrary amount of power, which is why this value must also be queried first. Depending on the temperature of the high-voltage battery unit or on a heating or an air-conditioning request by the driver, the heating and air-conditioning system also needs electrical power. This value is the third important input signal for the high-voltage power management in charging mode. Using this information the externally requested power is controlled and distributed to the consumers.

4.9. Voltage supply for other high-voltage consumers

The electrical machine electronics supplies voltage not only to the electrical machine.
The convenience charging electronics is directly connected with the electrical machine electronics and ensures the voltage supply on the high-voltage level for the electric A/C compressor and electrical heating.

However, there is no complex control function in the convenience charging electronics for this. Instead, the electrical machine electronics serves as a simple distributor of the high-voltage direct current voltage which is provided by the high-voltage battery unit. In order to protect the high-voltage cable for the two high-voltage consumers against overloading in the event of a short circuit, the electrical machine electronics contains a high-voltage fuse for the EKK and a high-voltage fuse for the electrical heating. The high-voltage fuse has a nominal current level of 80 A.

⚠

This high-voltage fuse cannot be replaced separately. The EME must always be replaced.

4.10. Activating the electrical vacuum pump

The EME receives the signals of the brake vacuum sensor via the CAN bus from the DME. The EME only provides the hardware for the activation of the electrical vacuum pump. The EME control unit also receives values, such as the driving speed and brake pedal operation, from the DSC control unit.

The brake vacuum sensor is mainly known from conventionally driven vehicles with automatic engine start-stop function. Similar to those vehicles, it is also installed in the F30 PHEV at the housing of the brake servo.

The sensor is supplied with voltage from the DME and returns a voltage signal depending on the vacuum in the brake servo. This analogue sensor signal is converted to the actual brake vacuum by the DME control unit and made available to the EME via the CAN bus.

The EME control unit evaluates the brake vacuum signal, includes dynamic handling characteristics (e.g. the driving speed) and the brake pedal actuation and determines whether the electrical vacuum pump should be switched on. In addition, the function logic takes a hysteresis into account so that the electrical vacuum pump is not continuously switched on and off. Instead, it remains switched on until a requested minimum level of the brake vacuum is reached.

The electrical machine electronics contains an output stage (semiconductor relay), with whose help the voltage supply of the electrical vacuum pump can be switched on and off. Upon request the output voltage of the DC/DC converter can be shifted through directly to the electrical vacuum pump. Switch-on currents of up to 30 A can occur in the process. The current level is restricted electronically to protect the output stage and the line. There is no control of the power or engine speed for the electrical vacuum pump – it is simply switched on and off.

A malfunction of the electrical vacuum pump is identified using a brake vacuum sensor by means of the no longer available vacuum. The legally prescribed deceleration (increased brake pedal force) is available at least. The DSC will realize a type of hydraulic brake-servo assistance, i.e. depending on the driver pressure a hydraulically reinforced circuit pressure is generated.

Advantage: Lower brake pedal force also in this fault scenario.

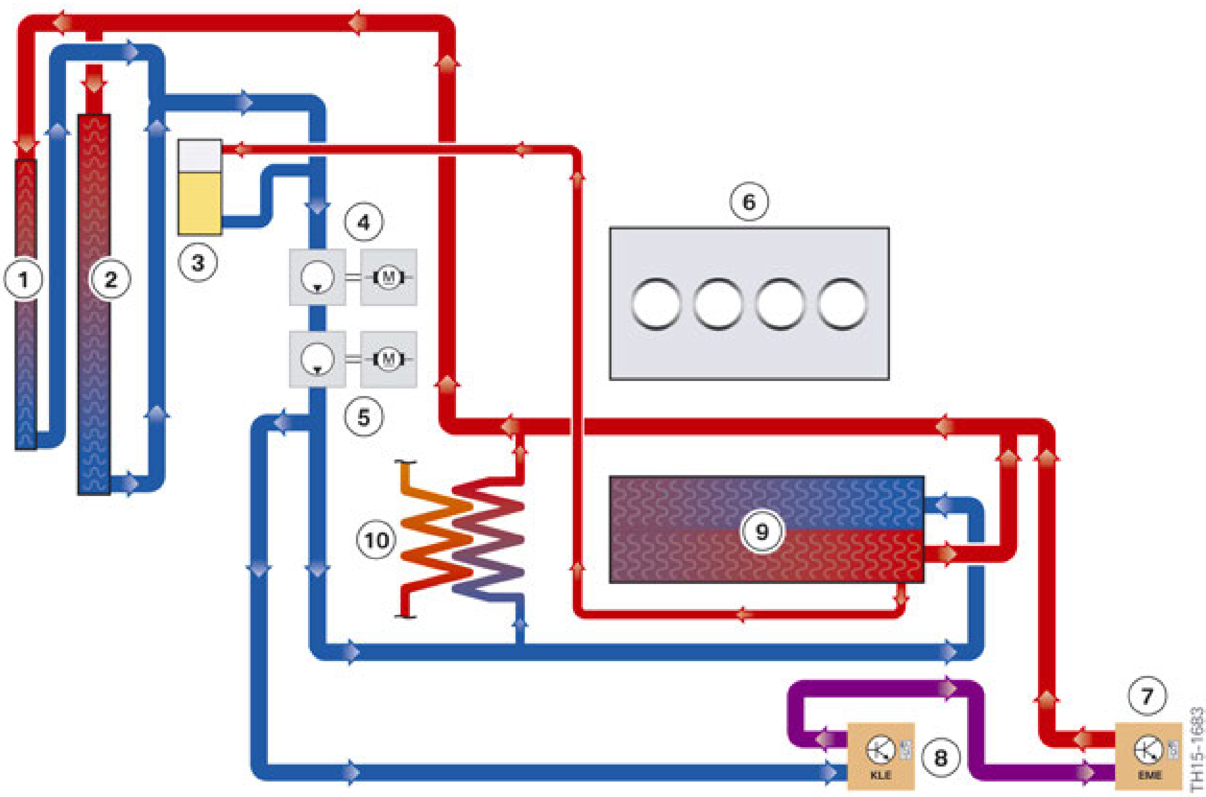
Disadvantage: Altered pedal feedback.

F30 PHEV High-voltage Components

4. Electrical Machine Electronics

4.11. Cooling

The electrical machine electronics and convenience charging electronics are cooled by an independent coolant circuit.



F30 PHEV, low-temperature coolant circuit

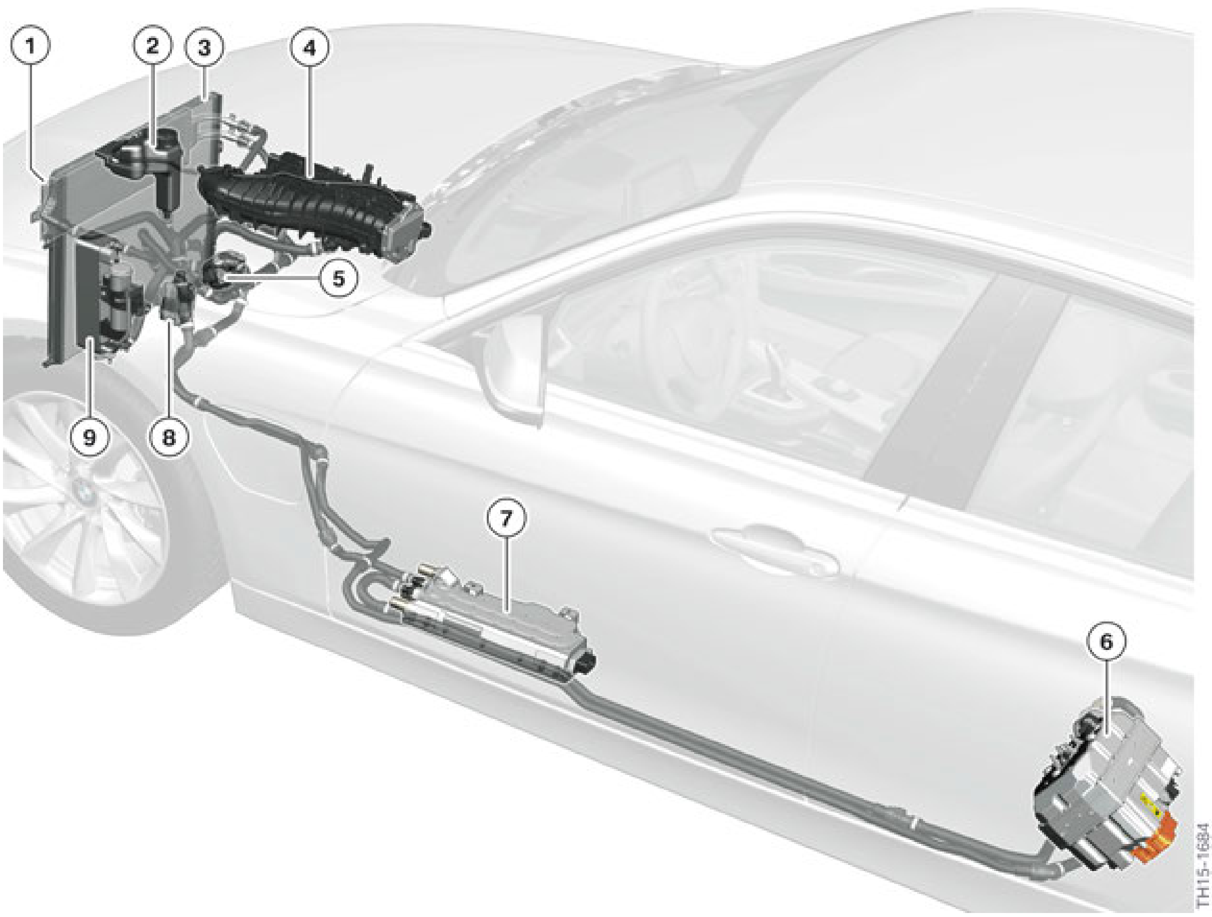
Index	Explanation
1	Coolant/air heat exchanger
2	Coolant/air heat exchanger
3	Coolant expansion tank
4	Electric coolant pump (80 W)
5	Electric coolant pump (80 W)
6	Combustion engine
7	Electric Motor Electronics (EME)
8	Convenience charging electronics (KLE)
9	Charge air cooler
10	Coolant-refrigerant heat exchanger

F30 PHEV High-voltage Components

4. Electrical Machine Electronics

The coolant circuit comprises:

- A coolant-refrigerant heat exchanger
- Two air-coolant heat exchangers
- A charge air cooler
- Two electric coolant pumps (each 80 W)
- Expansion tank
- Coolant lines



F30 PHEV, low-temperature coolant circuit installation locations

Index	Explanation
1	Coolant/air heat exchanger
2	Coolant expansion tank
3	Coolant/air heat exchanger
4	Charge air cooler
5	Electric coolant pump (80 W)

Index	Explanation
6	Electric Motor Electronics (EME)
7	Convenience charging electronics (KLE)
8	Electric coolant pump (80 W)
9	Coolant-refrigerant heat exchanger

Both coolant-air heat exchangers are integrated in the cooling module. Depending on the cooling requirement of the electrical machine electronics, the electric coolant pumps and the electrical fan are activated according to requirements thus contributing to a reduction in consumption levels.

Thanks to the demand-driven activation of the electrical fan and electric coolant pump, large temperature deviations which would have a negative effect on the service life of the electronics are avoided and energy-optimized cooling is achieved.

If the cooling power is insufficient, an additional coolant-refrigerant heat exchanger is used to cool the EME and the KLE.

There is no electrical level sensor installed in the expansion tank. But the following special feature should be noted for Service: A loss of coolant, for example due to a leak, in the cooling system is not identified directly due to the lack of an electrical level sensor. Instead, with a loss of coolant the temperature of the electrical machine electronics will rise above the normal operating range. In this case the power of the electrical machine electronics is reduced and a corresponding Check Control message is issued. The Service employee must check the following fault causes during troubleshooting:

- Loss of coolant, e.g. by a leak
- Coolant-air heat exchanger blocked
- Electric fan does not work or is restricted
- Coolant pump does not work
- Coolant lines or connections damaged
- Components to be cooled are faulty (EME)

If excess temperature is displayed in the cooling system, then this may have several causes, including also the loss of coolant. Therefore, during troubleshooting all components of the cooling system must be checked systematically.

For the ventilation of the coolant circuit of the electrical machine electronics, proceed in the same way as the procedure for conventional vehicles.

The familiar mixture of water and antifreeze and corrosion inhibitors G48 in BMW vehicles is used as a coolant.

While the high-voltage battery unit is being charged, the power electronics in the EME is working. Due to the huge electrical power which is transformed in the EME, heat also arises. This must be dissipated using the coolant circuit described here. Therefore, the electric coolant pump and the electric fan may also run during charging at a correspondingly high temperature in the EME.

⚠

The coolant pump and the electric fan can be switched on automatically when charging the high-voltage battery unit. The high-voltage battery unit must therefore not be charged when working with the engine compartment lid open or on the coolant circuit of the EME.

The activation of the coolant pump and electric fan can be effected in the following vehicle conditions:

- Terminal 15 switched on, driving readiness
- Terminal 15 switched on, no driving readiness
- High-voltage battery unit is charged

The power electronics switching of the electrical machine electronics are already working when terminal 15 is switched on. Both the high-voltage electrical system (EKK and electrical heating EH) and the 12 V vehicle electrical system are supplied with energy by the DC/DC converter. If due to the arising heat a cooling requirement is identified, the coolant pump is switched on, and if required also the electric fan.

⚠

When terminal 15 is switched on the coolant pump and electric fan can be switched on automatically. Therefore always ensure terminal 15 is switched off when working with an open engine compartment lid or at the coolant circuit of the EME.

F30 PHEV High-voltage Components

5. High-voltage Battery Unit

5.1. Overview

The high-voltage battery unit is a complete system, which is made up of the following essential components:

- Cell modules with the actual cells
- Cell Supervision Circuits (CSC)
- Control unit for battery management electronics (SME)
- Safety box
- Connections (electrical system, coolant, venting)
- Heat exchanger
- Wiring harnesses
- Housing and fastening parts

The primary task of the high-voltage battery unit is to absorb electrical energy from the high-voltage electrical system, store it and make it available again later as necessary, as well as converting this energy into chemical energy. In addition, it assumes important tasks that contribute to the safety of the high-voltage system, such as the high-voltage interlock loop. The high-voltage battery unit can be charged by brake energy regeneration (energy recovery) and via the external power supply system.

In order to reach the desired electrical range of the F30 PHEV, the energy reserve to be stored must be dimensioned accordingly. This has an effect on the volume and the weight of the high-voltage battery unit. The high-voltage battery unit is installed in the luggage compartment and secured at the body by means of three attachment points.

The high-voltage safety connector (also called "Service Disconnect") is not an element of the high-voltage battery unit in the F30 PHEV. It is located in the luggage compartment to the right instead of under the cover.

⚠

The high-voltage battery unit is a complex, high-voltage component: it is imperative that the handling and safety regulations are followed. In particular, lithium-ion batteries must not be overcharged or subjected to excessively high temperatures. Otherwise there is a risk of fire!

F30 PHEV High-voltage Components
5. High-voltage Battery Unit

⚠

Work on live high-voltage components is expressly prohibited. Prior to every operation which involves a high-voltage component, it is essential to disconnect the high-voltage system from the voltage supply and to secure it against unauthorized return to service.

1. Switch off terminal 15.
2. Charging plug is not connected at the vehicle.
3. Wait until the vehicle is in "Sleep" mode (can be detected if writing in the START-STOP button is not illuminated).
4. Open high-voltage safety connector.
5. Secure the high-voltage safety connector against restart.
6. Switch on terminal 15.
7. Wait until the Check Control message "High-voltage system switched-off" is displayed in the instrument cluster.
8. Switch off terminal 15 and terminal R.

5.1.1. Technical data

The high-voltage battery unit of the F30 PHEV is manufactured by BMW in Dingolfing, Germany. The cells of the high-voltage battery unit are manufactured by Samsung. The high-voltage battery unit was also developed by BMW AG itself.

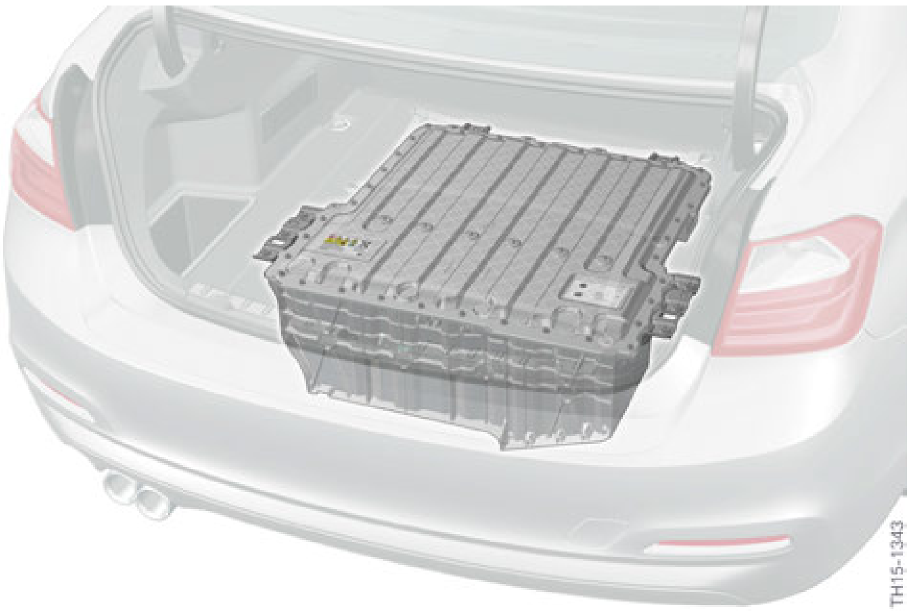
The battery cells used in the high-voltage battery unit of the F30 PHEV are lithium-ion cells (cell type NMCo/LMO blend). The anode material of lithium-ion batteries is generally a lithium metal oxide. The designation NMCo/LMO mixture refers to the metals used for this cell type: It is a mix of nickel, manganese and cobalt on the one hand, and lithium manganese oxide on the other hand.

The characteristics of the high-voltage battery unit for use in a hybrid vehicle were optimized through the selection of the anode material (high energy density, high number of cycles). Graphite is normally used for the cathode. The lithium ions are deposited in the cathode during discharging. As a result of the materials used, the nominal voltage of the battery cells is **3.66 V**.

Voltage	292.8 V (nominal voltage) Min. 269 V - max. 327.6 V (voltage range)
Battery cells	80 battery cells in series (each 3.66 V and 26 Ah)
Storable amount of energy Usable energy	7.8 kWh 5.8 kWh
Maximum power (discharge)	65 kW (short-term) / 45 kW (continuous)
Maximum power (AC charging)	3.75 kW
Total weight	88.1 kg / 194 lbs
Dimensions	769 mm x 827 mm x 319 mm
Cooling system	Refrigerant (R134a)

5. High-voltage Battery Unit

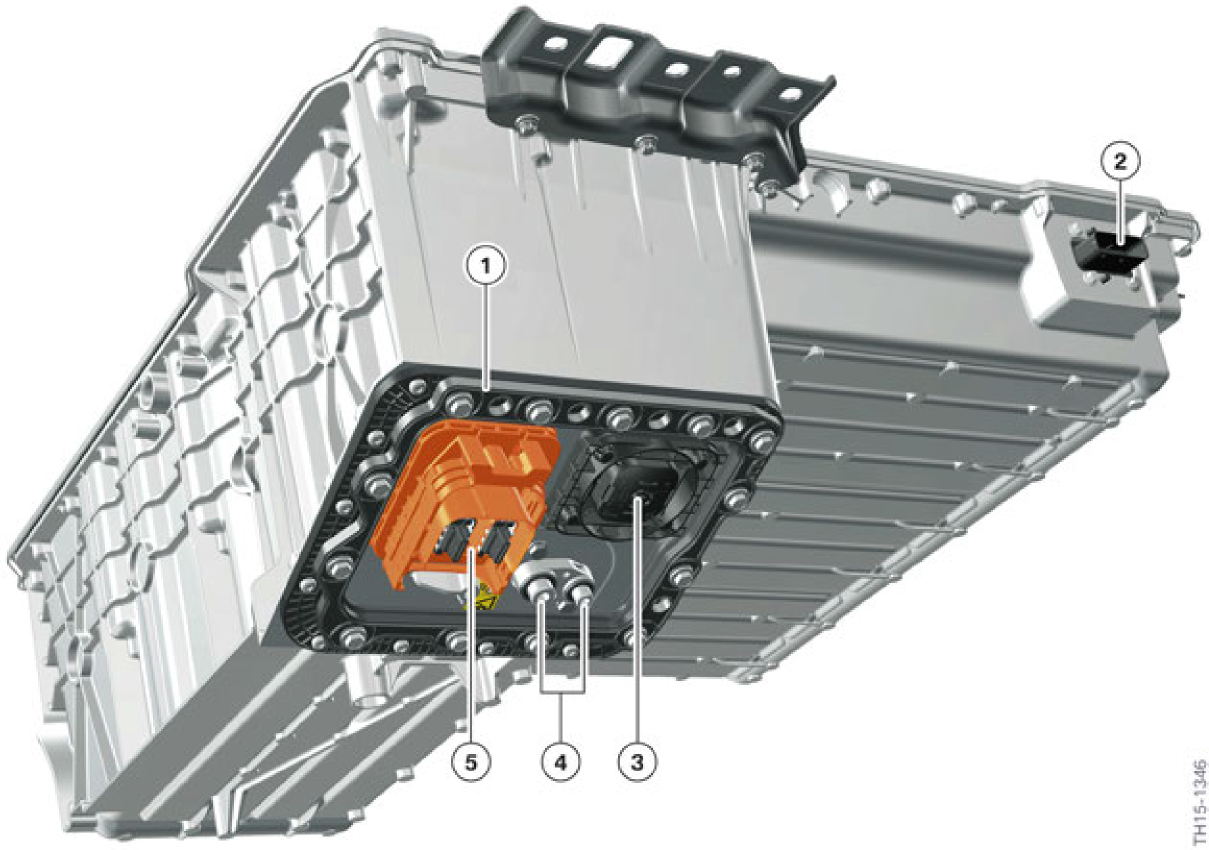
5.1.2. Installation location



F30 PHEV, installation location of the high-voltage battery unit

The high-voltage battery unit is installed in the luggage compartment under the roller cover for luggage compartment. This has the advantage that the rear seat backrests in the F30 PHEV can be folded down to consequently create an even luggage compartment. The optional equipment "through-loading system" is also available. The high-voltage battery unit is covered by a the luggage compartment floor and is therefore not directly visible. The connections of the high-voltage battery unit are accessed from below. This means that the vehicle must be raised in order to reach the connections.

5. High-voltage Battery Unit



Connections of the high-voltage battery unit

Index	Explanation
1	Gasket
2	Signal connector
3	Venting unit
4	Connections for refrigerant lines
5	High-voltage connection

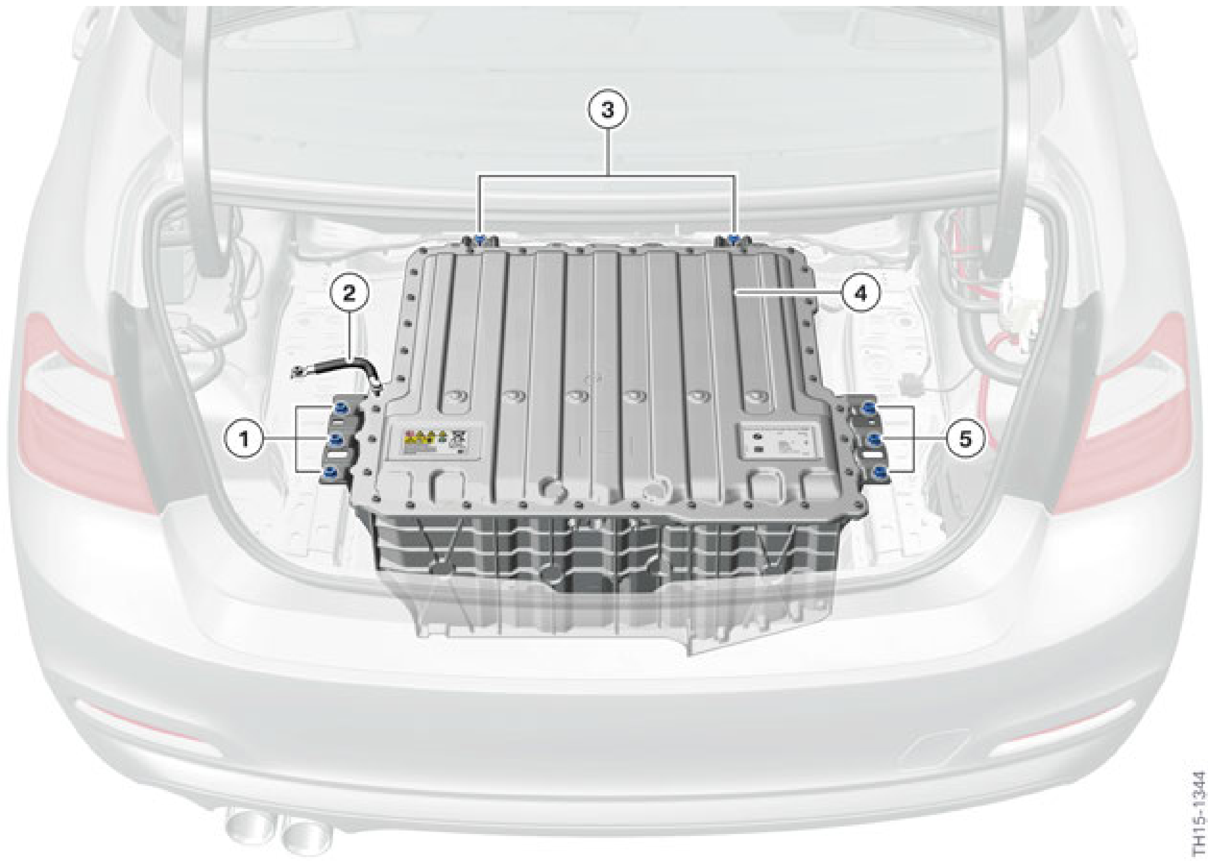
The high-voltage battery unit also has a signal connection, as well as the high-voltage connection. The control units integrated in the high-voltage battery unit are supplied with voltage, data bus, sensor and monitoring signals via this interface. The high-voltage battery unit is integrated in the refrigerant circuit in order for this to be cooled.

The electrical lines (high-voltage and signal connection), as well as the refrigerant lines, can be disconnected without having to remove the high-voltage battery unit.

Part of the high-voltage battery unit is located in the vehicle interior. If a chemical reaction occurs inside the battery cells as a result of a massive fault (short circuit in a cell), the gases produced must be transported outwards via a venting unit in order to enable pressure compensation. Sealing around the venting unit, high-voltage connection and refrigerant connection provides the seal to the vehicle interior.

F30 PHEV High-voltage Components

5. High-voltage Battery Unit



F30 PHEV, mounting of the high-voltage battery unit

Index	Explanation
1	Mounting nuts left
2	Potential compensation line
3	Mounting nuts front
4	High-voltage battery unit
5	Mounting nuts right

The high-voltage battery unit is connected to the vehicle body with four brackets and nuts. This way the weight and the acceleration forces occurring during the trip are supported at the body. The mounting bolts are not directly accessible from the luggage compartment, meaning that several trim panels have to be removed beforehand to loosen the screws.

For the removal of the high-voltage battery unit firstly all preliminary work specified in the repair instructions (diagnosis, disconnecting from the power supply, disassembling the trim panels, etc.) has to be performed. There will be a special workshop crane with corresponding special tool available to the Service workshops to facilitate removal and installation of the high-voltage battery unit.

Potential compensation

The electrical connection between the housing of the high-voltage battery unit and the body is established via a separate potential compensation line.

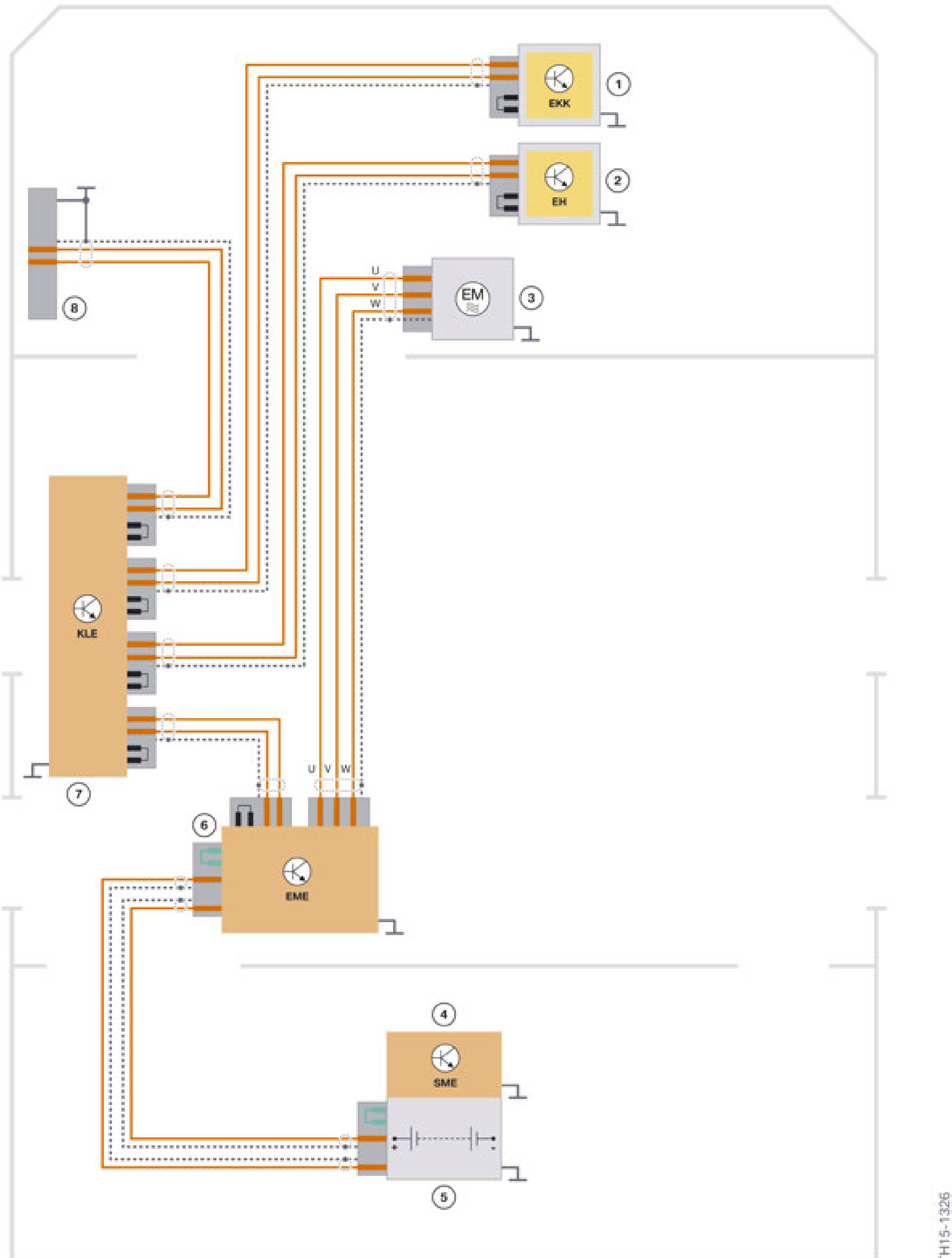
The low resistance connection between the housing of the high-voltage battery unit and ground is a crucial prerequisite for the fault-free function of the automatic insulation monitoring. This is why the specified tightening torque must be observed.

It is also important to ensure that neither the housing of the high-voltage battery unit nor the body at the respective bore holes is painted, corroded or dirty.

Follow the exact procedure when fitting the mounting bolts:

- Clean contact surfaces and have checked by a second person.
- Tighten mounting bolts to specified torque.
- Have torque checked by second person.
- Both persons must record this in the vehicle records for the correctness of the version.

5.1.3. System wiring diagram



F30 PHEV, system wiring diagram for high-voltage battery unit in the high-voltage network

Index	Explanation
1	Electric A/C compressor (EKK)
2	Electrical heating (EH)
3	Electric motor
4	Battery management electronics (SME)
5	Cell modules of the high-voltage battery unit
6	Electric Motor Electronics (EME)
7	Convenience charging electronics (KLE)
8	Charging socket

5.2. External features

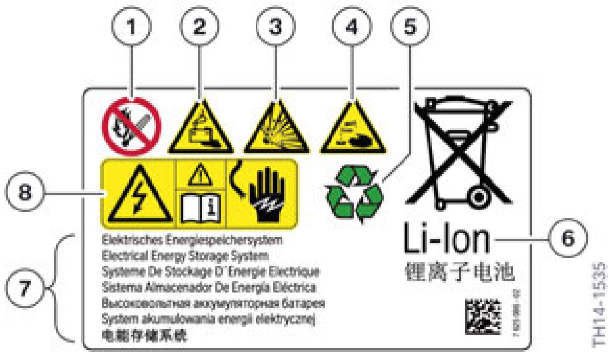
5.2.1. Labels

There is a sign on the housing of the high-voltage battery unit which warns against the dangers when working on the high-voltage battery unit.

F30 PHEV, warning labels on the high-voltage battery unit

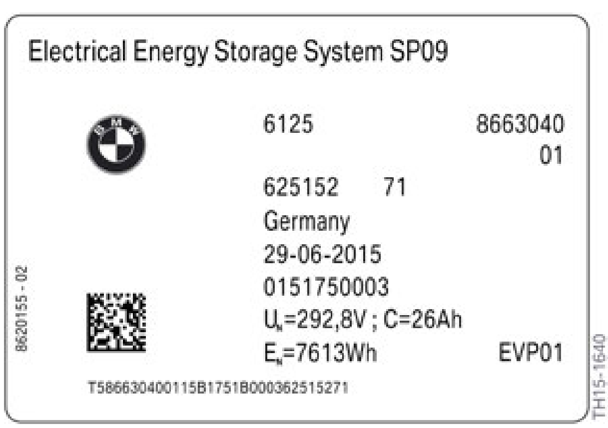
F30 PHEV High-voltage Components

5. High-voltage Battery Unit



F30 PHEV, warning sticker

Index	Explanation
1	Warning symbol: Prohibition symbol: No flame or smoking
2	Warning symbol: Warning against dangers of batteries
3	Warning symbol: Warning against explosive substances / materials
4	Warning symbol: Warning against caustic substances / materials
5	Reference to disposal of high-voltage battery unit: Recycling by specialist personnel possible, not to be disposed of in domestic waste. Note: Observe repair instructions!
6	Note about the high-voltage battery technology
7	Note indicating that this is a high-voltage battery (languages)
8	Warning symbol: Identification of a high-voltage component and note about the danger of an electric shock. Observe repair instructions.



F30 PHEV, type plate on the high-voltage battery unit

5.2.2. Electrical connections

Low-voltage connection

There is a signal connection on the right side of the high-voltage battery unit of the F30 PHEV. It connects the high-voltage battery unit to the 12 V vehicle electrical system.

The signal connection has the following lines:

- Voltage supply of the SME control unit with terminal 30F and ground connection.
- Terminal 30 crash message for the voltage supply of the electromechanical switch contactors.
- Wake-up line of the front electronic module (FEM).
- Input and output of the line for the high-voltage interlock loop.
- Output (+12 V and ground) for the actuation of the combined expansion and shutoff valve as part of the cooling system.
- PT-CAN2.

High-voltage connection

There is a high-voltage connection at the bottom right of the high-voltage battery unit with which the high-voltage battery unit is connected to the electrical machine electronics.

5.2.3. Vent hole

The venting unit performs two tasks. The first task is to offset large pressure differences between the inside and outside of the high-voltage battery unit. Such pressure differences can only arise in the event of a damaged battery cell. In this case for safety reasons the housing of the cell module with the damaged battery cell is opened to reduce the pressure. The gases are initially located in the housing of the high-voltage battery unit. From there they can be transported outwards via the venting unit.

The second task of the venting unit is to transport outwards condensate arising in the inside of the high-voltage battery unit. Besides the technical components, there is also air inside the high-voltage battery unit.

If the air or the housing is cooled by a lower ambient temperature or by a refrigerant through the activation of the air conditioning function, some of the water vapor from the air condenses. This means small amounts of condensate can form in the inside of the high-voltage battery unit. This has no effect on the function.

During the next heating of the air or the housing the condensate evaporates again and, at the same time, the pressure in the housing rises slightly. The venting unit permits pressure compensation by allowing the warm air to escape outwards. The water vapor in the air is also transported outwards and also the previously liquid condensate.

5.3. Cooling system

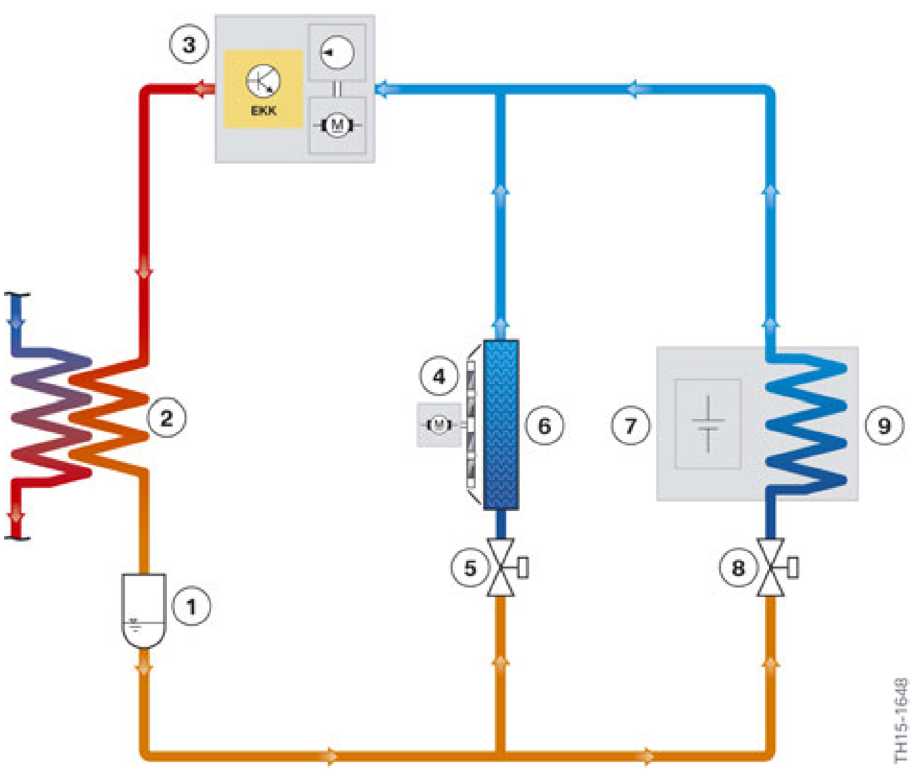
To maximise the service life of the high-voltage battery and obtain the greatest possible power, it is operated in a defined temperature range. The high-voltage battery unit is essentially operational at an ambient temperature of -40° C to +60° C (-40° F to 140° F).

However, the optimal range of the temperature with regard to service life and performance is more limited. It is between +25° C and +40° C (77° F to 104° F). The cell temperature is meant here, not the ambient temperature. If the cell temperature is continuously significantly above this range with simultaneously high performance, this has a negative effect on the service life of the battery cells. To counteract this effect, as well as ensure maximum performance at all ambient temperatures, the high-voltage battery unit of the F30 PHEV has an automatic cooling function.

If the F30 PHEV is parked for an extended period (e.g. a few days) at a very low ambient temperature, the battery cells also take on this low ambient temperature. In this situation it is possible the full electrical driving power is not available at the start of the trip.

There is no heating function for the high-voltage battery unit in the F30 PHEV.

5.3.1. Overview

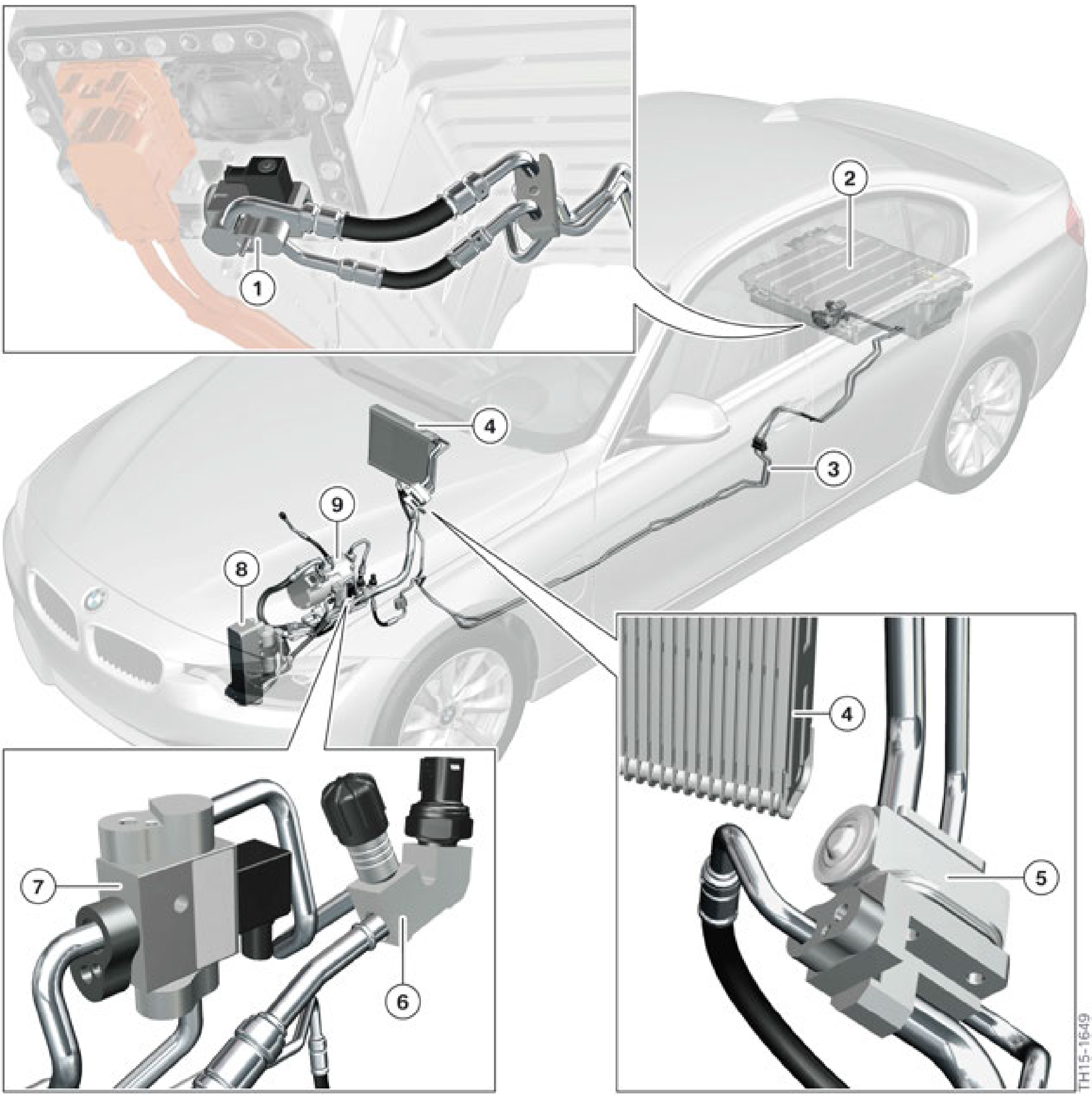


F30 PHEV, system overview of climate control

Index	Explanation
1	Dryer flask
2	Heat exchanger (coolant and refrigerant)
3	Electric A/C compressor (EKK)
4	Blower for passenger compartment
5	Shutoff valve (vehicle interior)
6	Evaporator, passenger compartment
7	High-voltage battery unit
8	Combined expansion and shutoff valve
9	Cooling unit (refrigerant heat exchanger)

F30 PHEV High-voltage Components

5. High-voltage Battery Unit



F30 PHEV, system overview of climate control – Installation locations

Index	Explanation
1	Combined expansion and shutoff valve
2	High-voltage battery unit
3	Refrigerant lines to high-voltage battery unit
4	Evaporator, passenger compartment
5	Expansion valve for vehicle interior

Index	Explanation
6	Connection for filling and evacuation
7	Shutoff valve (vehicle interior)
8	Coolant-refrigerant heat exchanger
9	Electric A/C compressor (EKK)

5.3.2. Functions

The cooling system has two operating conditions:

- Cooling OFF
- Cooling ON

Cooling OFF operating condition

The "Cooling OFF" operating condition is adopted when the cell temperature is in or below an optimal range. This is generally the case if the vehicle is moved at moderate ambient temperatures and at low electrical power. The "Cooling OFF" operating condition is particularly efficient because no additional energy is required for cooling the high-voltage battery.

The components involved work as follows:

- The electric A/C compressor is not in operation or runs at reduced power if only the vehicle interior needs to be cooled.
- The combined expansion and shutoff valve at the high-voltage battery unit is closed.

Cooling ON operating condition

If the battery cells heat up to temperatures of approx. 30° C (86° F), cooling of the high-voltage battery unit already starts. The SME control unit sends a cooling requirement to the IHKA control unit with two priorities. The IHKA decides whether the passenger compartment or the high-voltage battery unit is cooled or both are cooled. The cooling requirement may be refused by the IHKA in the event of a cooling requirement by the SME with low priority and a high cooling requirement in the vehicle interior. However, the high-voltage battery unit is always cooled for a cooling requirement by the SME with high priority.

For the cooling the IHKA requests electrical power from the high-voltage power management in the electrical machine electronics for the EKK.

The components act as follows in "Cooling" operating condition:

- The SME control unit requests a cooling requirement.
- Following release by the IHKA the SME control unit activates the combined expansion and shutoff valve at the high-voltage battery unit. This valve opens and refrigerant flows into the high-voltage battery unit.
- The EKK is in operation.

As a result of the pressure drop after the expansion valve, the refrigerant in the lines and coolant ducts of the high-voltage battery unit evaporates. In the process the refrigerant absorbs heat energy from the cell modules or battery cells and cools them. The evaporated refrigerant then leaves the high-voltage battery unit, is compressed by the electric A/C compressor and liquefied in the coolant/refrigerant heat exchanger. Although energy is required from the high-voltage electrical system for this procedure, it is of utmost importance. Only this way can a long service life and a high degree of efficiency of the battery cells be guaranteed.

If the temperature of the battery cells is significantly below the optimal operating temperature of 20° C (68° F), their performance would be temporarily restricted and the efficiency of the energy conversion would not be optimal. This is an unavoidable chemical effect of lithium-ion batteries.

If the F30 PHEV is parked for an extended period (e.g. a few days) at a very low ambient temperature, the battery cells also take on this low ambient temperature. In this situation it is possible the full electrical driving power is not available at the start of the trip. This remains unnoticed by the customer as the combustion engine assumes the drive of the vehicle in this case.

5.3.3. System components

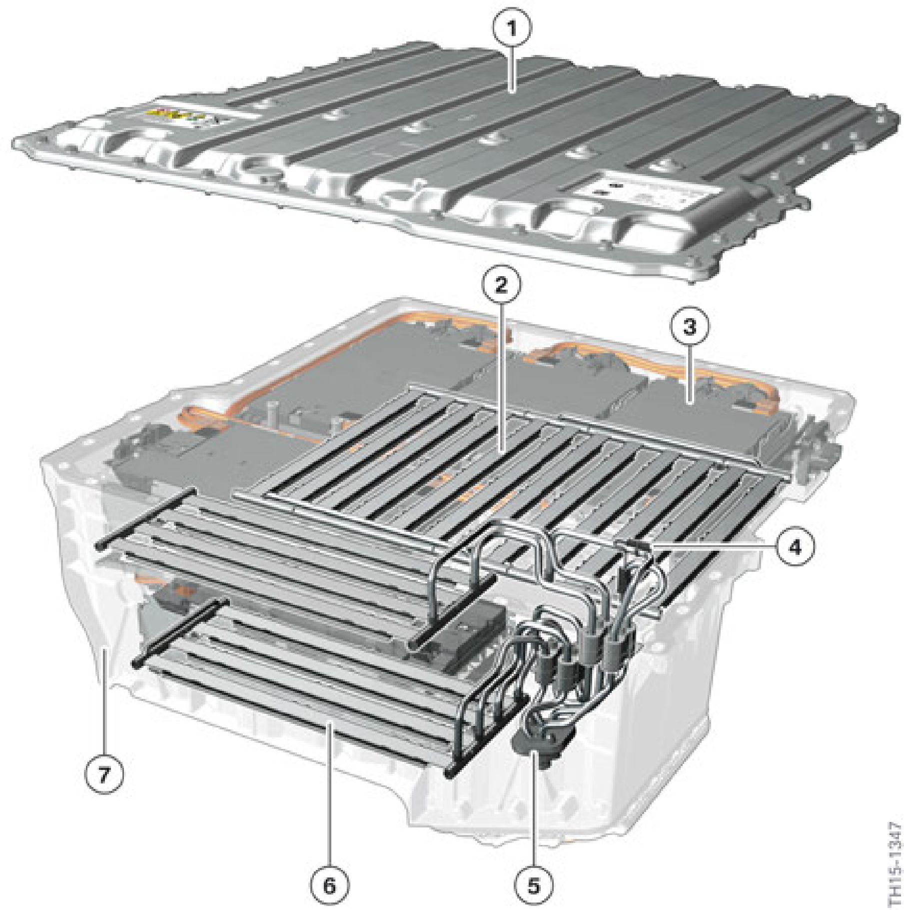
Heat exchanger

In the inside of the high-voltage battery units the refrigerant flows through lines and coolant ducts made from aluminium. The refrigerant flowing in through the inlet piping is distributed after the connection at the high-voltage battery unit to the upper and lower heat exchanger. The refrigerant flowing through the feed line is distributed into two coolant ducts in the heat exchanger and absorbs the heat of the cell modules en route through the coolant ducts.

At the end of the coolant ducts the refrigerant is directed to the neighboring coolant ducts, flows back and absorbs further heat from the cell modules.

At the end, the two return lines of each heat exchanger are joined in a common return line. This common return line returns the evaporated refrigerant to the connection of the high-voltage battery unit.

A temperature sensor is installed at the feed line of the upper heat exchanger. The signal from this sensor is used for controlling and monitoring the cooling function. It is read directly by the SME control unit.

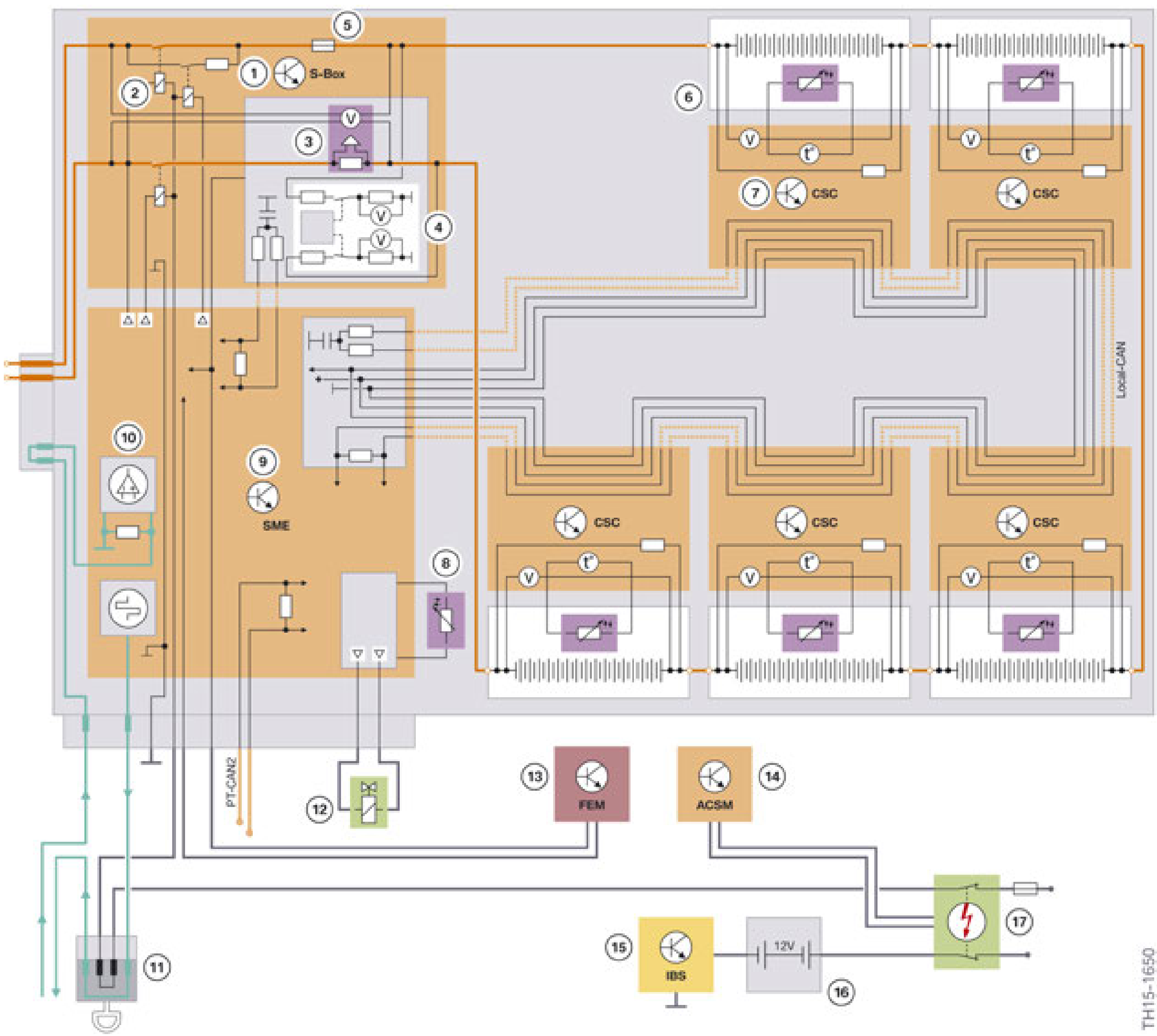


F30 PHEV components for cooling in the high-voltage battery unit

Index	Explanation
1	Upper housing half
2	Upper heat exchanger (two-part)
3	Cell module
4	Temperature sensor for refrigerant line
5	Connecting flange for combined expansion and shutoff valve
6	Lower heat exchanger
7	Lower housing half

5.4. Inner structure

5.4.1. Electrical and electronic components



F30 PHEV, system wiring diagram for high-voltage battery unit

Index	Explanation
1	Safety box
2	Switch contactors
3	Voltage/current sensor (shunt)
4	Resistance measurement (for insulation monitoring)
5	Safety fuse (350 A)
6	Cell module
7	Cell Supervision Circuits (CSC)

Index	Explanation
8	Coolant temperature sensor
9	Battery management electronics (SME)
10	Control of the circuit of the high-voltage interlock loop
11	High-voltage safety connector ("Service Disconnect")
12	Combined expansion and shutoff valve
13	Front Electronic Module (FEM)
14	ACSM with control lines for activating the safety battery terminal
15	Intelligent Battery Sensor (IBS)
16	12 V battery
17	Safety battery terminal

It can be seen from the wiring diagram shown above that the high-voltage battery unit of the F30 PHEV contains the following electrical/electronic components in addition to the actual battery cells, which are combined in five cell modules:

- Control unit for battery management electronics (SME)
- Five Cell Supervision Circuits (CSC)
- Safety box with switch contactors and sensors

In addition to the electrical components, the high-voltage battery unit is also made up of refrigerant lines and coolant ducts, as well as mechanical retaining elements for the cell modules. These internal components, as well as the high-voltage safety connector, are described in the following chapters.

