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BMW ActiveHybrid X6

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BMW ActiveHybrid X6

Model: E72

Production: From Start of Production

OBJECTIVES

After completion of this module you will be able to:

- Explain the differences between the E71 and E72
- Identify the components that make up the BMW ActiveHybrid X6 propulsion system
- Explain the operation of the high voltage battery
- Explain the power down procedure for the high voltage system
- Explain the operation of the Kombi and CID hybrid displays

Introduction

The first stage of the BMW Group BMW EfficientDynamics was to develop a variety of measures to promote efficiency. These improvements were introduced through the entire model range via the normal series production vehicles.

BMW ActiveHybrid is an important component within the second stage and development strategy of BMW EfficientDynamics. It is based on the concept "Best of Hybrid". This enables the integration of each best component for different vehicle segments.

This poses two seemingly opposing development goals. On the one hand, a considerable increase in efficiency, so a consumption reduction up to 20 percent while still fulfilling the legal emissions standards and with a decreased CO_2 emissions from BMW models with conventional propulsion. On the other hand, the BMW Group must offer the most dynamic hybrid vehicles in the competitive environment.

BMW launches its first series vehicle with hybrid technology to the market in December of 2009 as the BMW ActiveHybrid X6 (E72). Unlike all other hybrid vehicles currently on the market, this sets a record as the world's first sports activity Coupe with hybrid drive. This vehicle characterizes itself as having high efficiency, high power output and similar agility while reducing the average fuel consumption of the BMW X6 xDrive50i 20 percent.

The BMW EfficientDynamics results are achieved via the use of a full hybrid drive system which features a combination of V8 gasoline engine (N63) and electric propulsion. The BMW ActiveHybrid Technology enables driving via the following three means:

- purely electrical driving
- powerful internal combustion engine
- combination of both.

ActiveHybrid X6

Purely electric mode allows CO2-free driving up to 40 mph. The internal combustion engine can then seemlessly start and take over the propulsion requirements.

This Drive system of the BMW ActiveHybrid X6 consists of a 400 hp strong V8 engine with BMW TwinPower Turbo technology and two electrical machines that are capable of creating 91 hp and 86 hp. The maximum possible combined system performance is 480 hp and the torque reaches a maximum of 575 lb-ft of torque.

The BMW ActiveHybrid X6 is characterized as the most powerful hybrid vehicle in the world. Its estimated acceleration time from 0 - 60 mph is under 5.4 seconds.

E72 Complete Vehicle.

Introduction > Recognition feature > Exterior

What are the specific exterior design details of E72?

E72 Complete Vehicle.

What are some of the specific underhood characteristics of the E72?