Battery management electronics (SME)

High demands are placed on the service life of the high-voltage battery unit (service life of the vehicle). In the interest of satisfying these demands, it is not permitted to operate the battery in any manner one likes. Instead, the high-voltage battery unit is operated in a precisely defined range so as to maximise its service life and performance. This includes the following marginal conditions:

- Operate battery cells in the optimal temperature range (by cooling and if required restricting the current level).
- Adjusting the state of charge of the individual cells where necessary to one another.
- Use storable energy of the battery in a certain range.

To comply with these marginal conditions, a control unit, the battery management electronics (SME), is installed in the high-voltage battery unit of the F30 PHEV.

5. High-voltage Battery Unit

The SME control unit must fulfil the following tasks:

- Controlling the starting and shutting down of the high-voltage system at the request of the Electrical Machine Electronics (EME).
- 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 unit.
- Determining the State of Charge (SoC) and the State of Health (SoH) of the high-voltage battery unit.
- Determining the available power of the high-voltage battery unit and where necessary requesting limitation from the electrical machine electronics.
- Safety function (e.g. voltage, current and temperature monitoring, high-voltage interlock loop).
- Identification of fault statuses, storing fault code entries and communication of fault statuses to the electrical machine electronics.

The SME control unit can generally be accessed and programmed via the diagnosis system.
For troubleshooting it is important to know that not only control unit faults can be entered in the fault memory of the SME control unit, but also links to faults of other components in the high-voltage battery unit. The fault code entries can be divided into different categories which are dependent on their 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 unit may suffer damage as a result of the fault, the high-voltage system is shut down immediately and the contacts of the electromechanical switch contactors are opened. The driver can allow the vehicle to roll and for example park it at the side of the road. The steering assistance, brake-servo assistance and DSC control operation are provided with energy from the 12 V vehicle electrical system.
- Restricted performance:
  If the high-voltage battery unit is no longer able to supply full power or full energy, the drive power and the range are restricted to protect the components. In this case the driver can continue a short distance at significantly reduced drive power and, in the best scenario, reach the next BMW Service or park the vehicle at a location of his choice.
- Fault without direct effect for the customer:
  If, for example, communication between SME or CSC control units is disrupted for a short time, this does not result in a functional restriction or put the safety of the high-voltage system at risk. This is why only one fault code entry is generated which must be analyzed by the BMW Service using the diagnosis system. A Check Control message does not appear.
  The functionality for the customer is not restricted.

The SME control unit is accessible via the service cap of the high-voltage battery unit.

5. High-voltage Battery Unit

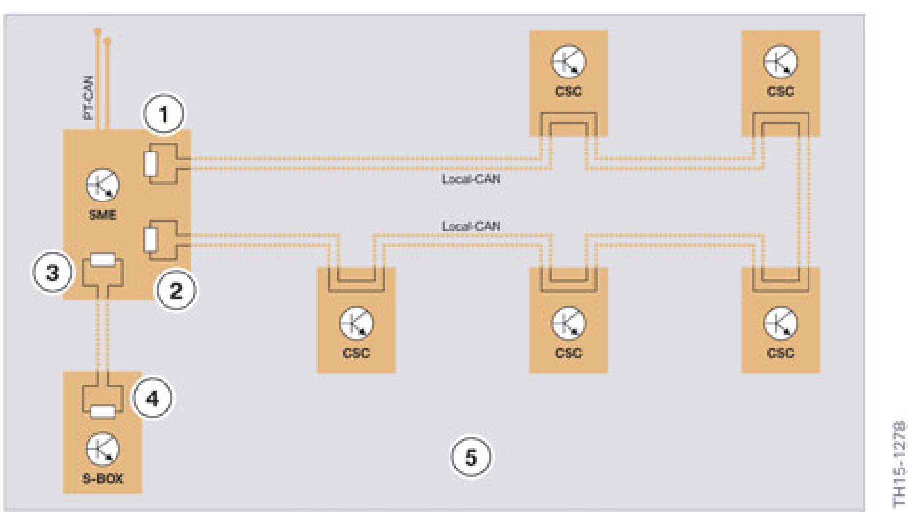
The electrical interfaces of the SME control unit are:

- 12 V supply for SME control unit (terminal 30 from luggage compartment power distribution box and terminal 31)
- 12 V supply for switch contactors (terminal 30 crash message)
- PT-CAN2
- Local CAN, 2x
- Wake-up line from the Body Domain Controller (BDC)
- Input and output for high-voltage interlock loop
- Line for activating the combined expansion and shutoff valve at the cooling unit
- Coolant temperature sensor

The switch contactors in the high-voltage battery unit are supplied with voltage via a special 12 V line. This line is called terminal 30 crash message, **terminal 30C for short.** The C in the terminal designation indicates that this 12 V voltage is switched off in the event of an accident (crash). This line is a (second) output of the safety battery terminal. This means that when the safety battery terminal is activated this supply lead is also interrupted.

This line also runs through the high-voltage safety connector so that the supply to the switch contactors is interrupted also when the high-voltage system is disconnected from the power supply. In both these cases the two switch contactors in the high-voltage battery unit are opened automatically.

The local CAN connects the SME control unit to the Cell Supervision Circuits (CSC) (see next chapter). The safety box is also connected to the SME control unit via its own local CAN.



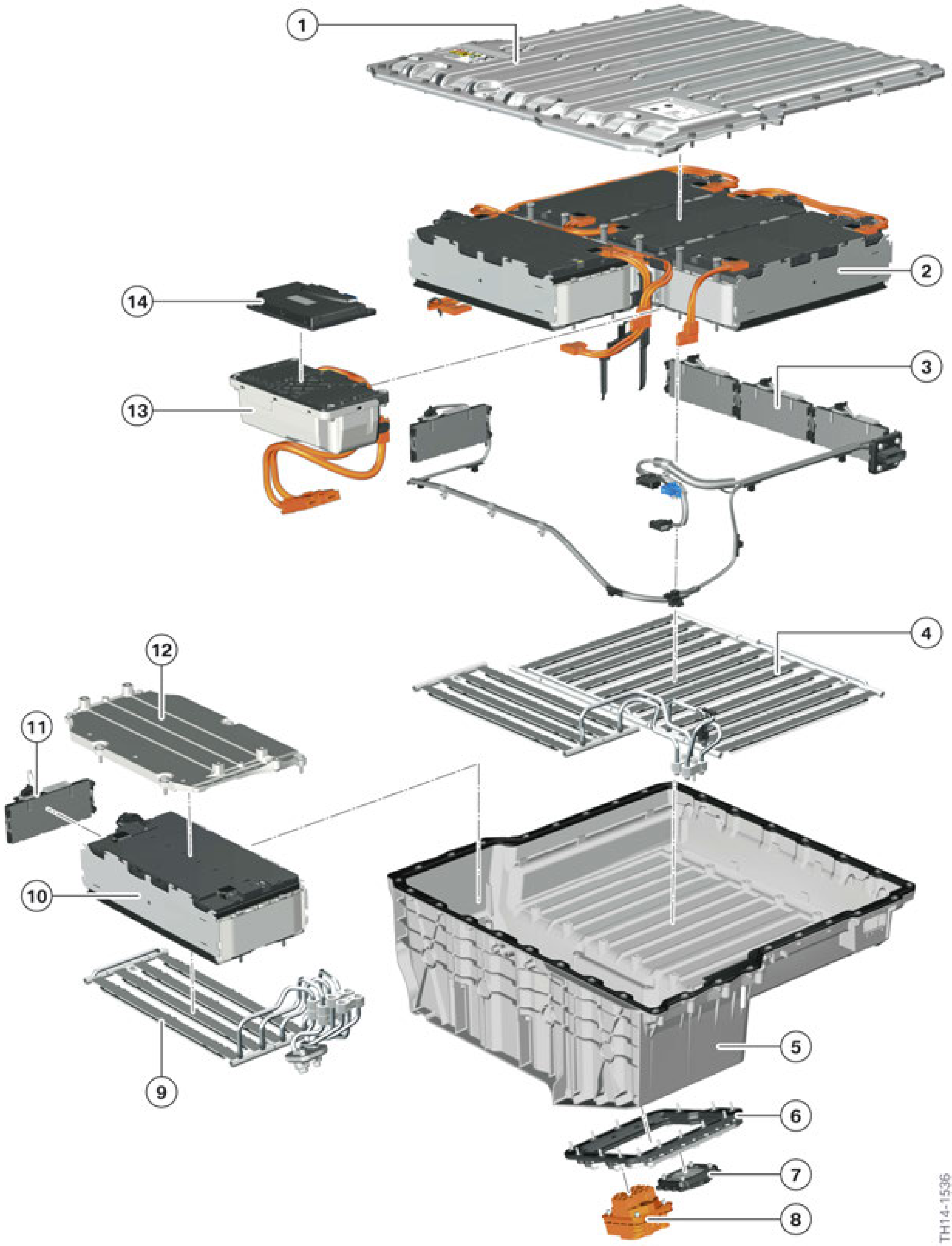
F30 PHEV, system wiring diagram local CAN (SME to CSC)

5. High-voltage Battery Unit

Index	Explanation
1	Terminating resistor, local CAN, CSC wiring harness
2	Terminating resistor, local CAN, CSC wiring harness
3	Terminating resistor, local CAN, SME
4	Terminating resistor, local CAN, safety box
5	High-voltage battery unit

Cell modules

The high-voltage battery unit is made up of five cell modules switched in series. A cell supervision circuit is assigned to each cell module. The cell module itself is made up of 16 cells switched in series. Each cell has a nominal voltage of 3.66 V and a nominal capacity of 26 Ah.



F30 PHEV Structure of the high-voltage battery unit

5. High-voltage Battery Unit

Index	Explanation
1	Cover
2	Upper cell modules
3	Cell supervision circuit, upper modules
4	Heat exchanger upper section
5	Housing
6	Gasket
7	Venting unit
8	High-voltage connector
9	Heat exchanger lower section
10	Lower cell module
11	Cell supervision circuit, lower module
12	Carrier housing for the upper cell module
13	Safety box
14	Battery management electronics (SME)

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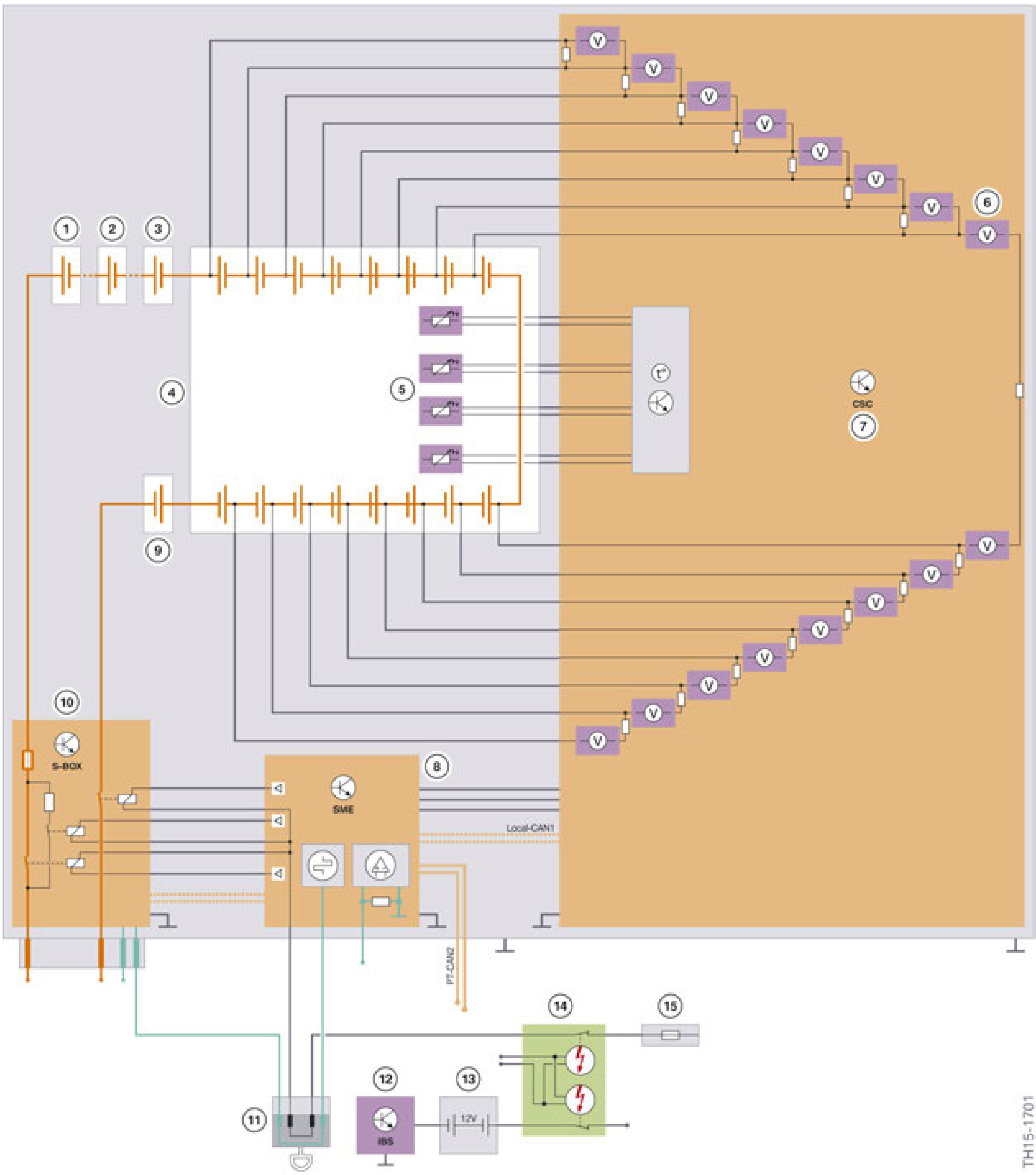
The cell modules are located in the high-voltage battery unit. All work on the cell modules and their mounting parts must be performed only by qualified workshop personnel.

Cell supervision circuits

Certain conditions must be observed for fault-free operation of the lithium-ion cells in the F30 PHEV: The cell voltage and the cell temperature cannot exceed or drop below certain values as otherwise the battery cells may suffer long-term damage. For this reason the high-voltage battery unit has five Cell Supervision Circuits (CSC).



F30 PHEV, cell supervision circuit

Index	Explanation
1	Cell module 1
2	Cell module 2
3	Cell module 3
4	Cell module 4

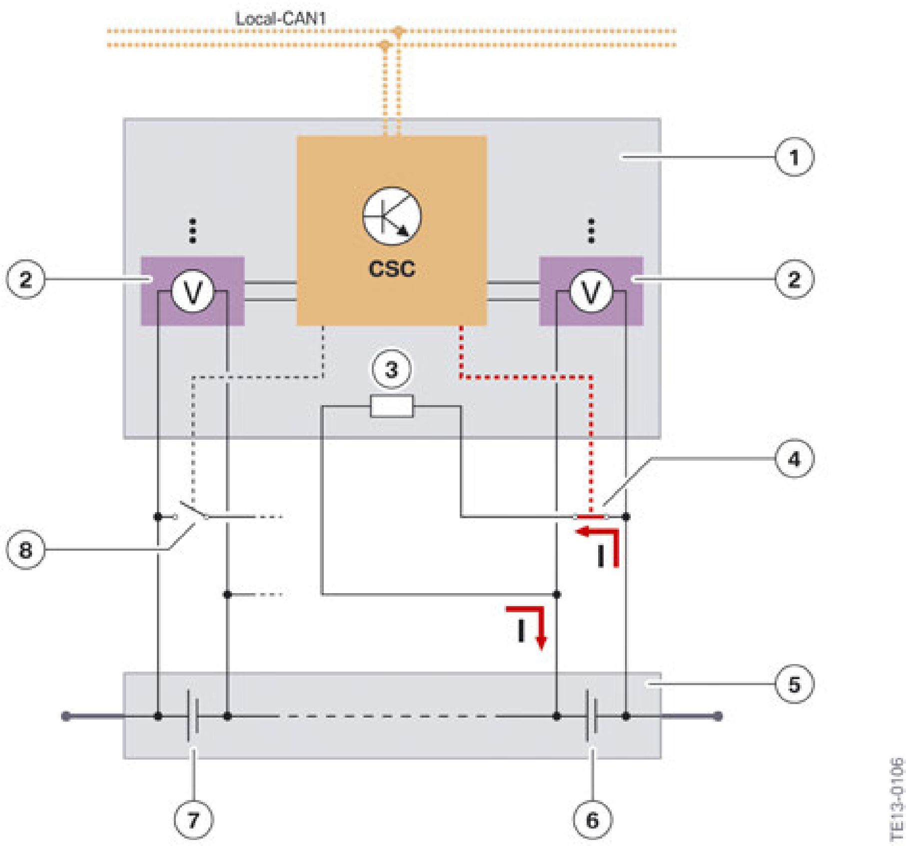
Index	Explanation
5	Temperature sensors at the cell module
6	Voltage measurement at the cells
7	Cell supervision circuit
8	Battery management electronics (SME)
9	Cell module 5
10	Safety box
11	High-voltage safety connector ("Service Disconnect")
12	Intelligent Battery Sensor (IBS)
13	12 V battery
14	Safety battery terminal (SBK)
15	Power distribution box, luggage compartment

The measurement of the cell voltage is effected at a very high sampling rate. The end of the charging procedure, as well as the discharging procedure, can be identified using the voltage measurement. The temperature sensors are arranged at the cell modules so that the temperature of the individual battery cells can be determined from their measured values. Using the cell temperature, an overload or electrical fault can be identified. In such a case the current level must be reduced immediately or the high-voltage system shut down completely in order to avoid progressive 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. The cell temperature is measured for each cell module by three negative temperature coefficient temperature sensors.

The cell supervision circuits communicate the values measured by them via the local CAN. This local CAN connects all cell supervision circuits to each other, as well as to the SME control unit. In the SME control unit the evaluation of the measured values takes place and a response is introduced if required (e.g. control of the cooling system).

If one or several of the battery cells were to have a significantly lower cell voltage than the other battery cells, the usable energy content of the high-voltage battery unit would be restricted. The end of energy consumption for the discharging procedure is determined by the weakest battery cell. If the voltage of the weakest cell has fallen to the discharge limit, the discharging procedure must be terminated, also if the other battery cells still have enough energy stored. If the discharging procedure is continued however, the weakest battery cell may incur permanent damage. For this reason there is a function to adjust the cell voltage to approximately the same level. This process is also called "cell balancing".

5. High-voltage Battery Unit



F30 PHEV, principle wiring diagram: Adjusting the cell voltages

Index	Explanation
1	Cell supervision circuit
2	Sensors for measuring the cell voltage
3	Discharge resistor
4	Closed (active) contact for discharging a battery cell
5	Cell module
6	Battery cell whose cell voltage is reduced by discharging
7	Battery cell not being discharged
8	Open (inactive) contact for discharging a battery cell

The SME control unit compares all cell voltages. The battery cells with a significantly higher cell voltage than the other battery cells are discharged during this procedure. The discharge is started by the SME control unit with a request via the local CAN1 to the cell supervision circuits that belong to these battery cells. Each cell supervision circuit has an ohmic resistance for each battery cell, via which the discharge current can flow as soon as the respective electronic contact has been closed. After the discharging procedure is started this is performed or continued independently by the cell supervision circuits, also if the main control units have switched to rest state in the meantime. This is made possible by the fact that the CSC control units obtain their voltage supply from the battery management electronics which is connected directly to terminal 30F.

5. High-voltage Battery Unit

The discharging procedure is automatically ended if the voltage of all battery cells is in a specified narrow range. The cell balancing is continued until all cells have the same voltage.

The adjustment of the cell voltages is a procedure which involves losses. However, the electrical energy lost is very low. In contrast, the advantages are that the attainable range and the service life of the high-voltage battery unit are maximized. That is why balancing of the cell voltages is sensible and necessary. This procedure can naturally be performed when the vehicle is at a standstill.

The conditions for adjusting the cell voltages are as follows:

- Terminal 15 switched off and vehicle or vehicle electrical system asleep AND
- High-voltage system shut down AND
- Deviation of the cell voltages or the individual States of Charge of the cells are greater than a threshold value AND
- Total SoC of the high-voltage battery unit is greater than a threshold value.

The adjustment of the cell voltages is effected automatically when the specified conditions are fulfilled. The customer therefore does not receive a Check Control message nor does he have to implement a special measure.

If the cell voltages however have too great a deviation or the adjustment of the cell voltage is not successful, a fault code entry must be created in the battery management electronics control unit. The customer is made aware of this fault status by a Check Control message. With help of the diagnosis system the fault memory must then be evaluated and the faulty components of high-voltage battery unit replaced.

⚠

The cell supervision circuits are located in the high-voltage battery unit. All work on the cell supervision circuits must only be performed by qualified workshop personnel.

Safety box

In each high-voltage battery unit there is an interface unit with its own housing, which is also called a "safety box" or "S-box" for short.

The following components are integrated in the safety box:

- Current sensor in the current path of the negative battery terminal (shunt).
- Safety fuse (350 A).
- Two electromechanical switch contactors (one switch contactor per current path).
- Pre-charge switch for slow start-up of the high-voltage system.
- Voltage sensors for monitoring the switch contactors and for measuring the total battery voltage.
- Resistance measurement for monitoring the isolation resistance.

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

The safety fuse in the safety box cannot be replaced as a separate component. In the event of a fault in the safety box, this must always be replaced as an overall component.

Wiring harnesses

There are two wiring harnesses in the high-voltage battery unit.

- Wiring harness for the connection of the CSC's to the SME control unit.
- Wiring harness for connection of the SME with the safety box and the signal connection.

5.5. Functions

In the F30 PHEV central functions of the high-voltage system are controlled and coordinated by the Electrical Machine Electronics (EME).

The high-voltage battery unit and the SME control unit are of decisive importance for the central functions of the high-voltage system. They are:

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

5.5.1. Starting

The sequence for starting the high-voltage system is always the same irrespective of which of the following events was the trigger:

- Terminal 15 is switched on or driving readiness is established.
- Charging the high-voltage battery unit should start.
- Preparation of the vehicle for the trip (climate control of the high-voltage battery unit or the vehicle interior).

The individual steps for starting the high-voltage system are:

1 EME control unit requests starting via bus telegrams at the PT-CAN2.
2 The high-voltage electrical system is checked using self-diagnosis functions.
3 The voltage in the high-voltage circuit is increased continuously.
4 The contacts of the switch contactors are fully closed.

5. High-voltage Battery Unit

The high-voltage electrical system is mainly checked by the EME control unit and the SME control unit. Criteria relevant for safety, for example the circuit of the high-voltage interlock loop or the isolation resistance, are checked. Functional preconditions such as the operating readiness of all subsystems must also be fulfilled for starting.

As the high-voltage circuit capacitors have high capacity values (link capacitors in the power electronics), the contacts of the electromechanical switch contactors cannot be easily closed. Extremely high current pulses would damage both the high-voltage battery unit and the link capacitors and the contacts of the switch contactors. First of all, the switch contactor at the negative terminal is closed. Parallel to the switch contactor at the positive terminal is a switchable current path with resistance. This is now activated and a switch-on current restricted by the resistance charges the link capacitors. If the voltage of the link capacitors has reached the approximate value of the battery voltage, the switch contactor at the positive terminal of the high-voltage battery unit is closed.
The high-voltage system is now fully operational.

⚠

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

If there is no fault in the high-voltage system, the entire starting of the high-voltage system is completed in approx. 0.5 seconds.

The SME control unit communicates successful starting via the PT-CAN2 to the EME control unit. Fault statuses are also communicated in the same way, if, for example, a contact of a switch contactor was unable to be closed.

5.5.2. Regular shutdown

When it comes to shutting off the high-voltage system a distinction is made between regular shut-off and fast shut-off. The regular shutdown described here protects all respective components on the one hand, and, on the other hand, includes the monitoring of components of the high-voltage system which are relevant for safety.

If the following preconditions or criteria are present, the high-voltage system is shutdown in the regular manner:

- Terminal 15 is switched off by the driver and the after-running period is expired (controlled by EME).
- End of the functions stationary cooling, auxiliary heater or conditioning of the high-voltage battery unit.
- End of the charging procedure for the high-voltage battery unit.
- End of the charging procedure for the system battery.
- Programming procedure of a high-voltage control unit.

F30 PHEV High-voltage Components

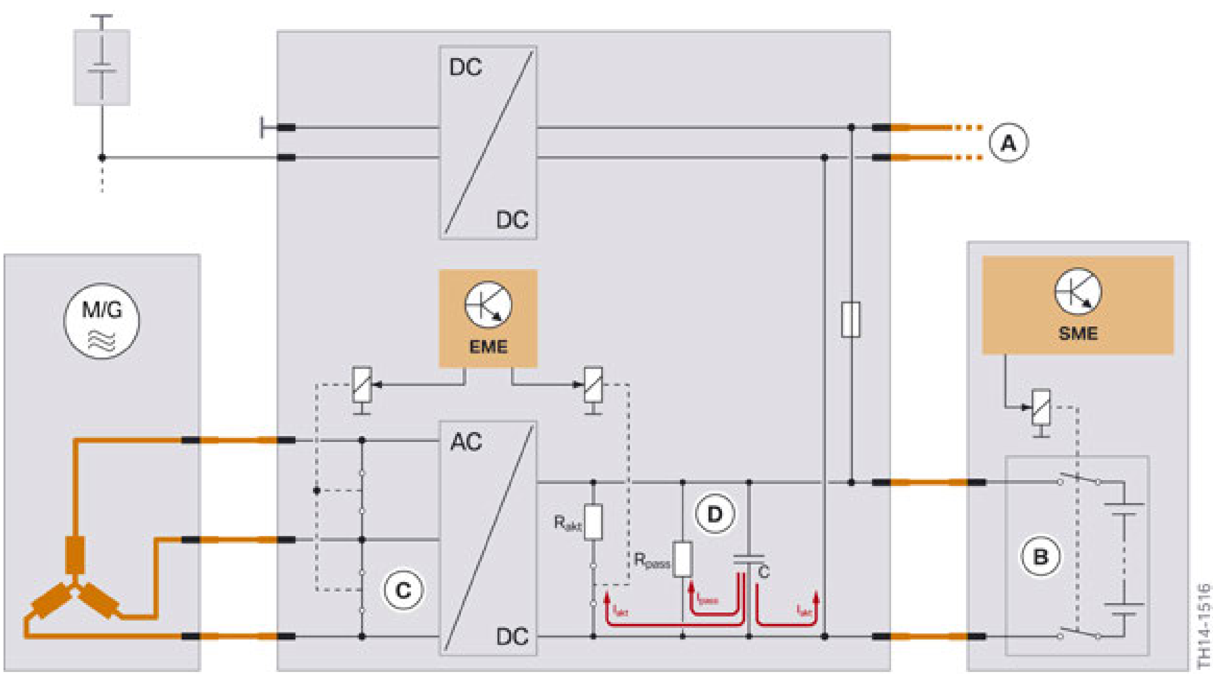
5. High-voltage Battery Unit

The sequence for the regular shutdown is generally the same irrespective of the trigger. The individual steps are:

1. EME orders the shutdown after the after-running period has expired via bus telegrams at the PT-CAN2.
2. The systems in the high-voltage vehicle electrical system (EME, EKK, EH) reduce the currents in the high-voltage vehicle electrical system to zero.
3. Opening the switch contactors in the high-voltage battery unit (controlled by SME).
4. The coils of the electrical machine are short-circuited.
5. Checking the high-voltage system, e.g. as to whether the contacts of the electromechanical switch contactors were correctly opened.
6. Discharging of the high-voltage circuit, i.e. active discharging of the link capacitors (EME).

Discharging of the link capacitors takes place in several stages as necessary

1. First, it is attempted to supply the stored energy to the 12 V system battery.
2. If this is not possible, the link capacitors are discharged via activatable resistors.
3. If the link capacitors have not been discharged below a voltage of 60 V within 5 s, they are discharged via passive resistors.



F30 PHEV Schematic diagram of regular shutdown

Index	Explanation
A	Switch-off of all high-voltage components
B	Opening of switch contactors
C	Short-circuit of the coils of the electrical machine
D	Discharge of the link capacitors

Both the after-running period after switching off terminal 15 and the shutdown itself can last a few minutes. The automatic monitoring functions are a reason for this, for example. The regular shutdown is interrupted if in the meantime either a request for a renewed start-up is made or a condition has arisen to request a quick shutdown.

5.5.3. Quick shutdown

The overriding aim here is to shut down the high-voltage system as quickly as possible. This quick shutdown is then always carried out if for safety reasons the voltage in the high-voltage system has to be reduced to a safe value as quickly as possible. The following list describes the triggering conditions and the functional chain leading to the quick shutdown.

- Accident:
  Advanced Crash Safety Module (ACSM) identifies an accident. Depending on the severity of the accident, the shutdown is requested via data bus telegrams or forced by disconnecting the safety battery terminal from the positive terminal of the 12 V battery. In the second scenario the voltage supply of the electromechanical switch contactors is automatically interrupted and their contacts open automatically.
- Overload current monitoring:
  With help of a current sensor in the high-voltage battery unit the current level in the high-voltage electrical system is monitored. If too high a current level is identified, the battery management electronics control unit causes a hard opening of the electromechanical switch contactor. Considerable wear occurs to the contacts of the switch contactors as a result of this opening under a high current, which must be accepted to protect the other components from damage.
- Protection in the event of a short circuit:
  In each high-voltage battery unit there is an overcurrent fuse which interrupts the high-voltage circuit in the event of a short circuit.
- Critical cell state:
  If a cell supervision circuit identifies extreme undervoltage, overvoltage or excess temperature at a battery cell, this also leads to a hard opening of the electromechanical switch contactors - controlled by the SME control unit. Although this may lead again to increased wear at the contacts, this quick shutdown is necessary to prevent destroying the respective battery cells.
- Malfunction of the 12 V voltage supply of the high-voltage battery unit:
  In this case the battery management electronics control unit no longer works and it is no longer possible to monitor the battery cells. For this reason the contacts of the electromechanical switch contactors also open here automatically.

- High-voltage interlock loop:
  The SME control unit evaluates the signal of the high-voltage interlock loop and checks whether there is an open circuit with this circuit. In the event of an open circuit, the battery management electronics control unit can cause the high-voltage system to perform a quick shutdown. If the high-voltage interlock loop is disconnected at the high-voltage safety connector ("Service Disconnect"), the shutdown is no longer effected via the battery management electronics control unit, but the switch contactors are opened directly.

In addition to the interruption of the high-voltage circuit, the link capacitors are also discharged (EME) and the coils of the electrical machines (EME, EKK) are short-circuited. The high-voltage control units receive the request on the one hand by bus signals and identify this condition on the other hand by the sudden drop in the current level in the high-voltage circuit.

5.5.4. Charging

The SME control unit also plays an important role when charging the high-voltage battery unit, regardless of whether it is by energy recovery, raising the load point of the combustion engine or from the external power supply system. 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 unit can currently absorb. This value is transmitted in the form of a bus signal via the PT-CAN2 to the EME control unit. The high-voltage power management function coordinates the individual power requirements.

During charging, the SME control unit constantly identifies the state of charge already reached and monitors all sensor signals of the high-voltage battery unit. In order to ensure optimal progress of the charging procedure, the SME control unit constantly calculates current values for the maximum charging power based on these values and communicates these to the EME control unit. The cooling system of the high-voltage battery unit is continuously controlled by the SME control unit during the charging procedure. This contributes to a quick and efficient charging procedure.

In order to achieve the highest possible electrical range, a preheating/precooling of the passenger compartment should be effected when the charging cable is connected. The electrical energy required can thus be fed back immediately to the high-voltage battery unit. In the same way the lithium-ion batteries are also simultaneously brought up to the operating temperature.

Further details on the charging procedure, in particular the supply of power to the convenience charging electronics in the F30 PHEV, are provided in the following chapter.

5.5.5. Monitoring functions

There is a large number of monitoring functions in which the high-voltage battery unit and the battery management electronics play a substantial role. This includes:

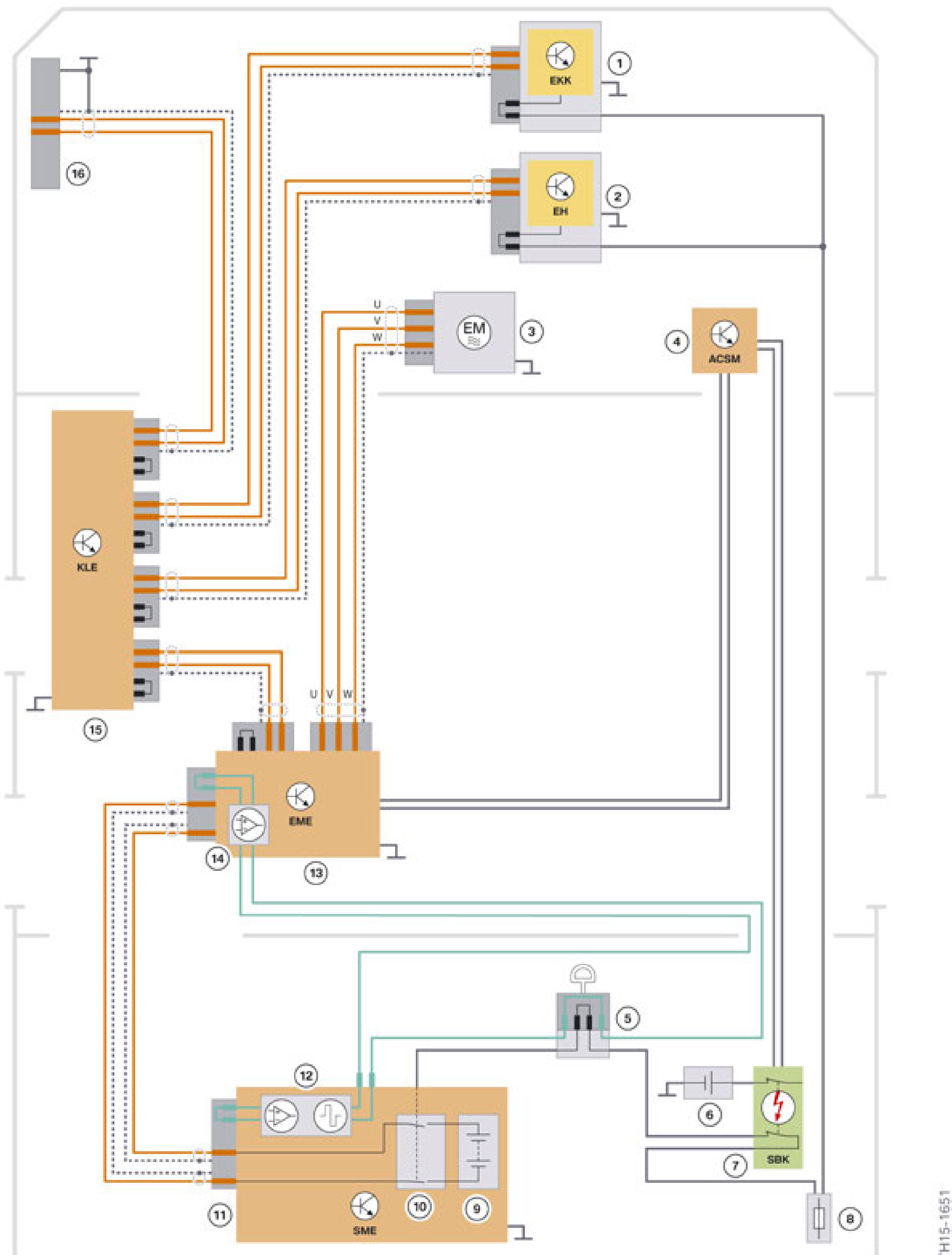
- Monitoring functions to ensure the safety of the high-voltage system.
- Monitoring functions to ensure optimal operating conditions of the high-voltage battery.

For the safety-related monitoring functions, we will specifically discuss the role of the high-voltage battery unit in the high-voltage interlock loop and the insulation monitoring.

The **high-voltage interlock loop** is a circuit for avoiding dangers when working on high-voltage components if the high-voltage electrical system has not been switched off properly beforehand. If this circuit is interrupted, the voltage supply of the high-voltage system is switched off or switched on if the voltage supply of the high-voltage system is prevented.

The principle of the high-voltage interlock loop is familiar from the "Fundamentals of Hybrid Technology" product information bulletin. In the F30 PHEV the high-voltage interlock loop is made up of the high-voltage components pictured below.

5. High-voltage Battery Unit



F30 PHEV, system wiring diagram of high-voltage interlock loop

F30 PHEV High-voltage Components

5. High-voltage Battery Unit

Index	Explanation
1	Electric A/C compressor (EKK)
2	Electrical Heating (EH)
3	Electric motor
4	Advanced Crash Safety Module (ACSM)
5	High-voltage safety connector ("Service Disconnect")
6	12 V battery
7	Safety battery terminal
8	Voltage supply for EKK and EH (luggage compartment power distribution box)
9	Cell modules
10	Switch contactors
11	High-voltage battery unit
12	Evaluation circuit and signal generator for test signal of the high-voltage interlock loop in the battery management electronics
13	Electric Motor Electronics (EME)
14	Evaluation circuit for test signal of the high-voltage interlock loop in the electrical machine electronics
15	Convenience charging electronics (KLE)
16	Charging socket

The electronics for controlling and generating the test signal for the high-voltage interlock loop is integrated in the F30 PHEV in the battery management electronics (SME). Generating the test signal starts when the high-voltage system is to be started and ends when the high-voltage system has been shut down. A rectangular alternating current signal is generated as the test signal by the battery management electronics and supplied to the test lead. The test lead has a ring topology (similar to that of the MOST bus). The signal of the test lead is evaluated at two points in the ring: in the electrical machine electronics and finally right at the end of the ring, in the battery management electronics. If the signal is outside a permanently defined range, an interruption of the circuit or a short circuit in the test lead is detected and the high-voltage system is shut down immediately. If the high-voltage interlock loop at the high-voltage safety connector (“Service Disconnect”) is disconnected, then the switch contactors are opened directly. In addition, all high-voltage components are switched off.

The **insulation monitoring** determines whether the insulation resistance between active high-voltage components (e.g. high-voltage cables) and earth is above or below a required minimum value. If the insulation resistance falls below the minimum value, the danger exists that the vehicle parts will be energized with hazardous voltage. If a person were to touch a second active high-voltage component, he or she would be at risk of electric shock. There is therefore fully automatic insulation monitoring for the high-voltage system of the F30 PHEV.

5. High-voltage Battery Unit

In contrast to the previous high-voltage battery units, the isolation monitoring is now located in the safety box. This has the advantage that it is no longer necessary to route high-voltage lines to the SME. Isolation monitoring is performed at regular intervals (approx. every 5 sec.) by way of a resistance measurement (indirect isolation monitoring) while the high-voltage system is active. Earth serves as the reference potential. Without additional measures only local isolation faults in the high-voltage battery unit could be determined in this way. However, it is equally important to identify isolation faults from the high-voltage cables in the vehicle to ground. For this reason all the electrically conductive housings of high-voltage components are conductively connected to ground. This enables isolation faults in the entire high-voltage vehicle electrical system to be identified from a central point, the high-voltage battery unit.

⚠

The proper electrical connection of all high-voltage component housings to GND is an important prerequisite for the proper functioning of the insulation monitoring. Accordingly, this electrical connection must be restored carefully if it has been interrupted during repair work.

The insulation monitoring responds in two stages. When the insulation resistance drops below a first threshold value, there is still no direct danger to people. The high-voltage system therefore remains active; no Check Control message is output, but the fault status is naturally stored in the fault memory. In this way the Service employee is alerted the next time the car is in the workshop and can then check the high-voltage system. When the insulation resistance drops below a second, lower threshold value, this is accompanied not only by the storage of the fault in the fault memory, but also by the appearance of a Check Control message prompting the driver to visit a workshop.

However, the Service employee does not have to perform a fundamental measurement of the isolation resistance himself – this task is performed by the high-voltage system through the insulation monitoring. When an insulation fault is detected, the Service employee must run through a test schedule in the diagnosis system to find the actual location of the insulation fault.

In addition to the high-voltage interlock loop and insulation monitoring, there are further monitoring functions which are as follows:

- 12 V supply voltage from the safety battery terminal:
  To be able to perform a quick shutdown of the high-voltage system in the event of an accident of corresponding severity, the solenoids of all electromechanical switch contactors are supplied with 12 V from the safety battery terminal. If the safety battery terminal is severed in the event of an accident, this supply voltage is no longer necessary and the contacts of the switch contactors open automatically.
  In addition, the SME control unit evaluates the voltage on this line electronically and also causes the high-voltage system to shut down including discharge of the link capacitors and the active short circuit of the electrical machine.
- Contacts of the switch contactors:
  After the battery management electronics control unit has requested the contacts of the switch contactors to open during the shutdown of the high-voltage system, with help of a voltage measurement a check parallel to the contacts checks whether they have actually been opened. In the highly unlikely case that the contact of a switch contactor does not open, there is no direct danger for the customer or the Service employee. However, for safety reasons a renewed start-up of the high-voltage system is prevented.

- Pre-charge switch:
  If for example during the start-up of the high-voltage system a fault is identified with the pre-charge switch, then the start-up is cancelled immediately and the high-voltage system is not put into operation.
- Excess temperature:
  The cooling system of the high-voltage battery unit ensures in all operating conditions that the temperature of the battery cells is in the optimal range. If due to a fault the temperature of one or several battery cells increases to the extent that the optimal range is left, the power is reduced initially to protect the battery cells. If the temperature continues to increase and thus threatens damage to the battery cells, the high-voltage system is switched off in good time.
- Undervoltage:
  Undervoltage at a battery cell is avoided by the constant monitoring and adjustment of the cell voltage as required. The total voltage of the entire high-voltage battery unit is also monitored and used to determine the state of charge. If the total voltage has fallen to the extent that the high-voltage battery unit is discharged completely, a further discharge is prevented.

5.6. Repair

5.6.1. Safe working practices for working on a high-voltage system

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The following description of the repair of the high-voltage battery unit is only a general list of the content and the procedure. **In general, only the specifications and instructions in the current valid edition of the repair instructions apply.**

⚠

Before working on high-voltage components of the F30 PHEV, it is essential to observe and implement the electrical safety rules:

1. The high-voltage system must be disconnected from the supply.
2. The high-voltage system must be secured against restart.
3. The safe isolation of the high-voltage system must be verified.

The following chapter provides brief descriptions on how to implement the electrical safety rules in the F30 PHEV.

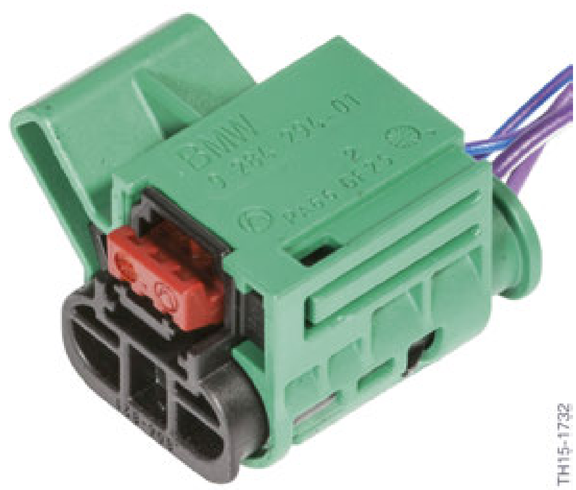
Preparations

Prior to beginning any work, the vehicle must be secured against rolling away (engage the parking lock of the transmission and activate the parking brake). Terminal 15 and terminal R must be switched off. Any charging cable connected in the vehicle must be disconnected. The vehicle electrical system must also be in "Sleep" mode. This can be detected by the non-illuminated START-STOP button.

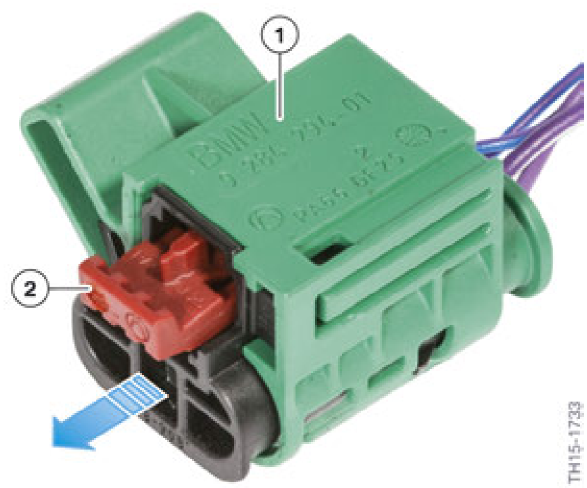
Disconnect the high-voltage system from the supply

The high-voltage system in the F30 PHEV is disconnected from the supply with the high-voltage safety connector. To disconnect from the supply, the connector must be pulled from the relevant bush. The circuit of the high-voltage interlock loop is interrupted and the high-voltage system is disconnected from the supply. In addition, the voltage supply of the switch contactors is also interrupted.

This figure shows the installation location of the high-voltage service disconnect (green). The high-voltage service disconnect is connected. The circuit of the high-voltage interlock loop is not interrupted.



To pull apart the bush and the connector, the red mechanical lock shown in the image must be removed.



As soon as the lock (1) has been removed, the connector can be pulled from the bush (2) a few millimeters.

⚠

Do not pull any further or harder if resistance can be felt. The connector and bush of the high-voltage safety connector cannot be disconnected from each other completely.

Provide the high-voltage system with a safeguard against unintentional restarting

Securing against restart is also effected at the high-voltage safety connector. A commercially available U-lock (for example ABUS® 45/40) is required for this purpose.

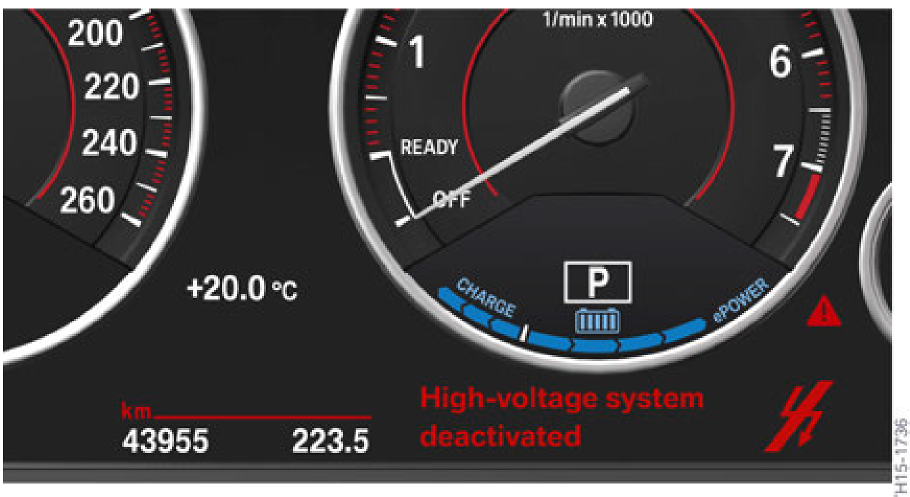
By separating the bush and connector of the high-voltage safety connector, a bore hole (1) becomes free through both parts. The loop of a typical U-lock must be inserted in this bore hole.

The U-lock can now be closed. The key must be stored in a safe place during work on the high-voltage system so that an unauthorized person cannot unlock the lock.
The connector can no longer be used by inserting and closing the U-lock at the high-voltage safety connector. This is an effective way of ensuring that the high-voltage system is not switched on again without the knowledge and consent of the Service employee.

Verifying safe isolation from the supply

The de-energized state is not verified using a measuring device or via the BMW diagnosis system in the BMW Service workshop. Instead, the high-voltage components measure the voltage themselves and transmit the measuring result via bus signal to the instrument cluster.

The instrument cluster does not generate the Check Control message to display the de-energized state unless all involved high-voltage components consistently signal the de-energized state. This Check Control symbol in red shows a crossed-out flash symbol. The text message "High-voltage system deactivated" also appears.



Check Control symbol "High-voltage system deactivated"

In order to verify the de-energized state, you must switch on terminal 15 and wait until you see the Check Control message with the symbol shown above on the instrument cluster. Then, and only then, you have ensured that the high-voltage system is de-energized. After the de-energized state has been verified, terminal 15 and terminal R must be switched off again before you can start the actual work.

⚠

If the Check Control message is not displayed, you must not carry out any work on high-voltage components! Contact the Technical Support (PUMA) of BMW Group in this case!

5.6.2. Procedure after an accident

The safety concept of the high-voltage system ensures that, even during or after an accident, there is no danger to the customer, the rescue services or the Service employee. The high-voltage system is automatically deactivated in the event of an accident in such a way that no dangerous voltages are applied at those points on the high-voltage components which are accessible from the outside. Deactivation of the high-voltage system is effected as follows:

In normal operation, the battery management electronics are supplied via terminal 30. The coils of the electromechanical switch contactors are also supplied. Deactivation in the event of an accident is effected by an extended battery safety terminal. It contains an additional normally closed contact. This switch contact opens when the battery safety terminal is triggered at the same time as the positive battery cable is severed. Opening this switch contact causes the switch contactors in the high-voltage battery unit to open directly so that no more dangerous voltage can be fed into the high-voltage electrical system from the high-voltage battery unit. The electrical machine electronics receives a crash signal from the Advanced Crash Safety Module (ACSM). The electrical machine electronics then discharges the link capacitors immediately.

After an accident the safety battery terminal remains in the state described above such that the high-voltage battery unit is not operational. Thus the high-voltage system remains inactive even if terminal 15 is switched on again.

⚠

Before working on the high-voltage components or on the safety battery terminal of a F30 PHEV which has been involved in an accident with a triggered battery safety terminal, contact the Technical Support (PUMA) of the BMW Group.

5.6.3. Second separation point for the emergency services

F30 PHEV, installation location of emergency separation point

A second emergency separation point is necessary as a result of the requirements of the emergency services, which state that vehicles with an electrical drive system must have two separate emergency separation points. The second separation point is always found opposite the high-voltage service disconnect in the vehicle. If the high-voltage service disconnect is located in the luggage compartment, the emergency separation point is then located in the engine compartment.

The emergency separation point is a line with terminal 30C. Terminal 30C supplies the switch contactor in the safety box with voltage. This line is cut through at the marked point to ensure that the switch contactors open. The emergency separation point can be repaired after it has been cut through.

5.6.4. Transport mode

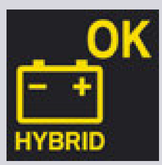
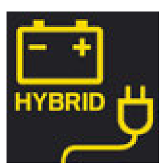
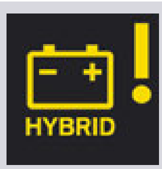
To protect the high-voltage battery unit, the following functions are not available in transport mode:

- Electric driving
- Boost function
- Automatic Engine Start-Stop

The high-voltage battery unit is always charged in transport mode if the combustion engine is running.

Display of the state of charge

Like with other vehicles, in transport mode the state of charge of the 12 V battery is displayed as a Check Control message. In the F30 PHEV, also in transport mode a Check Control message is displayed for the state of charge of the high-voltage battery unit. The state of charge of the high-voltage battery unit is displayed in three stages:

Battery condition	Display in instrument cluster	Action
State of charge of the high-voltage battery unit is OK		No further work necessary
High-voltage battery unit is discharged		Charge high-voltage battery unit!
High-voltage battery unit is deep-discharged		Replace high-voltage battery unit!

If the high-voltage battery unit was dead, the display in the instrument cluster remains until the high-voltage battery unit is replaced. After resetting transport mode, there are no Check Control messages on the state of charge of the high-voltage battery unit in the instrument cluster.

F30 PHEV High-voltage Components

6. Charging the HV Battery Unit

6.1. General information on charging

6.1.1. Introduction

The "charging" procedure for an electric vehicle corresponds to "refuelling" a conventionally driven vehicle. Accordingly, in this chapter "charging" means:

- Charging the high-voltage battery unit in the vehicle
- while at standstill (not through brake energy regeneration)
- by supply of electrical energy,
- which is provided by an AC voltage network outside the vehicle
- and is fed to the vehicle via a charging cable.

As a charging cable is used, one also refers to conductive (grid-bound) charging.

Components inside and outside the vehicle are required for charging. In the vehicle a charging socket and power electronics are required for the voltage conversion. Outside the vehicle a device which performs the protection and control functions is needed, in addition to the AC voltage network and a charging cable. This device is called "Electric Vehicle Supply Equipment (EVSE)" in the standards and in development.

The Electric Vehicle Supply Equipment (EVSE) can either be integrated in the charging cable or be an element of a fixed public charging station or domestic wallbox. The EVSE establishes the connection to the AC voltage network and serves for the fulfilment of requirements for electrical safety when charging the vehicle. Communication to the vehicle can also be set up via the so-called pilot line. As a result, it is possible to safely start the charging procedure and exchange the charging parameters (e.g. maximum current level) between vehicle and EVSE. Details on the possible versions, structure and functioning of the EVSE are described in one of the following chapters.

The voltage of the AC voltage network can be in the range of 100 V to 240 V. It is fed to the vehicle via a single-phase supply. From the AC voltage network side, in theory a maximum charging power of $P_{max} = U_{max} \times I_{max}$ = 230 V x 16 A = 3.7 kW is possible.

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

⚠

Refuelling the vehicle while the high-voltage battery unit is charging is not permitted!

When the charging cable is inserted, do not refuel and keep a safe distance from highly flammable materials. Otherwise, in the event of incorrect connection or removal of the charging cable, there is a risk of personal injury or material damage, for example by burning fuel.

⚠

While the F30 PHEV is connected to the AC voltage network for charging, no work may be performed at the high-voltage system.

⚠

During the charging procedure the electric coolant pumps and the electric fan can be switched on automatically for cooling the electrical machine electronics. It is for this reason that no work may be performed on the cooling system of the electrical machine electronics and high-voltage battery unit, or on the electric fan, when a charging cable is connected to the F30 PHEV.

⚠

Work at the charging cable, at the Electric Vehicle Supply Equipment, at household sockets or charging stations can only be performed by qualified electricians, and **not** by BMW Service employees.

6.1.2. Overview of charging options

The high-voltage battery unit of the F30 PHEV can generally only be charged by alternating current (AC charging) at a maximum charging power of 3.7 kW. The charging option for the high-voltage battery unit in the F30 PHEV is generally determined by the country-specific charging infrastructure. The following table provides an overview of the worldwide charging options. The charging powers and the resulting charging times always relate to the mains power and not the charging power used to charge the high-voltage battery unit. The charging power is always less than the available mains power.

Charging with direct current (DC charging) is not supported by the F30 PHEV.

Country	Charging power	Charging time	Connector (type)	Charging accessories
ECE	1-phase, 3.7 kW AC	~3:50 h (2.7 kW) ~2:45 h (3.7 kW)	Type 2 IEC62196-2	Charging cable 2.7 kW AC charging station 3.7 kW
US	1-phase, 3.7 kW AC	~7:40 h (1.4 kW) ~2:45 h (3.7 kW)	Type 1 IEC62196-2	Charging cable 1.4 kW AC charging station 3.7 kW
Japan	1-phase, 3.7 kW AC	~7:50 h (1.3 kW) ~2:45 h (3.7 kW)	Type 1 IEC62196-2	Charging cable 1.3 kW AC charging station 3.7 kW
China	1-phase, 3.7 kW AC	~5:15 h (1.8 kW) ~2:45 h (3.7 kW)	Type CN	Charging cable 1.8 kW AC charging station 3.7 kW

6.1.3. Electric Vehicle Supply Equipment

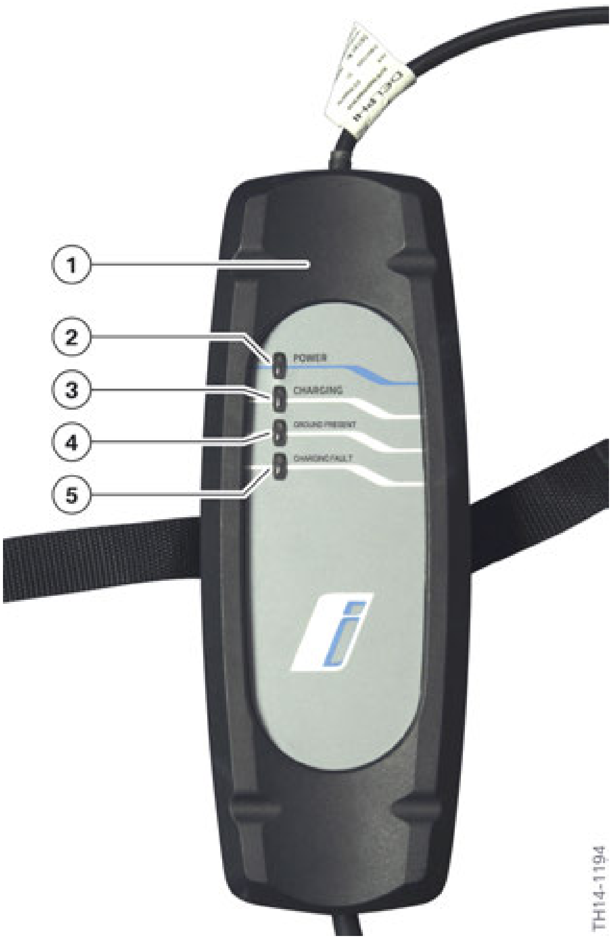
The EVSE establishes the connection to the AC voltage network and serves for the fulfilment of requirements for electrical safety when charging the vehicle. Communication to the vehicle can also be set up via the so-called pilot line. As a result, it is possible to safely start the charging procedure and share the charging parameters (e.g. maximum current level) with the vehicle. The EVSE can either be integrated in the charging cable (mobile solution) or be an element of a fixed public charging station or a domestic wallbox.

In both cases the EVSE contains the following subcomponents:

- Ground leakage circuit breaker (FI)
- Display whether the AC voltage network is connected and available
- Disconnecting switch for phase (L1) and neutral conductor (N)
- Electronic switching for generating the pilot signal
- Continuous protective earth (PE)

Mobile solution

The version integrated in the charging cable is designated in the standard as ICCPD (In-Cable Control and Protection Device) or “In-Cable-Box” for short and is intended for mobile use. The volume and weight of this solution is low and the charging and EVSE can be easily transported in the vehicle.



F30 PHEV, EVSE for mobile use

Index	Explanation
1	BMW i mobile EVSE
2 (yellow)	Display for the availability of the voltage supply
3 (green)	Display for charging
4 (yellow)	Display for ground present
5 (red)	Display for fault during charging

As a typical household power socket is used for the connection of this EVSE to the AC voltage network, the maximum current level is restricted for charging.

⚠

Please consult the operating instructions of the respective manufacturer for the operation and use of a charging cable with an integrated EVSE.

Employees in BMW Service cannot perform any maintenance or repair work on the charging cable or the EVSE. In the event of a defect with or a malfunction of the charging cable or the EVSE, the manufacturer must be contacted.

F30 PHEV High-voltage Components

6. Charging the HV Battery Unit

Permanent charging station

This version of the Electric Vehicle Supply Equipment must be installed permanently owing to its size and electrical requirements, e.g. at the house or in the customer's garage. Such a charging station can also be built at public places, e.g. car parks.

⚠

The installation, maintenance and repair of permanent charging stations can only be performed by suitably qualified electricians. Employees in BMW Service are **not** authorised to perform these tasks.

AC charging stations

The connection of the AC charging stations to the AC voltage network can be via a two-phase (US market) or three-phase (typical in Germany) supply – the connection to the F30 PHEV is, however, always designed as a single-phase supply. In comparison to the mobile solution, a maximum current level of 32 A is possible. These maximum values are, however, still dependent on the size of the line cross-section, which was used in the electrical installation at the charging site. The electrician configures the charging station during installation according to the line cross-section so that the applicable maximum current level is transmitted to the vehicle using the pilot signal.

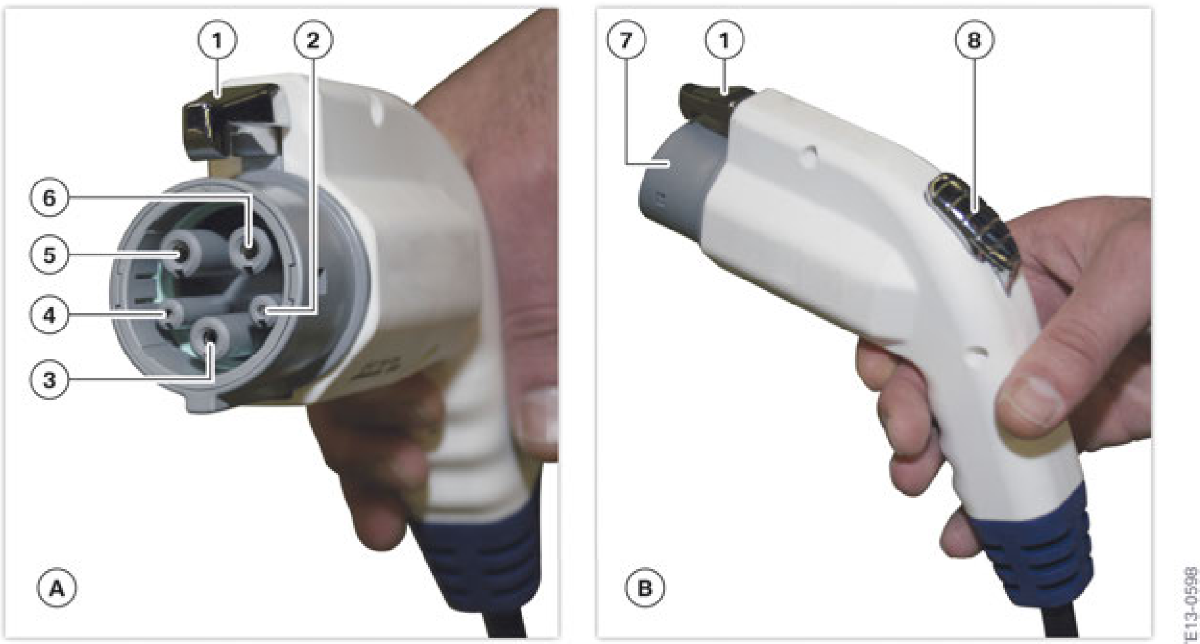
The convenience charging electronics (KLE) of the F30 PHEV generally only support charging at a maximum power of 3.7 kW. Charging at an excessive current level is avoided through communication via the pilot line and the proximity (charging plug detection) resistor.

The following graphic shows an AC charging station for the US market.

F30 PHEV, example of a permanently installed charging station (wallbox) AC charging station for the US market, manufactured by AeroVironment

6. Charging the HV Battery Unit

Index	Explanation
1	Display of the operating condition
2	Button for starting and stopping the charging procedure
3	Charging cable with connector for the connection at the vehicle (stored in the AC charging station)



F30 PHEV, Connector of the charging cable for the connection to the vehicle (standardized i.a.w. IEC 62196-2: Type 1)

Index	Explanation
A	View from the side of the electrical connection
B	View from the side of the handle
1	Mechanical locking
2	Connection for pilot line
3	Connection for protective earth
4	Connection for proximity line
5	Connection for phase L1
6	Connection for neutral conductor (N)
7	Mechanical guide/connector housing
8	Button for the mechanical unlocking of the connector before removal

AC charging stations from other manufacturers or the versions for other countries may differ from the versions shown here.

6.2. Charging with AC voltage

Although the high-voltage battery unit of the F30 PHEV can also be partially charged by energy recovery via the electrical machine, the "normal" charging procedure takes place when the F30 PHEV is connected to the AC voltage network of the local power supply company. Energy is taken from the AC voltage network and fed to the direct current voltage high-voltage electrical system of the F30 PHEV.

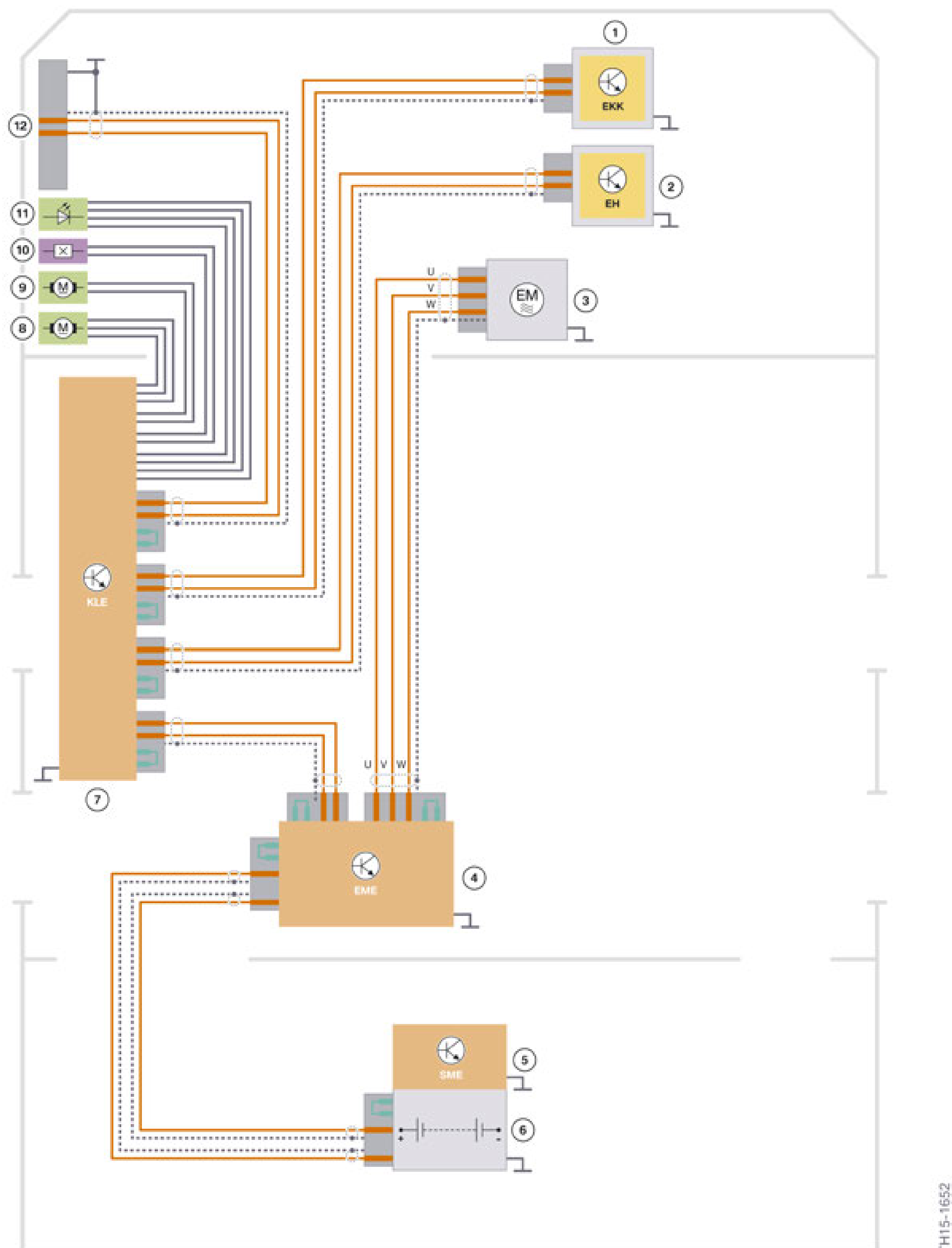
The F30 PHEV can be connected to an AC charging station or charged via the "In-cable box".

The advantage of this charging option is that for charging the high-voltage battery unit the charging cable can be connected at any typical household power socket with protective contact.

The charging procedure is never carried out with the maximum possible charge current. At the start, charging takes place with constant current. Switchover to constant voltage takes place towards the end. The actual charging time is increased as a result, and the service life of the battery cells is extended.

If the F30 PHEV is connected to an AC charging station, the maximum possible charging power of approx. 3.7 kW is also available (provided the AC charging station is designed for this).

6.2.1. System wiring diagram



F30 PHEV, system wiring diagram for AC charging with 3.7 kW

Index	Explanation
1	Electric A/C compressor (EKK)
2	Electrical Heating (EH)
3	Electric motor
4	Electric Motor Electronics (EME)
5	Battery management electronics (SME)
6	High-voltage battery unit
7	Convenience charging electronics (KLE)
8	Drive, connector fastener
9	Drive, charging socket cover
10	Charging socket cover sensor
11	Locator and status lighting
12	Charging socket at the vehicle

6.2.2. Charging cable

Charging cable with integrated mobile version of the Electric Vehicle Supply Equipment (Charging mode 2 i.a.w. IEC 61851)

Index	Explanation
1	Connector for the connection at the vehicle
2	Electric Vehicle Supply Equipment (integrated, also called "In-Cable box")
3	Connector for connection at typical household power socket

The charging cable is used to join the following components:

- Specific national-market connection for typical household power socket with protective contact.
- Plug connection between specific national-market connector and "In-Cable box".
- "In-Cable box" (EVSE).
- Plug connection between "In-Cable box" and connector for vehicle connection.
- Connector for vehicle connection.

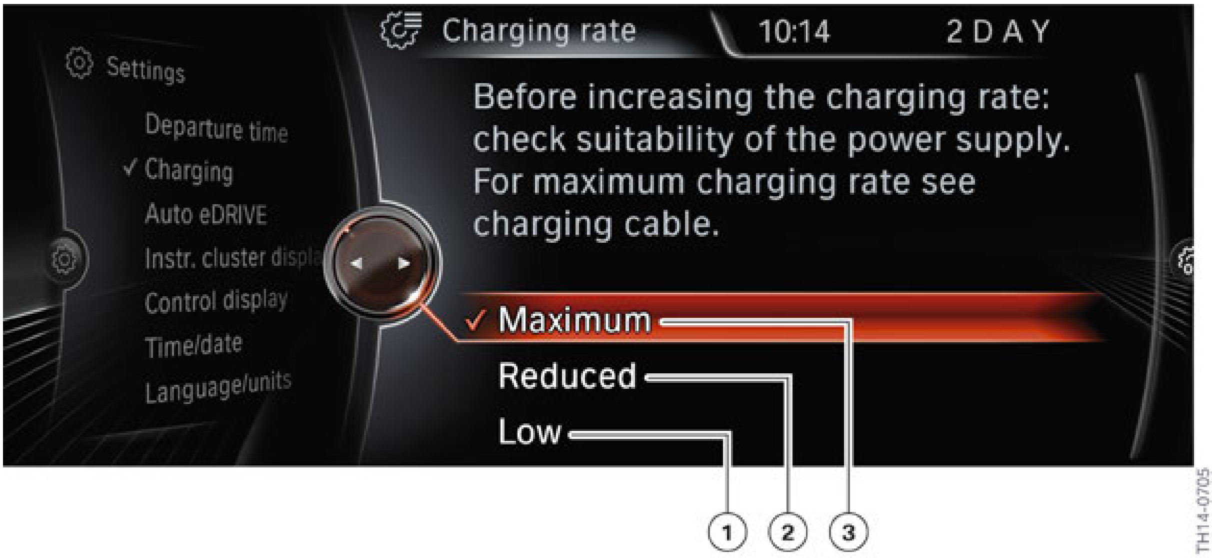
The charging cable is the electrical connection between the AC voltage network and the direct current voltage high-voltage electrical system of the vehicle. The connection at the AC voltage network is effected at a typical household power socket with protective contact, which includes no EVSE. In this case the switching and functions of the EVSE are integrated in the charging cable. This is called an "In-Cable box". This charging cable for the F30 PHEV is always designed for single-phase supply, in line with the charging socket at the vehicle (phase L1 and neutral conductor N) and always includes the Protective Earth (PE), as well as the pilot line and line for charging plug detection. The connector is designed so that the connection is first made with the protective contact. The ground is earthed via the protective earth.

The charging cable can be stored in the charging cable area in the luggage compartment.

⚠

Please consult the operating instructions of the respective manufacturer for the operation and use of a charging cable with an integrated EVSE.

Employees in BMW Service cannot perform any maintenance or repair work on the charging cable or the EVSE. In the event of a defect with or a malfunction of the charging cable or the EVSE, the manufacturer must be contacted.



F30 PHEV, menu for the setting of the current level

Index	Explanation
1	Charge current "Low", approx. 50 % of possible current level (information via the line for charging plug detection), but at least 6 A.
2	Charge current "Reduced", 75 % of possible current level (information via the line for charging plug detection), however, minimum 6 A.
3	Charge current "Maximum", 100 % of possible current level (information via the line for charging plug detection).

The maximum current level when charging using the standard charging cable at the socket can be restricted via the "Settings" menu in the vehicle. If the maximum permitted current level at the power socket is insufficient or unknown, it is recommended to adjust the current level to "Reduced" or "Low".

If the current level set by the customer has been changed during a workshop visit, it is imperative to ensure that it is reset again before handing over the vehicle to the customer. Otherwise there is a risk that the private household supply network of the customer is overloaded, and the activation of the household fuses could then be interpreted as a fault by the customer.

⚠

The maximum charge current must always be reset to the customer's settings before handover of the vehicle.

6.2.3. What must be observed when charging the high-voltage battery unit?

⚠

It is not permitted to simultaneously charge the high-voltage battery unit and fill the fuel tank!

When the charging cable is connected, do not fill the fuel tank and keep a safe distance from highly flammable materials. Otherwise, in the event of an improper connection or if the charging cable is pulled out, there is a risk of personal injury or material damage, for example by burning fuel.

Charging the high-voltage battery unit using a typical household power socket results in a high continuous load on the power socket, which does not occur with other household appliances. Therefore, the following information must be observed:

- Do not use an adapter or extension cable.
- First connect the EVSE to the household socket, then to the charging socket at the vehicle.
- After charging, plug the charging plug into the vehicle first and then into the wall.
- Avoid tripping hazards and mechanical loads for charging cables and power sockets.
- Do not insert the charging plug in damaged power sockets.
- Do not use damaged charging cables.
- The charging plug and charging cable may become warm when charging the high-voltage battery unit. If they become too hot, the power socket is not suitable for charging or the charging cable is damaged. Stop charging immediately and have the power socket and charging cable checked by an electrician.
- In the event of repeated charging faults or terminations contact a suitably qualified Service employee.
- Only use power sockets protected against moisture and weathering.
- Do not touch contact areas of connectors with fingers or objects.
- Never repair or modify a charging cable yourself.
- Remove cable on both sides before cleaning. Do not immerse in fluids.
- Do not wash car while charging HV battery
- Only charge at power sockets checked by an electrician
- Observe special information in the operating instructions for charging at unknown or unfamiliar infrastructure/power sockets. Set the charging current in the vehicle to "Low".

6.2.4. Charging socket at the vehicle

The charging socket at the F30 PHEV is located on the left side of the front side panel. The charging socket cover is locked and unlocked using an electric motor. This electric motor drive is controlled by the convenience charging electronics. The charging socket cover can be opened only in selector lever position P and with unlocked vehicle central locking system. It can be opened after unlocking by pressing on the charging socket cover. The charging socket cover and the connector assignment are shown in the following graphic.

F30 PHEV, charging socket at the vehicle

Index	Explanation
1	Locator lighting / status lighting
2	Connection for neutral conductor N
3	Connection for phase L1
4	Connection for proximity line
5	Connection for protective earth (ground)
6	Connection for pilot line

The high-voltage cables of the charging socket are connected to the convenience charging electronics. Phase L1 and neutral conductor N are designed as shielded high-voltage cables and are terminated with a round high-voltage connector at the alternating current connection of the convenience charging electronics. The pilot line and the line for the charging plug detection (proximity line) are realized as simple signal lines. These signal lines are also shielded and are terminated via a plug adapter at a connector in the convenience charging electronics. The protective earth is connected electrically to ground in close proximity to the charging socket. This way the ground is earthed.

F30 PHEV High-voltage Components

6. Charging the HV Battery Unit

For the US, (Type 1/CN connector), the connector is locked as long as the vehicle is locked.

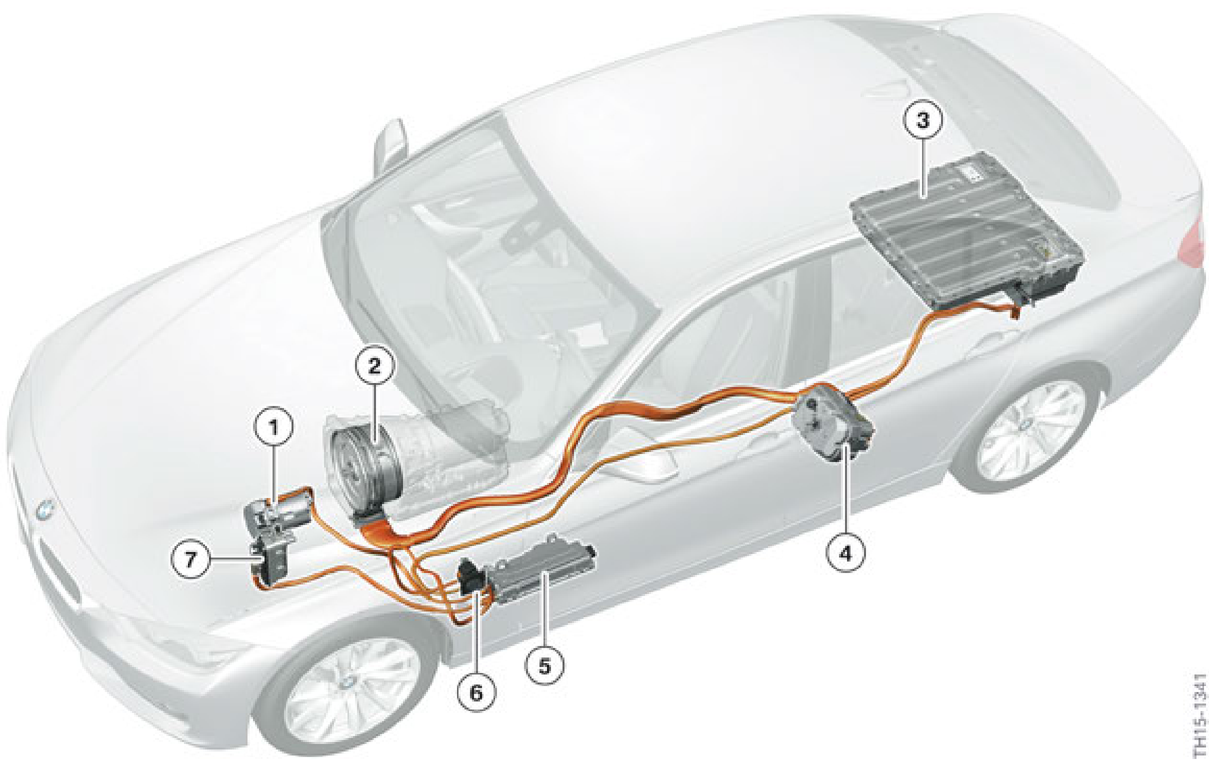
A ring-shaped fibre-optic conductor runs around the charging socket at the vehicle, which is used to show the charging status. The fibre-optic conductor is illuminated by an RGB LED, which is controlled by the convenience charging electronics.

⚠

The charging socket at the vehicle can only be replaced together with the high-voltage cable as one unit.

6.2.5. Convenience charging electronics

The convenience charging electronics KLE enables communication between the vehicle and charging station. The convenience charging electronics can also wake up the control units in the vehicle electrical system when the charging cable is connected. The convenience charging electronics convert the AC charging voltage into a direct current voltage and forward this to the EME, which can now charge the high-voltage battery unit.



F30 PHEV High-Voltage Components

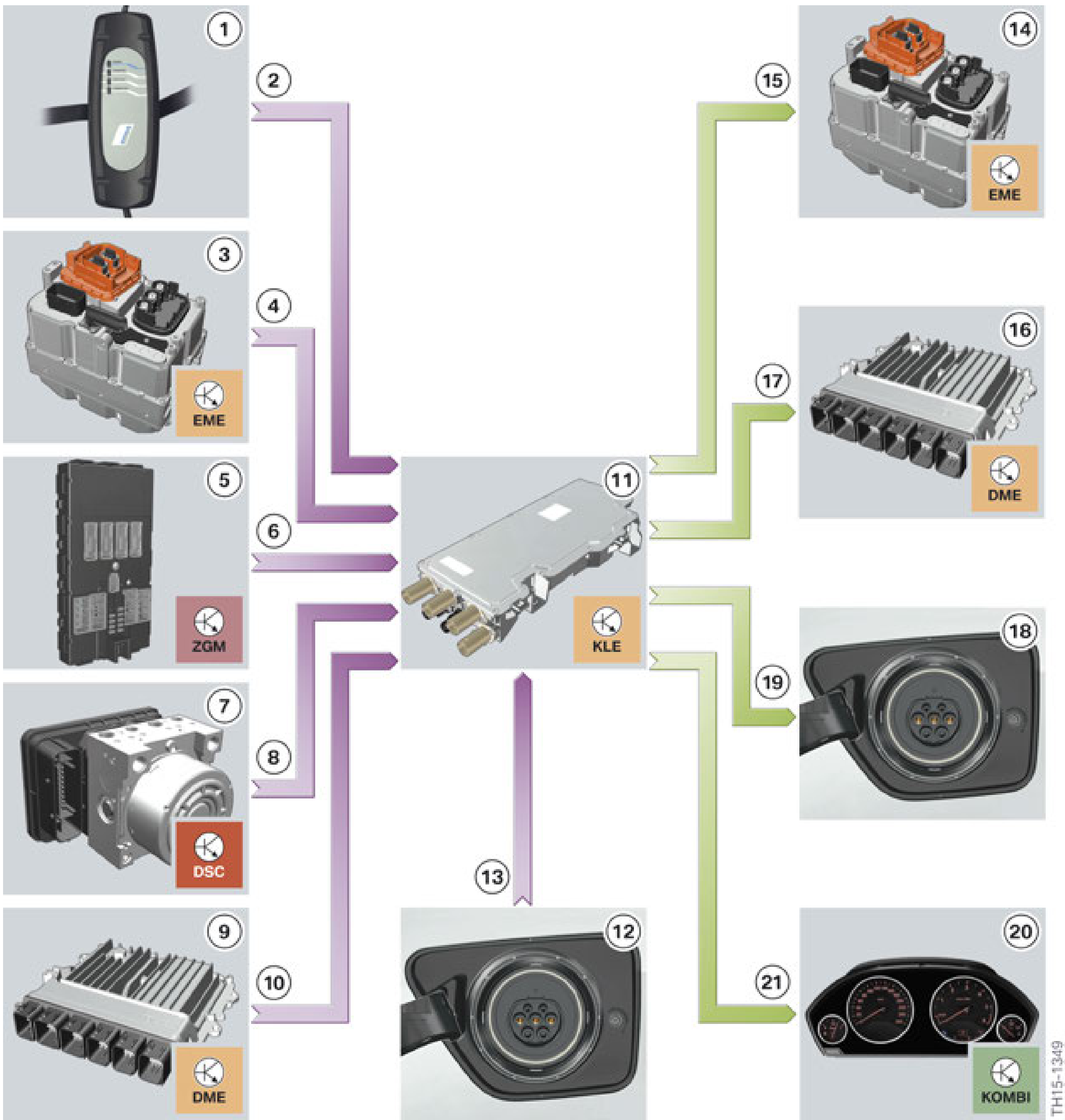
6. Charging the HV Battery Unit

Index	Explanation
1	Electric A/C compressor (EKK)
2	Electric motor
3	High-voltage battery unit
4	Electric Motor Electronics (EME)
5	Convenience charging electronics (KLE)
6	Charging socket
7	Electrical Heating (EH)

The main tasks of the convenience charging electronics are:

- Communication with EVSE via pilot line and line for charging plug detection.
- Activation of the LEDs for displaying the charging status.
- Detection of the status of the charging socket cover.
- Activation of the electric motor for locking the charging plug.
- Converting the AC voltage into direct current voltage (AC/DC converter).
- Supplying the electric A/C compressor with high voltage.
- Supplying the electrical heating with high voltage.

6. Charging the HV Battery Unit



F30 PHEV, convenience charging electronics input/output

Index	Explanation
1	Electric Vehicle Supply Equipment (EVSE)
2	Information whether the AC voltage network is available and the charging cable is correctly connected, as well as the maximum available current level.
3	Electric Motor Electronics (EME)
4	Requested charging power, charging voltage and charging current level (setpoint values).

6. Charging the HV Battery Unit

Index	Explanation
5	Central gateway module (ZGM)
6	Terminal status, driving readiness switched off
7	Dynamic Stability Control (DSC)
8	Vehicle speed
9	Digital Motor Electronics (DME)
10	Status of parking lock
11	Convenience charging electronics (KLE)
12	Charging socket at the vehicle
13	Status of the charging socket cover and the charging plug
14	Electric Motor Electronics (EME)
15	Actual value of the set charging power, charging voltage and charging current level, charging release.
16	Digital Motor Electronics (DME)
17	Information whether the charging cable is connected and the charging procedure is active.
18	Charging socket
19	Activation of the LED for locator lighting and charging status display, activation of the charging plug lock.
20	Instrument panel
21	Signals for the display of charging information.

Communication with EVSE via pilot line and line for charging plug detection

The pilot line and the line for the charging plug detection are realized as simple signal lines. These signal lines are shielded and are terminated at a connector in the convenience charging electronics.

Via the line for the charging plug detection the connection of the charging plug in the charging socket at the vehicle is identified, and the maximum current carrying capacity of the charging cable is determined. An ohmic resistor is connected in the connector of the charging cable between the proximity connection and the PE conductor. The convenience charging electronics applies a measurement voltage and calculates the resistance value in the line for the charging plug detection. The resistance value specifies which maximum current level is allowed for the charging cable used (dependent on the line cross-section). The assignment of resistance – current level is specified in the standard IEC 61851 - 1. ed. 3.

6. Charging the HV Battery Unit

The pilot line is required for the determination and transmission of the maximum available charging current level. The pilot signal is a bipolar rectangle signal (-12 V to +12 V). The voltage and the duty cycle are used for the communication of different statuses between EVSE and F30 PHEV:

- Electric vehicle is ready to charge (Yes/No)
- Fault present (Yes/No)
- Maximum charge current which can be provided by the AC voltage network
- Charging complete

Coordinating the charging procedure

Coordination for starting and ending the charging procedure is performed by the high-voltage power management in the EME.

There are two actions required by the customer at the start of the charging procedure:

1 Set the start time for charging.

2 Connect the charging cable.

F30 PHEV, menu for the setting of the start of charging

Using the controller and the menu in the Central Information Display (CID) the customer can set and adjust the start time for charging in the vehicle. The customer can select to start the charging procedure immediately after connecting the charging cable or specify a time at which the charging procedure should start.

When the customer connects the charging cable connected to the AC voltage network, the convenience charging electronics wakes up the control units in the vehicle electrical system (if they have not already been woken up by another event). The convenience charging electronics uses the wake-up line wired directly to the BDC control unit for this purpose. The convenience charging electronics then checks the functional prerequisites for charging and receives information about the conditions relevant for safety via the powertrain CAN.

6. Charging the HV Battery Unit

These checks are summarized in the following list:

- Driving readiness off AND
- Parking lock engaged AND
- Charging cable connected (proximity) AND
- Communication with EVSE OK (pilot) AND
- High-voltage system active and trouble-free.

When all prerequisites for charging are satisfied, the high-voltage power management in the EME requests a charging power from the convenience charging electronics and starts the charging procedure. The EME control unit sends not only setpoint values for the charging power, but also specifies limit values for the maximum charging voltage and the maximum charge current. These values are based on the current condition (e.g. state of charge and temperature) of the high-voltage battery unit and on the power requirement of the rest of the vehicle electrical system (e.g. for climate control). The EME control unit cleverly implements these setpoint values, i.e. it takes into consideration not only the setpoint values, but other marginal conditions. These include the actual status of the electrical machine electronics (fault, temperature), as well as the current level restricted by the AC voltage network and the charging cable.

The voltage is applied to phase L1 only after communication between the vehicle (KLE) and EVSE via the pilot line has been successfully started. This also gives further protection for customers and Service employees against the dangers of electricity.

Activation of the LEDs for displaying the charging status

A ring-shaped fibre-optic conductor runs around the charging socket at the vehicle and is used to display the charging status. This fibre-optic conductor is also used as locator lighting for the charging socket. The fibre-optic conductor is illuminated by an RGB LED, which is controlled by the convenience charging electronics.

TH15-1090

Locator lighting:
The locator lighting of the charging socket is used as an orientation aid by the driver for the connection and disconnection of the charging plug.
The RGB LEDs light up in white as soon as the charging socket cover has been opened. The locator lighting remains switched on as long as the bus systems are active. As soon as a charging plug has been identified as correctly connected, the locator lighting is switched off and the initialization status is displayed.

Initialization:
Initialization begins approx. 0 to 3 seconds after the charging plug has been inserted correctly.
The initialization phase takes up to 10 seconds
The RGB LEDs flash orange during this time at a frequency of 1 Hz.
After successful initialization, charging of the high-voltage battery unit can be started.

Charging active:
The currently active charging procedure of the high-voltage battery unit is indicated by blue flashing of the RGB LEDs. The flashing frequency is approx. 0.7 Hz.
Charging interval:
Charging interval or charging readiness present when the initialization phase was completed successfully and the charging start is sometime in the future (e.g.: charging at a less expensive time). In this case, the RGB LEDs light up permanently in blue.

Charging complete:
The state of charge of the high-voltage battery unit "fully charged" is indicated by illumination of the RGB LEDs in green.

Fault during charging:
If faults occur during the charging procedure, then this status is displayed by the RGB LEDs flashing in red. The RGB LEDs flash three times for 12 seconds long at a frequency of approx. 0.5 Hz and with an interval of approx. 0.8 seconds between the groups of three.

The RGB LEDs for these displays are activated for 12 seconds after the charging plug is connected or after unlocking/locking the vehicle. If during this time the vehicle is unlocked/locked again, the display lasts for another 12 seconds.

Opening the charging socket cover

The charging socket cover is locked by the central locking. After the unlocking, the charging socket cover must be pressed. An ejector is operated which pops up the charging socket cover.

A sensor is also installed in the cover of the charging socket (hall-effect sensor). The status of the hall-effect sensor provides information on the status of the charging socket cover (open/closed).

Locking the charging plug

For the US, (Type 1/CN connector), the connector is locked as long as the vehicle is locked. The electrical lock of the charging plug prevents the charging plug being disconnected when the vehicle is locked.

In the event of an electrical fault, e.g. malfunction of the locking motor, the charging plug can be unlocked manually. The cable for emergency release is located in the engine compartment at the front left wheel arch.

The charging plug is unlocked by pulling on this button.

6.2.6. Power electronics in the convenience charging electronics

The power electronics for the conversion of the AC voltage from the charging socket to direct current voltage, which is required for charging the high-voltage battery unit, are housed in the convenience charging electronics. The AC voltage is fed to the convenience charging electronics as a single-phase supply. The input voltage, which can be processed by the convenience charging electronics, may be in the following range: 100 V to 240 V, 50 Hz or 60 Hz.

The power electronics module is a unidirectional AC/DC converter, i.e. a rectifier.

At the output, which is separated galvanically from the input, the convenience charging electronics supplies an electronically adjustable direct current voltage or an electronically adjustable direct current flows. The specifications for the output voltage and the output current come from the function "High-voltage power management" in the EME control unit. The values are calculated and adjusted by the EME so that the high-voltage battery unit is optimally charged and the other consumers in the F30 PHEV are supplied with sufficient electrical energy.

The convenience charging electronics is designed so it can provide a maximum electrical power of 3.7 kW on the output side.

F30 PHEV High-voltage Components

7. Hybrid Brake System

7.1. Introduction

The function of the brake system of the F30 PHEV is to decelerate the vehicle safely under stable conditions. Vehicle deceleration is made up of a

- conventional hydraulic braking share and a
- regenerative braking share.

Thanks to regenerative braking it is possible to convert the kinetic energy of the vehicle into electrical energy with the help of the electrical machine, and to therefore charge the high-voltage battery unit.

The service brake of the F30 PHEV is based on that of a conventional F30. In this chapter only the hybrid-specific components and functions are described.

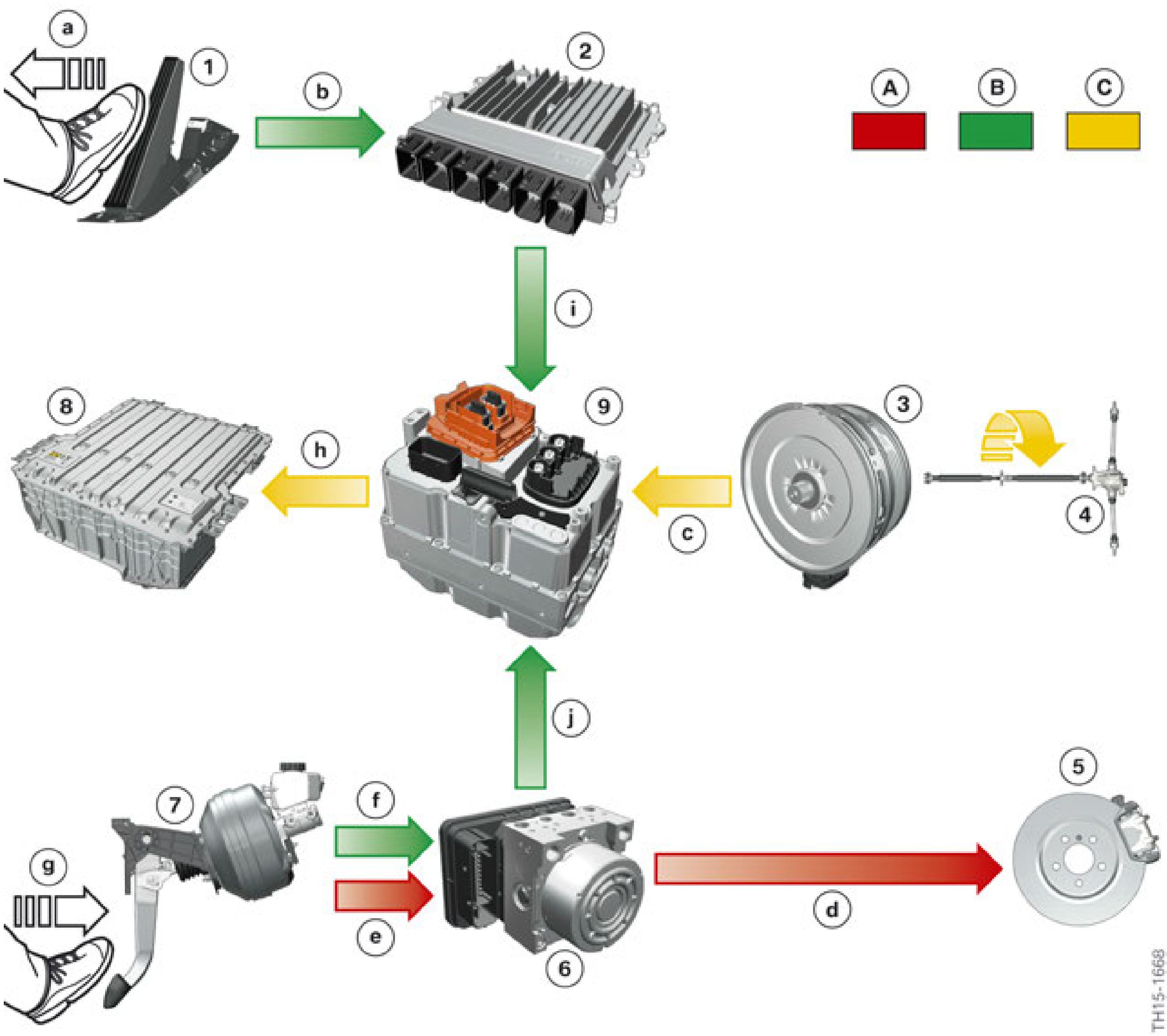
In comparison to the conventional F30, the following new or modified components are used:

- Brake pedal travel sensor
- Brake vacuum pressure sensor
- Modified vacuum brake system
- Modified DSC unit

F30 PHEV High-voltage Components

7. Hybrid Brake System

7.2. System overview



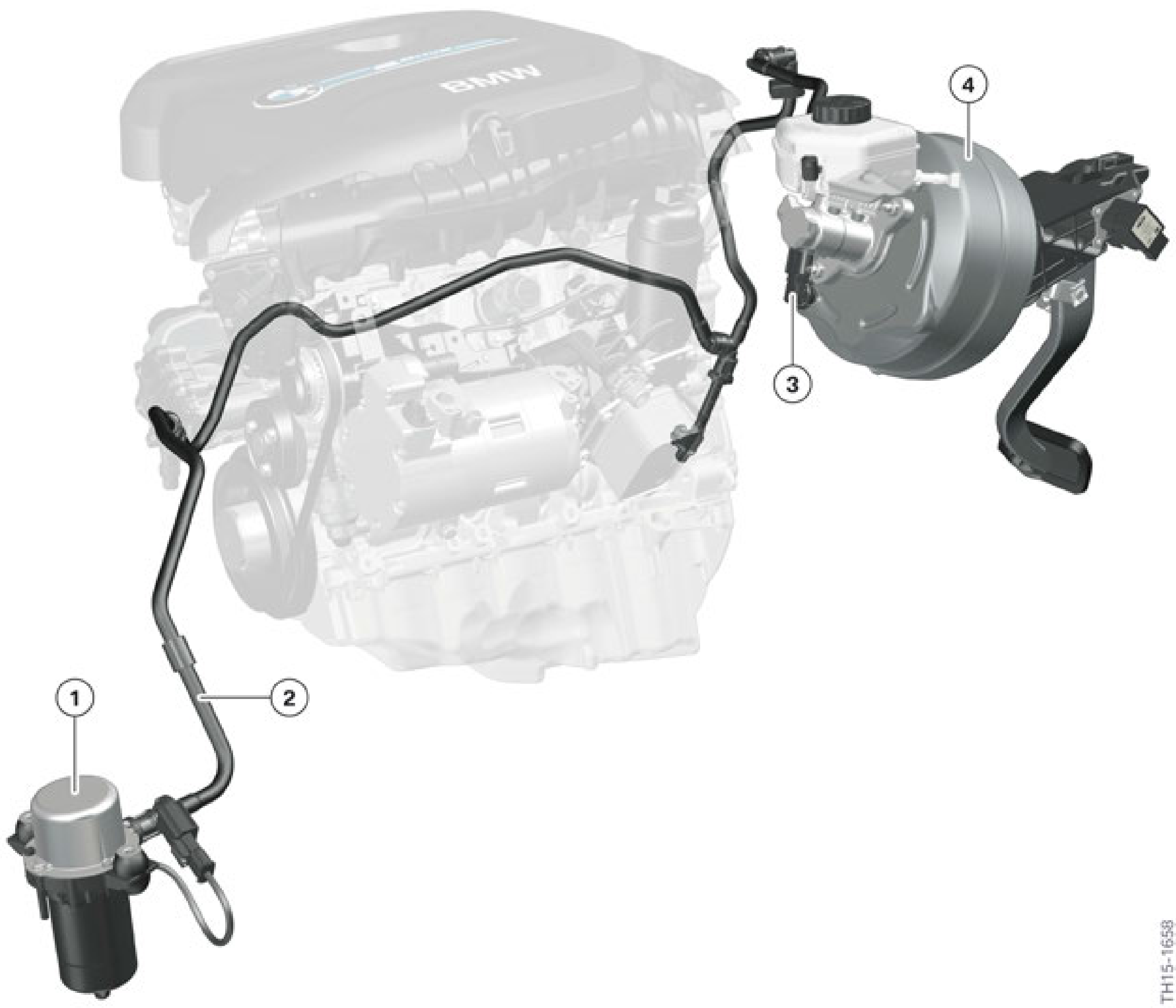
F30 PHEV, system overview of hybrid brake system

Index	Explanation
A	Hydraulic braking
B	Signal path
C	Regenerative braking
1	Accelerator pedal module
2	Digital Motor Electronics (DME)
3	Electric motor
4	Drivetrain
5	Rear wheel brake

Index	Explanation
6	Dynamic Stability Control (DSC)
7	Brake pedal with brake pedal angle sensor and brake booster
8	High-voltage battery unit
9	Electric Motor Electronics (EME)
a	Releasing the accelerator pedal
b	Electrical signal "Accelerator pedal angle" from the accelerator pedal module to the DME (energy recovery in coasting (overrun) mode)
c	Electrical energy generated by the electrical machine (AC voltage)
d	Hydraulic pressure from the DSC to the wheel brakes
e	Hydraulic pressure from the brake booster to the DSC
f	Electrical signal "Brake pedal angle" from the brake pedal angle sensor to the Dynamic Stability Control
g	Pressing of the brake pedal
h	Rectified high-voltage (DC) for storing in the high-voltage battery unit
i	Data bus message "Accelerator pedal angle" from the DME to the electrical machine electronics (energy recovery in coasting (overrun) mode)
j	Data bus message "Target braking torque" from the DSC to the electrical machine electronics

7.2.1. Vacuum pump

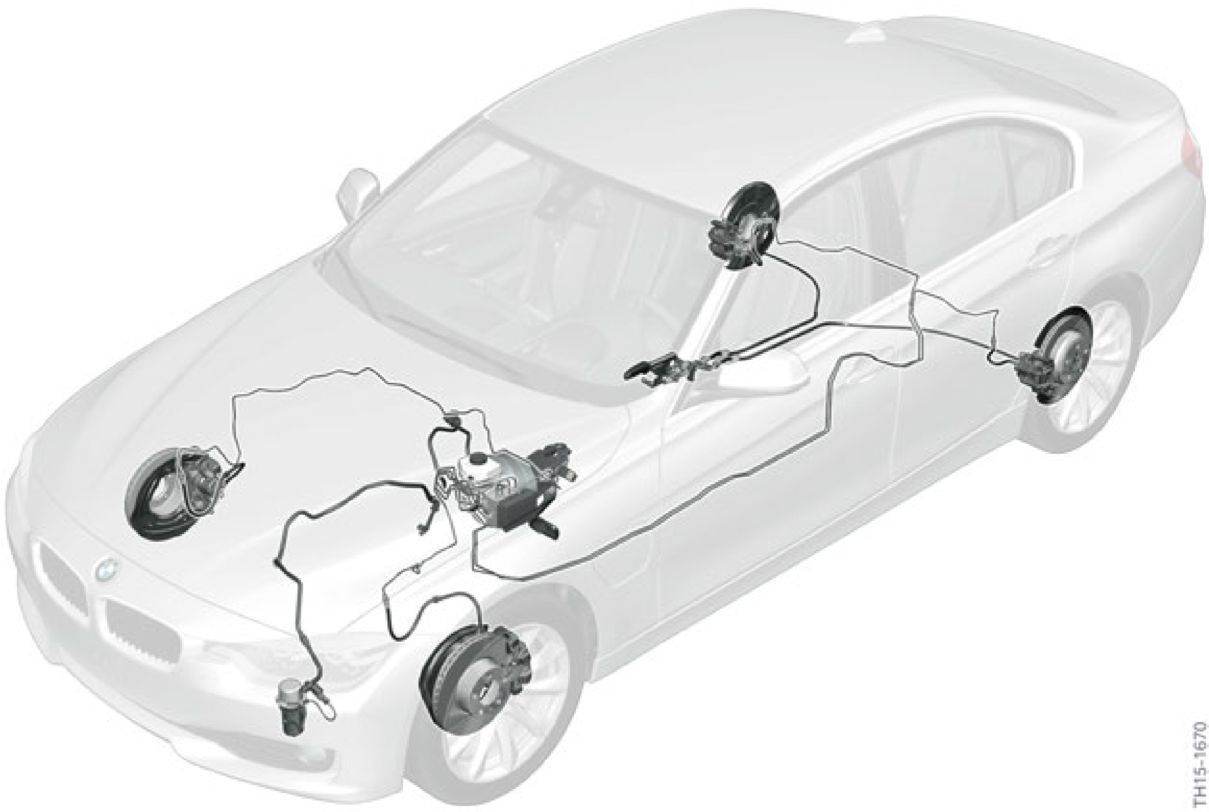
In the phases of complete electric driving the combustion engine is idle and can thus not activate the mechanical vacuum pump. To also ensure the supply of a brake vacuum in these driving situations, an auxiliary electrical vacuum pump is activated in the F30 PHEV. The activation and monitoring of the electrical vacuum pump is effected via the electrical machine electronics.