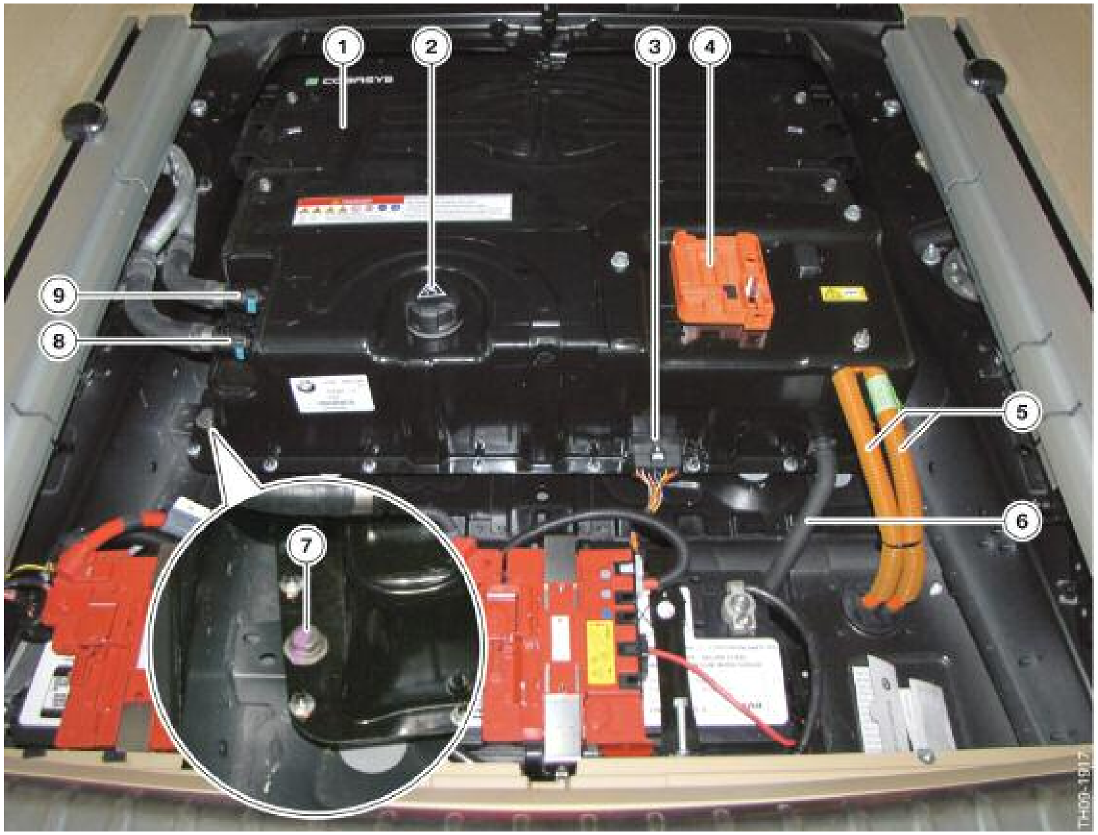
E72 Complete Vehicle.

Introduction > Recognition feature > Interior

What are the specific interior design details in E72?

E72 Complete Vehicle.

High voltage battery unit > Overview



Have a look at the installation location of the high voltage battery and take notes about the parts.

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Notes:

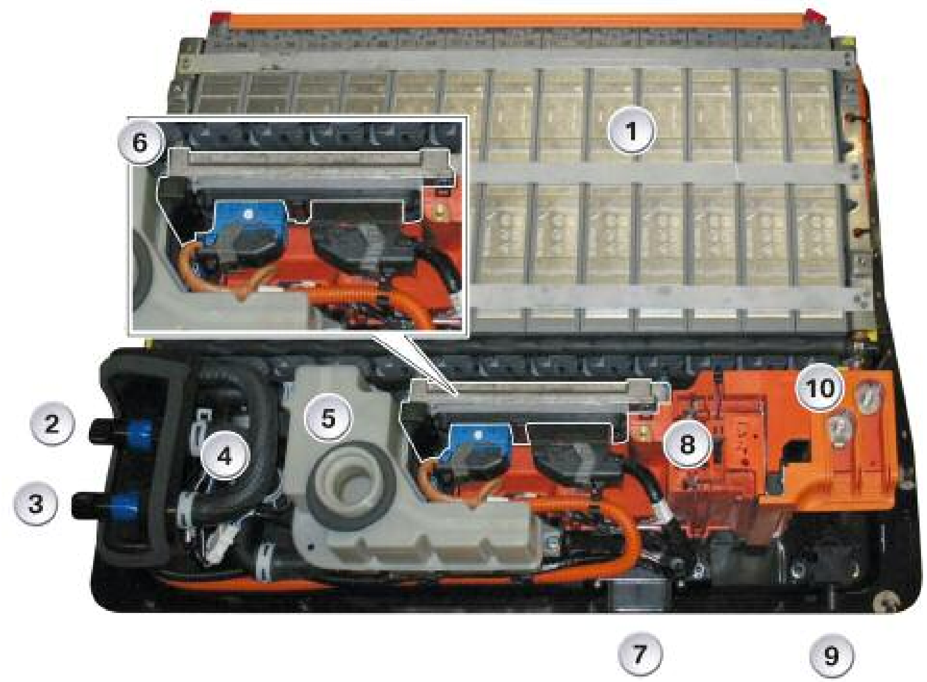
High Voltage Battery Pack (HV-ES)

One major component of the hybrid system is the high voltage battery pack or power supply (HV-ES). This component is located in the rear cargo area of the vehicle. Its approximate weight is 187 lbs (85 kg).
The battery pack is currently manufactured by Bosch GMbH but was originally developed by COBASYS. COBASYS was owned by GM before the 2008 financial crisis forced them to sell. The battery pack's development was a joint venture between the BMW Group, General Motors, DaimlerChrysler located in Troy Michigan.

The hight voltage Battery Pack is composed of several key components for the hybrid system on the E72. These components are:

- Battery modules x26
- High Voltage Contactors
- Ventilation
- Battery Monitoring Control Module
- Cooling Circuit
- Service Disconnect

Inside view of high voltage battery pack



Index	Explanation
1	Batteries (source of energy)
2	Coolant line connections - Outlet
3	Coolant line connections - Inlet
4	Coolant pump
5	Coolant reservoir
6	Battery Monitoring Control Module (BCM)
7	Vehicle harness (12 V connector)
8	Service Disconnect
9	Ventilation
10	High Voltage contacts controlled via relays and contacts

Battery Modules

The electric propulsion system is powered by 26 Nickel Metal Hydride battery modules connected in series. In order to maintain a compact design, the batteries are mounted as two 13 module units mounted on top of each other.

Each module is capable of 12 volts. This translates the total “static” voltage output of the battery pack is 312 volts (12 volts x 26 modules). Under various operating conditions, the actual battery output voltage is between 312 - 422 volts.

High Voltage Battery Packs (assembled)

NiMH Technology

Nickel Metal Hydride batteries were chosen as the battery technology on the E72. NiMH is not only proven technology but it also allows for very rapid charging/discharging with very little memory effect.

Battery cells in nickel metal hydride technology use water-diluted caustic potash (potassium hydroxide) as the electrolyte. Although this electrolyte used in liquid form exhibits hazardous characteristics, the battery modules are hermetically sealed so that electrolyte cannot leak either while driving or during service. However, if the housing of the high voltage battery and/or the modules are damaged due to an accident, for example, electrolyte can leak.

Each row of battery cells houses two temperature sensors which help to monitor the cell temperature and adjust the cooling power as needed. The voltage of each module is also monitored to prevent individual battery cells from total discharge or overload. The current level into and out of the high voltage battery is measured and electronically monitored using a current sensor.

High demands are placed on the service life of the high voltage battery (service life of the vehicle). To meet these demands, it cannot be operated however one likes, as for example with nickel metal hydride battery cells for household devices. Depending on how the batteries in these are used, they are often no longer usable after a year. Therefore the high voltage battery is operated in an exactly defined range, so that its service life is maximized. This includes the following marginal conditions:

- Maintaining cell temperature in the optimum range between +25 and +55°C (by "heating" or cooling).
- Not allowing charge current and discharge current to exceed temperature-dependent limits.
- Not fully depleting the battery's amount of storable energy.

High Voltage Contactors

The high voltage safety switch, which also contains a high-current circuit breaker, is switched right in the middle of the battery cells switched in series. The series connection is interrupted both by pulling the high voltage safety switch and by activating the fuse. Consequently, the outer terminals of the high voltage battery are no longer live. The same thing is achieved if the contacts of the electromechanical switch contactors are opened. These contacts are located on the positive terminal and the negative terminal, before the terminals of the high voltage battery are routed outwards. The electromechanical switch contactors are activated by the battery monitoring module. The supply voltage for the switch contactors is supplied through the safety battery terminal.