F30 PHEV, vacuum supply

Index	Explanation
1	Electrical vacuum pump
2	Vacuum line
3	Brake vacuum pressure sensor
4	Brake servo

7.3. Hydraulic braking



F30 PHEV, hydraulic braking

The brake servo is operated via the driver's foot operation and the brake actuation is determined by means of the brake pedal angle sensor. The signal of the brake pedal angle sensor leads to closing of a separator valve in the DSC unit. The separator valve separates the hydraulic brake circuit of the rear axle from the brake booster. The brake booster can now only build up hydraulic brake pressure on the front axle, controlled by the driver's foot operation.

The brake circuit of the rear axle is separated from the brake booster by the separator valve in the DSC. The braking power of the rear axle is provided by the available recuperative brake energy and supplemented by hydraulic brake energy if necessary. The hydraulic braking component is generated by the return pump.

The hardware of the Dynamic Stability Control (DSC) unit comes from Continental.

In order to be able to feed as much as energy as possible into the high-voltage battery during energy recovery, it is necessary to disconnect the hydraulic system at the rear axle for as many braking processes as possible. The vehicle is thus not decelerated with the friction brake of the rear axle at different operating points, but via energy recovery of the electrical machine.

7. Hybrid Brake System

The recuperation level is reduced or is not permitted in the following operating conditions:

1. The recuperation level at the rear axle is reduced if adversely affected driving stability is detected.
2. If emergency braking is detected, the braking request of the driver is realized purely hydraulically in order to ensure fast implementation of the hydraulic interventions at the individual wheels as required.
3. If no energy recovery is available (e.g. high-voltage battery fully charged), the driver's braking request is implemented as desired. In this case, the energy recovery level at the rear axle is zero and the return pump generates the complete hydraulic brake pressure required to achieve vehicle deceleration.

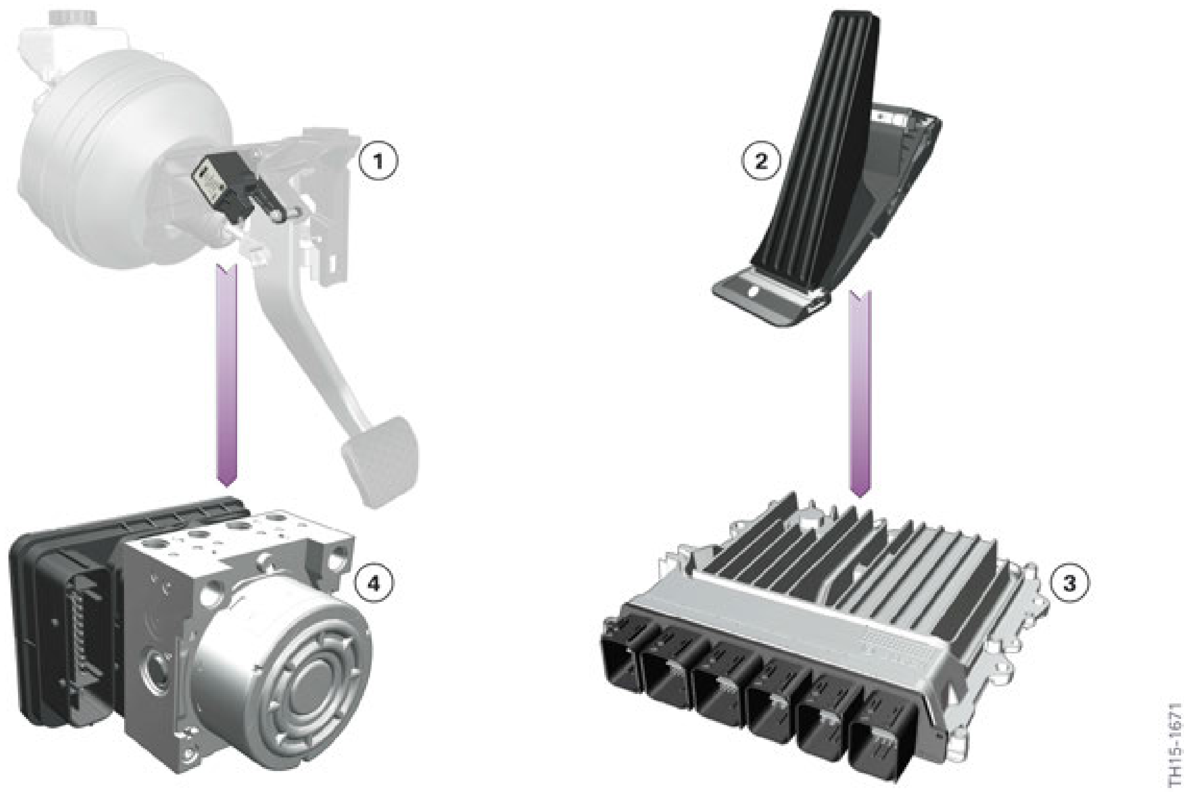
7.4. Regenerative braking

The regenerative braking makes possible brake energy regeneration. The electrical machine works here as an alternator and brakes the sprockets via automatic transmission – propeller shaft – rear axle differential – output shafts. The high-voltage battery unit is charged with the energy generated here via the electrical machine electronics.

In contrast to the F10H and F04, a brake pedal angle sensor is not used at the tandem brake master cylinder. Instead a brake pedal angle sensor is used directly at the brake pedal.

The free travel of the brake pedal has also been increased. In the event of brake actuation, braking is therefore purely regenerative in this range without hydraulic brake pressure. The brake pads of the wheel brakes are only applied at the brake discs in this operating condition. However, they do not generate braking power. This increases the efficiency of the drive, as more usable energy can be fed back into the high-voltage battery unit.

7. Hybrid Brake System



F30 PHEV, components for input signals of brake energy regeneration

Index	Explanation
1	Brake pedal with brake pedal angle sensor
2	Accelerator pedal module
3	Digital Motor Electronics (DME)
4	Dynamic Stability Control (DSC)

Decisive input variables for regenerative braking are the accelerator pedal angle and the brake pedal travel.

- The brake pedal angle is measured by the brake pedal angle sensor, converted to brake pedal travel and read in by the Dynamic Stability Control.
- The accelerator pedal angle is measured by the accelerator pedal module and read in by the DME.

The electrical machine is already operated as an alternator when the brake pedal is not operated but the accelerator pedal is already at an angle of zero degrees. The electrical machine electronics activates the electrical machine in such a way that a brake force is obtained for the complete vehicle which corresponds to a conventional vehicle in coasting (overrun) mode. Depending on the driving mode selected, the deceleration which occurs during the coasting energy recovery is different.

7.4.1. Emergency braking function

Regenerative braking with help of the drivetrain only effects the rear axle of the F30 PHEV. The brake force on the rear axle must not exceed a specific value in proportion to that on the front axle. This would otherwise compromise driving stability. This is also why there is a limit regarding the maximum deceleration that can be achieved through brake energy regeneration (maximum 0.07 g).

The maximum permissible brake force by brake energy recovery is subject to stability monitoring of slip, lateral accelerations and stability control processes. It is thus guaranteed that the vehicle constantly remains in a stable driving condition also during brake energy regeneration.

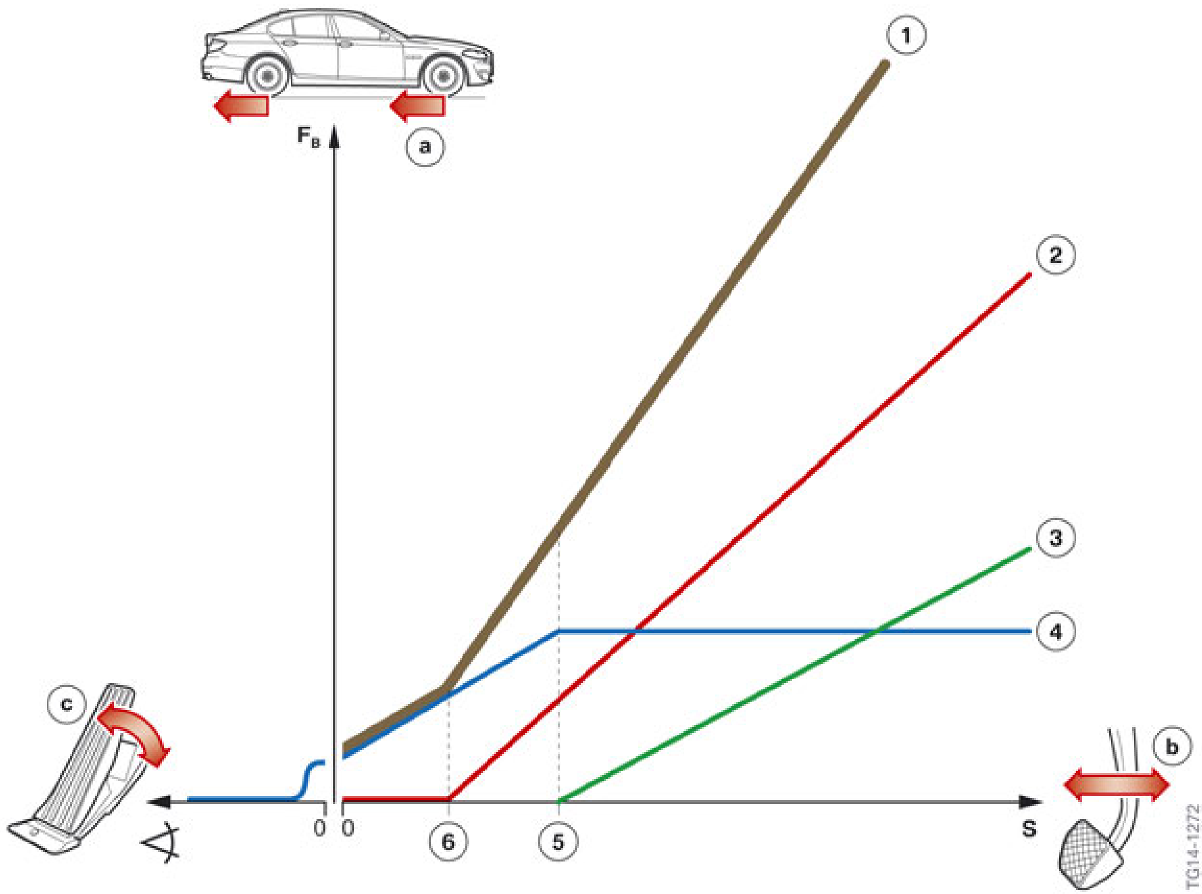
If the DSC control unit identifies an unstable driving condition, regenerative braking is waived and the DSC control unit intervenes with stabilizing measures.

When the driver depresses the brake pedal, a direct mechanical connection is established to the brake servo and thus to the hydraulic brake system. Activation is therefore the same as in a conventional vehicle.

7.5. Distribution of hydraulically and regenerative generated brake force

The following diagram summarizes how the entire brake force is distributed into the hydraulic and regenerative shares. In the diagram it is presupposed that there is no unstable driving state and the high-voltage battery is able to use electrical energy.

7. Hybrid Brake System



F30 PHEV, diagram for distributing the brake force

Index	Explanation
a	Brake force on the wheels
b	Brake pedal travel
c	Accelerator pedal angle
1	Total brake force
2	Hydraulically generated brake force of the front axle
3	Hydraulically generated brake force of the rear axle
4	Regenerative generated brake force
5	Brake pedal travel at which the maximum possible regenerative brake force acts
6	Brake pedal travel at which the hydraulic brake force begins (end of free travel at brake pedal)

8. Low-voltage Vehicle Electrical System

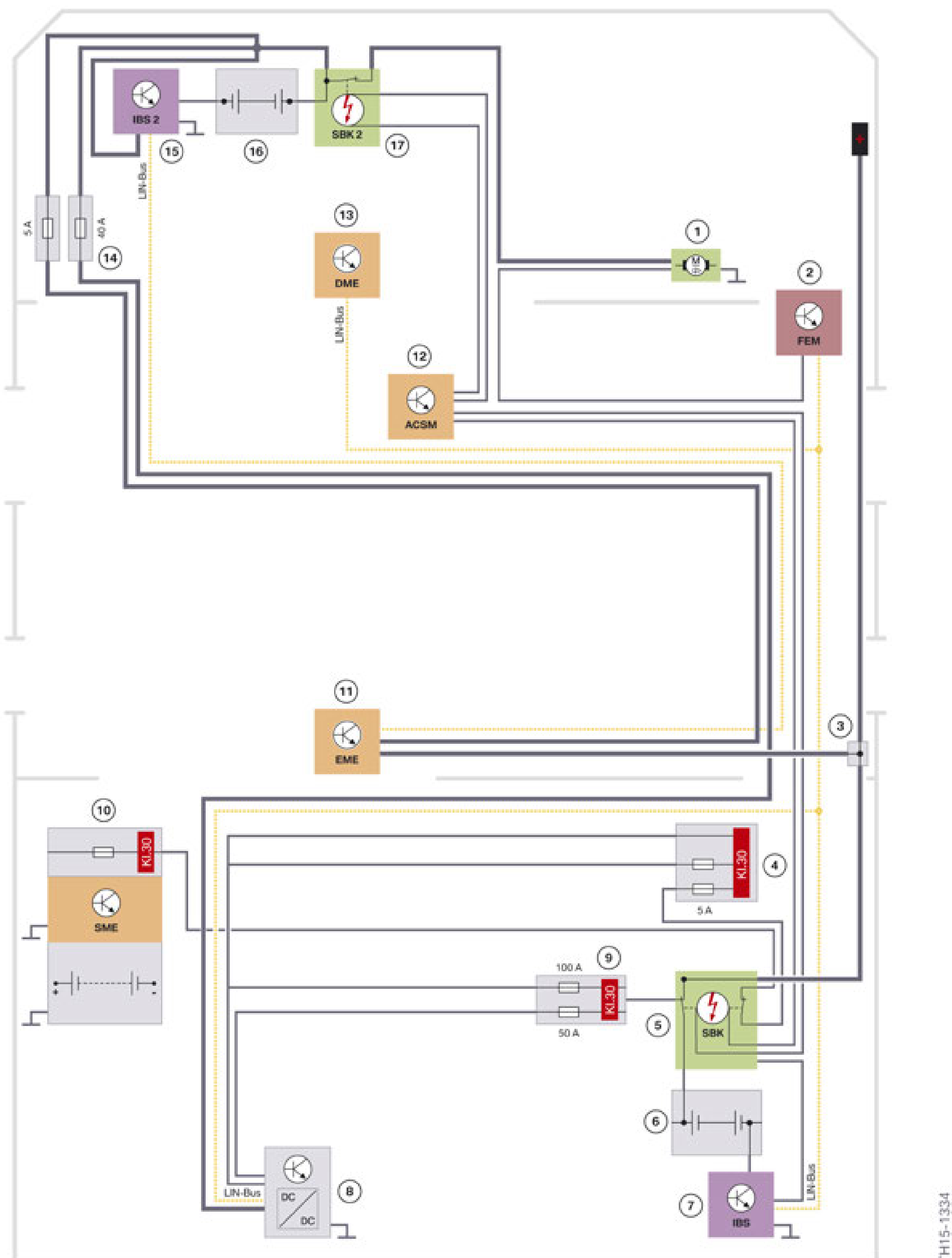
8.1. Voltage supply

The 12 V vehicle electrical system of the F30 PHEV is essentially the same as the energy electrical system of the F30. The main difference lies in the fact that the power supply is no longer by the alternator, but by the high-voltage electrical system. The high voltage of the high-voltage battery unit is converted to the lower voltage (approx. 14 V) using a DC/DC converter in the EME. The electric voltage supply of the 12 V vehicle electrical system is thus no longer dependent on the engine speed of the combustion engine when driving.

Another difference is that the starter motor and auxiliary battery form an independent 12 V vehicle electrical system, which is connected to the standard 12 V vehicle electrical system by the charging unit for the auxiliary battery (Battery Charge Unit (BCU)).

8. Low-voltage Vehicle Electrical System

8.1.1. System overview



F30 PHEV, system wiring diagram, 12 V voltage supply

F30 PHEV High-voltage Components

8. Low-voltage Vehicle Electrical System

Index	Explanation
1	Starter motor
2	Front Electronic Module (FEM)
3	Jump start terminal point
4	Power distribution box, rear
5	Safety battery terminal
6	12 V vehicle battery
7	Intelligent battery sensor
8	Battery Charge Unit (BCU)
9	Power distribution box at the 12 V battery
10	High-voltage battery with safety box (terminal 30C)
11	Electric Motor Electronics (EME)
12	Advanced Crash Safety Module (ACSM)
13	Digital Motor Electronics (DME)
14	Power distribution box of auxiliary battery
15	Intelligent battery sensor 2
16	Auxiliary battery
17	Safety battery terminal 2

8.2. Start-up system

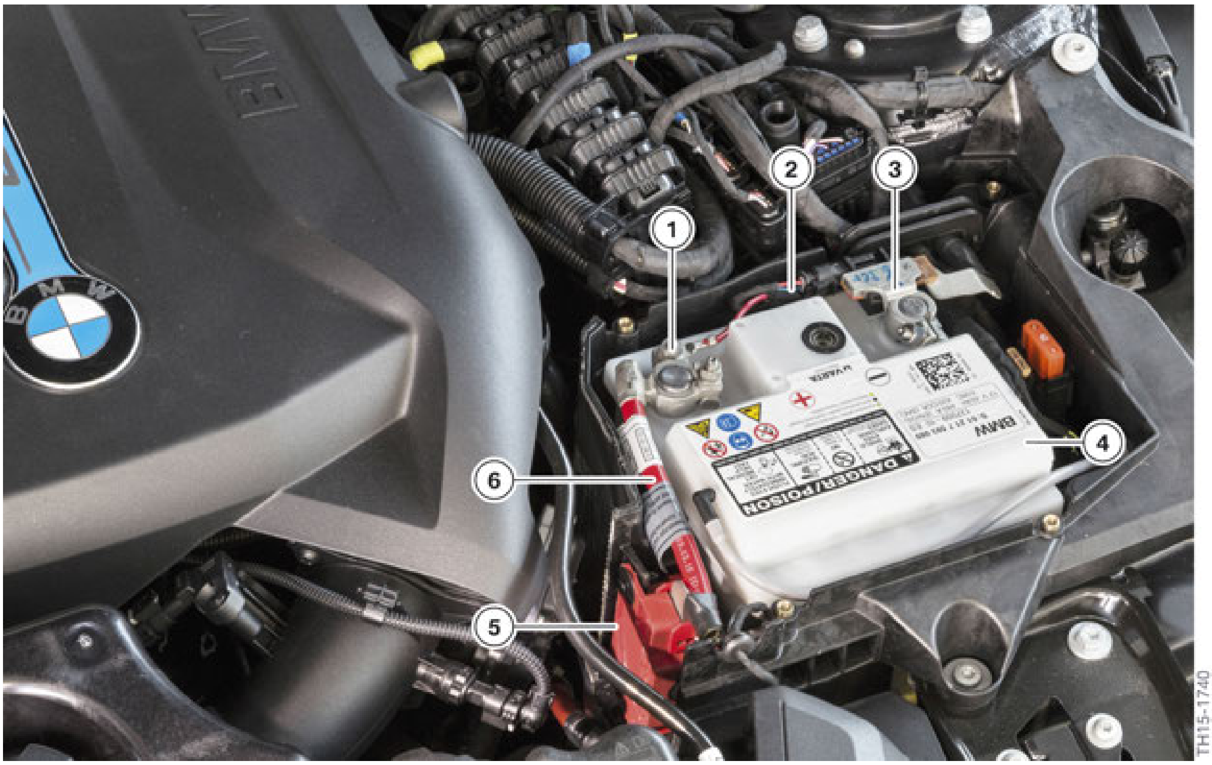
8.2.1. Starter motor

The combustion engine B48 can be started via the conventional starter motor and the electrical machine.

The following table shows when and under which conditions the respective start option is used.

Start via	Speed	Selector lever position	Temperature	Engine start through electrical machine	Engine start through pinion starter motor
START-STOP button	0 km/h (standstill) (0 mph)	Neutral	Transmission and engine > –10° C (14° F),	X	
			Transmission and engine < –10° C (14° F)		X
System start	0 km/h to 8 km/h (0 mph to 5 mph)	All positions	Transmission > 10° C (14° F) and engine > 0° C (32 ° F)	X	
			Transmission < 10° C (14 ° F) or engine < 0° C (32° F)		X
System start	> 8 km/h (>5 mph)	All positions	all		X

8.2.2. Auxiliary battery



F30 PHEV, auxiliary battery

Index	Explanation
1	Safety battery terminal of the auxiliary battery (SBK2)
2	Voltage supply for IBS2
3	Intelligent battery sensor of the auxiliary battery (IBS2)
4	Auxiliary battery (40 Ah)
5	Battery power distribution box
6	Positive battery cable from auxiliary battery to auxiliary battery power distribution box

The energy required by the starter motor is provided by the auxiliary battery. This is installed in the engine compartment. The auxiliary battery is a lead-acid battery with a capacity of 40 Ah.

Similar to the 12 V battery, the current, voltage and terminal temperature of the auxiliary battery are measured by an intelligent battery sensor, IBS2. The results are then forwarded via local interconnect network bus to the superior control unit, the Electrical Machine Electronics (EME). The EME forwards the signal via CAN bus to the DME.

In the event of an accident of sufficient severity, the safety battery terminal SBK2 ensures the disconnection of the positive battery cable between the auxiliary battery and starter motor.
The safety battery terminal SBK2 is located directly at the positive terminal of the auxiliary battery.
The pyrotechnic activation of the safety battery terminal SBK2 for the auxiliary battery is effected by the Advanced Crash Safety Module (ACSM).

8. Low-voltage Vehicle Electrical System

The intelligent battery sensor IBS2 receives the voltage supply via a line with a small cross-section from the safety battery terminal SBK2 of the auxiliary battery.

⚠

A change of the auxiliary battery must always be registered.

8.2.3. Power distribution box of auxiliary battery

The positive battery cable runs from the safety battery terminal SBK2 to the starter motor.

Three other lines also leave from the safety battery terminal SBK2:

- one as a voltage supply for IBS2 (without fuse)
- one to the BCU to charge the auxiliary battery (with 40 A fuse)
- one to the EME (with 5 A fuse)

8.2.4. Battery charging unit

The Battery Charging Unit (BCU) comprises a control unit, as well as a unidirectional DC/DC converter, and links the starter system to the standard vehicle electrical system. The charger unit for auxiliary battery is installed in the luggage compartment to the right above the vehicle battery.

It is responsible for charging the auxiliary battery. The battery charging unit receives the target voltage, at which the auxiliary battery is charged, via a LIN message from the DME. After the auxiliary battery has been fully charged, the battery charging unit is switched off by the DME. The energy consumption in the vehicle electrical system can be reduced during the electric trip or when driving on a motorway.

The advantage this system offers is the galvanic separation, which is effected in the BCU by the DC/DC converter. This galvanic separation prevents a voltage dip in the standard vehicle electrical system, when the combustion engine is started by the starter motor.

The BCU is able to detect if the 12 V vehicle electrical system is being charged via an external 12 V charger. With this function, the BCU can also charge the auxiliary battery when the vehicle is not awake but is being charged by an external charger (at the 12 V vehicle electrical system).

8.2.5. Jump start terminal point

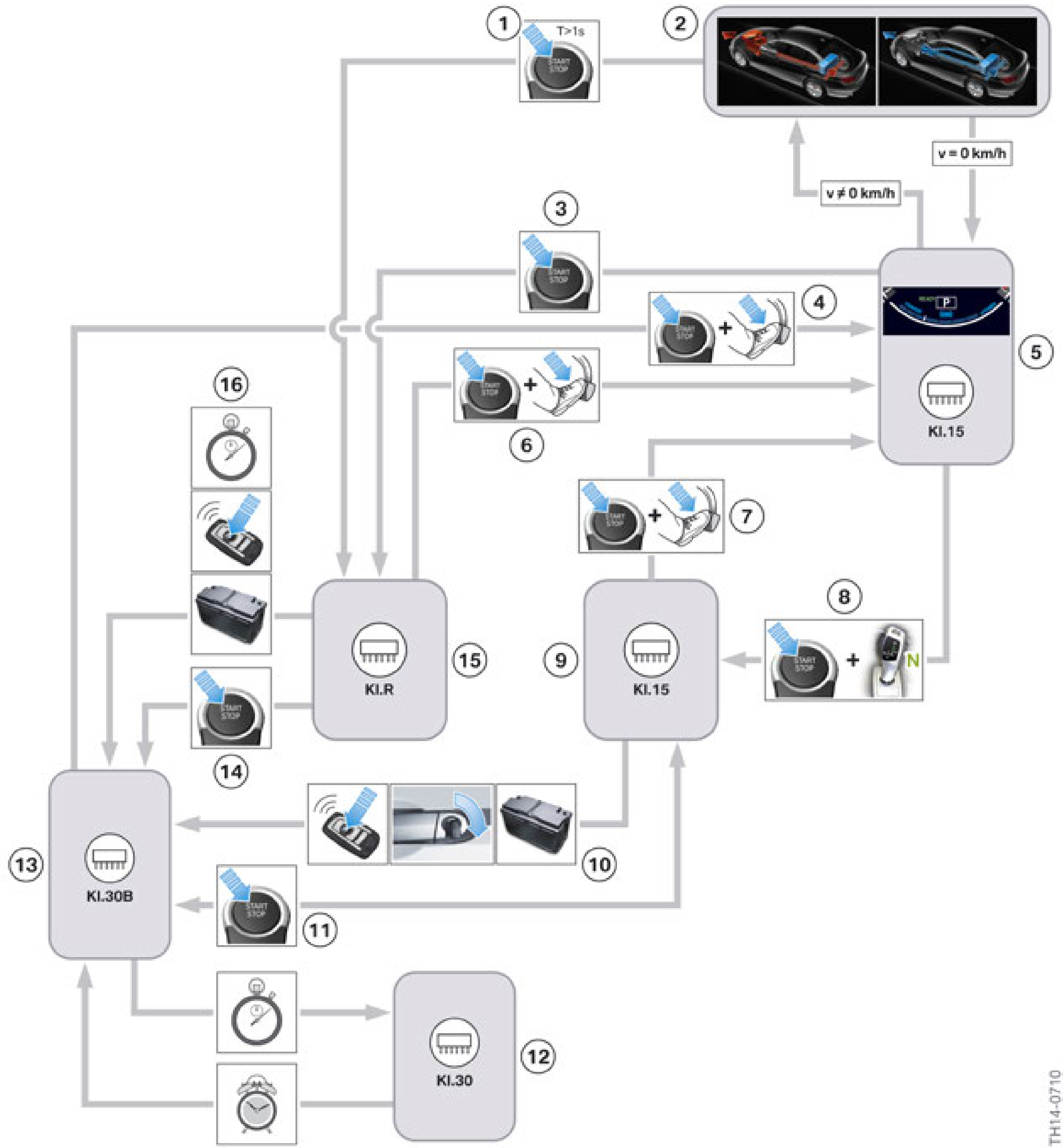
F30 PHEV, positive battery connection point

Next to the jump start terminal point is a label displaying the correct/incorrect polarity. In the F30 PHEV there is no reverse polarity protection module as is found in the ActiveHybrid vehicle.

F30 PHEV High-voltage Components

8. Low-voltage Vehicle Electrical System

8.3. Terminal control for driving readiness



Terminal control in the F30 PHEV from driver's view

Index	Explanation
1	By holding down the START-STOP button the terminal status changes from terminal 15 to terminal R (also functions when the START-STOP button is pressed three times within 4 seconds).
2	Driving with assistance of the combustion engine or the electrical machine.
3	When the START-STOP button is pressed the terminal status changes from terminal 15 to terminal R.
4	When the START-STOP button and the brake pedal are pressed simultaneously, the driving readiness is activated (with or without start-up of the combustion engine).
5	Driving readiness with activated terminal 15.
6	When the START-STOP button and the brake pedal are pressed simultaneously, the driving readiness is activated (with or without start-up of the combustion engine) (start from terminal R).
7	When the START-STOP button and the brake pedal are pressed simultaneously, the driving readiness is activated (with or without start-up of the combustion engine) (start from terminal 15).
8	When the selector lever is at "N" and driving readiness is ended with the START-STOP button, terminal 15 remains switched on for 15 minutes (car wash function).
9	Terminal 15 (still no driving readiness)
10	Terminal 15 is switched off when the vehicle has been locked, the state of charge of the battery is too low or the driver's door or the driver's seat belt has been opened, provided that there is no switch-off inhibitor for terminal 15.
11	When the START-STOP button is pressed the terminal status changes between terminal 15 and terminal 30B.
12	Terminal 30
13	Terminal 30B
14	When the START-STOP button is pressed the terminal status changes from terminal R to terminal 30B.
15	Terminal R
16	Change from terminal R to terminal 30B if more than eight minutes have passed or the car has been locked or the state of charge of the vehicle battery is too low.

The first driving readiness is activated when the brake pedal and the START-STOP button are pressed simultaneously. Here the driving readiness can be activated by any terminal status (terminal 30B, terminal R and terminal 15). The activated driving readiness is indicated to the driver by the illumination of "READY" in the bottom part of the rev counter.

With the status "Driving readiness" the vehicle can be driven off using the electrical drive or a combustion engine depending on the torque requirement. In comparison to the conventional vehicle with a single powertrain by the combustion engine, the driving readiness in a hybrid car cannot be recognized at the running combustion engine. The prerequisites for non-start of the combustion engine, the so-called "silent start", are a sufficiently charged high-voltage battery and a combustion engine at operating temperature or activated eDrive mode.

The driving readiness is deactivated by pressing the START-STOP button when the vehicle is stationary. The drive position "P" is automatically engaged in the process. The car wash function is an exception to this: If the driver engages the drive position "N" when the driving readiness is switched on and then presses the START-STOP button, the drive position "N" remains engaged and terminal 15 remains switched on.

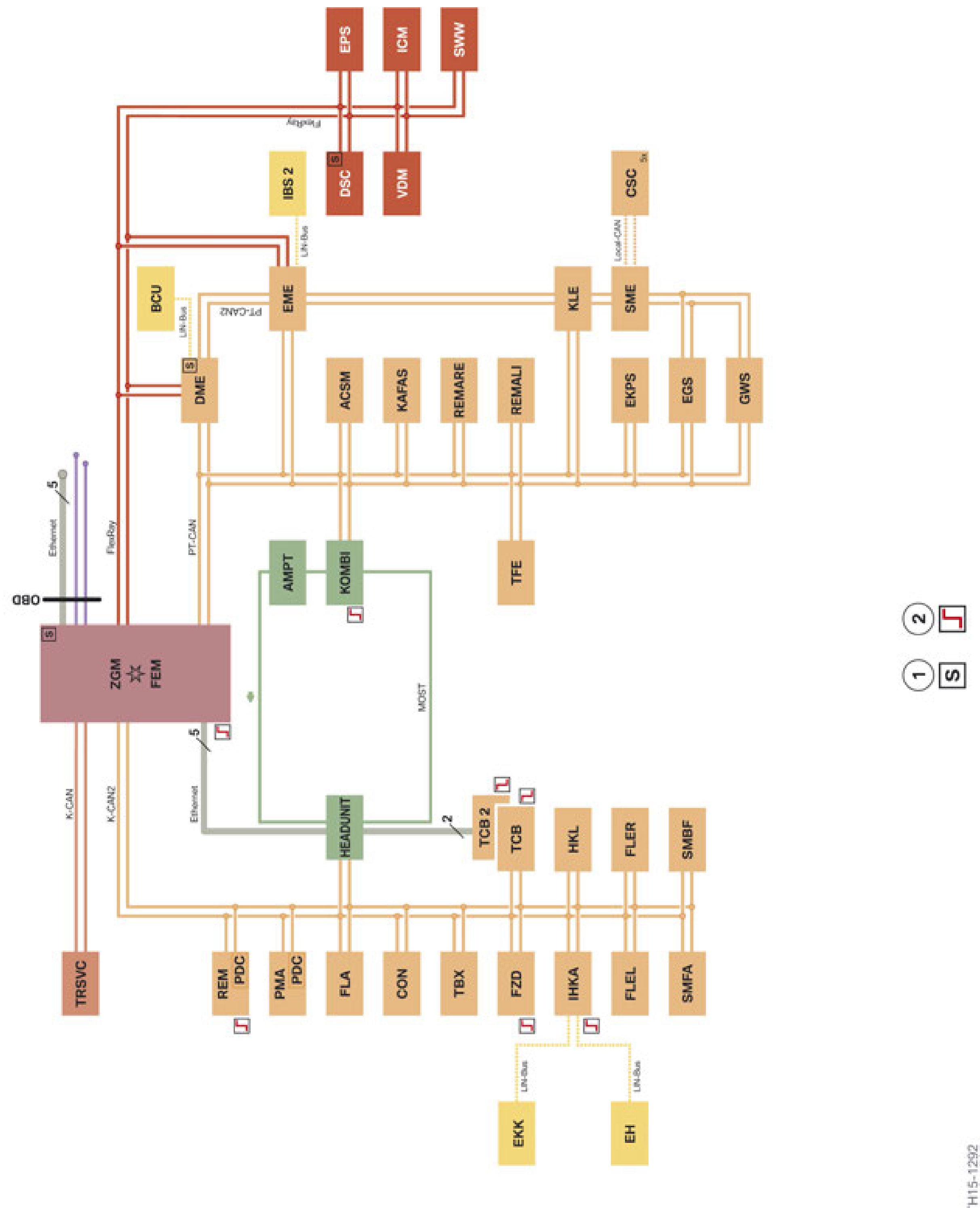
F30 PHEV High-voltage Components

9. Bus Systems

The bus systems of the F30 PHEV are based on the bus systems of the F30. All the main and sub-bus systems of the F30 are also used in the F30 PHEV. Compared with the bus systems of the F30, some new control units have been added, some have had to be adapted and some are not installed in the F30 PHEV at all. The resulting bus overview of the F30 PHEV is as follows.

9. Bus Systems

9.1. Bus overview



F30 PHEV, bus overview

F30 PHEV High-voltage Components

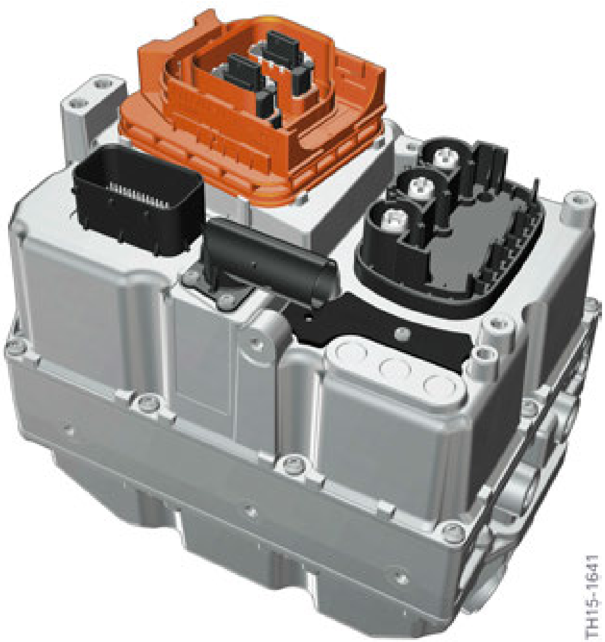
9. Bus Systems

Index	Explanation
1	Start-up nodes: Control units for start-up and synchronisation of the FlexRay bus system
2	Control units with wake-up authorisation
ACSM	Advanced Crash Safety Module
AMPT	Amplifier Top (Top HiFi amplifier)
BCU	Battery Charge Unit
CON	Controller
CSC	Cell Supervision Circuit
D-CAN	Diagnosis Controller Area Network
DME	Digital Motor Electronics
DSC	Dynamic Stability Control
EGS	Electronic transmission control
EH	Electrical Heating
EKK	Electric A/C compressor
EKPS	Electronic fuel pump control
EME	Electric motor electronics
EPS	Electric Power Steering (electromechanical power steering)
Ethernet	Cable-based data network technology for local data networks
FEM	Front Electronic Module
FLA	High-beam assistant
FLEL	Frontal Light Electronics Left
FLER	Frontal Light Electronics Right
FlexRay	Fast, real-time and fault-tolerant bus system for use in automotive sector
FZD	Roof function center
GWS	Gear selector
HEADUNIT	Head Uunit
ICM	Integrated Chassis Management
IBS 2	Intelligent Battery Sensor 2
IHKA	Integrated automatic heating / air conditioning
K-CAN	Body controller area network
K-CAN2	Body controller area network 2
KAFAS	Camera-based driver support systems
KLE	Convenience charging electronics
KOMBI	Instrument panel
LIN-Bus	Local Interconnect Network Bus

Index	Explanation
Local CAN	Local Controller Area Network
MOST	Media Oriented System Transport
OBD	Diagnostic socket
PDC	Park Distance Control
PMA	Parking Manoeuvring Assistant
PT-CAN	Powertrain Controller Area Network
PT-CAN 2	Powertrain Controller Area Network 2
REM	Rear Electronic Module
SMBF	Seat module, passenger
SME	Battery management electronics
SMFA	Seat module, driver
SWW	Lane change warning
TBX	Touchbox
TCB	Telematic Communication Box
TFE	Hybrid pressure refuelling electronic control unit
TRSVC	Control unit for rear view camera, Top View and Side View
VDM	Vertical Dynamics Management
ZGM	Central gateway module

9.2. New control units in the F30 PHEV compared to F30

9.2.1. Electric Motor Electronics (EME)



EME in the F30 PHEV

The function of the electrical machine electronics is to activate and regulate the permanently excited synchronous machine in the high-voltage electrical system. This necessitates the use of a bidirectional DC/AC converter which converts the high-voltage direct current voltage of the high-voltage battery unit into a three-phase AC voltage for the electrical machine. When the electrical machine is operating in generator mode, the high-voltage battery unit is recharged via the inverter.

The EME also incorporates the DC/DC converter which is responsible for the power supply to the low-voltage electrical system. The EME is connected to the PT-CAN, PT-CAN2 and FlexRay.

9.2.2. Battery management electronics (SME)

The SME control unit is integrated in the high-voltage battery unit. To maximise the service life of the high-voltage battery unit, the battery management electronics control unit ensures that it is operated in a precisely defined range (state of charge and temperature). Other tasks of the battery management electronics control unit include start-up and shut-down of the high-voltage system, safety functions (e.g. high-voltage interlock loop) and determination of the available power of the high-voltage battery unit. The battery management electronics communicates with other control units via PT-CAN2.

9.2.3. Cell supervision circuit (CSC)

Certain conditions must be observed for fault-free operation of the lithium-ion cells in the F30 PHEV: The cell voltage and the cell temperature cannot exceed or drop below certain values as otherwise the battery cells may suffer long-term damage. For this reason, each high-voltage battery unit has several Cell Supervision Circuits (CSC).

Communication between the six CSC's is effected via a local CAN. The local CAN connects all CSC's and is used to communicate with the SME. The battery management electronics control unit assumes the master function here. It is a low-voltage wiring harness with a maximum of 12 V.

9.2.4. Electric A/C compressor (EKK)

An electric air conditioning compressor is used in the F30 PHEV. To be able to provide the necessary power, the electric A/C compressor (EKK) is operated at high voltage. The EKK makes possible the refrigerant circuit of the air-conditioning system in all driving situations. In addition to cooling the passenger compartment, the coolant circuit of the high-voltage battery is also cooled via the refrigerant circuit. The electric A/C compressor control unit is located in the housing of the A/C compressor and is connected via the LIN bus to the integrated automatic heating / air-conditioning (IHKA).

9.2.5. Electrical Heating (EH)

Due to its hybrid concept, the combustion engine of the F30 PHEV generates significantly less heat loss in many driving situations and is not able to heat the coolant circuit to the necessary temperature. This is why the F30 PHEV has electrical heating. In principle, this functions similar to an instantaneous water heater. The electrical heating control unit is located in the housing of the electrical heating and is connected via the LIN bus to the integrated automatic heating / air-conditioning (IHKA).

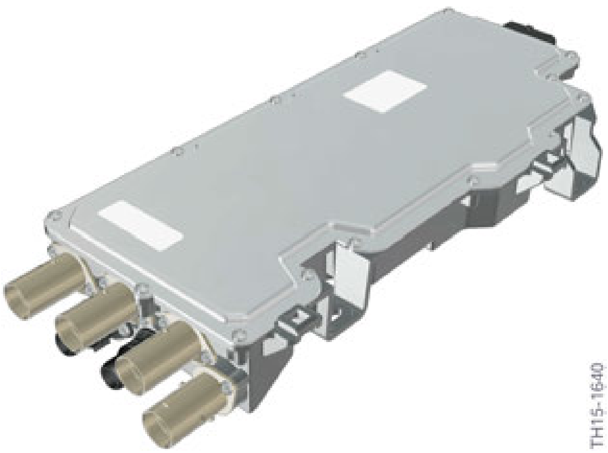
9.2.6. Intelligent battery sensor 2

The intelligent battery sensor 2 monitors the current, voltage and the pole temperature of the auxiliary battery. The results are forwarded via local interconnect network bus to the EME.

9.2.7. Hybrid pressure refuelling electronic control unit (TFE)

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

9.2.8. Convenience charging electronics



KLE in the F30 PHEV

The convenience charging electronics enable communication between the vehicle and charging station of the AC voltage supply in order to charge the high-voltage battery. The convenience charging electronics convert the AC voltage into high-voltage direct current voltage in order to charge the high-voltage battery unit in the vehicle. Charging of the vehicle takes place in parked position, normally overnight in the garage. Here the charging procedure must be adapted to the available grid power.

In addition, the convenience charging electronics have high-voltage connections for the electric A/C compressor (EKK) and the Electrical Heating (EH). This permits preheating/precooling of the vehicle as long as the charging cable is connected with the AC supply without energy being taken from the high-voltage battery unit. The convenience charging electronics also controls locking of the charging plug and charging socket cover. The lighting and display relating to the charging plug are also controlled by the convenience charging electronics.

9.3. Adapted control units

The **IHKA** had to be adapted to make possible the activation of the electric A/C compressor (EKK) in all operating conditions. The electric A/C compressor control unit communicates with the IHKA via the LIN bus.

To be able to show additional displays for driving readiness, electric driving, brake energy regeneration and state of charge of the high-voltage battery unit which are relevant to the driver, the **instrument cluster** was adapted. In addition, the Check Control messages were enhanced with hybrid-specific messages.

The software of the Digital Motor Electronics **(DME)** was adapted due to the torque coordination of the electrical machine/combustion engine.

Rollover detection is required for the hybrid cars on a worldwide scale so that the high-voltage system is deactivated in the event of the car rolling over. The rollover detection is realized with the help of the sensors integrated in the Integrated Chassis Management control units (roll rate sensor and vertical acceleration sensor). The **ACSM** had to be adapted with regard to the evaluation of these sensor signals. The safety battery terminal at the auxiliary battery is activated by the ACSM if required.

The software of the Dynamic Stability Control **(DSC)**was adapted for the regenerative braking. This includes reading the brake pedal angle sensor which is wired directly to the DSC control unit.

The **EGS** control unit was adapted due to the modified transmission. For instance the electric transmission oil pump is controlled by the EGS control unit.

The software in the **ZGM** control unit has also been adapted due to the modified terminal control (driving readiness).

F30 PHEV High-voltage Components

10. Displays and Controls

10.1. Electrical driving modes

F30 PHEV eDrive button and driving experience switch

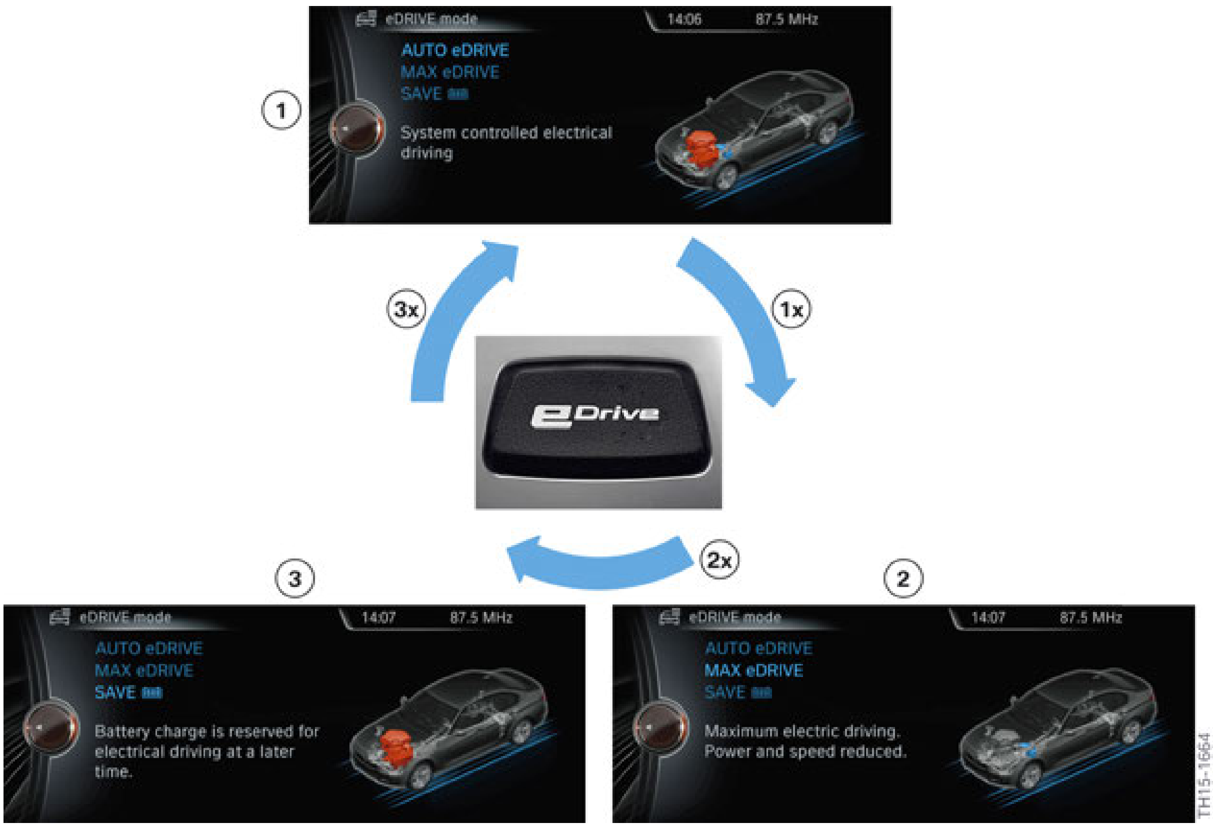
Index	Explanation
1	eDrive button
2	Driving experience switch

In the F30 PHEV, the electrical drive system can be configured in the following modes by means of the eDrive button:

- Automatic eDRIVE
- MAX eDrive
- SAVE BATTERY

For this purpose, the eDRIVE button is located in the center console. This button is designed as a toggle button. AUTO eDrive mode is selected automatically when waking up the vehicle or establishing driving readiness. The three eDrive drive modes can be combined with the familiar driving experience switch modes SPORT, COMFORT and ECO-PRO.

10. Displays and Controls



F30 PHEV eDRIVE modes

Index	Explanation
1	AUTO eDRIVE (restricted electric driving)
2	MAX eDRIVE (purely electric driving)
3	SAVE BATTERY (maintain SoC)

10.2. Automatic eDRIVE

AUTO eDRIVE is always active. Exception: The gear selector switch is in manual/Sport program position. In AUTO eDRIVE mode, the vehicle automatically selects the optimum drive combination depending on the state of charge of the high-voltage battery unit. In the instrument cluster, the driver is provided with a visual acknowledgement about the level of requested power.

If the driver's power request exceeds the maximum available electrical power, the combustion engine is activated automatically and comfortably.

AUTO eDrive mode can in principle be divided into two parts: The charge depleting phase and the charge sustaining phase. The usable SoC range of the high-voltage battery unit lies between 23% and 98%. In the charge depleting phase the F30 PHEV can be driven electrically up to approx.
80 km/h (50 mph). The combustion engine is activated at speeds above 80 km/h (50 mph) or for high power requirements. If the speed falls below 80 km/h (50 mph) into the electric driving range, the combustion engine is deactivated.

Outside this efficiency-optimized eDRIVE range, the combustion engine is started automatically when there are high load and speed demands.

10.3. MAX eDRIVE

When MAX eDrive mode is selected by means of the eDrive button and if the high-voltage battery unit is charged with a sufficient SoC, the driver can optionally drive without emissions with the maximum power of the electrical drive. A prerequisite for this is that the gear selector switch is not in the manual/ Sport program position. In this case, the maximum electrical speed is 120 km/h (75 mph). Here the amount of electrical power can be selected conveniently and easily using the accelerator pedal without the combustion engine being unintentionally activated. The activated MAX eDrive mode is indicated in the instrument cluster by the display of the "MAX eDrive" inscription in the rev counter next to the gear indicator. Nevertheless, it is possible in every driving situation to switch on the combustion engine and call on the full system power. Activation of the combustion engine can take place at any time by operating the gear selector switch by changing to S position or by pressing the accelerator pedal to kickdown.

In the process Automatic eDrive mode is automatically activated. The electrical range that can be attained is heavily dependent on the driving style (acceleration and speed) and the ambient temperature – and thus the secondary consumers. In order to reach a maximum electrical range, a preheating/precooling of the passenger compartment should be carried out during external charging. The energy which would be required for this during the trip can thus be used for a higher electrical range. If the vehicle is driven after a long immobilization period, at very cold ambient temperatures and in MAX eDRIVE mode, this may result in a power reduction of the electrical drive or it may not be available at all. A reason for this may be an excessively low cell temperature in the cell modules of the high-voltage battery unit.

10.4. SAVE BATTERY

Selection of SAVE BATTERY mode is also performed by means of the eDrive button. In this mode, the energy of the high-voltage battery unit is saved for later electric driving so that sufficient energy is available for subsequent urban driving. When SAVE BATTERY mode is activated, the current state of charge of the high-voltage battery unit is maintained. In SAVE BATTERY mode, energy is stored by energy recovery at States of Charge below 50% SoC or is generated by efficient load point adaptation as far as this is permitted by the respective driving situation.

10.5. Selector lever in M/S position

The Sport program of the transmission is activated by moving the selector lever to the left. Here the state of charge of the high-voltage battery unit can be increased to approx. 80%.

10.6. Displays in the instrument cluster

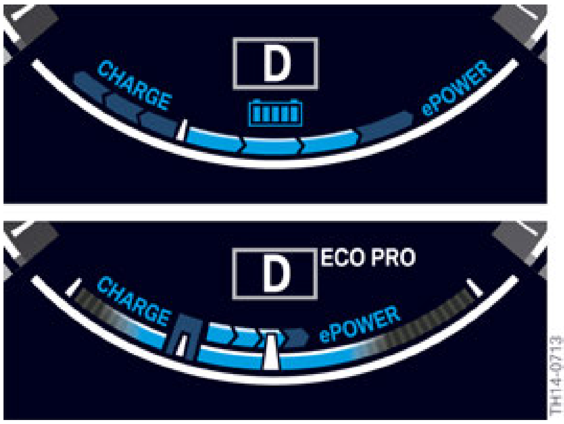
10.6.1. Displays of operating conditions

The hybrid-specific operating conditions and the state of charge of the high-voltage battery unit are displayed in the instrument cluster and if desired in the Central Information Display.

The following hybrid-specific operating conditions are shown:

The displays for the different operating conditions of the hybrid car are summarized in the following table.

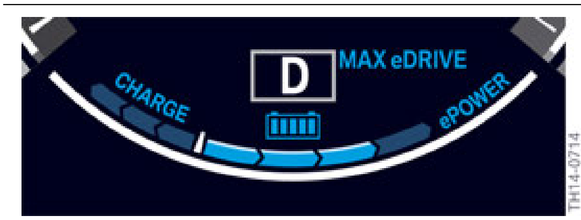
	**Driving readiness:** The driving readiness in the F30 PHEV is signalled to the driver via the needle in the engine speed display. Here the needle is at "READY". This means the vehicle is stationary and can be set in motion at any time by pressing the accelerator pedal. Depending on the state of charge of the high-voltage battery unit, the status of eDrive mode and the position of the accelerator pedal, the vehicle is either driven purely electrically or using a combustion engine. If, for example, the vehicle is stationary at a railway crossing or a red light, the driving readiness is switched on. However, if the combustion engine is started, e.g. due to a power requirement, it runs for approx. one minute in order to warm up the catalytic converter. If the customer has stopped the vehicle and wants to drive again a short time later, the driving readiness is switched on by pressing the START-STOP button. As the combustion engine is still at operating temperature and the high-voltage battery unit is still sufficiently charged, the combustion engine does not start.