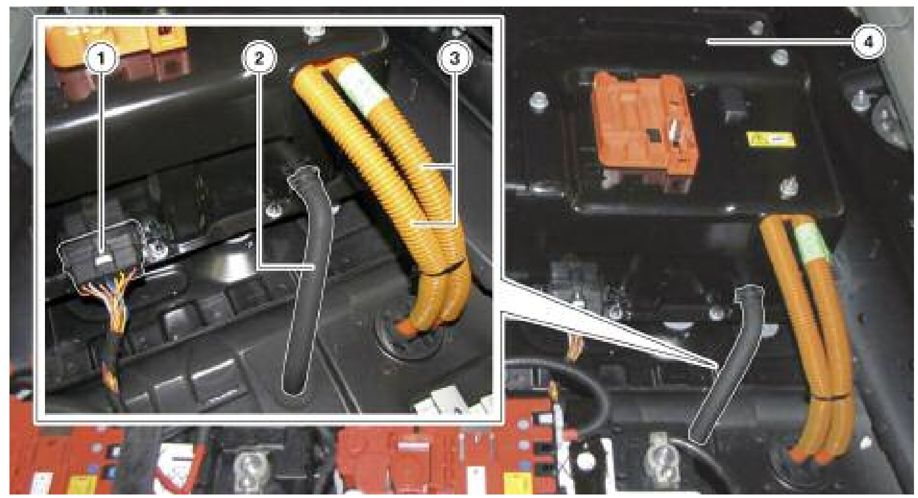
The connection of the high voltage battery unit to the high voltage electrical system is located under a separate cover. This cover is a high voltage safety cover, which is integrated into the high voltage interlock loop. In order to access the high voltage connections, this cover must be removed. By doing this, the bridge built into the cover is pulled off and the circuit of the high voltage interlock loop is interrupted. As long as this cover is removed, accidental activation of the high voltage system is impossible.

Before beginning work on the high voltage connection of the high voltage battery unit, the high voltage system must be de-energized and the de-energized state must be checked. Securing the system against being switched on again is not possible during this repair work. When removing the cover that is over the high voltage connection, the high voltage safety switch which is inserted the opposite way must be removed for a short while.

Ventilation

When charging or discharging nickel-metal hydride batteries, gases can result, including small quantities of hydrogen. The operational strategy reduces the generation of these gases to a minimum. If, despite this, larger quantities of gases arise, a vent valve in the high voltage battery unit is opened and the gases can escape to the outside via a vent hose. When the high voltage battery unit is removed, the vent hose must be disconnected from it.

When the high voltage battery is reinstalled, the vent hose must be reinstalled properly on the high voltage battery unit. Otherwise, escaping gases can enter the passenger compartment.



Index	Explanation
1	Connection for low-voltage cables
2	Vent hose
3	High-voltage cables
4	HV Battery

Battery Monitoring Control Module

The battery monitoring module (BCM) is housed within the high voltage battery unit and is not accessible from outside. The BCM is responsible for the following functions:

- Controlling the cooling circuit
- Determining the state of charge (SoC) and the state of health (SoH) of the high voltage battery
- Determining (and limiting, if necessary) the available power of the high voltage battery
- Controlling the starting and shutting down of the high voltage system on request using the hybrid master control unit
- Safety functions (e.g. high voltage interlock loop)
- Monitoring the voltage and temperature of the battery cells and the current level
- Communicating fault statuses to the hybrid master control unit

The battery monitoring module does not have its own fault memory. Instead, any faults detected by the battery monitoring module are transmitted to the hybrid master control unit via the hybrid CAN. The faults belonging to the high voltage battery are also stored in the hybrid master control unit for diagnostic purposes.

The electric connections of the BCM inside the high voltage battery unit are distributed to two connectors, one for low-voltage cables and one for high voltage cables. In particular, the signals and cables important for the BCM are:

- Its own 12 V voltage supply (terminal 30 switched and terminal 31, for control electronics and coolant pump respectively, terminal 30 from the safety battery terminal for supplying the switch contactors)
- Hybrid CAN and wake-up line
- High-voltage cables
- Switch contactors (activation and read back)
- Temperature signals for the battery cells (two pins per sensor, four temperature sensors in all)
- Temperature signals for coolant (two pins per temperature sensor, one temperature sensor each for inlet and return)
- Coolant pump supply/activation
- High-voltage circuit current sensor
- High-voltage interlock loop (signal source and return wire).

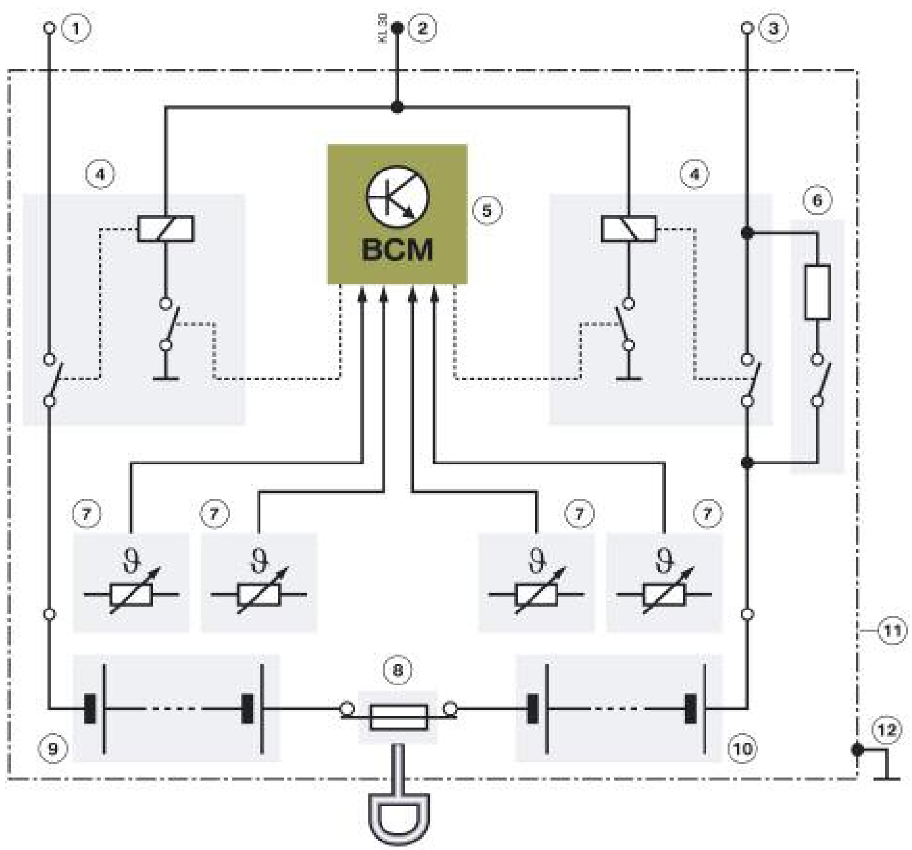
Towards the outside, in addition to the terminals for the high voltage cables, there is also a connector for low-voltage cables. The following are connected there:

- 12 V supply voltage (terminal 30 switched and terminal 31, for control electronics and coolant pump respectively, terminal 30 from the safety battery terminal for supplying the switch contactors)
- Hybrid CAN
- Two wake-up lines (from the hybrid interface module)
- Control signal for closing/opening the contacts of the switch contactors (pulse-width modulated signal from the power electronic box)
- Feed and return wire for high voltage interlock loop.

E72 Complete Vehicle.