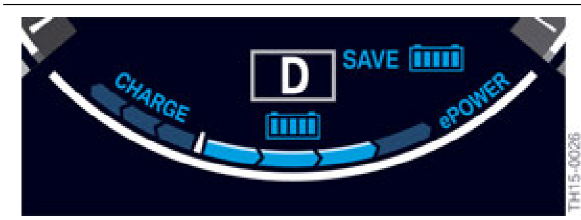
Electric driving:
The vehicle can be driven by purely electric means up to a driving speed of approx. 80 km/h (depending on the operating condition). The power output from the high-voltage battery unit is shown on the right side by blue arrows. Depending on the power requirement up to four arrows light up in succession. The needle of the rev counter is at "0" (combustion engine is off). Depending on the driving mode selected (COMFORT or ECO PRO), these arrows are shown differently.
If all four arrows are lit up, the combustion engine is switched on upon an additional power requirement, for example if acceleration is desired.

⚠

During electric driving please note that pedestrians and other road users cannot hear the usual engine noises of a typical conventional engine. Pay particular attention, for example, when parking!

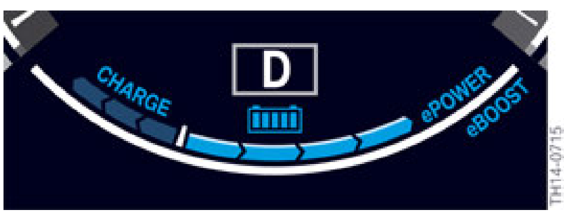


MAX eDrive:
Upon request the driver can drive using purely electrical means up to 120 km/h (75 mph) by activating MAX eDrive mode. The eDrive button in the center console must be pressed in order to activate this mode. The MAX eDrive mode can be activated in COMFORT and ECO PRO mode in order to prevent the combustion engine starting up.



SAVE BATTERY
In this mode, the energy of the high-voltage battery unit is saved for later electric driving so that sufficient energy is available for subsequent urban driving. When SAVE BATTERY mode is activated, the current state of charge of the high-voltage battery unit is maintained.

Operation using combustion engine:
The vehicle is powered by the combustion engine depending on the selected driving mode (SPORT). The rev counter typically displays the current engine speed. Only the display for the state of charge of the high-voltage battery unit is active on the hybrid-specific displays.

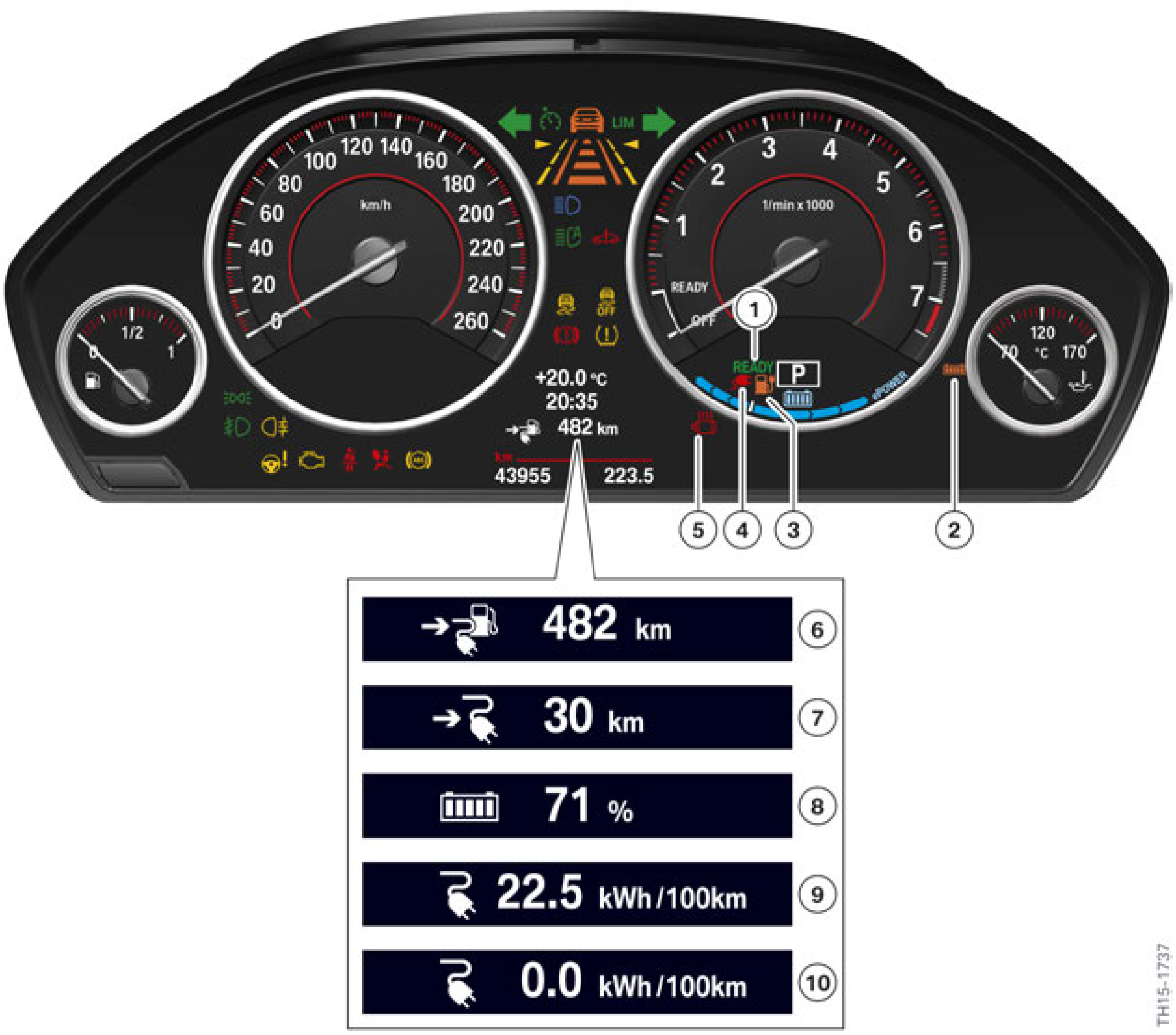


Boost function:
At strong acceleration, for example when overtaking, power from the electrical machine is called upon in addition to the combustion engine. This provides the driver with maximum power. The accelerator pedal must be pressed down powerfully for this. The rev counter shows the current engine speed and at the same time lights up all four arrows on the left side. The "eBOOST" writing also appears.

Brake energy regeneration:
The hybrid system enables kinetic energy to be converted to electrical energy, for example during braking or in coasting (overrun) mode. The high-voltage battery unit is charged by this energy recovery.
The energy recovery is shown on the left side by three blue arrows, depending on the driving mode selected. The blue arrow varies in length, depending on the deceleration or on the intensity of the brake pedal actuation.
Below a speed of roughly 15 km/h (10 mph) the display for brake energy regeneration does not light up although the vehicle is in coasting (overrun) mode or has just braked. Depending on the driving mode selected (COMFORT or ECO PRO),
these arrows are shown differently.

10.6.2. Permanent indicator lights and on-board computer displays

The instrument cluster contains hybrid-specific, legally required permanent lights.



F30 PHEV instrument cluster with fixed lights and on-board computer displays in China version

Index	Explanation
1	READY (driving readiness is active); this display is only available in the China version
2	State of charge of the high-voltage battery too low; this display is only available in the China version
3	High-voltage battery is being charged; this display is only available in the China version
4	Charging cable connected; this display is only available in the China version

Index	Explanation
5	Overheated electrical machine or power electronics; this display is only available in the China version
6	Total range
7	Range with electrical drive
8	State of charge of the high-voltage battery
9	Average consumption for the electrical drive
10	Current consumption for the electrical drive

The following displays appear in the instrument cluster in the bottom part of the engine speed display (depending on the driving situation):

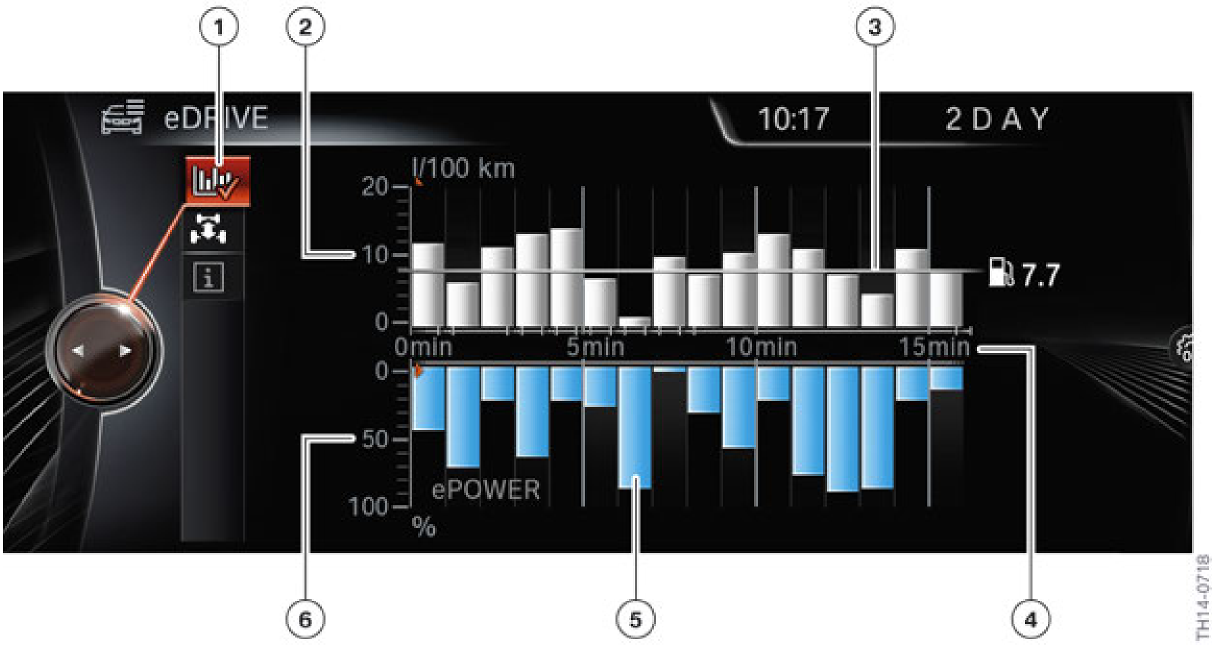
- "Ready to drive" display
- Display for electric driving
- Display for MAX eDrive
- Display for SAVE BATTERY
- Display for boost function
- Energy recovery

The hybrid-specific displays are called up in the CID via the "Vehicle Info > eDrive" menu. Both the displays in the CID and in the instrument cluster are activated when terminal 15 is switched on.

10.7. Displays in Central Information Display

The energy / power flows and the state of charge of the high-voltage battery unit can be shown in the CID in all the vehicle's operating conditions. In addition, the user can have the eDrive usage from the last 16 minutes and the ECO PRO information displayed upon request. This provides the driver with an overview of the operating principle of the hybrid system in different driving conditions, as well as optimal use of the hybrid vehicle.

10.7.1. eDrive usage



Display for utilization of the hybrid system

Index	Explanation
1	Selection of the display for eDrive usage
2	Consumption scale of the combustion engine
3	Average consumption of the combustion engine
4	Time axis (16 minutes)
5	Bar representing minutes
6	Percentage scale for use of the electrical machine

The utilization of the hybrid system in the last 16 minutes of driving can be shown in the CID. One bar stands for a period of one minute. The time is also counted during engine stop phases. The higher the bar, the higher the fuel consumption or the use of the electrical machine.

The grey bars show the fuel consumption of the combustion engine. A line and a value to the right beside the diagram show the average consumption.

The blue bars show the percentage in which the electrical machine has been used. The electrical machine can be operated here as an alternator (for brake recovery) or as an electric motor (for electric driving). The higher the bar, the greater the use of the hybrid system and thus higher fuel economy.

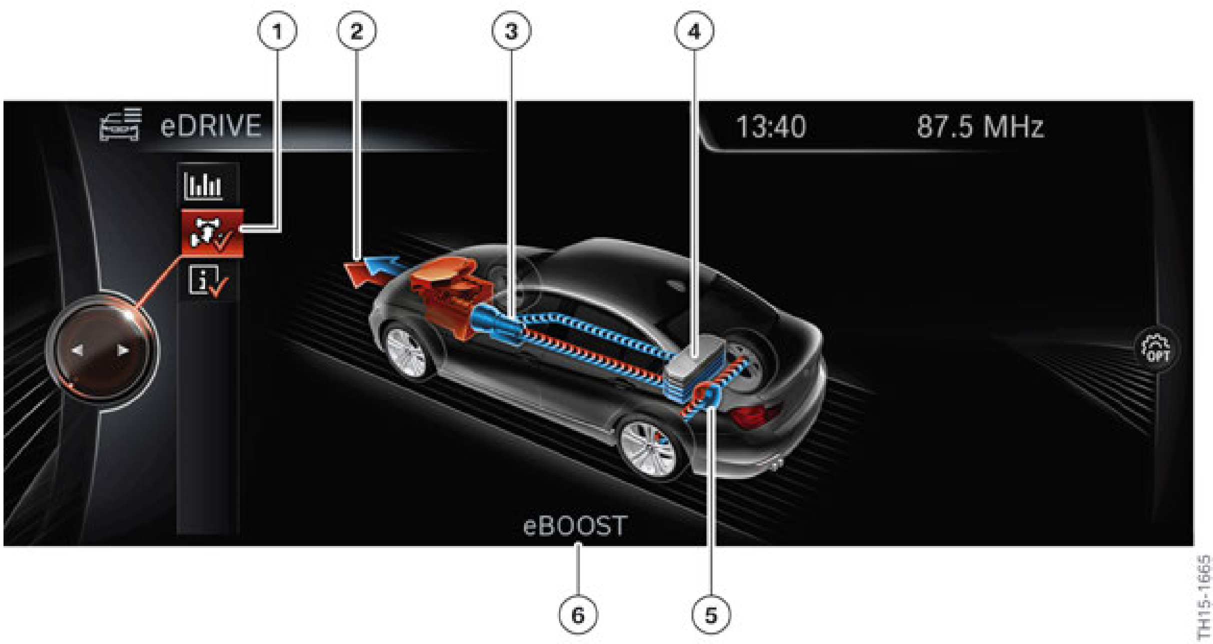
The two red marks on the vertical axis of the display indicate the bars from the last minute.

10.7.2. Energy/Power flows

The display of the energy / power flows in the CID functions according to the following principle:

- Blue: Electrical energy
- Red: Energy of the combustion engine
- Arrow: Direction of the energy / power flow

A driving situation is shown here as an example and the meaning of the symbols explained. The other driving situations can be deduced from this.



Hybrid display in the central information display during strong acceleration

Index	Explanation
1	Selection of display for energy / power flows
2	Drive arrow for combustion engine (red) and drive arrow for electrical machine (blue)
3	Automatic transmission with electric motor
4	State of charge of the high-voltage battery unit
5	Power flow to the rear axle
6	Text message for current driving condition (e.g. ePOWER, POWER, eBOOST, CHARGE)

In the CID the boost function is represented by a red arrow (combustion engine contribution) and a slightly smaller blue arrow (electric motor contribution). The combustion engine is shown in red here. The activity of the electrical machine in the automatic transmission is indicated by the blue color of the transmission. The five segments symbolize the state of charge of the high-voltage battery unit. In other words, one segment equals a state of charge of the high-voltage battery unit of 20 %.

The power flow to the wheels is illustrated with two arrows to show that it comes from both drive sources (combustion engine and electrical machine). The red arrow shows the combustion engine percentage and the blue arrow the electrical machine percentage. The current driving situation is also shown as a fade-in text message below the vehicle.

10.7.3. ECO PRO

The displays in the ECO PRO menu are described in the following chapter entitled "ECO PRO mode".

10.8. ECO PRO mode

The driver of a F30 PHEV can drive his vehicle even more efficiently upon request. Using the driving experience switch the particularly efficient mode – the so-called ECO PRO mode – can be activated. The ECO PRO mode consistently supports a driving style at reduced consumption levels and ensures coordination of the hybrid system for achieving maximum range of the vehicle.

10.8.1. Activation and display

TH15-1663

F30 PHEV eDrive button and driving experience switch

10. Displays and Controls

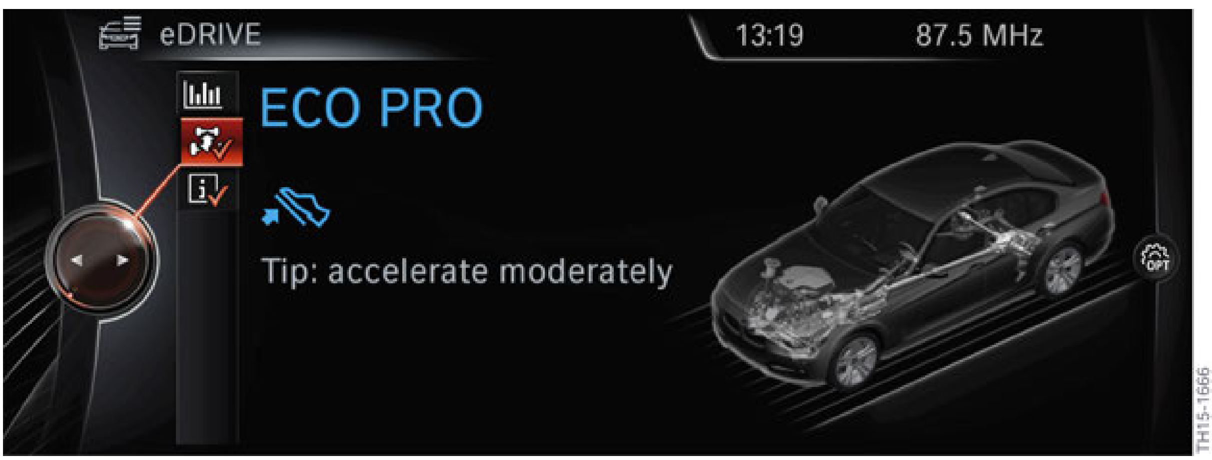
Index	Explanation
1	eDrive button
2	Driving experience switch

ECO PRO mode is activated using the driving experience switch. The "COMFORT" programme is set as standard. To activate ECO PRO mode, the driving experience switch must be pressed in the "COMFORT" direction when terminal 15 is switched on until "ECO PRO" is displayed in the instrument cluster.

ECO PRO mode is deactivated again when terminal 15 is switched off.

The activated ECO PRO mode is indicated in the instrument cluster by the display of the "ECO PRO" writing in the rev counter beside the gear indicator.

Upon activation of ECO PRO mode another window appears in the central information display to configure the ECO PRO mode.



F30 PHEV ECO PRO note

If the driver is not driving his vehicle efficiently, e.g. accelerating too hard or incorrect gear selection, this is shown to him on the CID.

10.8.2. What is affected in ECO PRO mode?

The ECO PRO mode supports the driver in adopting an optimized-consumption driving style and reduces fuel consumption through intelligent control of energy and A/C management. Essentially the following measures help to reduce fuel consumption:

- A modified accelerator pedal characteristic curve and shift program with automatic transmission helps the driver adopt a driving style that optimizes fuel consumption.
- Reduction of electric comfort consumers.
- Power reduction of heating/air-conditioning.
- Number and length of possible engine shutdown phases is maximized in ECO PRO mode.

10.9. Load point increase

Raising the load of the combustion engine at consistent engine speed is called load point increase. This results in an increase in performance and the option to operate the combustion engine in the optimal range. The arising resistance, which counteracts the combustion engine, must be compensated so that on the one hand the load of the engine increases, and on the other hand the speed remains constant. An example of this is the switching on of the air conditioning or the rear window heating in vehicles that are powered by combustion engine alone. The compensation of the additional resistance is assumed by the DME. The DME supplies the combustion engine with more fresh air by activating the throttle valve. The injected fuel quantity is also increased. The load of the combustion engine increases and is in a more optimal range in terms of efficiency and fuel consumption. However, this control happens so precisely that there is no engine speed increase, but only the occurring resistance is compensated.

In the F30 PHEV the electrical machine generates a counter-torque in alternator mode. As described above, the DME compensates this counter-torque and the combustion engine is operated more optimally. The electrical energy gained is used to charge the high-voltage battery unit. In this way, the combustion engine is also positively influenced during charging of the high-voltage battery unit.

The load point increase happens in addition to the already existing power requirement. This process is unnoticeable to the driver. Factors which are decisive over time and level of the load point increase:

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

10.10. Load point reduction

In order to reduce fuel consumption, the combustion engine can be relieved by a load point reduction if the high-voltage battery unit is sufficiently charged. The high-voltage battery unit is specifically discharged and the SoC value drops, although the vehicle is not driven by purely electrical means.

10.11. Proactive driving assistant

As in the ActiveHybrid vehicles of generation 2.0, the "coasting" function is also available in the F30 PHEV. "Rolling without energy consumption" (coasting) means that the combustion engine is also shut down at higher speeds up to approx. 160 km/h (100 mph) if it is not required for the drive. At the same time the separating clutch in the drivetrain is opened so that the vehicle rolls without engine braking effect. The advantage of increased efficiency through "coasting" is clearly visible: in this operating condition no fuel whatsoever is used.

Proactive driving assistant in the F30 PHEV

Index	Explanation
1	ECO PRO mode is selected
2	Symbol for reason to take foot off the accelerator pedal
3	Information for reason to take foot off the accelerator pedal

In the F30 PHEV, "coasting" is supported even more by the proactive driving assistant.
This RouteAhead Assist detects bends, entrances to towns/villages, roundabouts, T-junctions, speed limits and motorway exits using the data from the navigation system and can thus suggest to the driver in advance when to take the foot off the accelerator pedal.

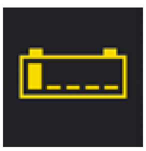
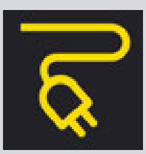
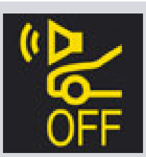
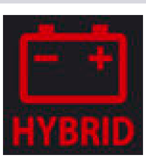
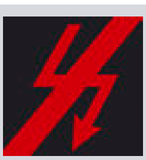
With the help of the proactive driving assistant, drivers who are not familiar with the route or area also have the option to drive more efficiently. Another prerequisite for the use of the RouteAhead Assist is the active route guidance.

F30 PHEV High-voltage Components

10. Displays and Controls

10.12. Hybrid-specific Check Control Messages

If faults occur in the F30 PHEV, the driver is informed thereof via Check Control messages.
The following table summarizes the key hybrid-specific Check Control Messages:

Check control message	Meaning	Cause
	Total range is low.	State of charge of the high-voltage battery is low. Fuel reserve is low.
	Current state of charge of the high-voltage battery during operation and transportation (state of charge is too low -> recharge).	State of charge of the high-voltage battery is low.
	Check charging cable.	Charging cable signal is faulty. Connected charging plug cannot be detected. Customer should check whether the connector is still connected before driving off.
	Charging not possible.	Fault in the charging system of the vehicle or in the infrastructure (charging cable, charging station, etc.).
	Acoustic pedestrian protection failed. (Not for US)	Internal fault in the VSG or fault with another control unit, which leads to the failure of the CAN communication. (Not for US)
	Isolation fault, fault in the high-voltage interlock loop.	High-voltage of high-voltage system faulty. After stopping the engine, may be no longer possible to continue trip. Please look for next BMW Service without delay.
	High-voltage system shut down.	High-voltage system is shut down and in de-energized state for maintenance, service and repairs. High-voltage safety connector (Service Disconnect) removed, circuit of high-voltage interlock loop interrupted.

11. Climate Control

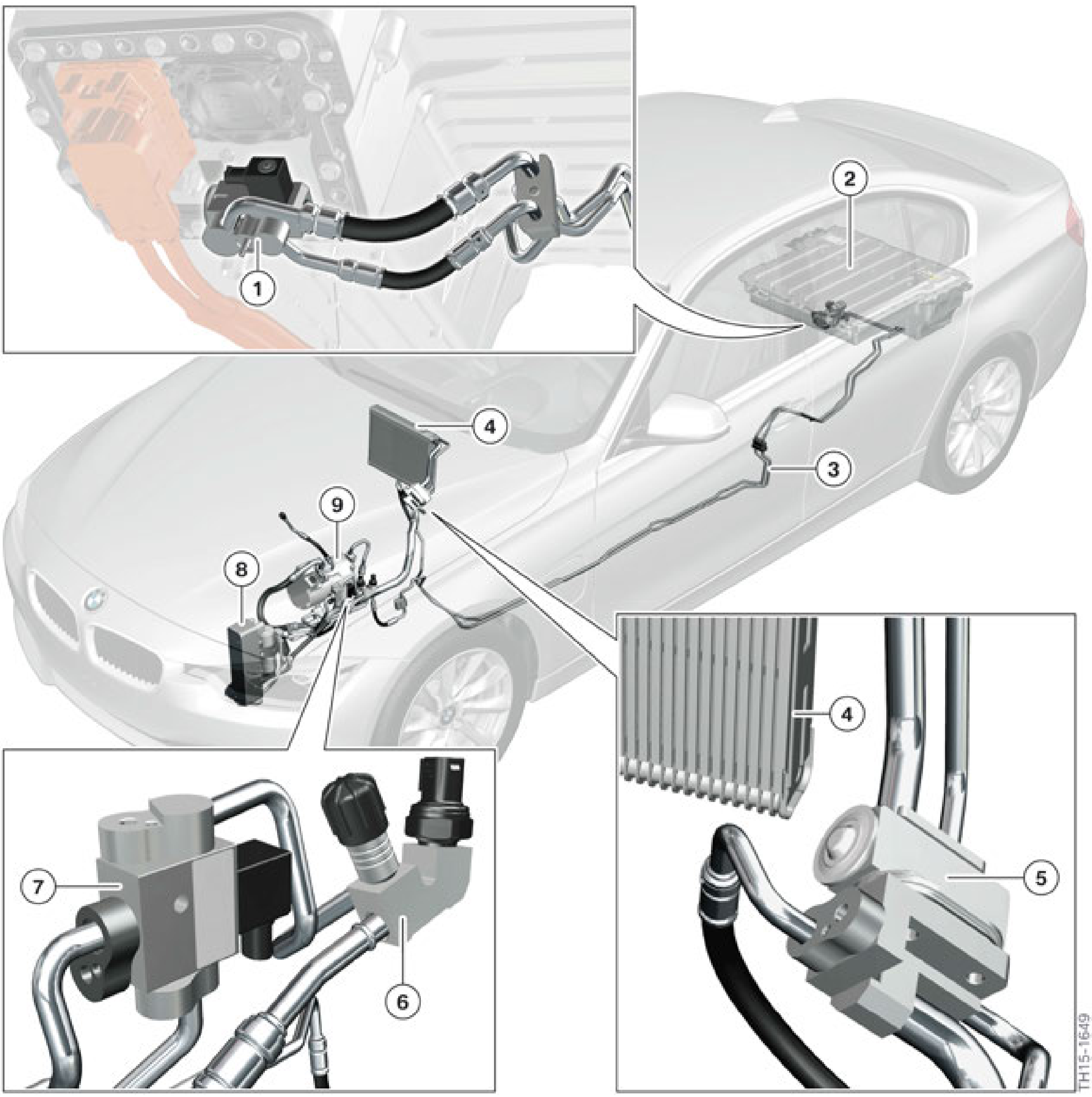
As in previous BMW hybrid vehicles, an electrically powered air conditioning compressor is used in the F30 PHEV. Because the A/C compressor has an electric motor, it is possible to operate the air conditioning independently of the combustion engine. Thus the customer can enjoy the cooling effect of the air conditioning even while driving in pure electric mode and while stopped. Special silencing provides for acoustic comfort. Thus, for example, even when the car is stationary and the combustion engine is switched off the air conditioning can barely be heard.

A cooling unit is used to cool the refrigerant in the refrigerant circuit of the high-voltage battery unit.

The stationary climate control is also available in the F30 PHEV.

11. Climate Control

11.1. System overview



F30 PHEV, system overview of climate control

Index	Explanation
1	Combined expansion and shutoff valve
2	High-voltage battery unit
3	Refrigerant lines to high-voltage battery unit
4	Evaporator, passenger compartment
5	Expansion valve for vehicle interior

Index	Explanation
6	Connection for filling and evacuation
7	Shutoff valve (vehicle interior)
8	Coolant-refrigerant heat exchanger
9	Electric A/C compressor (EKK)

The top graphic shows the refrigerant circuits in the F30 PHEV. The refrigerant circuit for cooling the high-voltage battery unit is switched parallel to the refrigerant circuit for cooling the vehicle interior.

Its temperature has a decisive influence on the service life of the high-voltage battery unit. The cells of the high-voltage battery unit should not deliver their power or absorb electrical power at too high or too low a temperature. The optimal cell temperature is approx. 20° C (68° F); the battery cells should not exceed a maximum temperature of 40° C (104° F).

R134a is used as the refrigerant, which circulates in a circuit, absorbing heat at one point in the system and releasing it at another point. The heat from the vehicle interior and the high-voltage battery unit is transferred to the coolant in the coolant-refrigerant heat exchanger. When the air-conditioning is activated for the vehicle interior or when cooling power is requested for the high-voltage battery unit, the electric A/C compressor is switched on and the system supplies the corresponding point with cold. The vehicle interior cooling and the cooling of the high-voltage battery can be operated independently of each other. The energy required for this is taken from the high-voltage battery unit by the electric A/C compressor. The BMW-approved PAG oil is used as the lubricant. The oil must be approved for the electric A/C compressors. So that the battery cooling and the vehicle interior cooling can be operated independently of each other, special expansion and shutoff valves are integrated in the refrigerant circuit. These open only the portion of the circuit that is actually required. This ensures high efficiency and proper control characteristics of the system.

If the shutoff valve in the refrigerant circuit is electrically activated and thus opened, liquid refrigerant flows into the cooling unit and evaporates. As part of this process, it removes heat energy from its environment. The electric A/C compressor compresses the refrigerant once again and it is then returned to a liquid state in the coolant-refrigerant heat exchanger. As a result, the refrigerant is once again able to absorb heat energy. The following table shows how the valves and the electric A/C compressor are controlled.

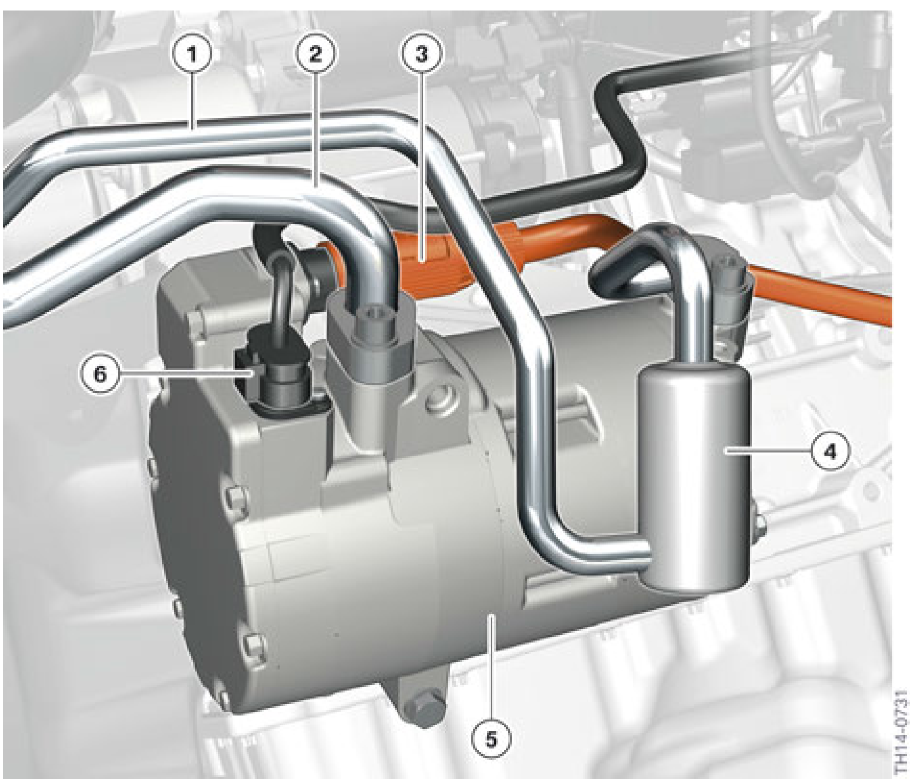
Cooling of	Shutoff valve for the evaporator (vehicle interior)	Combined expansion and shutoff valve for high-voltage battery unit	Electric A/C compressor (EKK)
High-voltage battery unit	Closed	Open	switched on
Passenger compartment	Open	Closed	switched on
High-voltage battery unit and passenger compartment	Open	Open	switched on
No cooling	Closed	Closed	Switched off

11. Climate Control

The request for the required cooling power is measured and determined by the IHKA control unit. On the one hand, the request can come directly from the customer to cool the passenger compartment. On the other hand, the battery management electronics control unit can send a request for the high-voltage battery unit to be cooled as a data bus message to the IHKA control unit. The IHKA control unit coordinates these cooling requirements and activates the electric A/C compressor via a local interconnect network bus. The cooling requirements are prioritized depending on the temperature, for example at a high ambient temperature and very warm passenger compartment, a higher cooling power is demanded with higher priority. If the desired temperature is reached, the cooling power is reduced to maintain the temperature and set to a lower priority.

It is similar for the temperature of the battery cells. If the battery cells heat up to temperature of approx. 30° C (86° F), cooling of the high-voltage battery unit already starts. The cooling requested by the battery management electronics control unit has an even lower priority here. It can for instance be declined by the high-voltage power management. At a higher cell temperature, the cooling request for the high-voltage battery unit receives top priority and is always carried out.

11.2. Electric A/C compressor (EKK)

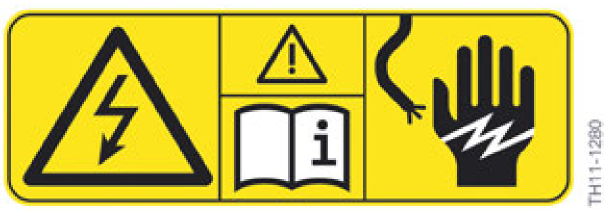


F30 PHEV, electric A/C compressor (EKK)

11. Climate Control

Index	Explanation
1	Connection for gaseous refrigerant with high temperature and high pressure (pressure line)
2	Connection for gaseous refrigerant with low temperature and low pressure (intake pipe)
3	High-voltage connector for compressor
4	Silencer (in the F30 PHEV, this is also found in the pressure line, however slightly further away from the EKK)
5	Electric A/C compressor (EKK)
6	Signal connector

The EKK is a high-voltage component!



Warning for high-voltage components

Each high-voltage component has on its housing an identifying label that enables Service employees and vehicle users to identify intuitively the possible hazards that can result from the high electric voltages used.

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Only Service employees who satisfy all the prerequisites are permitted to work on the designated high-voltage components: suitable qualifications, compliance with the safety rules, procedure following the repair instructions to the letter.

Before working on a high-voltage component, you must apply the safety rules to shut down the high-voltage system. Once this has been accomplished according to procedure, all high-voltage components are no longer live and work can proceed in safety. There is, of course, a remote possibility that the correct shutdown procedure might be omitted, so an extra safety precaution is implemented as a means of imposing an automatic shutdown of the high-voltage system.

A contact bridge is integrated in the high-voltage connector beside the contacts for the high voltage. This means when removing the high-voltage connector the contacts of the bridge in the high-voltage connector are separated first. The voltage supply of the EKK control unit is thus interrupted which in turn causes the power requirement on the high-voltage side to go to zero, even before the high-voltage connector is removed completely. No electric arc thus arises on the high-voltage contacts. The high-voltage contacts are protected from contact. The high-voltage connector of the EKK is not part of the circuit of the high-voltage interlock loop.

The operating principle of the compressor corresponds to the principle known from the F30H or the F01H. To compress the refrigerant, the spiral compressor (also known as the scroll compressor) is used. The electric power of the electric A/C compressor is 4.5 kW.

The high voltage for the EKK has a voltage range of approx. 205 V to 410 V. The power is reduced above and below this voltage range or the EKK is switched off.

The manufacturer of the electric A/C compressor is Visteon.

11.3. Independent air conditioning

Owing to the fact that the air conditioning compressor in the F30 PHEV is electrically operated and that the high-voltage battery unit has high energy and power densities, a stationary climate control function is offered to the customer in the F30 PHEV. For stationary air conditioning, the IHKA decides which measures are required for stationary heating, stationary cooling or stationary ventilation. Prerequisites for activation of the stationary climate control are:

- Sufficient state of charge of the high-voltage battery unit (state of charge > approx. 30%) or charging cable connected.
- Engine switched off or driving readiness deactivated.
- Ventilation outlets are open, allowing the air to escape.

The customer has various options for activating the stationary climate control:

- Via the menu in the CID, switch on directly or program a time.
- Via the button on the remote key (fourth button).
- Via BMW Remote app.

F30 PHEV High-voltage Components

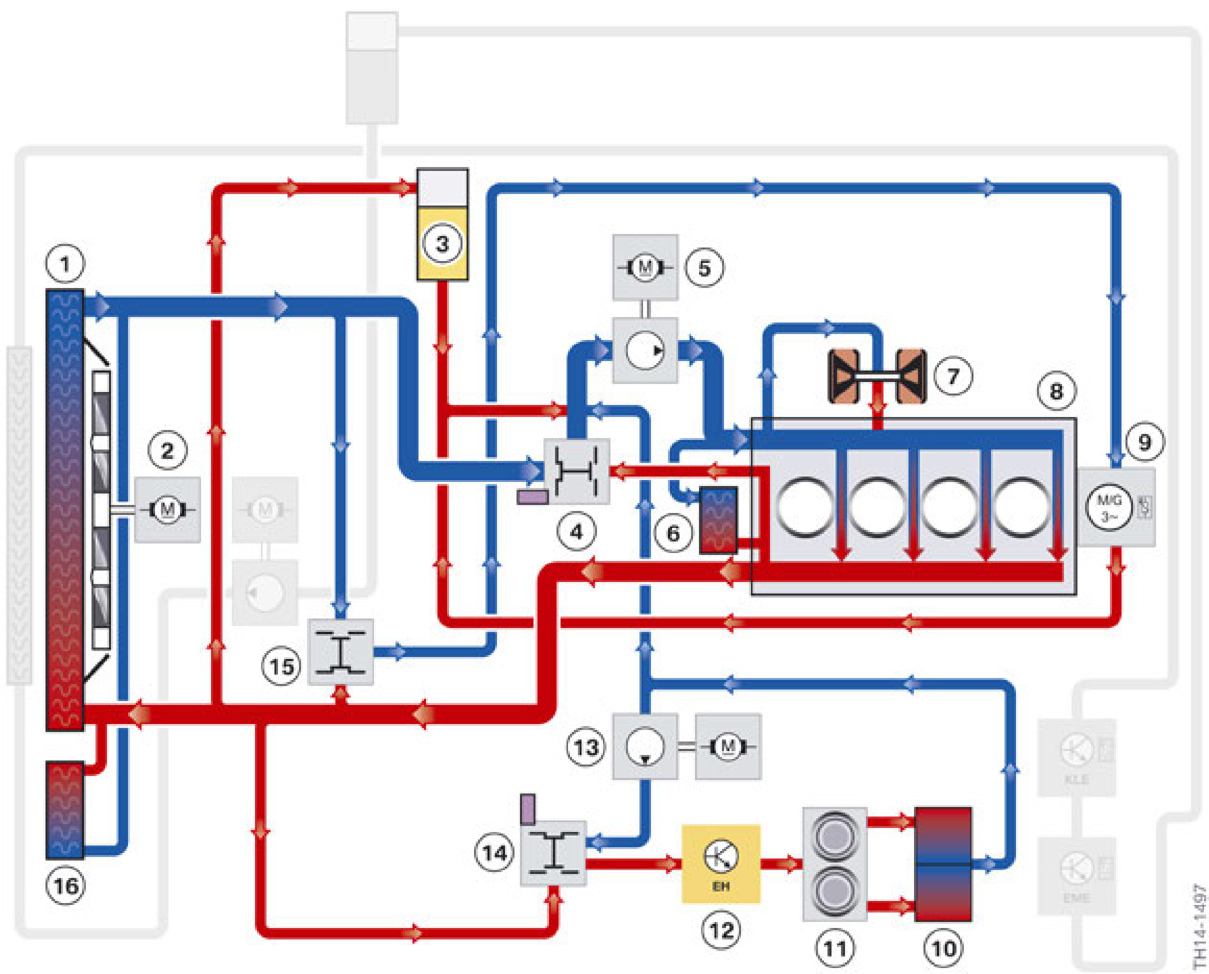
12. Electrical Heating

The heat exchanger for the heating system of the F30 PHEV is integrated in the coolant circuit of the combustion engine and electrical machine. With corresponding heating up by the combustion engine a sufficient heater output for heating the passenger compartment can be achieved. Due to its hybrid concept, the combustion engine of the F30 PHEV generates significantly less heat loss in many driving situations and is not able to heat the coolant circuit to the necessary temperature. This is why the F30 PHEV has electrical heating. In principle, this functions similar to an instantaneous water heater. Via a changeover valve a separate heater circuit can be formed, which is kept in circulation by an electric coolant pump.

The electrical heating is a high-voltage component!

⚠

Only Service employees who satisfy all the prerequisites are permitted to work on the designated high-voltage components: suitable qualifications, compliance with the safety rules, procedure following the repair instructions to the letter.



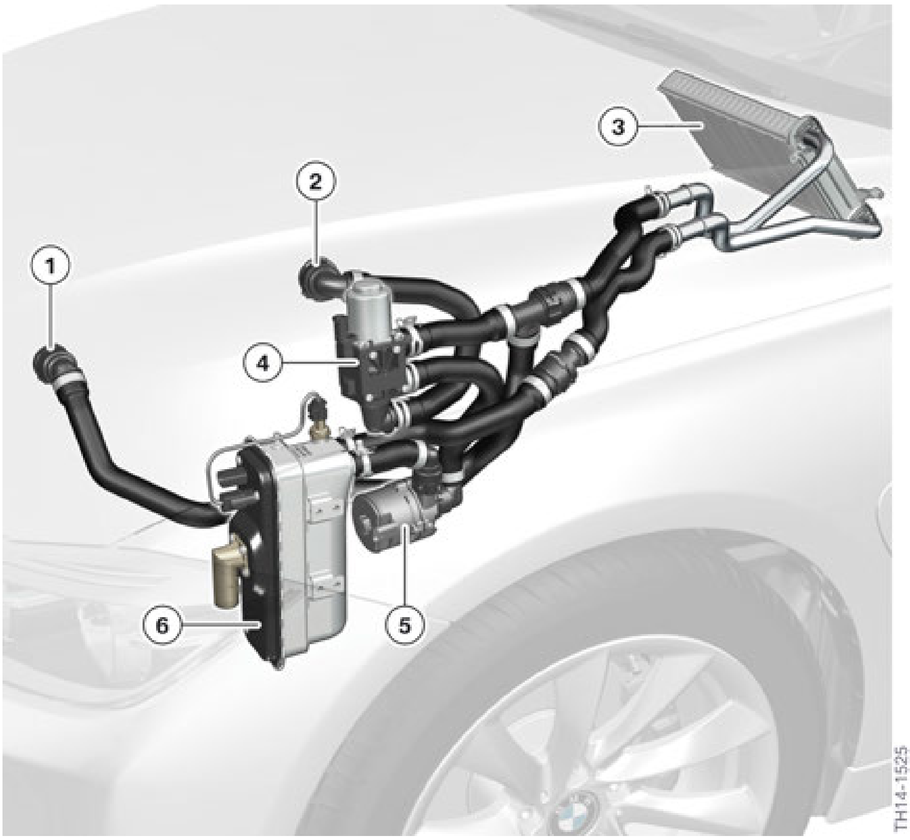
F30 PHEV, heater circuit in coolant circuit of combustion engine and electrical machine

Index	Explanation
1	Coolant/air heat exchanger (coolant circuit of combustion engine and electrical machine)
2	Electric fan
3	Coolant expansion tank (coolant circuit of combustion engine and electrical machine)
4	Data-map thermostat
5	Electric coolant pump (coolant circuit of combustion engine and electrical machine, 400 W)
6	Engine oil cooler
7	Exhaust turbocharger
8	Combustion engine
9	Electric motor
10	Heat exchanger
11	Double valve
12	Electrical heating
13	Electric coolant pump (for the heater circuit 20 W)
14	Electrical changeover valve
15	Thermostat for electrical machine
16	Separated coolant/air heat exchanger

F30 PHEV High-voltage Components

12. Electrical Heating

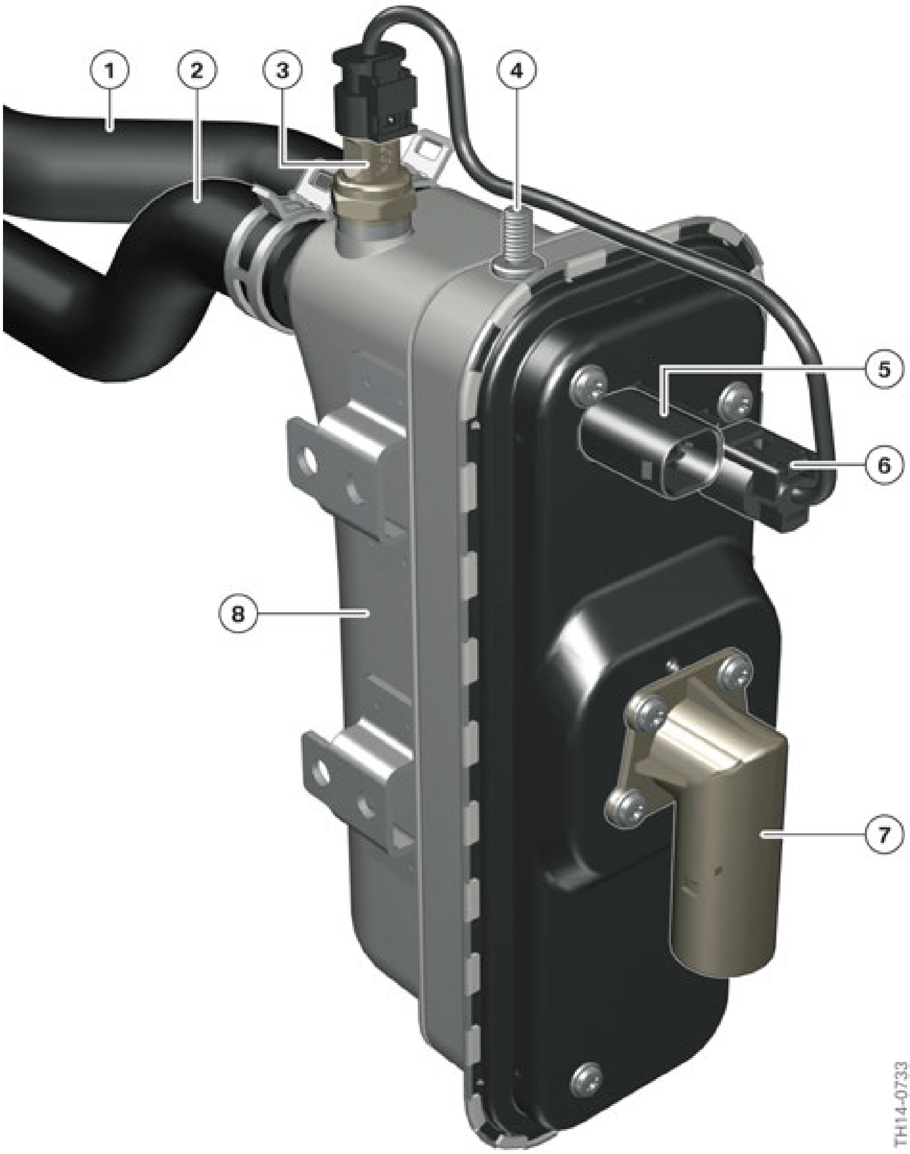
12.1. Installation locations and connections



F30 PHEV, heater circuit – Installation locations

Index	Explanation
1	Connection from the coolant circuit
2	Connection to the coolant circuit
3	Heat exchanger
4	Electrical changeover valve
5	Electric coolant pump (20 W)
6	Electrical heating

12. Electrical Heating



F30 PHEV, connections at the electrical heating

Index	Explanation
1	Connection for coolant feed line
2	Connection for coolant return line
3	Sensor for temperature of the coolant at the output of the electrical heating
4	Connection for potential compensation line
5	Signal connector (low-voltage connector)
6	Connection for sensor
7	Connection for high-voltage connector
8	Housing of the electrical heating

12.2. Operating principle

If the driver adjusts a desired temperature at the IHKA controls, the IHKA calculates a corresponding nominal temperature and compares it to the actual output temperature of the electrical heating. There is a temperature sensor at the electrical heating for this purpose. This way the IHKA control unit can decide whether the heat from the combustion engine is sufficient to heat the passenger compartment or whether the electrical heating should be switched on. If the temperature of the coolant is too low, the electrical heating can heat up in a total of six stages. The electrical heating is always condition-based thanks to this control operation.

12.2.1. Low coolant temperature

At a low coolant temperature, for example shortly after driving off or during purely electric driving, the electrical changeover valve is activated by the front electronic module. The electrical changeover valve blocks the supply from the coolant circuit of the combustion engine. The coolant is now pumped to the electrical heating by the electric coolant pump, heated and conveyed to the heat exchanger.

12.2.2. Coolant temperature, high

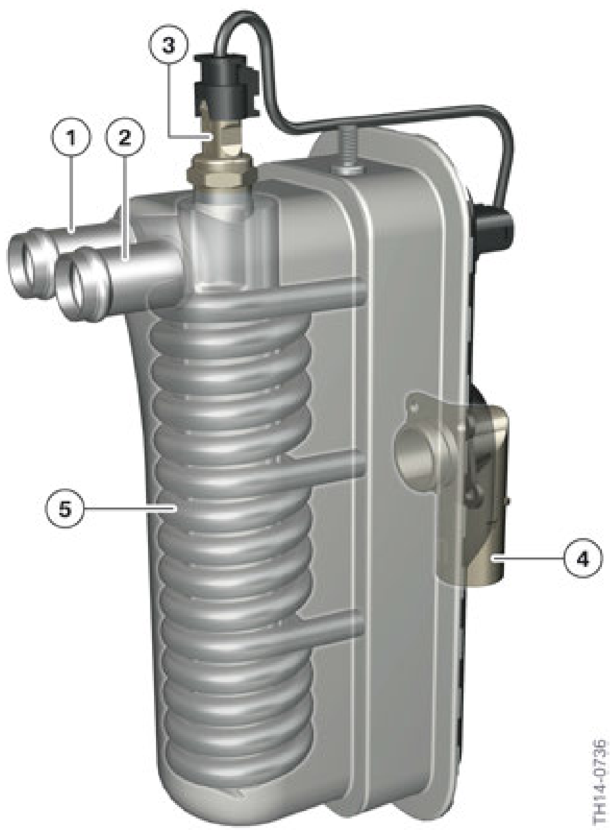
The coolant heated by the combustion engine flows through the de-energized, open changeover valve and the electrical heating to the heat exchanger. There some of the heat is released into the air flowing through the heat exchanger and ultimately reaches the coolant circuit of the combustion engine again. The electrical heating is switched off, but the electric coolant pump is active.

12. Electrical Heating

12.2.3. Heating control

The electric coolant pump and the electrical changeover valve are 12 V components and are activated by the front electronic module (FEM).

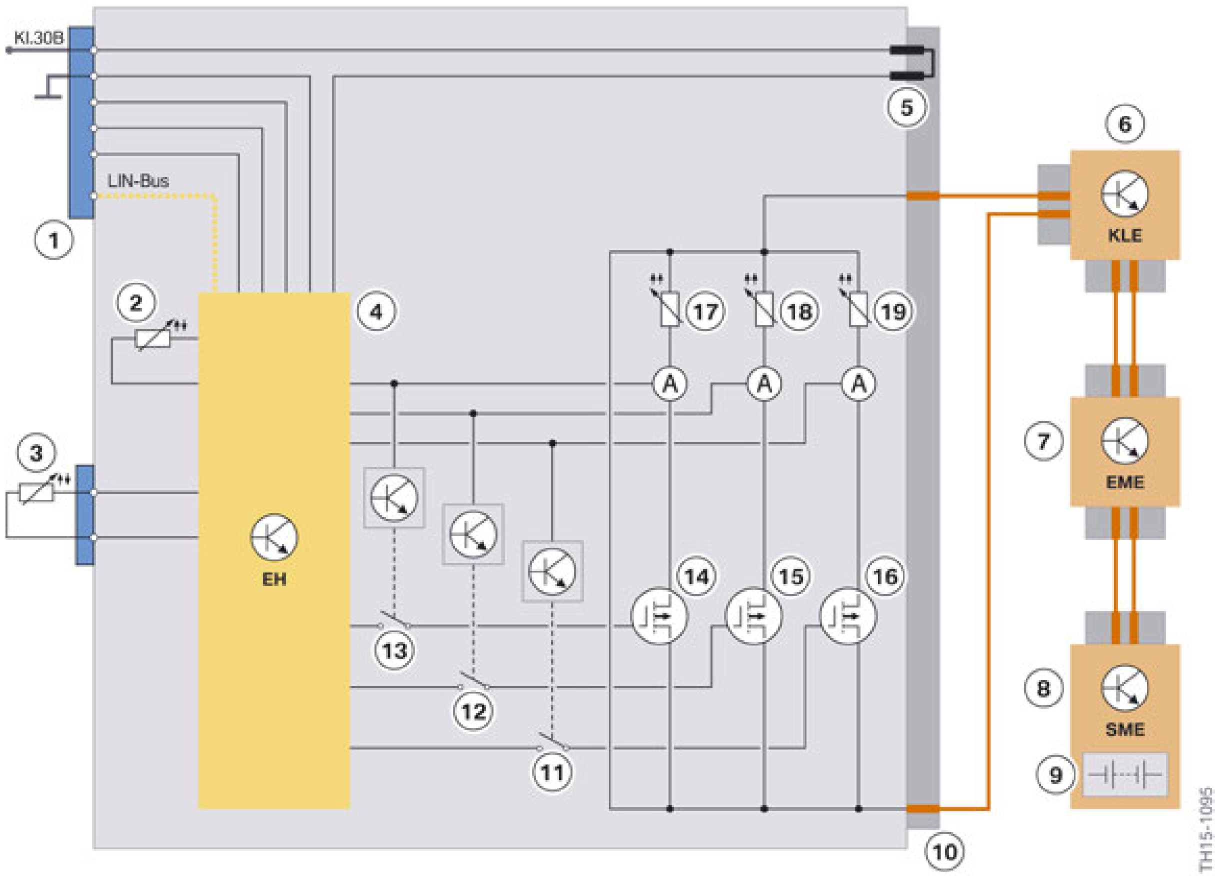
The maximum electrical power of the electrical heating is 4.6 kW (280 V and 20 A). The electrical heating is realized by three heater coils, each with a power of approx. 0.75 kW, 1.5 kW and 2.25 kW. The switching of the heater coils (individually or together) is effected within the electrical heating using an electronic switch (Power MOSFET).



F30 PHEV, heater coils in the electrical heating

Index	Explanation
1	Connection for coolant feed line
2	Connection for coolant return line
3	Sensor for temperature of the coolant at the output of the electrical heating
4	Connection for high-voltage connector
5	Three heater coils

12. Electrical Heating



F30 PHEV, functional wiring diagram for the electrical heating

Index	Explanation
1	Low-voltage connector
2	Sensor for temperature of the printed circuit board of the control unit for electrical heating
3	Sensor for temperature of the return coolant
4	Electrical heating (control unit)
5	Bridge in the high-voltage connector
6	Convenience charging electronics (KLE)
7	Electric Motor Electronics (EME)
8	Battery management electronics (SME)
9	High-voltage battery unit
10	High-voltage connector at electrical heating
11	Hardware shutdown in the event of excessive current in heater coil 3
12	Hardware shutdown in the event of excessive current in heater coil 2
13	Hardware shutdown in the event of excessive current in heater coil 1
14	Electronic switch (Power MOSFET) for heater coil 1

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12. Electrical Heating

Index	Explanation
15	Electronic switch (Power MOSFET) for heater coil 2
16	Electronic switch (Power MOSFET) for heater coil 3
17	Heater coil 1
18	Heater coil 2
19	Heater coil 3

The current through the individual strands is measured and controlled by the electrical heating control unit. A current of maximum 20 A flows in a voltage range of 250 V to 400 V. The power is reduced above and below this voltage range. At increased power consumption the energy supply by the hardware switching is interrupted. This switching is designed so that even in the event of a fault in the control unit a power cut is effected safely.

Inside the electrical heating a galvanic separation was realized between the high-voltage circuit and the low-voltage circuit.

The connections for local interconnect network bus and voltage supply (terminal 30B) are located at the low-voltage connector.

The high-voltage contacts of the round connector for the electrical heating are protected against contact. The high-voltage connector of the electrical heating is **not** part of the circuit of the high-voltage interlock loop.

A contact bridge is integrated in the high-voltage connector beside the contacts for the high voltage. The contacts of the bridge in the high-voltage connector are designed as leading contacts. This means when removing the high-voltage connector the contacts of the high-voltage bridge are separated first. The voltage supply of the EH control unit is thus interrupted which in turn causes the power requirement on the high-voltage side to go to zero, even before the high-voltage connector is removed completely. No electric arc thus arises on the high-voltage contacts.

Six heating stages can be set through separate or combined activation of the individual heater coils. The request for switching on the heating comes from the IHKA control unit via local interconnect network bus.

Heater coil	Heating stage	Heater output kW
1	1	0.75
2	2	1,5
3	3	2,25
1+3	4	3.0
2+3	5	3,75
1+2+3	6	4.5

When the maximum temperature is reached or if the maximum permissible current level is exceeded, the heater output is automatically restricted by the electrical heating.

The power of the electrical heating is also reduced in ECO PRO mode and from a certain state of charge of the high-voltage battery unit. The electrical heating is switched off in the event of system faults. The electrical heating is maintenance-free.

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Technical training.
Product information.

F30 PHEV High-voltage Battery Unit

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Technical Training
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BMW Service

General information

Symbols used

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

⚠

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

Information status and national-market versions

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

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

Additional sources of information

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

- Owner's Handbook
- Integrated Service Technical Application.

Contact: conceptinfo@bmw.de

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

Information status: **October 2015**
BV-72/Technical Training

F30 PHEV High-voltage Battery Unit

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F30 PHEV High-voltage Battery Unit

1. Introduction

This reference manual describes the design of the high-voltage battery unit in the BMW 330e with the development code F30 and the special features relating to its repair. This document is not a replacement for the repair instructions, but should provide the reader with the necessary background knowledge and supplementary notes.

Just like for BMW i models, it is now also possible for the first time for the 3rd generation GEN3 BMW hybrid vehicles to have components **inside** the high-voltage battery unit exchanged by qualified service employees in order to repair the unit. However, for the F30 Plug-in Hybrid Electric Vehicle the high-voltage battery unit is no longer available as a complete replacement part. As a result, it can also no longer be replaced without further repair work. Special qualification measures are offered to BMW dealership employees for the restoration of the high-voltage battery unit.

F30 PHEV High-Voltage Battery Unit

2. High-voltage Battery Unit

2.1. Overview

Technical data	Gen. 1.0	Gen. 1.5	Gen. 2.0	Gen. 3.0*	Gen. 3.0
Use	E72	F04	F01/F02H, F10H, F30H	F18 PHEV * China only	F15 Plug-in Hybrid Electric Vehicle
Manufacturer	Bosch	TEMIC	BMW	Bosch	BMW
Technology	Nickel metal hydride	Lithium-ion	Lithium-ion	Lithium-ion	Lithium-ion
Number of battery cells	260	35	96	96	96
Cell voltage Capacity	1.2 V7.7 Ah	3.6 V6.5 Ah	3.3 V4 Ah	3.78 V40 Ah	3.7 V26 Ah
Nominal voltage	312 V	126 V	317 V	363 V	355 V
Voltage range	234 - 422 V	n.n.	n.n.	269 -395 V	269 -399 V
Storable energy capacity	2.4 kWh	0.8 kWh	1.35 kWh	14.5 kWh	9.2kWh
Energy available for consumption	1.4 kWh	0.4 kWh	0.6 kWh	12 kWh	6.8 kWh
Max. output	57 kW, briefly	19 kW	43kW	90 kW, briefly 36, continuous	83 kW, briefly 43 kW continuous
Weight	83 kg (183 lbs)	28 kg (62 lbs)	46 kg (101 lbs)	218 kg (480lbs)	105 kg (231 lbs)

As in BMW ActiveHybrid motor vehicles the high-voltage battery unit is the energy storage device for the electrical drivetrain. The **F30 PHEV** follows the F15 PHEV as the second **P**lug-in **H**ybrid **E**lectrical **V**ehicle from BMW. The F30 PHEV is also equipped with the new generation high-voltage battery unit Gen. 3.0. In Gen. 3.0, the high-voltage battery unit is repaired in the event of possible faults.
This stands in contrast to Gen. 1.0 – Gen. 2.0 units, which had to be replaced completely.

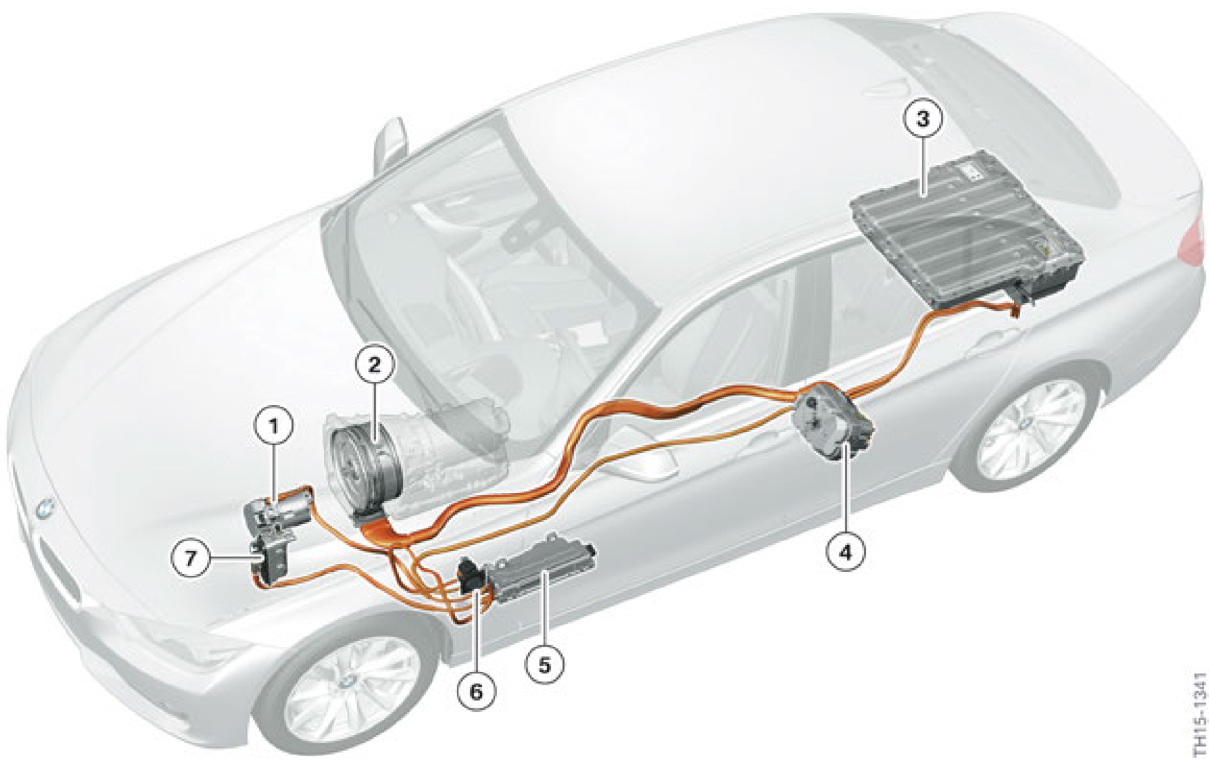
Like all BMW ActiveHybrid vehicles, the F30 PHEV is equipped with an electrical machine that can be used to charge the high-voltage battery. In addition to charging with the electrical machine, it is possible to charge the high-voltage battery unit of plug-in motor vehicles using an external, domestic charging socket. The high-voltage battery can also be charged by brake energy regeneration.

F30 PHEV High-voltage Battery Unit

2. High-voltage Battery Unit

The high-voltage battery of a vehicle with an electric motor is the equivalent to the fuel tank in a vehicle with a combustion engine: In order to reach the desired range of the F30 PHEV the amount of energy to be stored must be dimensioned accordingly. The high-voltage battery is installed centrally in the luggage compartment under the luggage compartment floor. The installation location of the high-voltage battery unit has made it possible to positively influence a number of vehicle characteristics:

- Thanks to the low installation location the centre of gravity of the vehicle is lowered, which reduces the roll tendency in bends, in particular.
- The vehicle interior is not restricted by the high-voltage battery unit in comparison to conventional vehicles, such as the BMW ActiveHybrid 3, 330i.
- Installing the unit in the vehicle underbody results in a flat loading platform and the option to load items through into the vehicle interior.



F30 PHEV, high-voltage components and high-voltage cables

Index	Explanation
1	Electric A/C compressor (EKK)
2	Electric motor
3	High-voltage battery unit
4	Electric Motor Electronics (EME)
5	Convenience charging electronics (KLE)
6	Charging socket
7	Electrical Heating (EH)

2. High-voltage Battery Unit

2.1.1. Technical data

Many of the components of the high-voltage battery unit of the F30 PHEV are identical with those of the F15 PHEV and are made up as follows:

- Cell modules (5 with 16 cells each)
- Cell Supervision Circuits (6 CSC)
- Safety box
- Control unit for battery management electronics (SME)
- Three-part heat exchanger
- Wiring harnesses
- Connections (electrical system, refrigerant, venting)
- Housing and fastening parts

The battery cells are supplied by the Korean company Samsung SDI to the BMW plant in Dingolfing. There the cell modules are assembled from the battery cells and mounted into complete high-voltage battery units with the other components. The manufacturer of the SME control unit and the Cell Supervision Circuit is Preh.

The battery cells used in the high-voltage battery of the F30 PHEV are lithium-ion cells (cell type NMCo/LMO mixture). The anode material of lithium-ion batteries is generally a lithium metal oxide. The designation NMCo/LMO mixture refers to the metals used for this cell type. It is a mix of nickel, manganese and cobalt on the one hand, and lithium manganese oxide on the other hand.

The characteristics of the high-voltage battery for use in an electric vehicle were able to be optimized through the selection of the anode material (high energy density, high cycle number). Graphite is normally used for the cathode. The lithium ions are deposited in the cathode during discharging. As a result of the materials used, the nominal voltage of the battery cells is **3.66 V.**

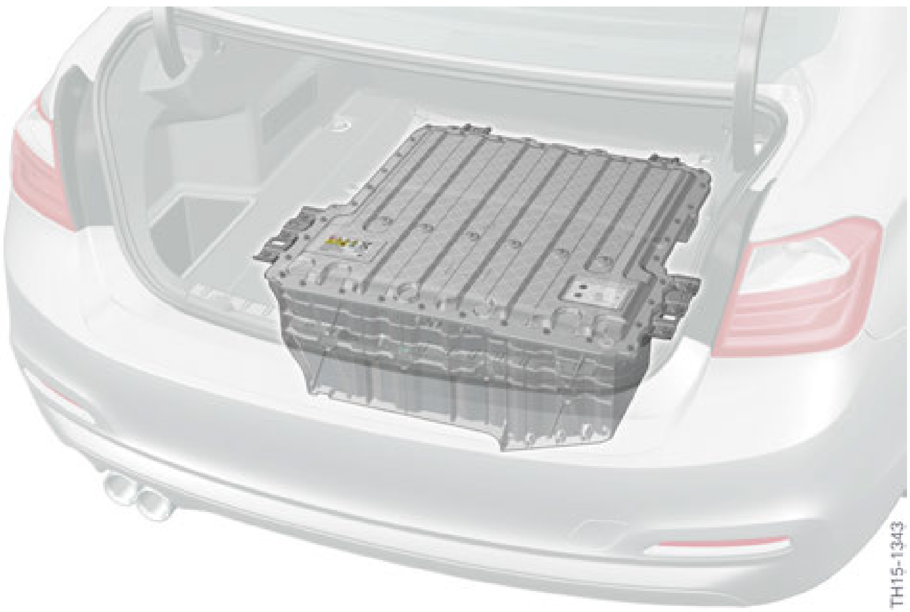
The following table summarizes some key technical data of the high-voltage battery in the F30 PHEV.

Voltage	292.8 V (nominal voltage) Min. 225 V – Max. 327.6 V (voltage range)
Battery cells	80 battery cells in series (each 3.66 V and 26 Ah)
Max. storable amount of energy Max. usable energy	7.8 kWh 5.8 kWh
Max. power (discharge)	65 kW (short-term) 45 kW (continuous)
Maximum power (AC charging)	3.7kW
Total weight	88.1 kg (194.2 lbs)
Dimensions	769 mm x 827 mm x 319 mm
Cooling system	Refrigerant R134a

2. High-voltage Battery Unit

2.1.2. Installation location

The high-voltage battery unit is installed in the luggage compartment under the luggage compartment floor. This has the advantage that the centre of gravity in the F30 PHEV was lowered, which in turn results in improved driving characteristics. In order to reach the connections of the high-voltage battery unit, it is necessary to remove a trim panel on the vehicle underbody.



The key external features of the high-voltage battery unit are:

- High-voltage cable or connection
- Interface for the 12 V vehicle electrical system
- Refrigerant lines or connections
- Labels
- Venting unit

The high-voltage battery unit also has an interface for the 12 V vehicle electrical system, in addition to the high-voltage connection. The control units integrated in the high-voltage battery unit are supplied with voltage, data bus, sensor and monitoring signals via this interface. It is incorporated in the refrigerant circuit for cooling the high-voltage battery.

The labels on the high-voltage battery unit inform people working with these components about the technology used and possible electrical and chemical dangers.

2. High-voltage Battery Unit

⚠

The electrical voltage of the high-voltage battery unit is well over 60 V. This is why **before** any work at the high-voltage battery unit the **electrical safety rules** must be observed:

1 **Disconnect** the system from the power supply.

2 **Secure** the service disconnect to prevent unintentional restarting.

3 **Verify** that the system is isolated from the power supply.

⚠

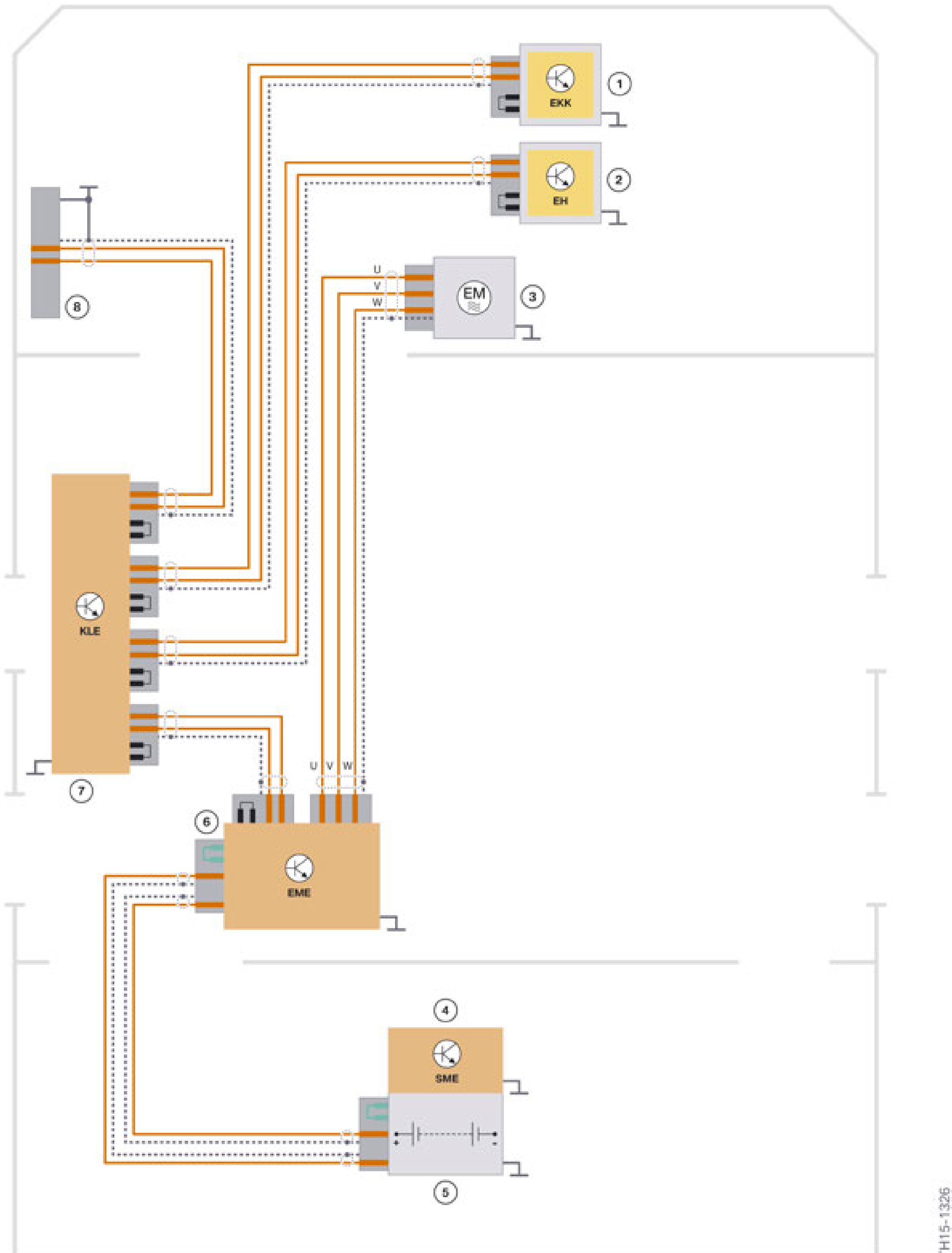
If the de-energized state cannot be clearly identified in the instrument cluster, further work at the vehicle is not allowed! **There is a danger to life!** The de-energized state must then be confirmed by a BMW qualified electrician using the appropriate measuring devices/measuring procedures. **In these cases, Technical Support or a BMW qualified electrician must be contacted!** Furthermore, the vehicle must be locked and restricted using barrier tape.

The electrical lines (high-voltage and interface for the 12 V vehicle electrical system), as well as the refrigerant lines, can be disconnected without having to remove the high-voltage battery unit.

The high-voltage battery unit is located in the passenger compartment. If the battery cells generate excess pressure due to a severe fault, the developing gases must be transported outwards. The venting unit on the upper housing section of the high-voltage battery unit is directly connected to the outside environment.

Just like in other ActiveHybrid motor vehicles the high-voltage service disconnect does not form part of the high-voltage battery unit. This component is located in the rear right luggage compartment behind a flap.

2.1.3. System wiring diagram

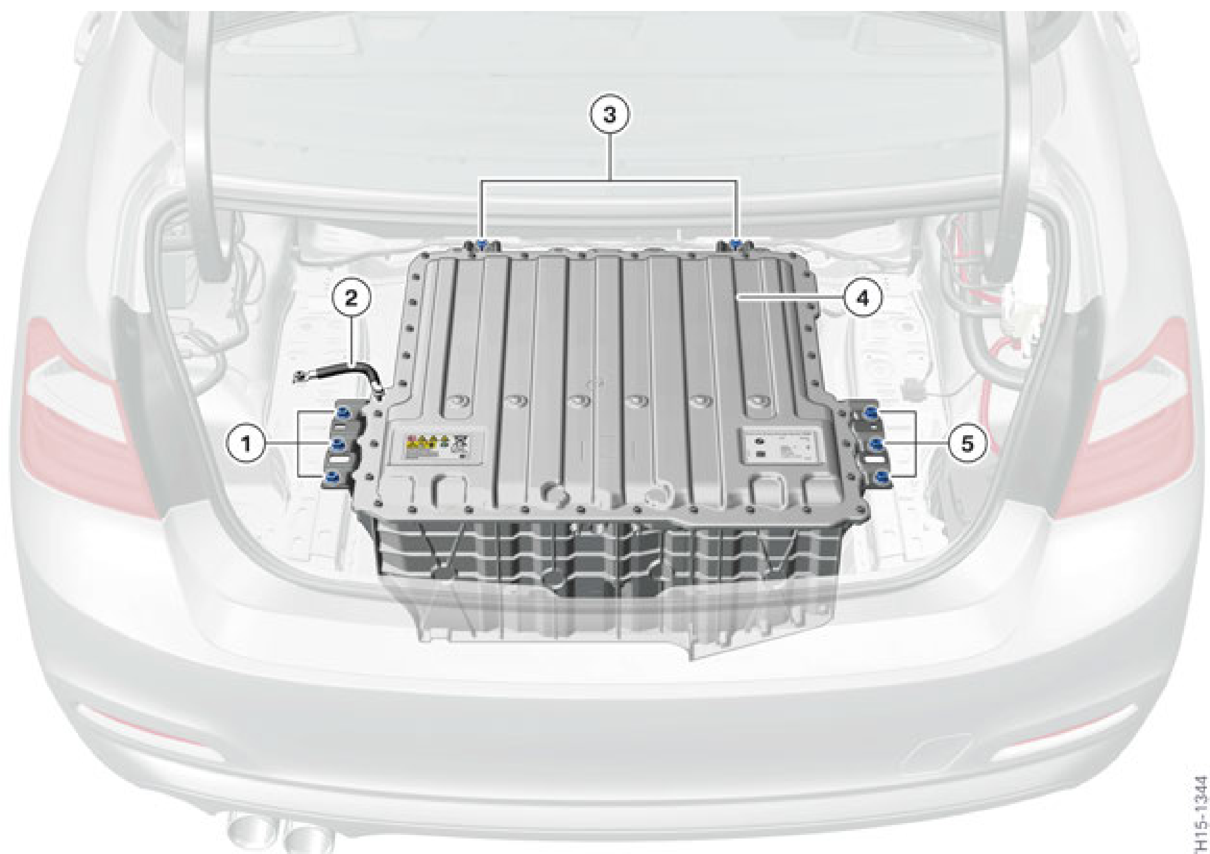


F30 PHEV, system wiring diagram for high-voltage battery unit in the high-voltage network

Index	Explanation
1	Electric A/C compressor (EKK)
2	Electrical Heating (EH)
3	Electric machine
4	Battery management electronics (SME)
5	Cell modules of the high-voltage battery unit
6	Electric Machine Electronics (EME)
7	Convenience charging electronics (KLE)
8	Charging socket

2.2. External features

2.2.1. Mechanical interfaces



F30 PHEV, mounting of the high-voltage battery unit

F30 PHEV High-voltage Battery Unit

2. High-voltage Battery Unit

Index	Explanation
1	Mounting nuts, left
2	Potential compensation line
3	Mounting nuts, front
4	High-voltage battery unit
5	Mounting nuts, right

The high-voltage battery unit is connected to the vehicle body by means of four bolts and nuts. This way the weight and the acceleration forces occurring during the journey are supported at the body. The mounting nuts are not directly accessible from the luggage compartment, which means that several trim panels have to be removed beforehand to undo the screws.

For the removal of the high-voltage battery unit firstly all preliminary work specified in the repair instructions (diagnosis, disconnecting from the power supply, disassembling the trim panels, etc.) has to be performed. There will be a special workshop crane (multi-function lifting tool 2 360 081) with corresponding special tools available to the Service workshops to facilitate removal and installation of the high-voltage battery unit.

The electrical connection between the housing of the high-voltage battery unit and the body is established by means of a separate potential bonding line.

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The low resistance connection between the housing of the high-voltage battery unit and ground is a crucial prerequisite for the fault-free function of the automatic insulation monitoring. This is why it is important to observe the correct tightening torque for all assembly screws.

It is also important to ensure that neither the housing of the high-voltage battery unit, nor the body are painted, corroded or contaminated around the corresponding bore holes. The bare metal must be exposed if necessary before the mounting screws can be secured.

2. High-voltage Battery Unit

Follow the exact procedure when mounting the assembly screws:

- Clean contact surfaces and have checked by a second person.
- Tighten assembly screws to specified torque.
- Have torque checked by second person.
- Both persons must record this in the vehicle records.

Only self-tapping screws have to be used for assembly procedures at the housing of the high-voltage battery unit. It is permitted to restore the thread at the lower housing cover using BMW approved threaded inserts.

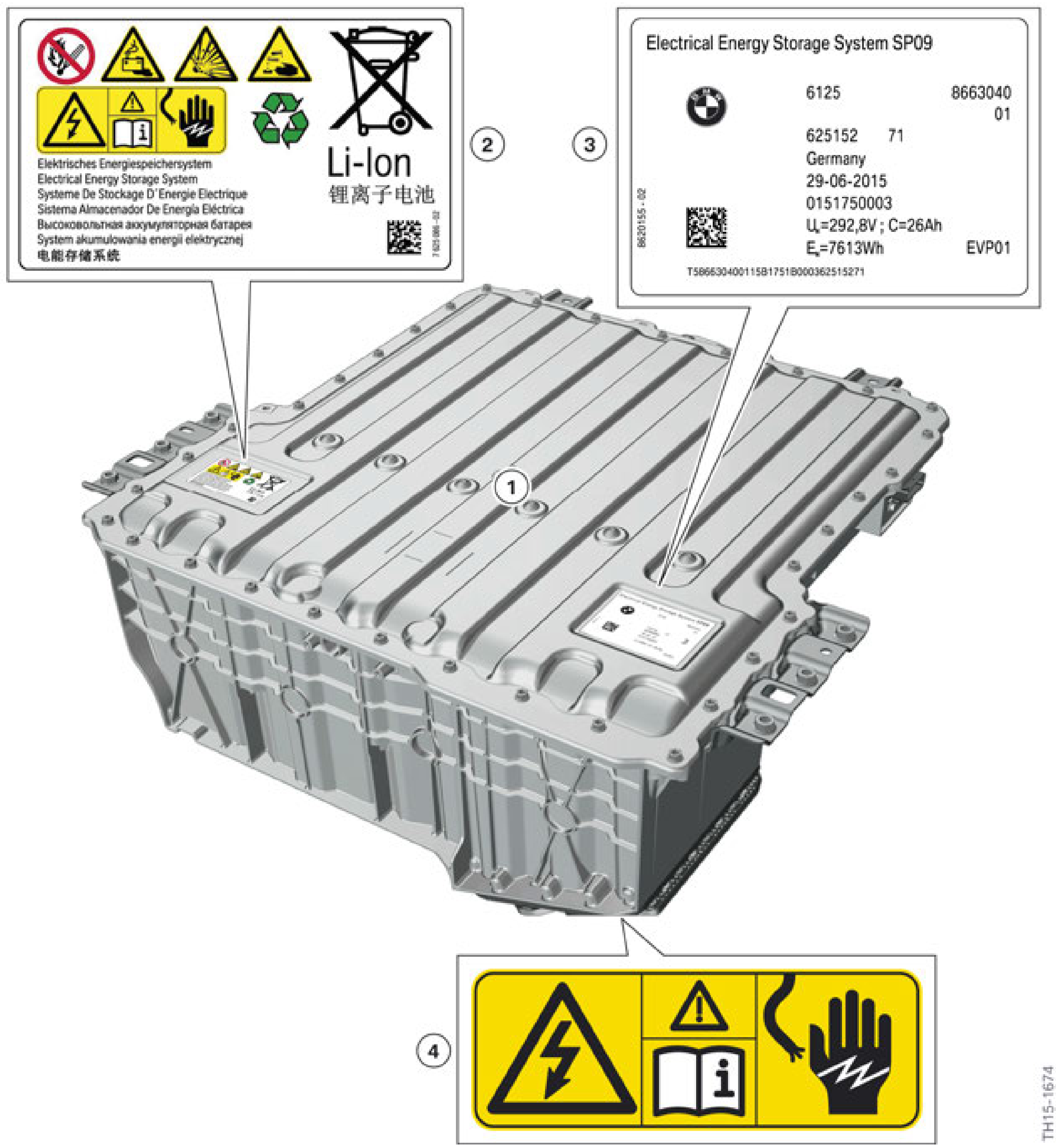
⚠

The Kerb Konus threaded inserts for thread repair of the hybrid Lithium ion battery case are part #41 00 2 288 195 and the insert tool part # 83 30 2 359 049.

Two labels are attached to the high-voltage battery unit of the F30 PHEV: a type plate and a warning sticker. The type plate provides logistical information (e.g. part number) and the key technical data (e.g. nominal voltage). The warning sticker highlights the lithium-ion technology and the high electrical voltage used within the high-voltage battery unit to alert users of any potential and associated dangers.

F30 PHEV High-voltage Battery Unit

2. High-voltage Battery Unit



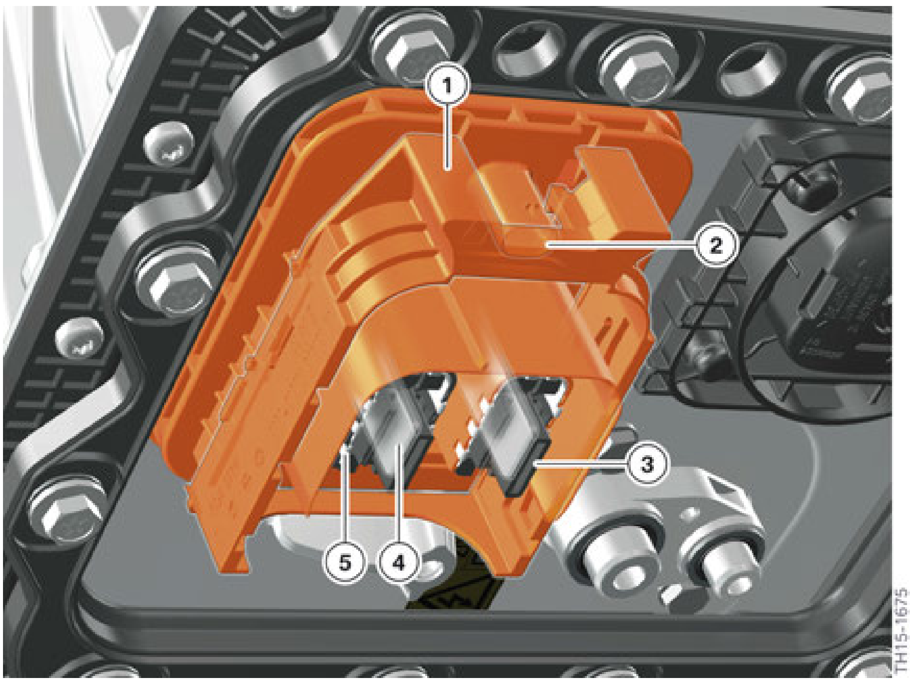
Signs on the F30 PHEV high-voltage battery unit housing

Index	Explanation
1	Upper housing section of the high-voltage battery unit
2	High-voltage battery unit warning sticker
3	Type plate with technical data
4	High-voltage component warning sticker

2.2.2. Electrical interfaces

High-voltage connection

There is a two-pin high-voltage connection at the high-voltage battery unit with which the high-voltage battery unit is connected to the high-voltage electrical system.



F30 PHEV High-voltage connection at the high-voltage battery unit

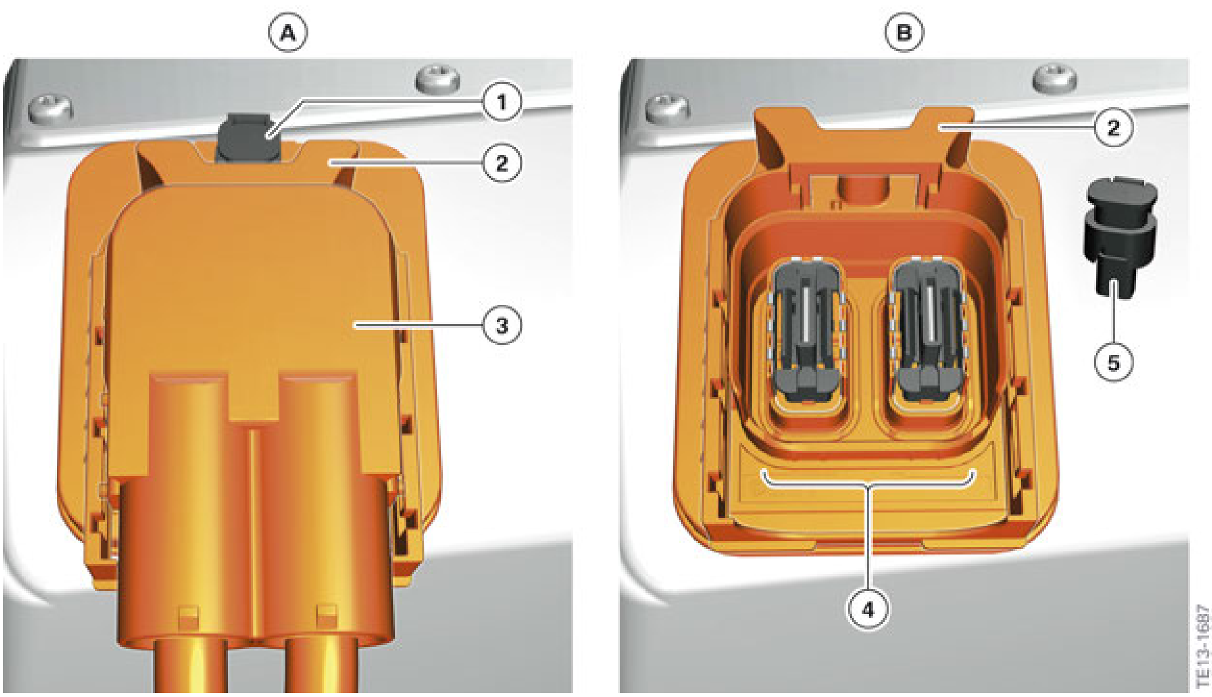
Index	Explanation
1	Mechanical slide
2	Socket with connection for bridge in the circuit of the high-voltage interlock loop
3	Contact protection
4	Contact for high-voltage cable
5	Contact for shielding

A contact is available for shielding around each of the two electrical contacts of the high-voltage cables. The shielding of the high-voltage cable (shielding for each cable) is continued into the housing of the high-voltage battery unit and thus contributes to the electromagnetic compatibility (EMC).

In addition, the high-voltage connection provides protection against contact with live parts.
The actual contacts are coated in plastic so that nobody can touch them directly. Only when the cable is connected is the coating pushed away and the contact established.

The plastic slide serves as the mechanical latch mechanism of the connector. It is also an element of a safety function: If the high-voltage cable is not connected, the slide conceals the connection for the bridge of the high-voltage interlock loop. Only when the high-voltage cable is properly connected and the connector is locked, is this connection accessible and the bridge can be inserted. This guarantees that only when a high-voltage cable is connected is the circuit of the high-voltage interlock loop also closed. This principle applies to all flat high-voltage connections in the F30 PHEV (high-voltage battery unit, Electrical Machine Electronics).

As a result, the high-voltage system is active only once all high-voltage connections have been connected to the Electrical Machine Electronics and the convenience charging electronics. This is additional protection against contact with contact surfaces, which otherwise may carry voltage.



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 the high-voltage cable
4	High-voltage connection
5	Bridge for high-voltage interlock loop (disconnected)

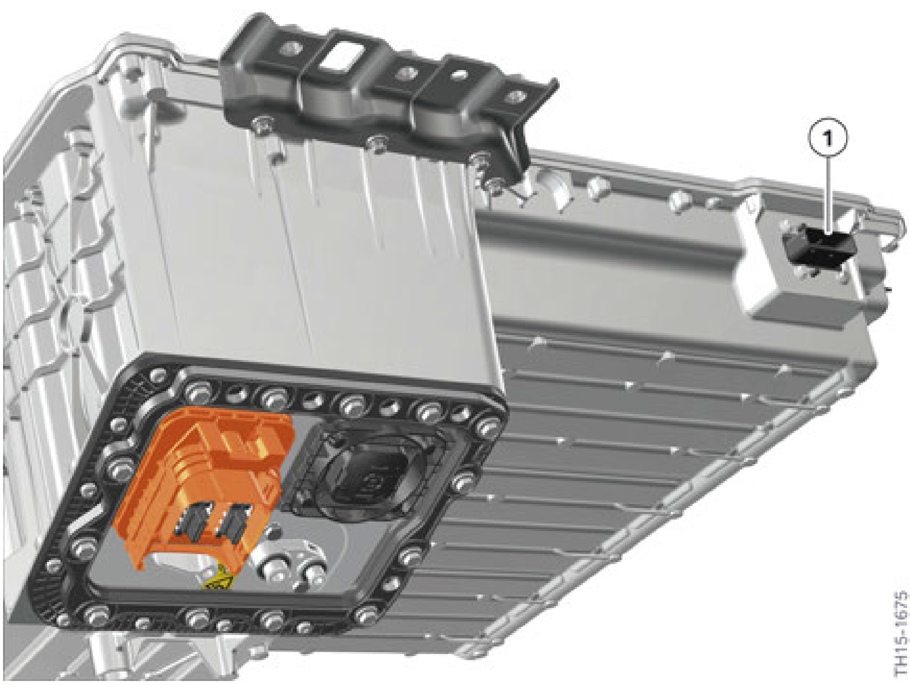
The high-voltage connection can be replaced as a separate component, just like all other components of the high-voltage battery unit. The prerequisites are qualified service employees and exact compliance with the repair instructions.

2. High-voltage Battery Unit

Interface for the 12 V vehicle electrical system

The high-voltage battery unit of the F30 PHEV features an interface to the 12 V vehicle electrical system with the following connections:

- Voltage supply of the SME control unit with terminal 30 and terminal 31.
- Terminal 30C crash signal for voltage supply of the electromechanical switch contactors.
- Wake-up line of the front electronic module.
- Input and output of the line for the high-voltage interlock loop.
- Output (+12 V and ground) for the activation of the combined expansion and shutoff valve.
- PT-CAN2.



F30 PHEV Signal connector on the high-voltage battery unit

Index	Explanation
1	Interface for the 12 V vehicle electrical system

2. High-voltage Battery Unit

High-voltage safety connector (Service Disconnect)

The high-voltage service disconnect of the F30 PHEV does not form part of the high-voltage battery unit. For this reason, the color of the high-voltage service disconnect was changed from orange to **green** as automotive standard. The high-voltage service disconnect is installed in the rear right luggage compartment as a separate component.


TH15-1731

As in ActiveHybrid motor vehicles the high-voltage service disconnect fulfils two tasks:

- Disconnecting the high-voltage system from the supply.
- Providing a safeguard to prevent unintentional restarting.

The high-voltage safety connector or the connected bridge is part of the circuit of the high-voltage interlock loop. If the connector and bush of the high-voltage safety connector are pulled apart, the circuit of the high-voltage interlock loop is interrupted.

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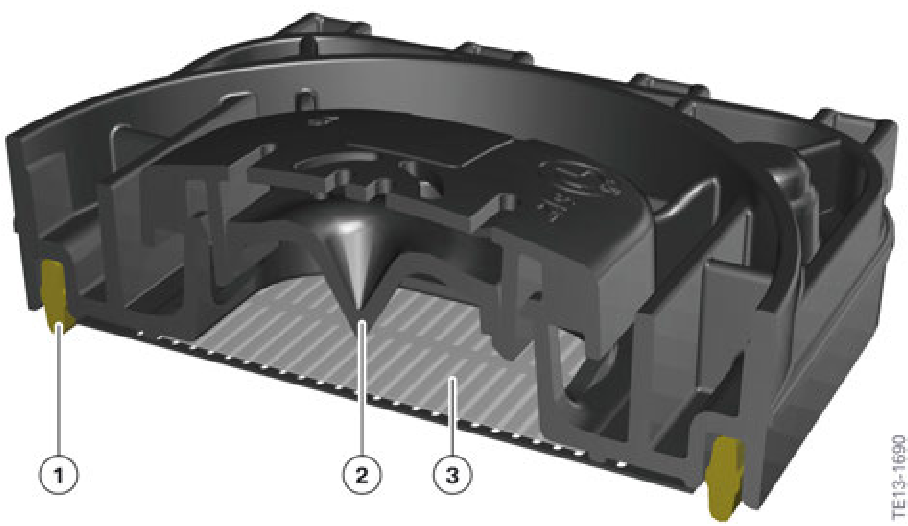
The connector and bush of the high-voltage safety connector cannot be disconnected from each other completely. Both parts are mechanically secured against complete separation. To interrupt the circuit of the high-voltage interlock loop, it is sufficient to separate the two parts far enough so that the U-lock can be used to secure against restart.

The precise procedure for disconnecting the power supply is described in the "F30 PHEV high-voltage components" information bulletin.

2.2.3. Venting unit

The venting unit performs two tasks. The first task is to offset large pressure differences between the inside and outside of the high-voltage battery unit. Such pressure differences can only arise in the event of a damaged battery cell. In this case for safety reasons the housing of the cell module with the damaged battery cell is opened to reduce the pressure. The gases are initially located in the housing of the high-voltage battery unit. From there they can be transported outwards via the venting unit. The pressure also increases if the heat exchanger is leaking and there is refrigerant emerging.



F30 PHEV cross-section through the venting unit

Index	Explanation
1	Gasket
2	Mandrel
3	Diaphragm

The second task of the venting unit is to transport outwards condensate arising in the inside of the high-voltage battery unit. Besides the technical components, there is also air inside the high-voltage battery unit.

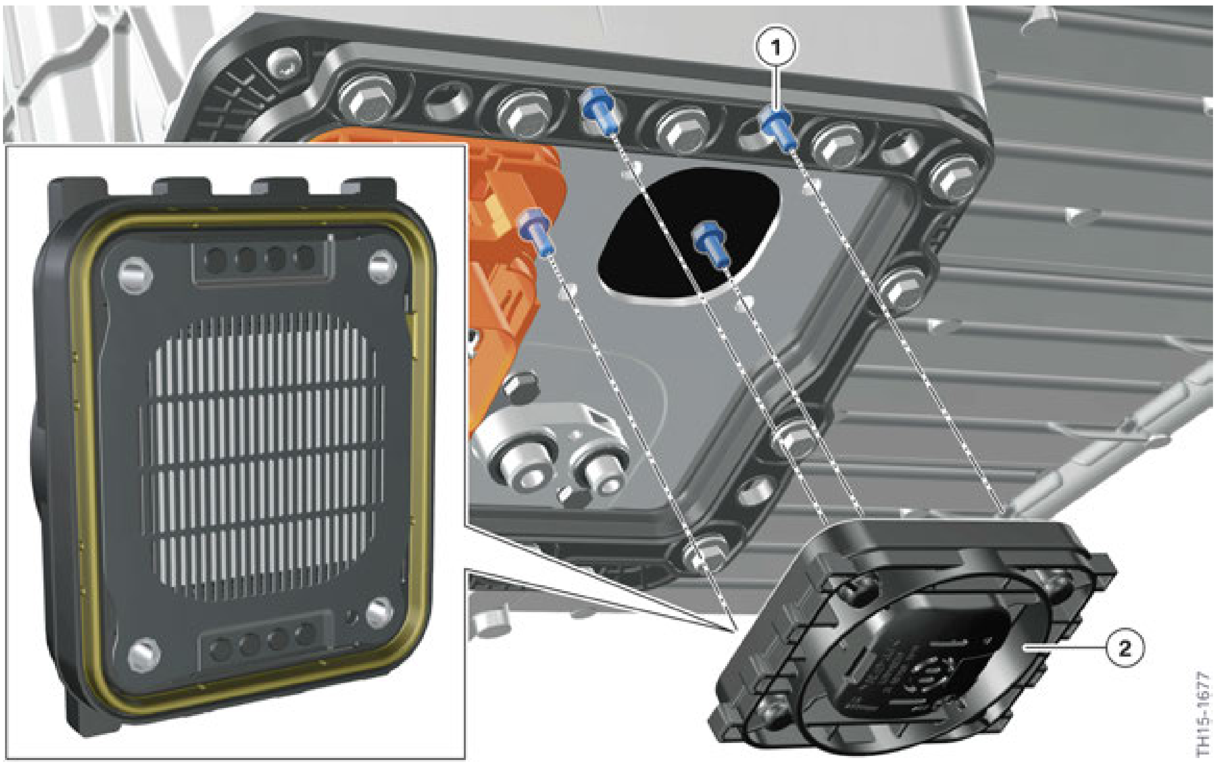
If the air or the housing is cooled by a lower ambient temperature or by a refrigerant through the activation of the air conditioning function, some of the water vapor from the air condenses.
This means small amounts of liquid water can form in the inside of the high-voltage battery unit. This has no affect on the function.

During the next heating of the air or the housing the water evaporates again and, at the same time, the pressure in the housing rises slightly. The venting unit permits pressure compensation by allowing the warm air to escape outwards. The water vapor in the air is also transported outwards and also the previously liquid condensate.

2. High-voltage Battery Unit

To fulfil these tasks the venting unit has a permeable diaphragm for gases (and water vapor) and an impermeable diaphragm for fluids. Above the diaphragm is a mandrel, which destroys the diaphragm in the event of severe excess pressure in the high-voltage battery unit. There is a two-part cover to protect against coarse contamination.

The installation location of the venting unit is on the upper housing section.



F30 PHEV mounting, venting unit

Index	Explanation
1	Mounting bolts
2	Venting unit

⚠

The venting unit can be replaced in Service as an entire unit. A replacement is recommended if the venting unit has suffered mechanical damage.

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Use the test adapter matching the F30 PHEV venting unit for the final test with the EoS diagnosis system (end of service).

2.2.4. Interface for the refrigerant circuit

It is incorporated in the refrigerant circuit of the heating and air-conditioning system for cooling the high-voltage battery. In order to be able to perform condition-based cooling, there is an electrically activated combined expansion and shutoff valve at the high-voltage battery unit.

The combined expansion and shutoff valve is hard-wired to the SME control unit and is activated directly by this control unit. The valve is closed in a currentless state, i.e. no refrigerant flows into the high-voltage battery unit. The valve only knows two positions, "closed" and "open". The amount of flowing refrigerant is adjusted thermally.

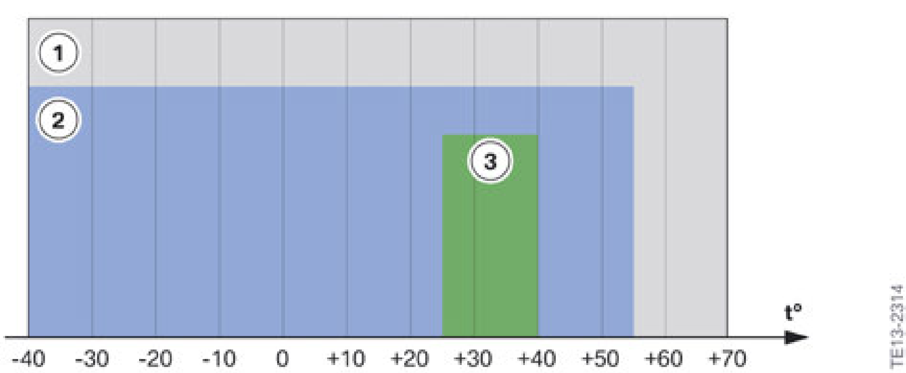
2.3. Cooling system

2.3.1. Overview

To maximize the service life of the high-voltage battery and obtain the greatest possible power, it is operated in a defined temperature range. The high-voltage battery unit is essentially operational in the range of -40 °C to +55 °C (-40 °F to + 131 °F actual cell temperature). In terms of temperature behavior the high-voltage battery unit is a slow-action system, i.e. it takes several hours until the cells assume the ambient temperature. Therefore having the battery spend a short period of time in an extremely hot or cold environment does not mean that the cells will already have assumed this temperature.

The optimal range of the temperature of the cell with regard to service life and performance is more limited. It is between +25 °C and +40 °C (77 °F and 104 °F). If the cell temperature is continuously significantly above this range with simultaneously high performance, this has a negative effect on the service life of the battery cells. To counteract this effect, as well as ensure maximum performance at all ambient temperatures, the high-voltage battery unit of the F30 PHEV has an automatic cooling function.

There is no heating function for the high-voltage battery unit in the F30 PHEV.



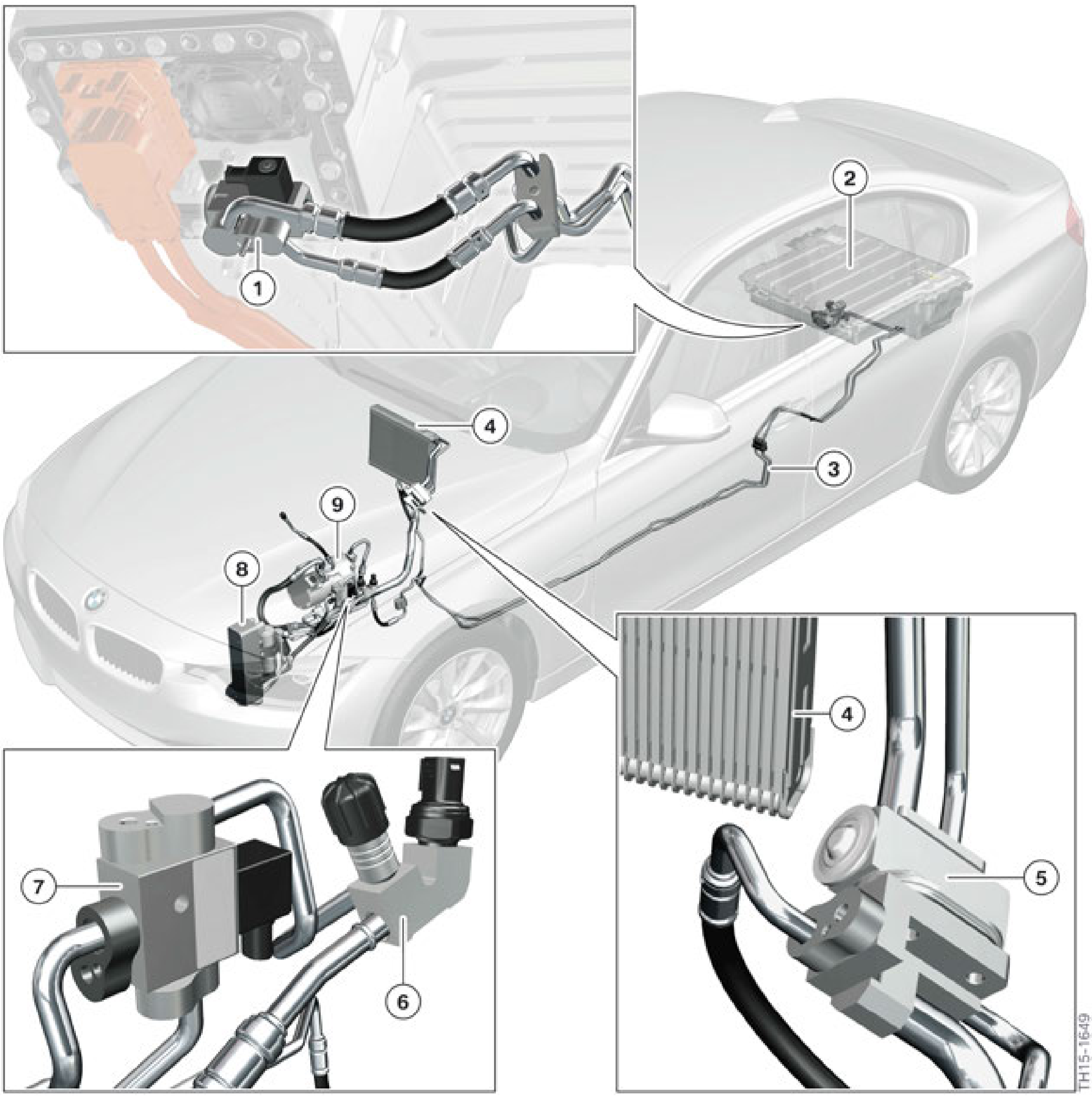
F30 PHEV high-voltage battery unit operating temperature range

Index	Explanation
1	General temperature range (storage area)
2	Operating range of the high-voltage battery unit
3	Optimal operating range of the high-voltage battery unit

F30 PHEV High-voltage Battery Unit

2. High-voltage Battery Unit

The F30 PHEV is equipped with a cooling system for the high-voltage battery as standard. For this purpose it is integrated in the refrigerant circuit of the heating and air-conditioning system.



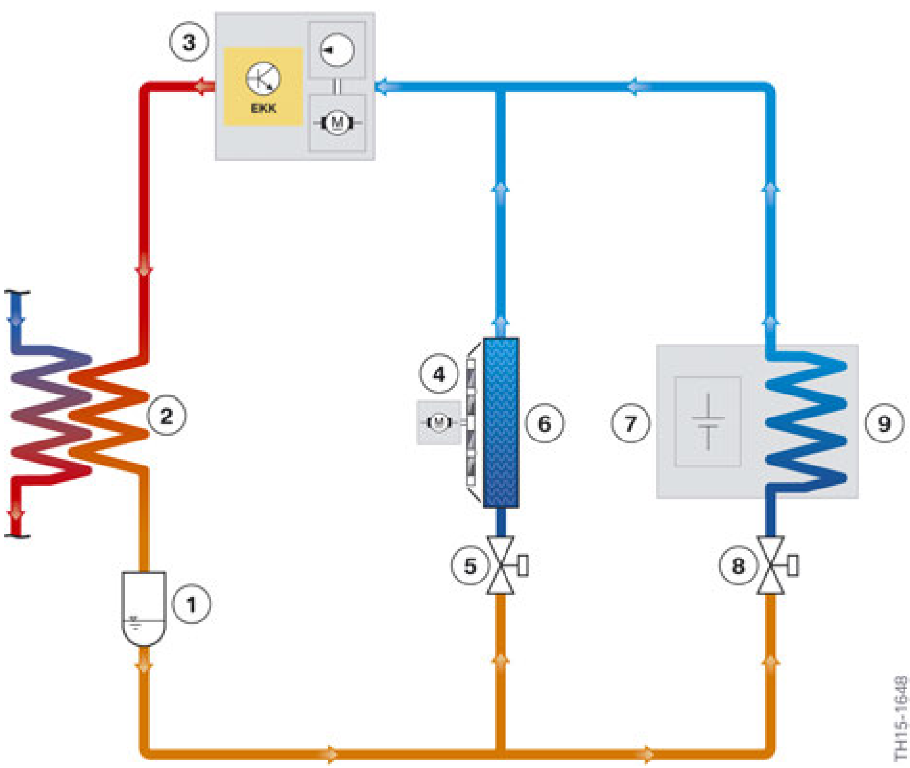
F30 PHEV Overall refrigerant system

Index	Explanation
1	Combined expansion and shutoff valve
2	High-voltage battery unit
3	Refrigerant lines to high-voltage battery unit
4	Evaporator, passenger compartment
5	Expansion valve for vehicle interior

Index	Explanation
6	Connection for filling and evacuation
7	Shutoff valve (vehicle interior)
8	Coolant/refrigerant heat exchanger
9	Electric A/C compressor (EKK)

Cooling system of the high-voltage battery unit

The high-voltage battery unit in the F30 PHEV is cooled directly using R134a refrigerant. For this reason, the refrigerant circuit of the air conditioning consists of two parallel branches. One for cooling the passenger compartment and one for cooling the high-voltage battery unit. Each branch features an expansion and a shutoff valve to be able to control the air conditioning functions independently of each other. The battery management electronics can activate and open the combined expansion and shutoff valve at the high-voltage battery unit by applying voltage. In this way refrigerant can flow to the high-voltage battery, where it expands, evaporates and cools the surrounding area. The cooling of the passenger compartment is also effected in a condition-based manner. The combined expansion and shutoff valve upstream from the evaporator can also be activated electrically and by the EME.



F30 PHEV refrigerant circuit with high-voltage battery unit

2. High-voltage Battery Unit

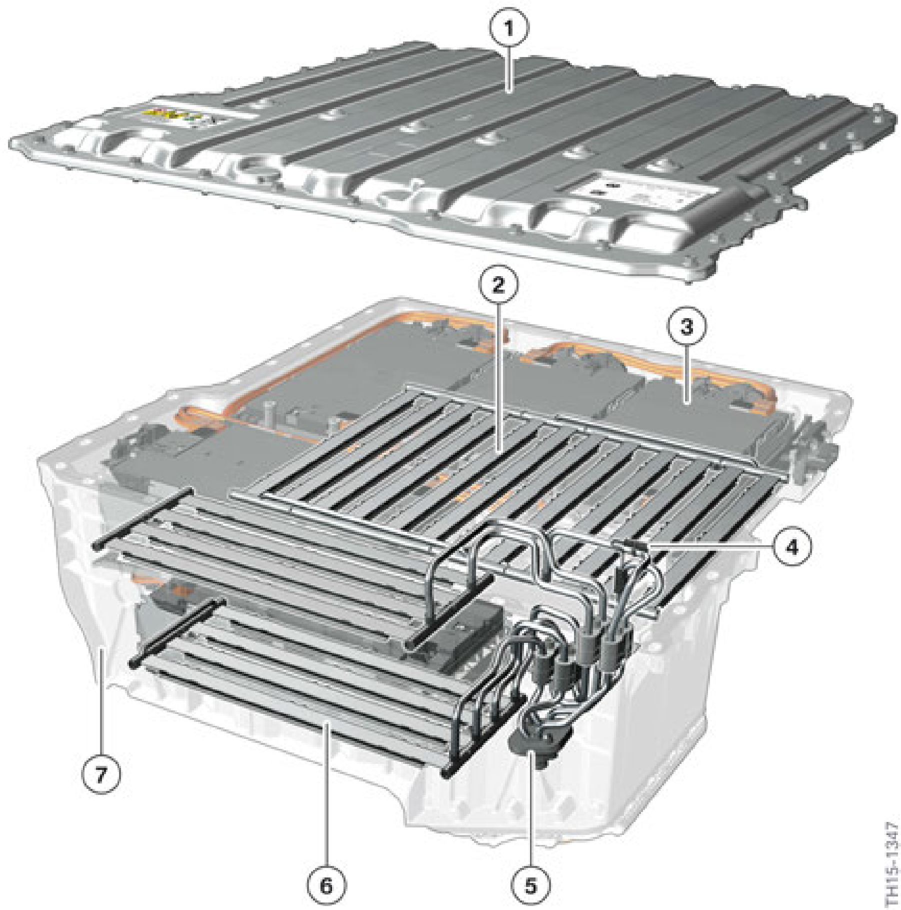
Index	Explanation
1	Dryer unit
2	Coolant-refrigerant heat exchanger
3	Electric A/C compressor (EKK)
4	Blower for passenger compartment
5	Expansion valve for vehicle interior
6	Evaporator, passenger compartment
7	High-voltage battery unit
8	Combined expansion and shutoff valve, high-voltage battery unit
9	Heat exchanger

The refrigerant evaporates with the injection of the liquid refrigerant in the heat exchanger. The evaporating refrigerant draws the heat from the ambient air, thus cooling it. Then the EKK compresses the gaseous refrigerant at a higher pressure level. The heat energy is transferred by the heat exchanger to the coolant and the refrigerant returns to liquid state of aggregation again.

In the F30 PHEV, the cell modules are arranged on two levels due to the installation location of the high-voltage battery unit. In order to ensure sufficient cooling of the battery cells by the refrigerant, a three-part heat exchanger is used. One heat exchanger is located under the three top cell modules, one heat exchanger under the fourth cell module at the top and one under the bottom cell module. It consists of flat aluminium pipes and is connected to the internal refrigerant lines.

F30 PHEV High-voltage Battery Unit

2. High-voltage Battery Unit



F30 PHEV components for cooling in the high-voltage battery unit

Index	Explanation
1	Upper housing half
2	Top heat exchanger (two-part)
3	Cell module
4	Temperature sensor for refrigerant line
5	Connecting flange for combined expansion and shutoff valve
6	Lower heat exchanger
7	Lower housing half

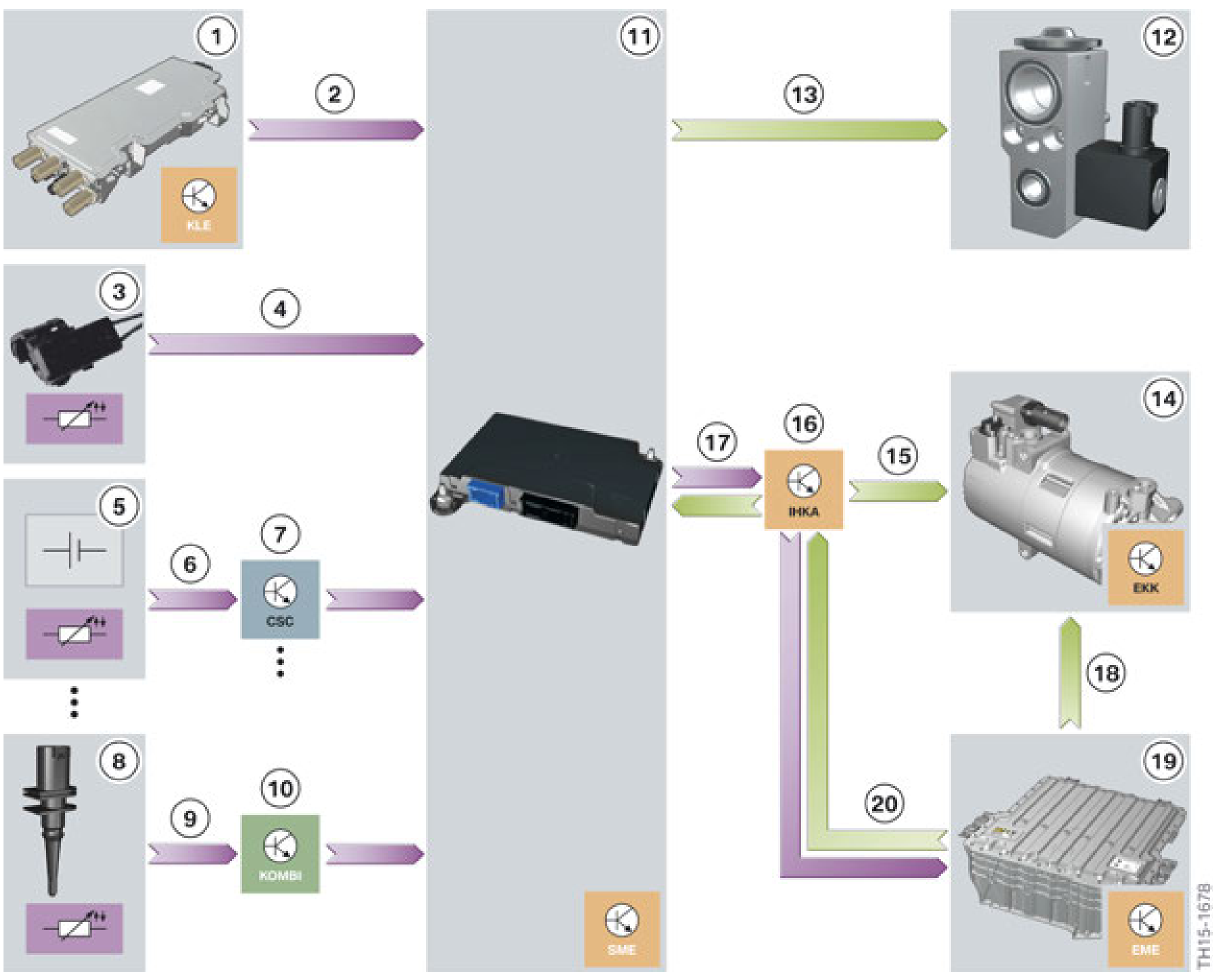
2.3.2. Function

The cooling system has two operating conditions:

- Cooling OFF
- Cooling ON

The operating conditions are generally dependent on the cell temperatures, the ambient temperature and the power used by or supplied to the high-voltage battery. The SME control unit decides which operating condition is necessary depending on the input variables.

The following graphic shows the input variables, the role of the SME control unit and which actuators are used for the control.



Input/output cooling system of the F30 PHEV high-voltage battery unit

2. High-voltage Battery Unit

Index	Explanation
1	Convenience charging electronics (KLE)
2	Information that the high-voltage battery unit is being charged externally
3	Refrigerant temperature sensor at the refrigerant line supply
4	Signal for refrigerant temperature
5	Temperature sensors at the cells of the high-voltage battery
6	Signal for cell module temperature
7	Cell Supervision Circuit (CSC)
8	Outside temperature sensor
9	Signal for ambient temperature
10	Instrument panel (KOMBI)
11	SME control unit (in the high-voltage battery unit)
12	Combined expansion and shutoff valve
13	Signal for activating the combined expansion and shutoff valve
14	Electric A/C compressor (EKK)
15	Signal for the activation of the EKK (via local interconnect network bus)
16	Integrated automatic heating / air conditioning
17	Cooling requirement
18	High-voltage power supply
19	Electric Motor Electronics (EME)
20	High-voltage power requirement

Cooling OFF operating condition

The "Cooling OFF" operating condition is adopted when the cell temperatures are in or below an optimal range. This is generally the case if the vehicle is moved at moderate ambient temperatures and at low electrical power. The "Cooling OFF" operating condition is particularly efficient because no additional energy is required for cooling the high-voltage battery.

The components involved work as follows:

- The EKK is not in operation or runs at reduced power if the passenger compartment has to be cooled.
- The combined expansion and shutoff valve at the high-voltage battery unit is closed.

Cooling ON operating condition

If the battery cells heat up to temperatures of approx. 30 °C / 86 °F, the cooling of the high-voltage battery has already begun. The SME control unit sends a cooling requirement to the IHKA control unit with two priorities. The IHKA decides whether the passenger compartment or the high-voltage battery unit is cooled or both are cooled. The cooling requirement may be refused by the IHKA for a cooling requirement by the SME with low priority and for a high cooling requirement in the passenger compartment. However, the high-voltage battery unit is always cooled for a cooling requirement by the SME with high priority.

For the cooling the IHKA requests electrical power from the high-voltage power management in the Electrical Machine Electronics for the EKK.

The components act as follows in "Cooling" operating condition:

- SME control unit requests cooling requirement.
- Following release by the IHKA the SME control unit activates the combined expansion and shutoff valve at the high-voltage battery unit. This valve opens and refrigerant flows to the high-voltage battery unit.
- The EKK is in operation.

As a result of the pressure drop after the expansion valve, the refrigerant in the lines and coolant ducts of the high-voltage battery unit evaporates. In the process the refrigerant absorbs heat energy from the cell modules or battery cells and cools them. The evaporated refrigerant leaves the high-voltage battery unit again, is compressed by the electric A/C compressor and returned to a liquid state in the coolant-refrigerant heat exchanger. Although energy is required from the high-voltage electrical system for this procedure, it is of utmost importance. Only this way can a long service life and a high degree of efficiency of the battery cells be guaranteed.

If the temperature of the battery cells is significantly below the optimal operating temperature of 20 °C / 68 °F, their performance would be temporarily restricted and the efficiency of the energy conversion would not be optimal. This is an unavoidable chemical effect of lithium-ion batteries.

If the F30 is parked for an extended period (e.g. a few days) at a very low ambient temperature, the battery cells also take on this low ambient temperature. In this situation it is possible the full electrical driving power is not available at the start of the journey. This remains unnoticed by the customer as the combustion engine assumes the drive of the vehicle in this case.

2.3.3. System components

Heat exchanger

In the inside of the high-voltage battery units the refrigerant flows through lines and coolant ducts made from aluminium. The refrigerant flowing in via the inlet piping is distributed after the connection at the high-voltage battery unit to the top and bottom heat exchangers. The refrigerant flowing through the feed line is distributed into two coolant ducts in the heat exchanger and absorbs the heat of the cell modules en route through the coolant ducts.

At the end of the coolant ducts the refrigerant is directed to the neighboring coolant ducts, flows back and absorbs further heat from the cell modules.

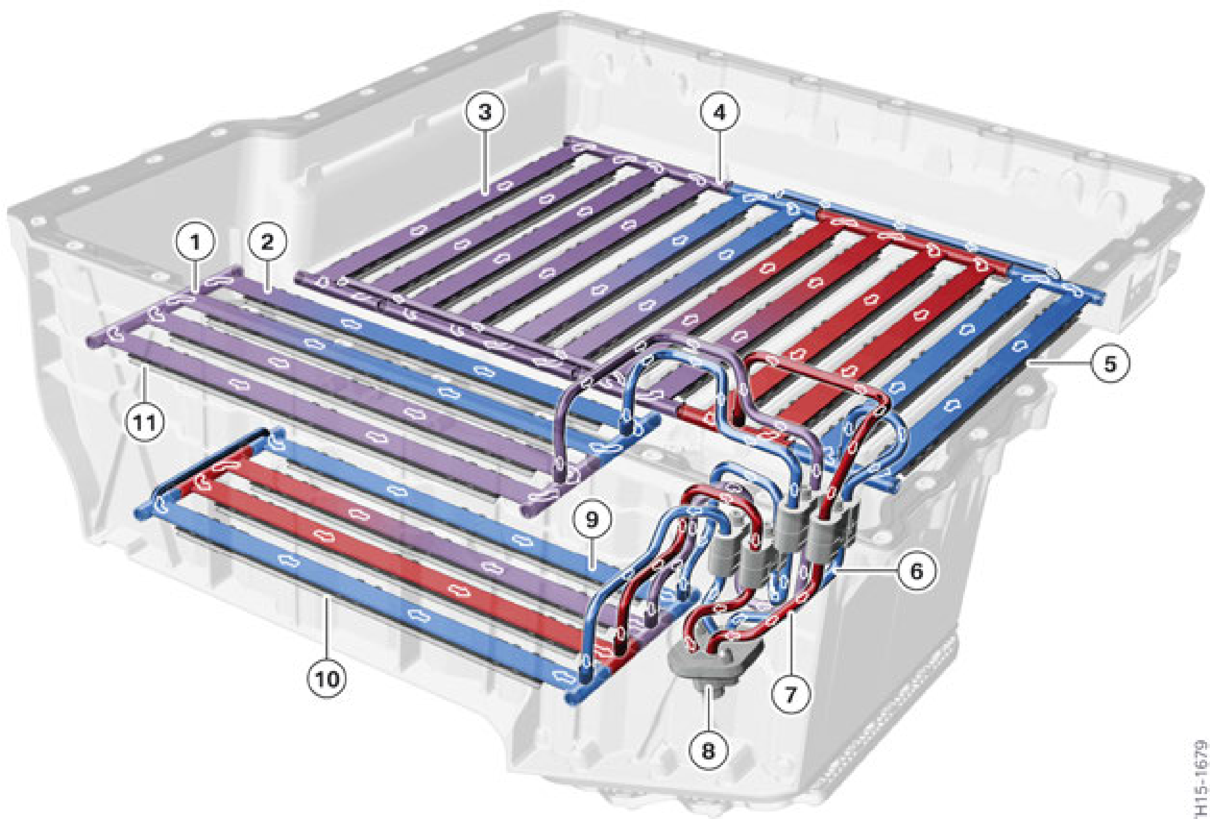
At the end the two return lines of each heat exchanger are joined in a common return line.

F30 PHEV High-voltage Battery Unit

2. High-voltage Battery Unit

This common return line returns the evaporated refrigerant to the connection of the high-voltage battery unit.

A temperature sensor is installed at the feed line of the lower heat exchanger, whose signal is used for controlling and monitoring the cooling function. It is read directly by the SME control unit.



F30 PHEV components for cooling in the high-voltage battery unit

Index	Explanation
1	Connecting pipe on intake side of small top heat exchanger
2	Input, pressure side, small top heat exchanger
3	Return line, intake side, top heat exchanger
4	Connecting pipe, intake side
5	Input, pressure side, top heat exchanger
6	Feed line, pressure side, top heat exchanger
7	Return line, top heat exchanger
8	Connecting flange for combined expansion and shutoff valve
9	Bottom heat exchanger (return line, intake side, bottom heat exchanger)
10	Input, pressure side, bottom heat exchanger
11	Return line, intake side, small top heat exchanger

So that the coolant ducts can fulfil their task of discharging heat energy from the cell modules, the whole area of the coolant ducts must be pressed onto the cell modules at an evenly distributed force. This contact pressure is generated by spring rods which are embedded in the coolant ducts. The spring roads are adapted to the geometry of the cell modules and the lower housing half.

The spring rod of the lower heat exchanger is supported at the lower housing half of the high-voltage battery unit and presses the coolant ducts onto the cell modules. The spring of the upper heat exchanger is supported at the aluminium rails lying between the cell module connectors.

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The refrigerant lines, coolant ducts and spring rails together form one unit, which can be replaced separately in the case of a repair. To simplify matters, this unit is also called a heat exchanger, but is not to be confused with the heat exchanger in the front of a conventional vehicle.

The three heat exchangers are very long components. However, the long coolant ducts in particular are not unitary, but have a relatively thin wall thickness. They have excellent heat conducting properties, but as a result their mechanical stability is low. This is not a disadvantage when it is installed because the mechanical stability is maintained by the high-voltage battery unit housing. However, extreme caution must be exercised when handling the heat exchanger in Service.

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For the replacement of the heat exchanger the repair instructions must be followed exactly and extreme caution must be exercised. Two persons are required for lifting a new heat exchanger in order to avoid damaging the new part.

Refrigerant temperature sensor

The temperature of the refrigerant is not measured directly. Instead, the temperature sensor is fitted at a segment of the refrigerant line in the high-voltage battery unit. The installation position is shown in the graphic in the chapter entitled "Heat exchanger".

Using the temperature of the refrigerant line, the temperature of the flowing refrigerant and thus also the available cooling power can be calculated. The refrigerant temperature sensor is hard-wired to the SME control unit where the signal is also evaluated.

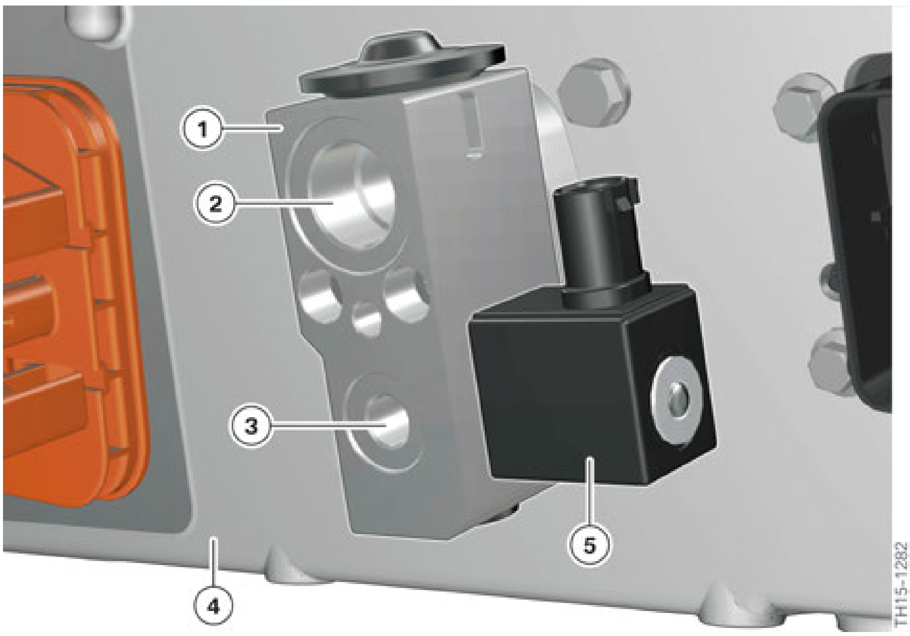
The sensor is a negative temperature coefficient, whose resistance value is reduced at increasing temperature.

The refrigerant temperature sensor can be replaced individually in the event of a fault.

2. High-voltage Battery Unit

Combined expansion and shutoff valve

The expansion and shutoff valve reduces the pressure of the refrigerant by constricting the flow cross-section, evaporating the refrigerant in the process. As a result, the heat is drawn from the surrounding area and the cell modules are cooled. It can also shut off the refrigerant circuit so that no more refrigerant flows into the heat exchanger.



F30 PHEV combined expansion and shutoff valve

Index	Explanation
1	Combined expansion and shutoff valve
2	Connection for refrigerant intake pipe
3	Connection for refrigerant pressure line
4	Lower housing section of the high-voltage battery unit
5	Electrical connection for combined expansion and shutoff valve

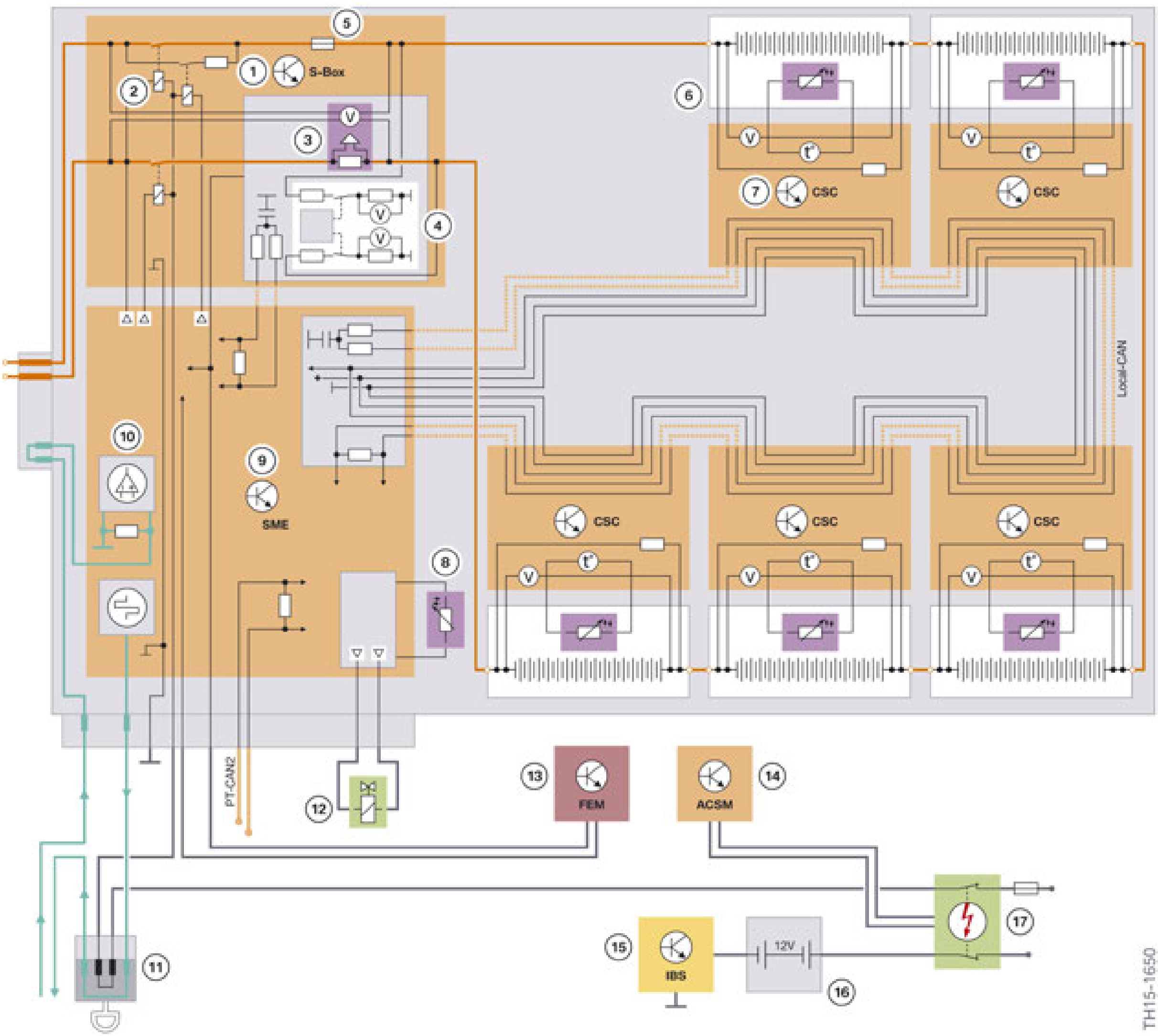
The combined expansion and shutoff valve is activated by the battery management electronics control unit using direct wiring.

The electrical activation has two conditions: An activation voltage of 0 V means that the valve remains closed. An activation voltage of 12 V opens the valve. Similar to conventional expansion valves in heating and air-conditioning systems, this expansion and shutoff valve also automatically adjusts its degree of opening thermally, i.e. depending on the refrigerant temperature.

2. High-voltage Battery Unit

2.4. Inner structure

2.4.1. Electrical and electronic components



F30 PHEV, system wiring diagram for high-voltage battery unit

Index	Explanation
1	Safety box
2	Switch contactors
3	Current and voltage sensor
4	Isolation monitoring
5	Main current fuse (350 A)
6	Cell module
7	Cell Supervision Circuit (CSC), refrigerant line

2. High-voltage Battery Unit

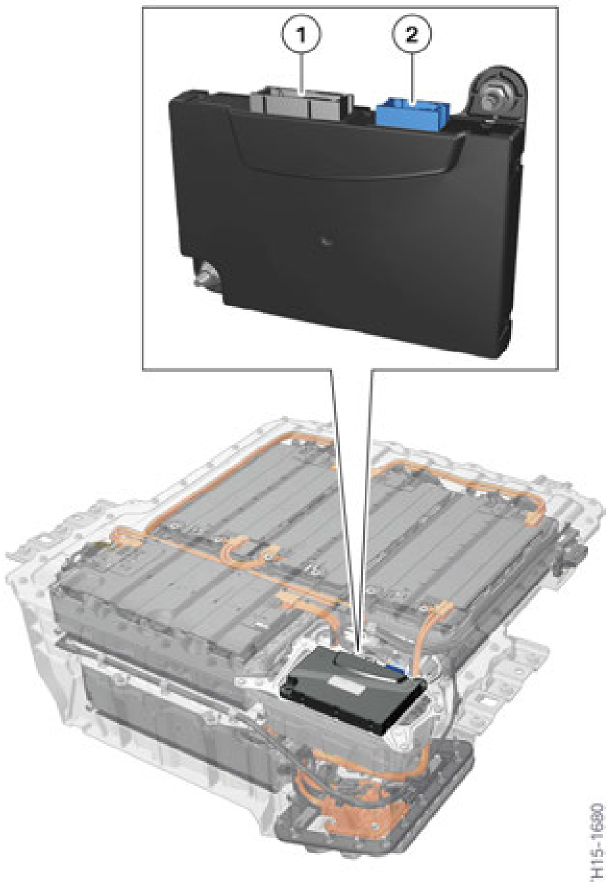
Index	Explanation
8	Temperature sensor for refrigerant line
9	Battery management electronics (SME)
10	Control of the circuit of the high-voltage interlock loop
11	High-voltage safety connector ("Service Disconnect")
12	Combined expansion and shutoff valve of the refrigerant line
13	Front Electronic Module (FEM)
14	ACSM with control lines for activating the safety battery terminal
15	Intelligent Battery Sensor (IBS)
16	12 V battery
17	Safety battery terminal (SBK)

The wiring diagram above shows that the high-voltage battery unit of the F30 PHEV contains the following electrical/electronic components in addition to the actual battery cells, which are combined in five cell modules:

- Control unit for battery management electronics (SME).
- Five Cell Supervision Circuits (CSC).
- Safety box with switch contactors, sensors, over current fuse and isolation monitoring.

In addition to the electrical components, the high-voltage battery unit is also made up of refrigerant lines and coolant ducts, as well as mechanical retaining elements for the cell modules. These internal components, as well as the high-voltage connection and the high-voltage safety connector, are described in the following chapters.

Battery management electronics (SME)



F30 PHEV battery management electronics installation location

Index	Explanation
1	Connection, communication wiring harness
2	Connection, Cell Supervision Circuit wiring harness

High demands are placed on the service life of the high-voltage battery (service life of the vehicle). It is not possible to operate the high-voltage battery according to personal preferences if these requirements must be satisfied. Instead, the high-voltage battery is operated in a precisely defined range as to maximize its service life and performance. This includes the following marginal conditions:

- Operate battery cells in the optimal temperature range (by cooling and if required restricting the current level).
- Adjusting the State of Charge of the individual cells where necessary to one another.
- Use storable energy of the battery in a certain range.

To comply with these marginal conditions, a control unit, the battery management electronics (SME), is installed in the high-voltage battery unit of the F30 PHEV.

The SME control unit must fulfil the following tasks:

- Controlling the starting and shutting down of the high-voltage system at the request of the Electrical Machine Electronics (EME).
- 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.
- Determining the State of Charge (SoC) and the State of Health (SoH) of the high-voltage battery.
- Determining the available power of the high-voltage battery and where necessary requesting a limitation from the Electric Motor Electronics.
- Safety functions (e.g. voltage and temperature monitoring, high-voltage interlock loop).
- Identification of fault statuses, storing fault code entries and communication of fault statuses to the Electrical Machine Electronics.

The SME control unit can generally be accessed and programmed via the diagnosis system.
For troubleshooting it is important to know that not only control unit faults can be entered in the fault memory of the SME control unit, but also links to faults of other components in the high-voltage battery unit. The fault code entries can be divided into different categories which are dependent on their 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 may suffer damage as a result of the fault, the high-voltage system is shut down immediately and the contacts of the electromechanical switch contactors are opened.
- Restricted performance:
  If the high-voltage battery is no longer able to supply full power or full energy, the drive power and the range are restricted to protect the components. In this case, drivers can always continue with considerably reduced drive power for a short period of time.
- Fault without direct effect for the customer:
  If, for example, communication between SME or CSC control units is disrupted for a short time, this does not result in a functional restriction or put the safety of the high-voltage system at risk. This is why only one fault code entry is generated which must be analyzed by the BMW Service using the diagnosis system. A Check Control message does not appear.
  The functionality for the customer is not restricted.

The SME control unit is not accessible from outside the high-voltage battery unit. To replace a SME control unit in the event of a fault, the high-voltage battery unit must be opened beforehand.

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Only qualified personnel is permitted to open the high-voltage battery unit. The repair instructions must also be followed exactly and it is particularly important to complete the prescribed checks prior to opening the unit.

The electrical interfaces of the SME control unit are:

- 12 V supply for SME control unit (terminal 30 from the rear power distribution box and terminal 31).
- 12 V supply for switch contactors (terminal 30C crash signal).
- PT-CAN2.
- Local CAN1 and 2.
- Wake-up line from the Body Domain Controller (BDC).
- Input and output for high-voltage interlock loop.
- Line for activating the combined shutoff and expansion valve in the refrigerant circuit.
- Refrigerant temperature sensor.

The switch contactors in the high-voltage battery unit are supplied with voltage via a special 12 V line. This line is called terminal 30 crash message, **terminal 30C for short.** The **C** in the terminal designation indicates that this 12 V voltage is switched off in the event of an accident (crash). This line is a (second) output of the safety battery terminal. This means that when the safety battery terminal is activated this supply lead is also interrupted.

This line also runs through the high-voltage safety connector so that the supply to the switch contactors is interrupted also when the high-voltage system is disconnected from the power supply. In both these cases the two switch contactors in the high-voltage battery unit are opened automatically.

The Local CAN1 connects the SME control unit to the Cell Supervision Circuits (CSC) (see next chapter). The Local CAN2 is used for communication between SME control unit and safety box. For example, the information on the measured current level is transmitted via this data bus.

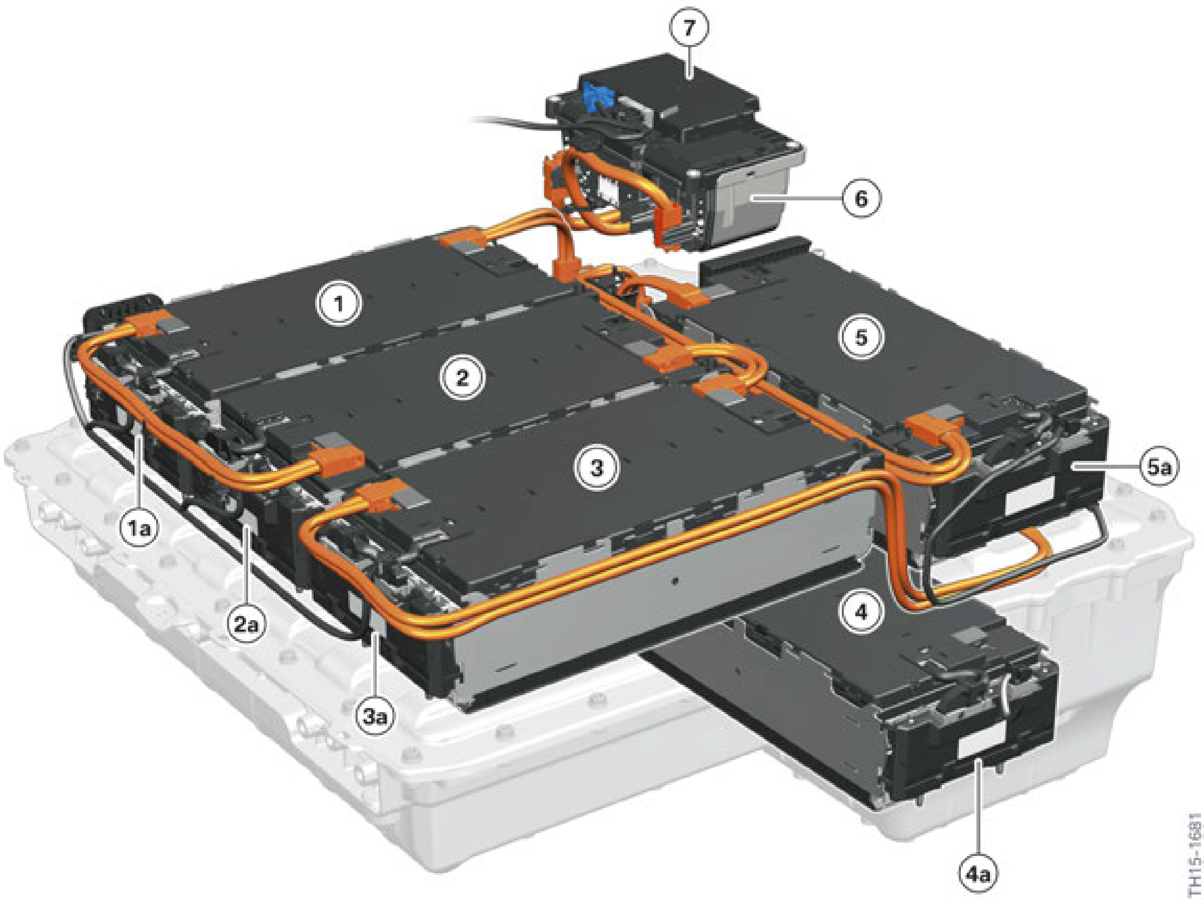
Cell modules

The high-voltage battery unit is made up of five cell modules connected in series. Only one Cell Supervision Circuit is assigned to each cell module. The cell module itself is made up of 16 cells switched in series. Each cell has a nominal voltage of 3.66 V and a nominal capacity of 26 Ah. The sequence of the cell modules is defined and starts at the top right.

⚠

Due to the electrical connection of the cell modules and the arrangement of the Cell Supervision Circuits, there are two different cell module types with respect to polarity. **This must be taken into account for replacement part orders!**

2. High-voltage Battery Unit



F30 PHEV cell module arrangement

Index	Explanation
1	Cell module 1
1a	Cell Supervision Circuit 1a
2	Cell module 2
2a	Cell Supervision Circuit 2a
3	Cell module 3
3a	Cell Supervision Circuit 3a
4	Cell module 4
4a	Cell Supervision Circuit 4a
5	Cell module 5
5a	Cell Supervision Circuit 5a
6	Safety box
7	Battery management electronics (SME)

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The order must be observed when replacing the cell modules as this is stored in the diagnosis system and is used for future evaluations.

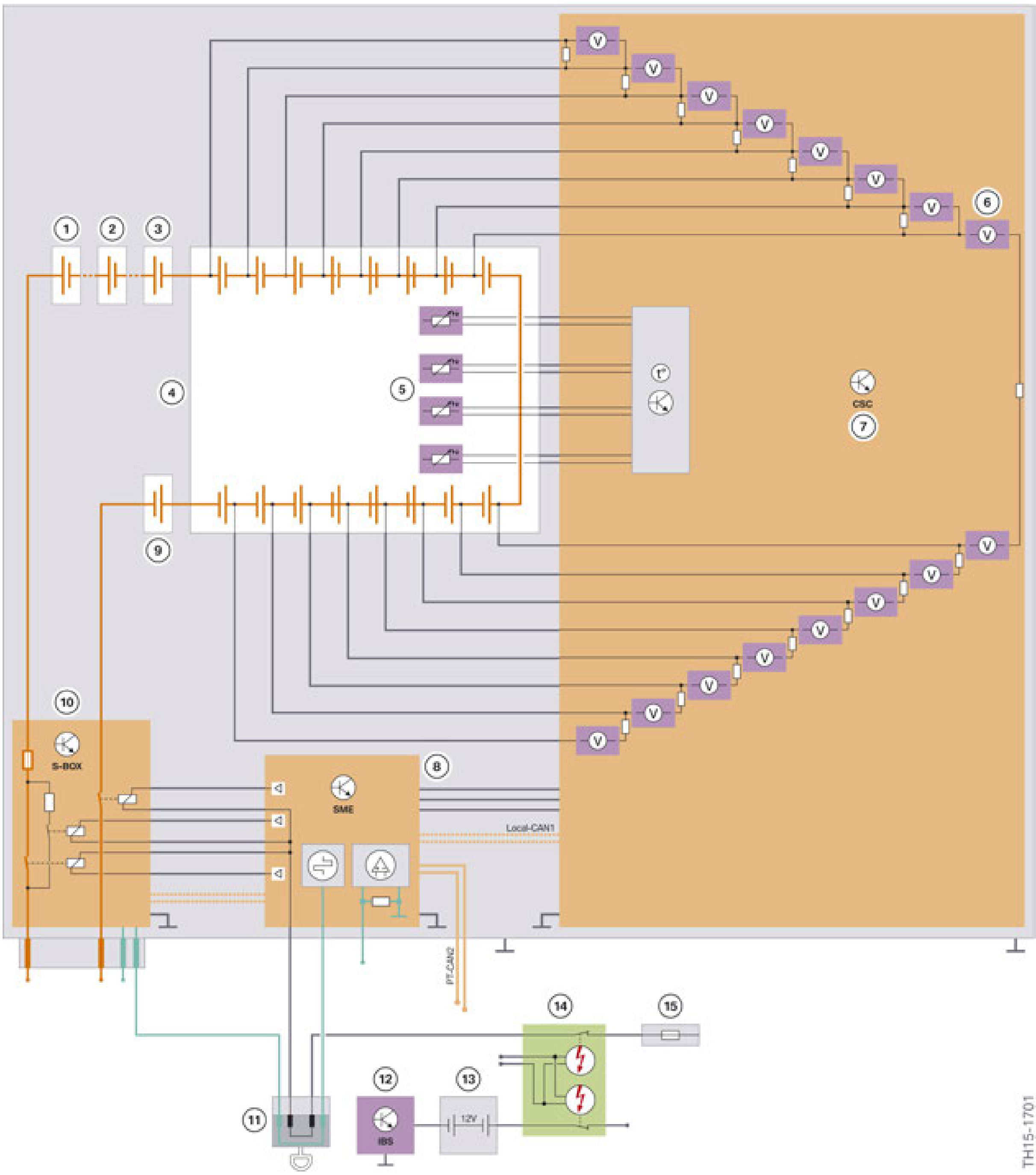
Cell monitoring

⚠

The Cell Supervision Circuits are located inside each high-voltage battery unit. For this reason, only qualified personnel is authorised for restorations.

Certain conditions must be observed for fault-free operation of the lithium-ion cells in the F30 PHEV: The cell voltage and the cell temperature cannot exceed or drop below certain values as otherwise the battery cells may suffer long-term damage. For this reason the high-voltage battery unit features six Cell Supervision Circuits (CSC), a term derived from its development.

The high-voltage battery unit of the F30 PHEV features one Cell Supervision Circuit per cell module. The Cell Supervision Circuit is identical with that of the F15 PHEV, which means that a total of 16 cells can be monitored.



F30 PHEV Cell Supervision Circuit

Index	Explanation
1	Cell module 1
2	Cell module 2
3	Cell module 3
4	Cell module 4

2. High-voltage Battery Unit

Index	Explanation
5	Temperature sensors at the cell module
6	Voltage measurement of the battery cells
7	Cell Supervision Circuit on module 4
8	Battery management electronics (SME)
9	Cell module 5
10	Safety box
11	High-voltage safety connector ("Service Disconnect")
12	Intelligent Battery Sensor (IBS)
13	12 V battery
14	Safety battery terminal (SBK)
15	Power distribution box, front

The Cell Supervision Circuits perform the following functions:

- Measurement and monitoring of the voltage of each individual battery cell.
- Measurement and monitoring of the temperature at several points of the cell module.
- Communication of the measured variables to the battery management electronics control unit.
- Implementation of the process for adjusting the cell voltage of the battery cells.

The measurement of the cell voltage is effected at a very high sampling rate (one measurement every 20 milliseconds). The end of the charging procedure, as well as the discharging procedure, can be identified using the voltage measurement. The temperature sensors are arranged at the cell modules so that the temperature of the individual battery cells can be determined from their measured values. Using the cell temperature an overload or electrical fault can be identified. In such a case the current level must be reduced immediately or the high-voltage system shut down completely in order to avoid progressive 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 is such an important variable, four NTC temperature sensors are installed for each cell module, of which one is redundant.

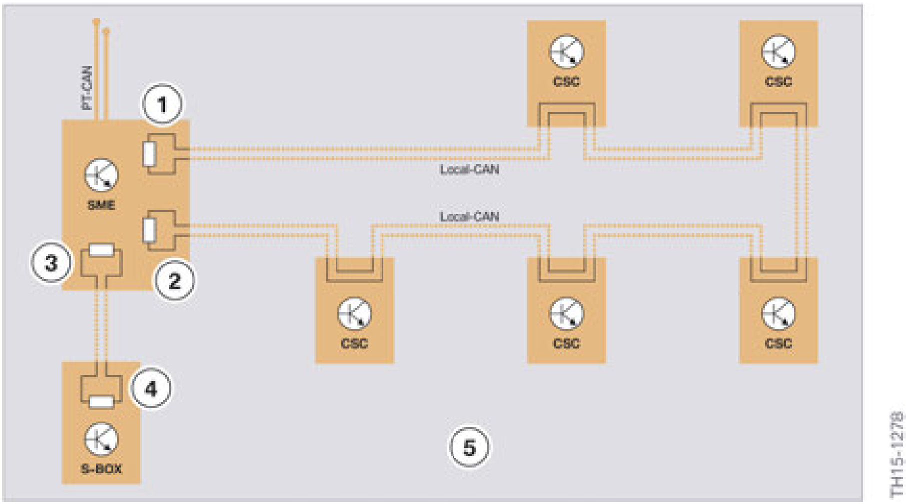
The Cell Supervision Circuits communicate the values measured by them via the Local CAN1. This local CAN1 connects all Cell Supervision Circuits to each other, as well as to the SME control unit. In the SME control unit the evaluation of the measured values takes place and a response is introduced if required (e.g. control of the cooling system).

Local CAN1 and 2 operate at a data transfer rate of 500 kBit/s. The bus lines are twisted, as is usual for CAN buses with this data transfer rate. Both Local-CANs are also terminated at their ends. The necessary terminating resistors of the Local-CAN1, each with 120 Ω of the Local CAN1 are located in the SME control unit.

The terminating resistors of the Local-CAN2, each with 120 Ω of the Local CAN2 are located:

- In the battery management electronics control unit.
- in the safety box control unit.

2. High-voltage Battery Unit



F30 PHEV principle wiring diagram of local CANs in the high-voltage battery unit

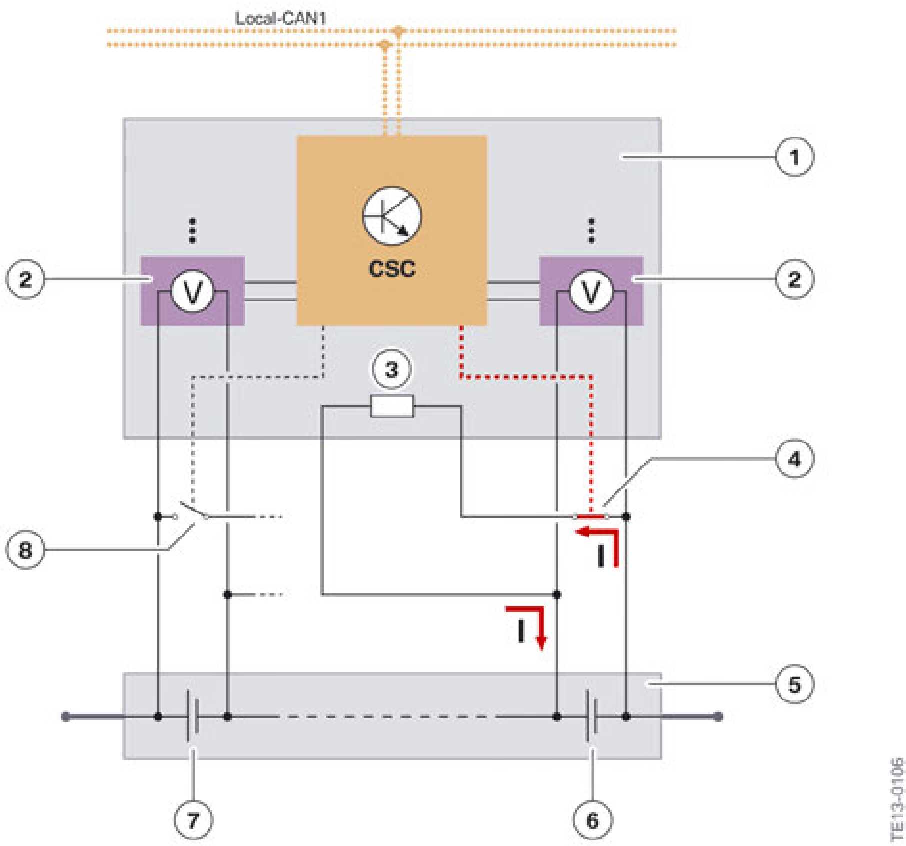
Index	Explanation
1	Terminating resistor of Local CAN1 in the SME control unit
2	Terminating resistor of Local CAN1 in the SME control unit
3	Terminating resistor of Local CAN2 in the SME control unit
4	Terminating resistor of Local CAN2 in the safety box
5	High-voltage battery unit

If the resistance is measured at the Local Controller Area Networks as part of troubleshooting, a value of approx. 60 Ω is obtained if all bus users are connected and the termination is OK.

If one or several of the battery cells has a significantly lower cell voltage than all other battery cells, the usable energy content of the high-voltage battery is restricted. The end of energy consumption for the discharging procedure is in fact determined by the "weakest" battery cell: If the voltage of the weakest cell has fallen to the discharge limit, the discharging procedure must be terminated, also if the other battery cells still have enough energy stored. If the discharging procedure is continued however, the weakest battery cell may incur permanent damage. For this reason there is a function to adjust the cell voltage to approximately the same level. This process is called "cell balancing".

The SME control unit compares all cell voltages. The battery cells with a significantly higher cell voltage than the other battery cells are discharged during this procedure. Discharging is started by the SME control with a request via the local CAN1 to the respective Cell Supervision Circuits for these battery cells. Each Cell Supervision Circuit has an ohmic resistance for each battery cell, via which the discharge current can flow as soon as the respective electronic contact has been closed. After the discharging procedure is started this is performed or continued independently by the Cell Supervision Circuits, also if the main control units have switched to rest state in the meantime. This is made possible by the fact that the Cell Supervision Circuit control units obtain their voltage supply from the battery management electronics, which is connected directly to terminal 30. The discharging procedure is automatically ended if the voltage of all battery cells is in a specified narrow range. The cell balancing is continued until all cells have the same voltage.

2. High-voltage Battery Unit



F30 PHEV, principle wiring diagram: Adjusting the cell voltages

Index	Explanation
1	Cell Supervision Circuit
2	Sensors for measuring the cell voltage
3	Discharge resistor
4	Closed (active) contact for discharging a battery cell
5	Cell module
6	Battery cell whose cell voltage is reduced by discharging
7	Battery cell not being discharged
8	Open (inactive) contact for discharging a battery cell

The adjustment of the cell voltages is a procedure which involves losses. However, the electrical energy lost is very low (less than 0.1 % SoC). In contrast, the advantages are that the attainable range and the service life of the high-voltage battery are maximized which makes sense overall and is necessary for balancing the cell voltages. This procedure can naturally be performed when the vehicle is at a standstill.

2. High-voltage Battery Unit

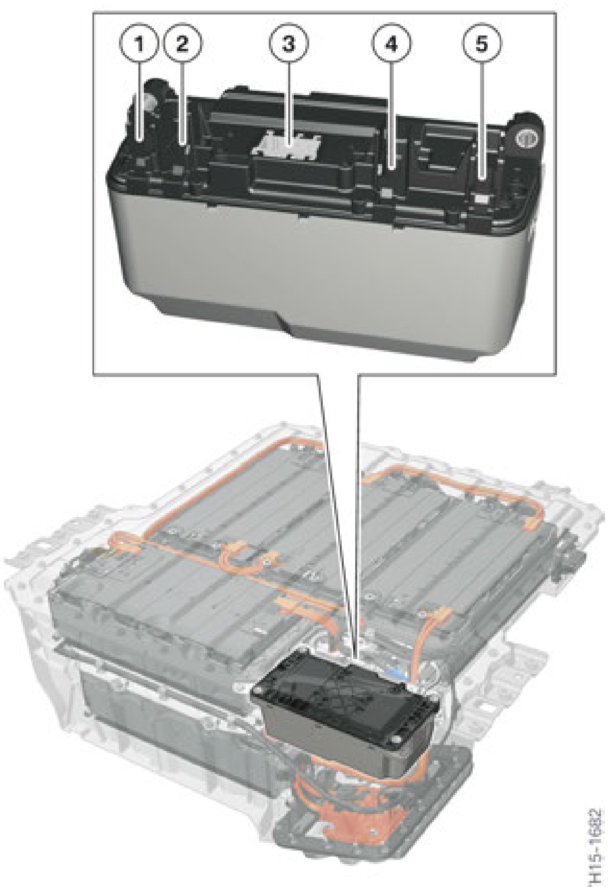
The conditions for adjusting the cell voltages are as follows:

- Terminal 15 switched off and vehicle or vehicle electrical system asleep AND
- High-voltage system shut down AND
- Deviation of the cell voltages or the individual states of charge of the cells are greater than a threshold value AND
- Total SoC of the high-voltage battery is greater than a threshold value.

The adjustment of the cell voltages is effected automatically when the specified conditions are fulfilled. The customer therefore does not receive a Check Control message nor does he have to implement a special measure. Also after the replacement of cell modules the SME control unit automatically identifies any necessary requirement to adjust cell voltages.

If the cell voltages however have too great a deviation or the adjustment of the cell voltage is not successful, a fault code entry must be created in the battery management electronics control unit. The customer is made aware of this fault status by a Check Control message. With help of the diagnosis system, the fault memory must then be evaluated and corresponding repair work carried out.

Safety box



F30 PHEV installation location of the safety box

Index	Explanation
1	Positive to high-voltage connector
2	Positive from cell module 5
3	Connection, communication wiring harness
4	Negative from cell module 1
5	Negative to high-voltage connector

In each high-voltage battery unit there is an interface unit with its own housing, which is also called a "safety box" or "S-box" for short. The component is located on the inside of the high-voltage battery unit and for this reason, it must be exchanged by qualified workshop personnel only.

The following components are integrated in the safety box:

- 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 switch for slow start-up of the high-voltage system.
- Voltage sensors for monitoring the switch contacts, measuring the overall battery voltage as well as monitoring the isolation resistance.
- Electrical wiring for isolation monitoring.

Wiring harnesses

There are two wiring harnesses in the high-voltage battery unit.

- Communication wiring harness for the connection of the Cell Supervision Circuits to the SME control unit.
- Communication wiring harness for connection of the SME and the safety box with the interface to the 12 V vehicle electrical system.

No repairs can be carried out on the wiring harness. If the connection between the cable and connector is faulty or loose, the entire wiring harness must be replaced.

2.4.2. Mechanical components

The mechanical components of the high-voltage battery unit include:

- Lid and lower housing section
- Seal between lid and lower housing section
- Top and bottom heat exchangers
- The venting unit
- Module intermediate base
- Battery management electronics and safety box holder

2. High-voltage Battery Unit

2.5. Functions

In the F30 PHEV **central functions of the high-voltage system** are controlled and coordinated by the Electrical Machine Electronics (EME). They are:

- Voltage conversion from direct current voltage in to three-phase AC voltage (electric motor mode).
- Voltage conversion from three-phase AC voltage to direct current voltage (charging mode).
- Voltage conversion from high voltage to low voltage (12V battery charge).
- High-voltage power management.
- Activation of 12 V actuators.
- Discharging the link capacitors.

The high-voltage battery unit and the SME control unit are of decisive importance for the central functions of the high-voltage system. They are:

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

2.5.1. Starting

The sequence for starting the high-voltage system is always the same irrespective of which of the following events was the trigger:

- Terminal 15 is switched on or driving readiness 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 EME control unit requests starting via bus signals at the PT-CAN/PT-CAN2.

2 The high-voltage system is monitored using self-diagnosis functions.

3 The voltage in the high-voltage system is increased continuously.

4 The contacts of the switch contactors are fully closed.

The high-voltage system is mainly monitored by the Electrical Machine Electronics control unit and the battery management electronics control unit. Criteria relevant for safety, for example the circuit of the high-voltage interlock loop or the isolation resistance, are checked. Functional preconditions such as the operating readiness of all subsystems must also be fulfilled for starting.

The high-voltage system features capacitors with high capacity values (link capacitors in the power electronics) and for this reason, it is not permitted to simply close the contacts of the electromechanical switch contactor. Extremely high current pulses would damage both the high-voltage battery and the link capacitors and the contacts of the switch contactors. First of all, the switch contactor at the negative terminal is closed. There is a pre-charging circuit with a resistor parallel to the switch contactor at the positive terminal. This is now activated and a switch-on current restricted by the resistor charges the link capacitors. When the voltage of the link capacitors has reached the approximate value of the battery voltage, the pre-charging circuit is opened and the switch contactor at the positive terminal of the high-voltage battery unit is closed. The high-voltage system is now fully operational.

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

If there is no fault in the high-voltage system, the entire starting of the high-voltage system is completed in approx. 0.5 seconds.

The SME control unit communicates successful starting via the PT-CAN2 to the EME control unit. Fault statuses are also communicated in the same way, if, for example, a contact of a switch contactor was unable to be closed.

2.5.2. Regular shutdown

When it comes to shutting off the high-voltage system a distinction is made between regular shut-off and fast shut-off. The regular shutdown described here protects all respective components on the one hand, and, on the other hand, includes the monitoring of components of the high-voltage system which are relevant for safety.

If the following preconditions or criteria are present, the high-voltage system is shutdown in the regular manner:

- Terminal 15 is switched off by the driver and the after-running period is expired (controlled by EME).
- End of the functions stationary cooling, auxiliary heater or conditioning of the high-voltage battery.
- End of the charging procedure for the high-voltage battery.

The sequence for the regular shutdown is generally the same irrespective of the trigger. The individual steps are:

1 EME orders the shutdown after the after-running period has expired via bus signals at the PT-CAN/PT-CAN2.

2 The systems at the high-voltage electrical system (EME, EKK, EH) reduce the currents in the high-voltage electrical system to zero.

3 The coils of the electrical machine are short-circuited.

4 Opening the switch contactors in the high-voltage battery unit (controlled by SME).

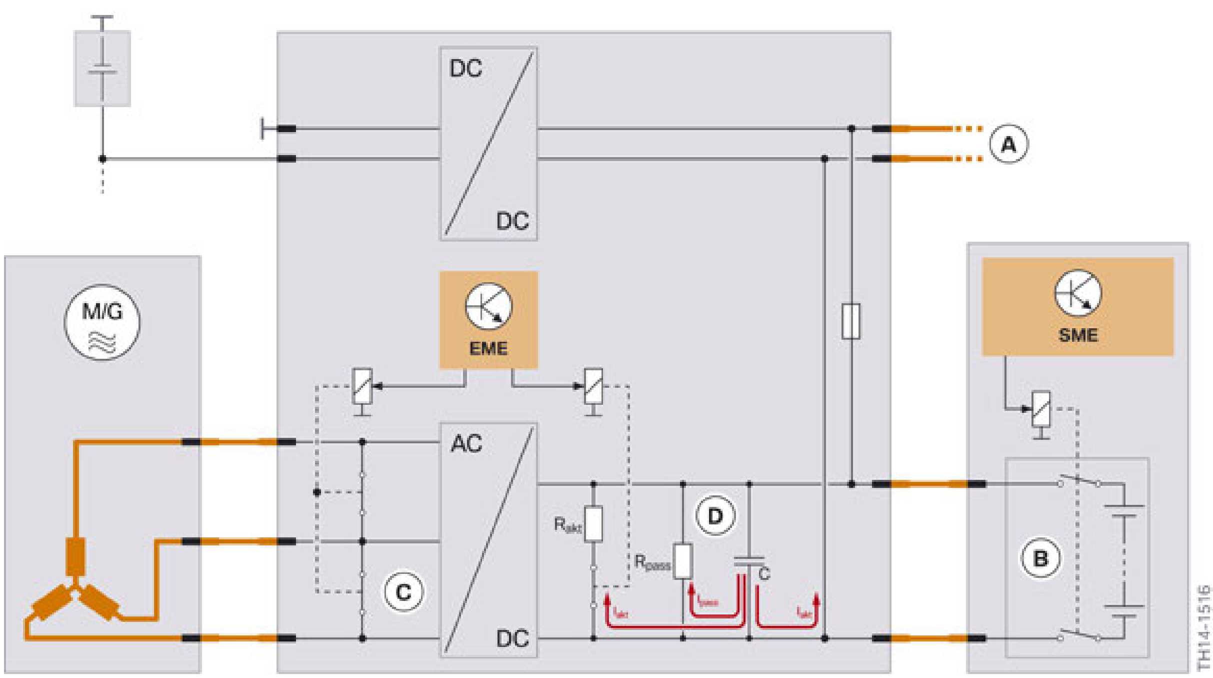
5 Checking the high-voltage system, e.g. as to whether the contacts of the electromechanical switch contactors were correctly opened.

The high-voltage system is discharged, i.e. active discharge of the link capacitors (EME):

1 First, it is attempted to supply the stored energy to the 12 V system battery.

2 If this is not possible, the link capacitors are discharged via activatable resistors.

3 If the link capacitors have not been discharged below a voltage of 60 V within 5 s, they are discharged via passive resistors.



F30 PHEV Schematic diagram of regular shutdown

Index	Explanation
A	Switch-off of all high-voltage components
B	Opening of switch contactors
C	Short-circuit of the coils of the electrical machine
D	Discharge of the link capacitors

Discharge of the link capacitors takes place in several stages as necessary.

Both the after-running period after switching off terminal 15 and the shutdown itself can last a few minutes. The automatic monitoring functions are a reason for this, for example. The regular shutdown is interrupted if in the meantime either a request for a renewed start-up is made or a condition has arisen to request a quick shutdown.

2.5.3. Quick shutdown

The overriding aim here is to shut down the high-voltage system as quickly as possible. This quick shutdown is then always carried out if for safety reasons the voltage in the high-voltage system has to be reduced to a safe value as quickly as possible. The following list describes the triggering conditions and the functional chain leading to the quick shutdown.

- Accident:
  Advanced Crash Safety Module (ACSM) identifies an accident. Depending on the severity of the accident, the switch-off is requested via bus signals or by a forced disconnection of the safety battery terminals from the positive terminal of both 12 V batteries. In the second scenario the voltage supply of the electromechanical switch contactors is automatically interrupted and their contacts open automatically.
- Overload current monitoring:
  With help of a current sensor in the high-voltage battery unit the current level in the high-voltage electrical system is monitored. If too high a current level is identified, the battery management electronics control unit causes a hard opening of the electromechanical switch contactor. Considerable wear occurs to the contacts of the switch contactors as a result of this opening under a high current, which must be accepted to protect the other components from damage.
- Protection in the event of a short circuit:
  In each high-voltage battery unit there is an over current fuse which interrupts the high-voltage circuit in the event of a short circuit.
- Critical cell state:
  If a Cell Supervision Circuit identifies extreme under voltage, over voltage or excess temperature at a battery cell, this also leads to a hard opening of the electromechanical switch contactors - controlled by the SME control unit. Although this may lead again to increased wear at the contacts, this quick shutdown is necessary to prevent destroying the respective battery cells.
- Malfunction of the 12 V voltage supply of the high-voltage battery unit:
  In this case the battery management electronics control unit no longer works and it is no longer possible to monitor the battery cells. For this reason the contacts of the electromechanical switch contactors also open here automatically.

In addition to disconnecting the high-voltage system the link capacitors are also discharged (Electrical Machine Electronics) and the coils of the electrical machine (Electrical Machine Electronics, EKK) are short-circuited. The high-voltage control units receive the request on the one hand by bus signals and identify this condition on the other hand by the sudden drop in the current level in the high-voltage circuit.

2.5.4. Charging

The SME control unit also plays an important role when charging the high-voltage battery, regardless of whether it is by energy recovery, raising the load point of the combustion engine or from the external power supply system. Using the State of Charge and the temperature of the battery cells, the battery management electronics control unit determines the maximum electrical power the high-voltage battery unit can currently absorb. This value is transmitted in the form of a bus signal via the PT-CAN2 to the EME control unit. The high-voltage power management function coordinates the individual power requirements.

During charging the SME control unit constantly identifies the State of Charge already reached and monitors all sensor signals of the high-voltage battery. In order to ensure optimal progress of the charging procedure, the SME control unit constantly calculates current values for the maximum charging power based on these values and communicates these to the EME control unit. The cooling system of the high-voltage battery is continuously controlled by the SME control unit during the charging procedure which contributes to a quick and efficient charging procedure.

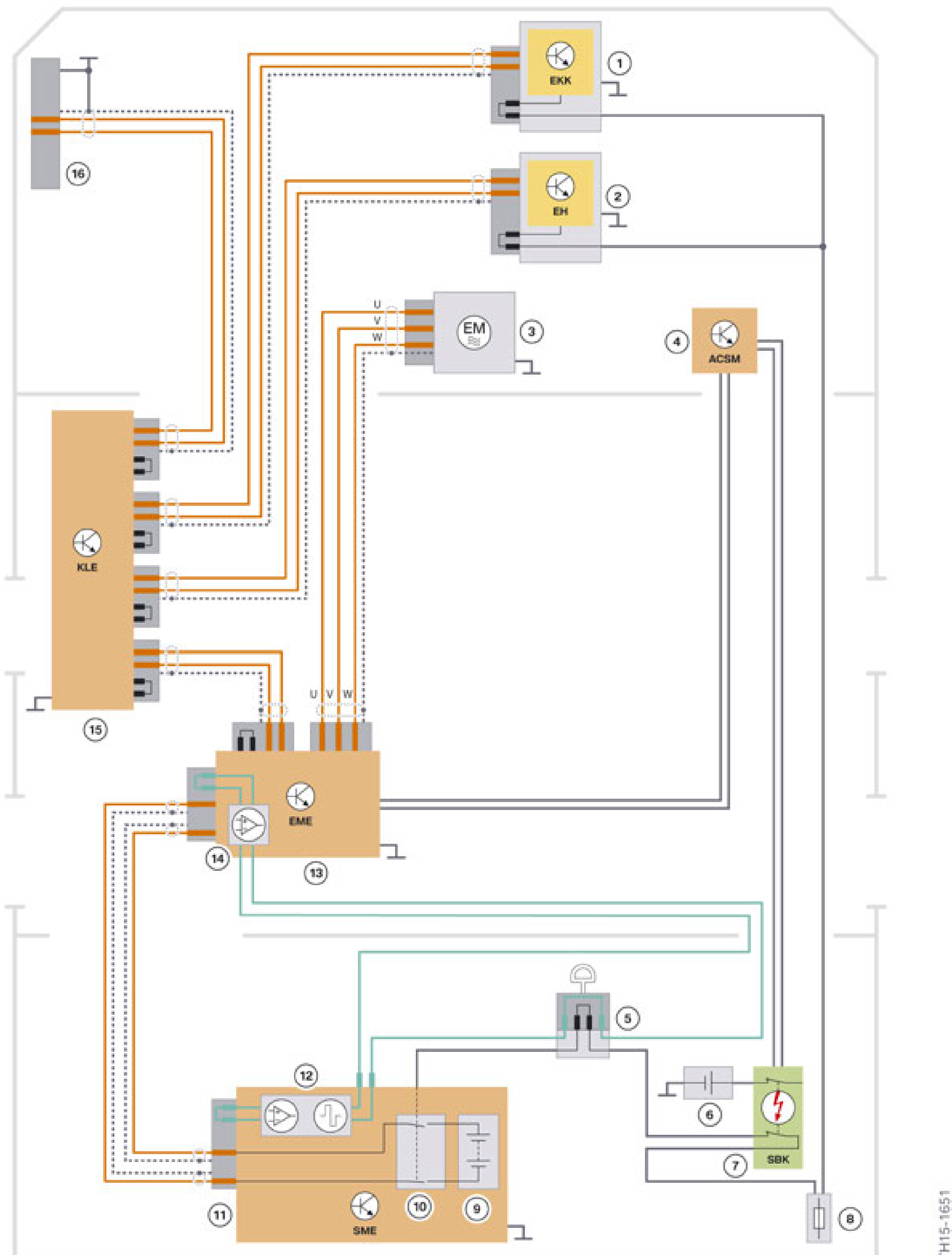
The vehicle interior must be preheated/precooled while the charging cable is connected to achieve the highest possible electrical range. Consequently the required energy is not drawn from the high-voltage battery unit, but supplied directly from the convenience charging electronics.

Further details on the charging procedure, in particular the power supply from a public power grid and the convenience charging electronics in the F30 PHEV are described in the "F30 PHEV high-voltage components" information bulletin.

Information on the individual charging strategies by energy recovery and load point shifts are described in the "F30 PHEV drivetrain" information bulletin.

2.5.5. Monitoring functions

- 12 V supply voltage from the safety battery terminal:
  To be able to perform a quick shutdown of the high-voltage system in the event of an accident of corresponding severity, the solenoids of all electromechanical switch contactors are supplied with 12 V from the safety battery terminal. If the safety battery terminal is disconnected in the event of an accident, this supply voltage is no longer necessary and the contacts of the switch contactors open automatically.
  In addition, the SME master control unit evaluates the voltage on this line electronically and also causes the high-voltage system to shut down including discharge of the link capacitors and the active short circuit of the electrical machine.
- High-voltage interlock loop:
  The SME control unit evaluates the signal of the high-voltage interlock loop and checks whether there is an open circuit with this circuit. In the event of an open circuit, the battery management electronics control unit can cause the high-voltage system to perform a quick shutdown.
  The principle of the high-voltage interlock loop is familiar from the "Fundamentals of Hybrid Technology" reference manual. In the F30 PHEV the high-voltage interlock loop is made up of the high-voltage components pictured below.



F30 PHEV, system wiring diagram of high-voltage interlock loop

2. High-voltage Battery Unit

Index	Explanation
1	Electric A/C compressor (EKK)
2	Electrical Heating (EH)
3	Electric motor
4	Advanced Crash Safety Module (ACSM)
5	High-voltage safety connector ("Service Disconnect")
6	Battery
7	Safety battery terminal
8	Power distribution box, rear
9	Cell modules
10	Switch contactors
11	Battery management electronics (SME)
12	Evaluation circuit for test signal of the high-voltage interlock loop in the battery management electronics
13	Electric Motor Electronics (EME)
14	Evaluation circuit for test signal of the high-voltage interlock loop in the Electrical Machine Electronics
15	Convenience charging electronics (KLE)
16	Charging socket

The electronics for controlling and generating the test signal for the high-voltage interlock loop is integrated in the F30 PHEV in the battery management electronics (SME). Generating the test signal starts when the high-voltage system is to be started and ends when the high-voltage system has been shut down. A square-wave AC signal with a frequency of approx. 88 Hz is generated as the test signal by the battery management electronics and fed into the test lead. The test lead has a ring topology (similar to that of the MOST bus). The signal of the test lead is evaluated at two points in the ring: in the Electrical Machine Electronics and finally right at the end of the ring, in the battery management electronics. If the signal is outside a fixed, defined range, a disconnection of the circuit or a short circuit to vehicle ground is identified in the test lead and the high-voltage system is switched off immediately. If the high-voltage interlock loop at the high-voltage safety connector (“Service Disconnect”) is disconnected, then the switch contactors are opened directly. In addition, all high-voltage components are switched off.

- Contacts of the switch contactors:
  After the battery management electronics control unit has requested the contacts of the switch contactors to open during the shutdown of the high-voltage system, with help of a voltage measurement a check parallel to the contacts checks whether they have actually been opened. In the highly unlikely case that the contact of a switch contactor does not open, there is no direct danger for the customer or the Service employee. However, for safety reasons a renewed start-up of the high-voltage system is prevented. It is no longer possible to continue the journey using the electric motor.

2. High-voltage Battery Unit

- Pre-charge switch:
  If for example during the start-up of the high-voltage system a fault is identified with the pre-charge switch, then the start-up is cancelled immediately and the high-voltage system is not put into operation.
- Excess temperature:
  The cooling system of the high-voltage battery ensures in all driving situations that the temperature of the battery cells is in the optimal range. If due to a fault the temperature of one or several battery cells increases to the extent that the optimal range is left, the power is reduced initially to protect the battery cells. If the temperature continues to increase and thus threatens damage to the battery cells, the high-voltage system is switched off in good time.
- Under voltage:
  Under voltage at a battery cell is avoided by the constant monitoring and adjustment of the cell voltage as required. The total voltage of the entire high-voltage battery unit is also monitored and used to determine the State of Charge. If the total voltage has fallen to the extent that the high-voltage battery is at risk of a total discharge, a further discharge is prevented. It is no longer possible to continue the journey using the electric motor.
- The insulation monitoring determines whether the insulation resistance between active high-voltage components (e.g. high-voltage cables) and earth is above or below a required minimum value. If the insulation resistance falls below the minimum value, the danger exists that the vehicle parts will be energized with hazardous voltage. If a person were to touch a second active high-voltage component, he or she would be at risk of electric shock. There is therefore fully automatic insulation monitoring for the high-voltage system of the F30 PHEV. In contrast to the previous high-voltage battery units, the isolation monitoring is now located in the safety box. This has the advantage that it is no longer necessary to route high-voltage cables to the battery management electronics. The safety box sends results to the battery management electronics control unit via local CAN and evaluates these results. When the high-voltage system is active, the safety box monitors isolation at regular intervals (approx. every 5 s) by measuring the resistance (indirect isolation monitoring). Earth serves as the reference potential.
  Without additional measures only local insulation faults in the high-voltage battery unit could be determined in this way. However, it is equally important to identify insulation faults from the high-voltage cables in the vehicle to earth. For this reason all the electrically conductive housings of high-voltage components are conductively connected to earth. This enables isolation faults in the entire high-voltage electrical system to be identified, from a central point in fact, the high-voltage battery unit.

The insulation monitoring responds in two stages. When the insulation resistance drops below a first threshold value, there is still no direct danger to people. The high-voltage system therefore remains active; no Check Control message is output, but the fault status is naturally stored in the fault memory. In this way the Service employee is alerted the next time the car is in the workshop and can then check the high-voltage system. When the insulation resistance drops below a second, lower threshold value, this is accompanied not only by the storage of the fault in the fault memory, but also by the appearance of a Check Control message prompting the driver to visit a workshop.

As there is no direct danger for the customer or Service employee by such an isolation fault, the high-voltage system remains active and the customer is able to continue the journey. Nevertheless, the high-voltage system should be checked by BMW Service as soon as possible. In order to identify the component in the high-voltage system which caused the isolation fault, the fault must be narrowed down by the Service employee. However, the Service employee does not have to perform a fundamental measurement of the isolation resistance himself – this task is performed by the high-voltage system through the insulation monitoring. When an insulation fault is detected, the Service employee must run through a test plan in the diagnosis system to find the actual location of the insulation fault.

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The proper electrical connection of all high-voltage component housings to ground is an important prerequisite for ensuring that the insulation monitoring functions properly. Accordingly, this electrical connection must be restored carefully if it has been interrupted during repair work.

2.6. Service information

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Before working on high-voltage components of the F30 PHEV, it is essential to observe and implement the electrical safety rules:

1. **Disconnect** the high-voltage system from the power supply.
2. **Secure** high-voltage system against restart.
3. **Verify** the safe isolation of the high-voltage system.

F30 PHEV High-voltage Battery Unit
3. Repair

3.1. Preconditions

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The following description of the repair of the high-voltage battery unit is only a general list of the content and the procedure. **In general, only the specifications and instructions in the current valid edition of the repair instructions apply.**

3.1.1. Organizational matters

Some organizational prerequisites must be fulfilled so that a repair to the high-voltage battery unit is allowed and can be adequately performed. These prerequisites concern both the dealership and the Service employee.

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Repair of high-voltage battery units is permitted only in outlets with suitably qualified workshop personnel.

The dealership must also make available the necessary special tools and a suitable workbay for the repair. The most important special tools are:

- Two-post vehicle hoist.
- Mobile workshop crane and multi-purpose lift to install and remove the high-voltage battery unit.
- Mobile MHT 1200 assembly lifting table with adapters to fix the high-voltage battery unit.
- Charger for cell modules of the high-voltage battery unit.
- EoS diagnosis system for the start-up of the repaired high-voltage battery unit.
- Lifting device for the installation and removal of the cell modules.
- Panel wedge made from plastic, number 2 298 505, for removing the clips in the high-voltage battery unit.
- Special tool to attach cable straps.
- Barrier tape.
- Yellow warnings with flash labels are recommended.

The workbay for the repair of the high-voltage battery unit must be clean, dry and free of flying sparks. Therefore, avoid direct proximity to vehicle cleaning areas or work stations at which repair work to the body is performed. If necessary, use partition walls and barrier tape to separate areas.

3. Repair

The Service employee performing the repair of the high-voltage battery unit must also satisfy key prerequisites:

1 Qualifications.
2 Strict use of the diagnosis system and the special tools.
3 Follow repair instructions exactly.

Only Service employees qualified in the repair of the high-voltage battery unit can perform this work. This includes successful completion of the training “Expert in working on high-voltage intrinsically safe vehicles”, training on the high-voltage system of the F30 PHEV and specifically on repairing the high-voltage battery unit of the F30 PHEV or another high-voltage battery unit of Generation 3 (GEN 3).

The diagnosis system must be used for troubleshooting before the removal and opening of the high-voltage battery unit. Only if the test schedule specifies it and the prerequisite "no external mechanical damage" is fulfilled, can the high-voltage battery unit be opened and the component identified as faulty by the test schedule replaced.

Apart from the replacement of faulty components, no repair work in the high-voltage battery unit is allowed. For example, a faulty wiring harness cannot be repaired, it can only be replaced by a new one. To carry out a replacement of a faulty component, it is extremely important the operations specified in the repair instructions are followed exactly. It is also very important to use the prescribed special tools. When the Service employee satisfies all these prerequisites he can safely perform the repair of the high-voltage battery unit and deliver the high quality expected.

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The high-voltage battery unit must be replaced if one or more airbags have been deployed as a result of an accident, i.e. a complete new high-voltage battery unit must be set up.

3.1.2. Safety rules

- The workbay for high-voltage battery unit repair must be clean (no grease, dirt or swarf), dry (no escaping fluids) and there must be no flying sparks (not located in the vicinity of body repair work). Therefore, avoid direct proximity to vehicle cleaning areas (wash systems) or work stations at which repair work to the body is performed. If necessary, use partition walls to separate areas.
- Barrier tape is necessary to protect the workbay against unauthorized access (insufficient qualification, customers, visitors, etc.), as well as in the event of a lack of intrinsic high-voltage safety or unclear condition of the component. It is recommended to position yellow warnings with a lightening flash when the working area is left unattended.
- Moisture residue and coarse dirt contamination in the cover area of the high-voltage battery unit must be removed before removing the cover.
- A careful visual inspection of the components being processed must be performed before and after each operation. For example, during the removal of a component other components which become loose as a result of the removal must be checked for damage.

3. Repair

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If the housing or internal high-voltage components are damaged, please contact Technical Support. Exceptions include minimal scratch marks. **Work on the high-voltage battery unit must be terminated immediately for safety reasons.**

- The first step after the housing cover is opened for the repair of the high-voltage battery unit is a visual inspection for mechanical damage.
- Before working in the open high-voltage battery unit, always disconnect the high-voltage cable between cell modules 3 and 4 in order to interrupt the series connection.
- In the event of work interruptions attach the removed housing cover again and secure against unintentional opening by screwing in some screws. Position yellow warning cones on the housing cover and cordon off the working area using barrier tape.
- Do not use tools or other objects with a point or sharp blades/edges at the high-voltage components or connections or in their immediate vicinity. Screwdrivers, diagonal cutting pliers, knives, etc. are prohibited. Panel wedges are allowed.
- Open cable straps on the low-voltage wiring harness using combination pliers only. Open cable straps on the high-voltage cables only using combination pliers in order to disassemble the high-voltage cable including the bracket. Use the corresponding special tools to install cable straps.
- During the removal and installation of the cell modules ensure when slackening and removing the screws that the plastic cover of the cell modules is not removed. The live cell contact system is located underneath.

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The repair instructions 6127 ... "Notes on opening and closing cable straps on electric and hybrid vehicles" must always be observed when opening and replacing cable straps.

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If the plastic cover is loose this must be secured. If it is not possible to secure the cover or the cover is broken, the cell module must be replaced.

- In the event of dirt contamination in the high-voltage battery unit, the affected areas must be cleaned thoroughly after clarification of the cause. The following cleaning agents are approved:
  - Spirit
  - Windscreen cleaning agent
  - Glass cleaning agent
  - Distilled water
  - Vacuum cleaner with plastic attachment
- Do not leave any tools inside; before closing the housing cover check the tools in the tool kit for completeness.

- In the high-voltage battery unit lost/fallen small parts/screws must be removed. To avoid losing screws during repair work in the high-voltage battery unit, it is generally recommended to use magnetic tools.
- Due to the extremely flat design of the heat exchanger there is an increased risk of damage during disassembly and installation. Exercise extreme caution when handling the heat exchanger as the cooling of the cell modules can no longer be guaranteed if the heat exchanger is damaged (bent, dented). Consequently, the available range and power of the vehicle are reduced considerably.
  Seals and sealing surfaces (venting unit, high-voltage connector, 12 V connector, heat exchanger connection) must be cleaned with the specified cleaning agents before reassembly.
- Electrolyte:
  The majority of electrolyte is bound in the solid cathode material, primarily lithium-nickel-manganese-cobalt-oxide, and in the solid anode material, mainly graphite. The amount of the free electrolyte in the high-voltage battery unit is very small. In the event of a leak, electrolyte and solvent vapors may be released. Wash thoroughly using clear water in the event of contact with the skin or eyes and seek immediate medical advice.
  Mainly flammable gases, asphyxiating gases and hazardous substances such as carbon monoxide, carbon dioxide, hydrogen and hydrocarbons develop in the event of a fire.
  Attention! Do not breathe in! There must be adequate fresh air. If breathing stops use an artificial respiratory device and contact a doctor immediately.
  Inform the fire department in the event of a fire. Clear the area straight away and secure the scene of the accident. Only try to extinguish the fire if it does not pose a danger and use a suitable extinguisher, e.g. water, foam or CO_2 fire extinguisher.

3.1.3. Electrical and mechanical diagnosis

- Analysis of faults preventing removal (e.g. duplicate contactor label).
- Analysis of faults which do not permit you to draw a precise conclusion about the internal condition of the high-voltage battery unit, (e.g. internal isolation fault).
- Determine repair measure from test schedule (diagnosis) and print out location diagram.

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The fault memory can only be deleted after the high-voltage battery unit has been fully repaired.

- If cell modules are to be replaced, determine the State of Charge or the voltage of the intact cell modules.
- Use the State of Charge of a **new** cell module as the reference value when exchanging **all** cell modules. Read out: Connect charger/discharging device to a new cell module, read out State of Charge/voltage and use as nominal voltage for all other cell modules.
- Visual inspection for dirt contamination and damage to housing when installed, as well as to the connections and venting unit. Damage to the diaphragm of the venting unit may indicate damaged cells. If this is the case, special care must be taken when checking the inside of the open high-voltage battery unit.

3.1.4. Removal of the high-voltage battery unit from the vehicle

1 Evacuate refrigerant.
2 Disconnect the high-voltage system from the power supply using Service Disconnect (high-voltage safety connector) and identify de-energized state.
3 Remove luggage compartment floor.
4 Disconnect connections (12 V vehicle electrical system, high-voltage, refrigerant) .
5 Close connections for refrigerant lines with plugs.
6 Position the mobile workshop crane including multi-purpose lifting tool on the high-voltage battery unit, secure it and visually check it is positioned correctly.
7 Undo the mounting bolts on the high-voltage battery unit.
8 Lever out the high-voltage battery unit.
9 Visual inspection for dirt contamination and damage to housing on all sides.
10 Check thermal abnormalities in the event of faults which may indicate unclear condition of the high-voltage battery unit.
11 Transport the component to the mobile assembly lifting table as the restoration workbay.

3.2. Repair of the removed high-voltage battery unit

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The following description of the repair of the high-voltage battery unit is only a general list of the content and the procedure. **In general, only the specifications and instructions in the current valid edition of the repair instructions apply.**

3.2.1. General and preliminary measures

The high-voltage battery unit is a component with large dimensions and heavy weight. Only the combination of the housing and the cell modules secured inside give the high-voltage battery unit complete stability (rigidity), as is required when driving.

For the replacement of cell modules and Cell Supervision Circuits it is extremely important to enter the serial number and the installation position of the components replaced in the print-out of the report and in the battery management electronics (SME). There is a Service function in the diagnosis system for the start-up of the high-voltage battery unit after repair. Otherwise, the new installation position is automatically assigned by the battery management electronics (SME). The results are not correct location data.

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In the event of a subsequent repair of the high-voltage battery unit the diagnosed faults are displayed for the installation position and the incorrect cell module or Cell Supervision Circuit is replaced.

3.2.2. Work before opening

Prepare the workbay

- Prepare the mobile assembly lifting table with adapters.
- Cleanliness of the workbay.
- Keep away from emerging fluids.
- No tools or other objects at the workbay.
- Spatial separation from other work stations by a separate room or using barrier tape is recommended.
- No flying sparks in the vicinity, apart from that erect corresponding partition walls.

3.2.3. Disassembly of the housing sections of the high-voltage battery unit

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In general, for all operations at the high-voltage battery unit **the current repair instructions** must be followed.

The following procedure is prescribed for the disassembly of the housing parts: Firstly, all dirt contamination and any moisture must be removed from the housing cover. The following cleaning agents are approved:

- Spirit
- Windscreen cleaning agent
- Glass cleaning agent
- Distilled water
- Vacuum cleaner with plastic attachment

Undo the screws of the housing cover and remove any contamination from the screw holes using a vacuum cleaner. Carefully remove the housing cover. Visually check the open high-voltage battery unit for any damage and ingress of moisture.

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Immediately stop work if damage is visible and contact a specialist BMW qualified electrician or technical support.

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The screws of the housing parts must be replaced each time after disassembly. Clean the contact surfaces of the seals on the upper housing section and the lower housing section.

3.2.4. Removal of the cell modules

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The following description of the repair of the high-voltage battery unit is only a general list of the content and the procedure. **In general, only the specifications and instructions in the current valid edition of the repair instructions apply.**

Print the position plan from the diagnosis system before removing the cell modules or Cell Supervision Circuits (CSC). First and foremost, you must comply with the safety rules and disconnect the high-voltage cable between cell module three and cell module four. Now all cell modules and Cell Supervision Circuits must be numbered using a waterproof pen according to the location diagram.

Before it is possible to remove the bottom cell modules, it is first necessary to remove the safety box, the battery management electronics as well as the intermediate shelf.

It is now possible to remove the affected cell modules. The high-voltage connectors of the cell modules must be disconnected for this. Then unlock and undo the Cell Supervision Circuit connectors. The Cell Supervision Circuits are removed together with the cell modules.

Then the mounting bolts of the cell modules can be slackened. If necessary, remove the CSC ring wiring harness. Use a panel wedge if required. Under no circumstances use any sharp objects. Carefully lift out the cell module. Use the special tool for lifting to simplify the procedure. Ensure sufficient clearance between the cell modules. Set down the cell module with base on a clean surface and ensure it is positioned so it does not slip or tilt.

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Hold the heat exchanger at each end to remove it. Otherwise, there is a risk of damage due to the length or low mechanical stability.

3.2.5. Preparation before the installation of a cell module

Before the installation of a new cell module its State of Charge is brought to the level of the remaining cell modules, which was read out beforehand. Clean the high-voltage battery unit, heat exchanger and cell module flooring panel prior to installing the cell module.

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If all cell modules have to be replaced, alternatively the voltage of one cell module can be used as a nominal charging voltage for all other cell modules in order to minimise the charging times (read out using charger).

3.2.6. Installation of the cell modules

Mount the Cell Supervision Circuits to the cell module prior to installing the cell modules. Carefully lift the cell module using a special tool. Pay attention to neighboring parts. Tighten the screws of the cell module to the specified torque during installation. After installing the bottom cell module, connect the Cell Supervision Circuit wiring harness connector to the Cell Supervision Circuits. Connect the high-voltage connector of the respective cell module. Before installing the module intermediate shelf, carry out a visual check to ensure that all lines and connectors are correctly routed and connected.

You can subsequently mount the top heat exchanger. Carefully lift the upper cell modules onto the heat exchanger using the special tool and tighten the mounting bolts to the specified torque. In the next step, the wiring harness of the Cell Supervision Circuits and corresponding connectors can be locked. In a final step, connect the high-voltage cable between cell modules three and four.

Take a note of the serial number of the new cell module and its installation position in the high-voltage battery unit from the note printed out from the diagnosis system. There is a Service function in the ISTA workshop information system for the start-up of the high-voltage battery unit after repair. Here the serial numbers of the new cell modules must be entered in the battery management electronics control unit.

3.2.7. Removal of the Cell Supervision Circuits

Before the removal of the cell modules or Cell Supervision Circuits (CSC) the location diagram must be printed out from the diagnosis system. First observe the safety rule and disconnect the high-voltage cable between cell modules three and four. Now all cell modules and Cell Supervision Circuits must be numbered using a waterproof pen according to the location diagram. Detach the Cell Supervision Circuit ring wiring harness over a wide area. Use a panel wedge for this if required. Under no circumstances use any sharp objects. Disconnect and remove the connectors of the upper Cell Supervision Circuit . Remove the cell modules in order to remove the bottom Cell Supervision Circuit . The Cell Supervision Circuit can then be unclipped.

3.2.8. Installation of the Cell Supervision Circuits

Note down the serial number of the new Cell Supervision Circuit and its installation position in the high-voltage battery unit on the slip printed out from the diagnosis system. Connect and attach the Cell Supervision Circuits to the cell module. The components previously disassembled are installed in reverse order. In a final step, connect the high-voltage cable between cell modules three and four. There is a Service function in the ISTA workshop information system for the start-up of the high-voltage battery unit after repair. Here the serial numbers of the new cell modules must be entered in the battery management electronics control unit.

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Special features when replacing several Cell Supervision Circuits:

The documentation and entry of serial numbers and the installation position is extremely important. Otherwise, the installation position is automatically assigned. If an incorrect installation position is entered, all faults reported for a later defect of the Cell Supervision Circuit are displayed for this incorrect installation position and as a result the Cell Supervision Circuit is replaced at the wrong location!

3.2.9. Removal of heat exchanger

The top cell modules must be disassembled when removed the top heat exchangers. When removing the bottom heat exchanger, it is also necessary to disassemble the module intermediate shelf and bottom cell module as well as the Cell Supervision Circuit ring wiring harness.

⚠

Hold the heat exchanger at each end to remove it. Otherwise, there is a risk of damage due to the length or low mechanical stability.

3.2.10. Installation of the heat exchangers

If the heat exchangers are only removed and installed, the sealing rings at the radiator connection must be replaced. The plastic pin must be aligned in accordance with the repair instructions before installing the bottom heat exchangers. A faulty plastic pin must be replaced.

⚠

Hold the heat exchanger at each end to install it. Otherwise, there is a risk of damage due to the length or low mechanical stability.

After installing the bottom heat exchanger, carefully lift in the bottom cell module using the special tool. It must be ensured that the Cell Supervision Circuit is mounted on the cell module. Position the cell module screws and tighten to the specified torque. After installing the bottom cell module, connect the Cell Supervision Circuit wiring harness connectors to the Cell Supervision Circuit . Connect the high-voltage connectors of the respective cell modules. The module intermediate shelf must be secured before the top heat exchangers are installed.

The two top heat exchangers can then be mounted. Carefully lift the upper cell modules onto the heat exchangers using the special tool and tighten the mounting bolts to the specified torque. In the next step, secure the Cell Supervision Circuits on the cell modules and lock the associated connectors. In a final step, connect the high-voltage cable between cell module three and four.

3.2.11. Installation of the housing cover of the high-voltage battery unit

Check the sealing surface of the housing cover and lower housing section and clean if necessary. The gasket of the housing sections must be replaced. Before the housing cover is mounted, check whether the high-voltage cable is connected between cell module three and four. Ensure that the seal does not come into contact with sharp edges when installing the housing cover.

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The screws are self-tapping, therefore they must be manually positioned before work is continued using the tool. Otherwise, there is a risk of damage to the thread of the lower housing section.
Use of power screwdrivers is not allowed as otherwise the screws/threads may tear. The screws must be replaced.

Replace any screw connections where the screw does not reach the specified torque or if the thread is damaged. A minimum of one screw connection must be undamaged and it must not be necessary to rework this screw connection. All other screw connections can be reworked. The upper housing section must be in contact with the high-voltage battery unit to rework the threads to prevent contamination by swarf. Replace the lower housing section if all screw connections have been damaged.

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In the event of repairs on a damaged screw thread in the lower housing section the housing bore must be restored using a Kerb Konus insert. Any swarf must be removed from the high-voltage battery unit.

Tighten the new screws to the specified torque.

3.3. Reworking

3.3.1. Final test with EoS tester

EoS tester

Index	Explanation
1	Touch screen for operation
2	USB interface for updates
3	Connection of mains lead and main switch
4	Pressure bell I01
5	Connecting line
6	High-voltage connector
7	F30 PHEV pressure box
8	Relay box for high-voltage test

Before installation, a test must be performed with the EoS tester. Mount the appropriate test adapter for the venting unit. Connect the test connections for the pressure connection, high-voltage connector and interface to the 12V on-board mains connector.

To start the complete test, it is first necessary to select the corresponding vehicle and the high-voltage battery unit. Then the tests for de-energized state, isolation resistance and SME isolation monitoring are carried out. Now the fault memory is read and if there are no faults a test code is issued.

If a fault is established in the leakage test, the test will not be aborted immediately. All electrical checks will be performed first and then the result presented. Switch-over to leakage detection mode will take place if the electrical checks are OK. If the electrical check also fails, a message will be displayed with a request to contact technical support.

Read out the test code and take a note of it for subsequent transfer to the diagnosis system or scan the Data Matrix Code (DMC) directly. Finally, the EoS tester sets the transport bit so that the switch contactors cannot be activated. During final diagnosis the service function for high-voltage battery start-up resets the transport bit after having entered the test code to activate the switch contactors and transfer FASTA data to the workshop system.

3.3.2. Installation of the high-voltage battery unit in the vehicle

Carefully insert the high-voltage battery unit into the vehicle using the mobile workshop crane and the multi-purpose lifting tool. Make sure the high-voltage battery unit is correctly locked and centred during lifting. Before installing the high-voltage battery unit, make sure that the seal is positioned correctly. Slowly lower the high-voltage battery unit and align the screw holes. Position the mounting bolts and completely lower the high-voltage battery unit. Tighten the mounting bolts to the specified torque.

The exact procedure must be followed when installing the potential bonding line:

1 Clean the contact surfaces and have them checked by a second person.
2 Tighten the mounting bolts to the specified torque.
3 Have the torque checked by a second person.
4 Both persons must record this in the vehicle records for the correctness of the version.

The O-rings must be replaced before mounting the heating and air-conditioning cables. Then the connectors for the high-voltage cables and the interface for the 12 V vehicle electrical system lines must be connected.

3.3.3. Final electrical diagnosis

In the diagnosis system the service function for the start-up of the high-voltage battery unit must be started. Enter the test code of the EoS diagnosis system or scan via DMC. The serial numbers and the installation positions of the replaced components are transferred by the battery management electronics to the diagnosis system and documented in vehicle operation and service data transfer and analysis. The switch contactors are enabled by the diagnosis system. Then the fault memory is read. Finally, the high-voltage battery unit is fully charged and the heating and air-conditioning system is filled.

F30 PHEV High-voltage Battery Unit

4. Disposal

4.1. Storage of damaged batteries

A battery is considered damaged if:

- the high-voltage battery unit has visible sings of overheating (locally or otherwise).
- there is smoke or gasses emerging from the high-voltage battery unit.
- the high-voltage battery unit has a deformed or torn outer skin.

As soon as the defective batteries is identified:

- Technical service should be contacted and PuMA case should be created.
- If the vehicle has a damaged high-voltage battery it must be parked outside (for at least 48 hours) or until further recommendations are provided via a PuMA case.
- The disabled vehicle should be parked at a predetermined storage location which must be at least 5 meters away from buildings, vehicles or other combustible materials, for example waste containers.

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Only especially trained and certified BMW Technical Service personal should ever remove and handle externally damaged HV batteries. BMW dealer technicians are not permitted to remove nor handle high voltage batteries with external damage. If a HV battery is found to be externally damaged the vehicle should be isolated and Technical Service (electromobility) should be notified in the way of a PuMA case. Technical Service will then instruct the technician as to how to proceed.

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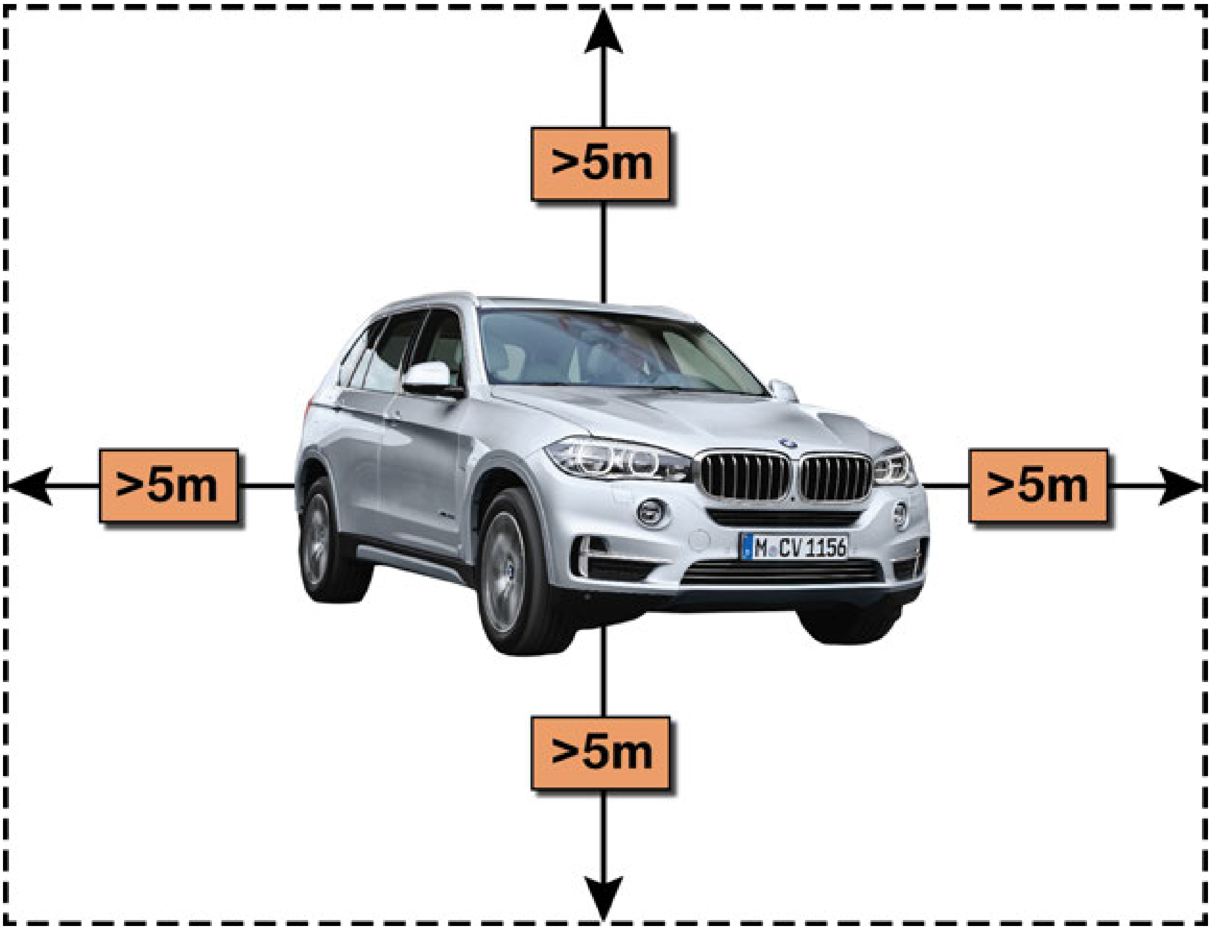
4. Disposal



Vehicle with an externally damaged HV battery should isolated and parked at a predetermined storage location which must be at least 5 meters away from buildings. (F15 shown)

4.2. Establishing suitability for transportation

The analysis and assessment of the high-voltage battery unit must be performed by a person properly trained by BMW Technical Training. The certification of suitability for transportation is the responsibility of the qualified person.

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To establish the suitability for transportation the repair instruction 6125... "Assessing the suitability for transportation of the high-voltage battery unit in Service workshops" must be followed and the appropriate form filled out and placed in vehicle file.

Establishing the suitability for transportation is divided into two areas:

- Electrical assessment
- Visual assessment

4.2.1. Electrical assessment

For checking the suitability for transportation the procedure for the cell modules has to be completed first via the diagnosis system, during which the electrical assessment of the suitability for transportation is established. The following information is available as a result:

1 The evaluation of the fault code entries indicates that the high-voltage battery unit does **not have any faults preventing transportation.** For further steps please refer to the repair instructions "Assessing the suitability of transportation of the high-voltage battery unit in Service workshops". The serial numbers of the high-voltage battery unit and the SME control unit which must be noted are also displayed.

2 The evaluation of the fault code entries indicates that the high-voltage battery unit **cannot be transported** without further measures. The causes are the following stored and current fault code entries:

- 21F016 high-voltage battery unit, voltage supply of the evaluation electronics for cell module X, short circuit to ground.
- 21F080 high-voltage battery unit, cell module X, over voltage of at least one cell. For further steps please refer to the repair instructions "Assessing the suitability of transportation of the high-voltage battery unit in Service workshops".

4.2.2. Visual assessment

The following criteria must be checked during the visual assessment:

- Smoke
- Visual localized overheating
- Areas hot to the touch
- Crack or opening on the housing
- Dents in the housing or deformation
- Heavy corrosion
- Loose or damaged connections
- Serial number/label of safety label illegible
- Suspected water damage

If one or more points are answered with yes, the further course of action must be clarified with Technical Support and a PuMA case started!

If the vehicle battery fails the Electrical or Visual assessment, apply the following; the removed high-voltage battery unit must be isolated using barrier tape. If the high-voltage battery unit is still in the vehicle the vehicle must be isolated, locked and restricted as previously explained.

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Repair of the high-voltage battery is only allowed in a retail service center that has qualified and certified service technicians. These technicians must have completed the ST1403b I01 High-voltage Battery and Maintenance instructor led course and successfully passed the hands-on certification.

4.3. Disposal of high-voltage battery unit

If a high-voltage battery unit must be disposed of, the specified disposal company should be contacted to arrange pickup and recycling of battery. In the event of non-defective batteries the transport packaging for spare parts can be used. **Please refer to the latest BMW parts bulletin for the most current information regarding the distribution and recycling of high voltage batteries.**

In the event of a damaged battery, standard transport packaging may not be used. Contact Technical Service for further support.

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For more information regarding the appropriate procedure and guidelines on how to handle defective or damaged high voltage batteries, please refer to the latest BMW parts bulletin.

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