High voltage battery unit > Internal Components

With the information provided by the facilitator, fill in the table below



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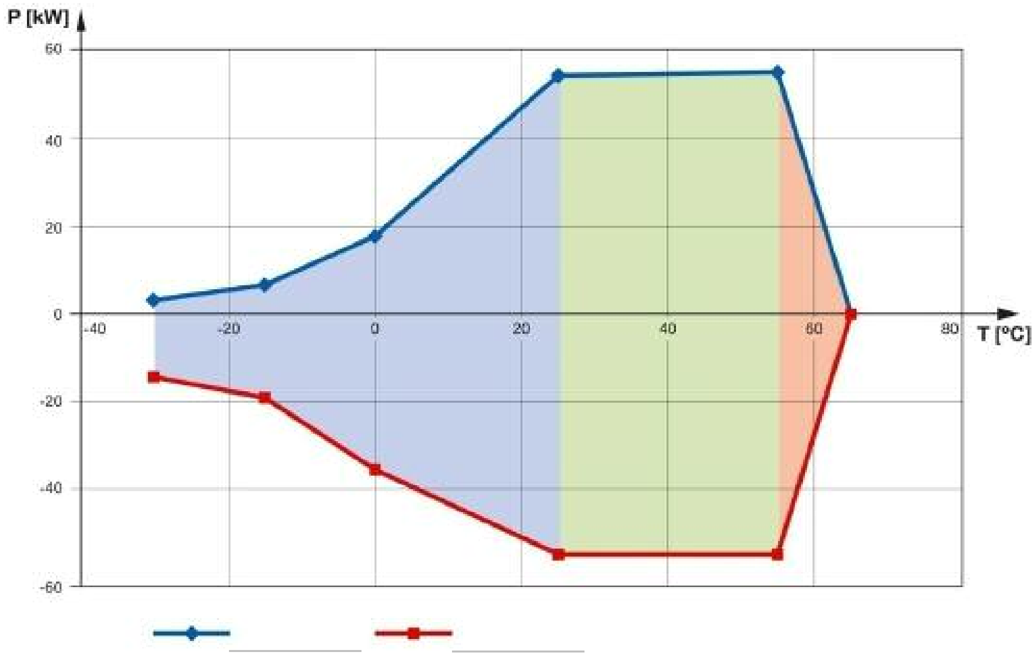
When and why is the power output of the high voltage battery limited?



What can be done to increase the battery temperature if necessary?

What can be done to stop the battery temperature from rising further?

Cooling Circuit

To maximize the service life of the high voltage battery and obtain the greatest possible power, it is operated in a defined temperature range.

In the low temperature range, the chemical reactions when charging or discharging the battery cells take place slowly. The transport of the charge carriers is slower, so that the maximum current level and thus the maximum power is limited. In this low temperature range, the cooling system is inactive. Instead, the operational strategy attempts to warm up the high voltage battery. This takes place through continuously repeated charging and discharging cycles. The resulting current flows create thermal energy at the internal resistor of the battery cells that increases the cell temperature.

The constant charging and discharging of the NiMH batteries can cause the temperature of the battery modules to increase. If the temperature of the batteries increase too much it will have several negative attributes on the battery. The major effect is that the charge capacity of the batteries will be impaired.

In the medium temperature range, the maximum power of the battery is purposely limited (using software in the battery monitoring module) to maximize the service life of the battery. The cooling system is already active here, and attempts to keep the cell temperature in the optimal range between 35°C and 45°C.

Particularly in the high temperature range, powerful cooling of the high voltage battery is required, while a great decrease in power is required at the same time. At high cell temperatures, the internal pressure would increase and the vent valve would have to be opened. This would also dissipate small amounts of the electrolyte, which, if occurring repeatedly, would result in rapid aging of the battery.

Therefore, the battery power is limited, accepting the disadvantage that this restricts the hybrid functionality, e.g. with regard to driving in pure electric mode or brake energy recovery.


Cutaway view of battery

The cooling system works with liquid coolant as the cooling medium. Here, the coolant flows through the battery modules themselves, allowing effective dissipation of the excess thermal energy.

In order to prevent a failure of the batteries due to high temperature, the battery pack is equipped with an independent cooling circuit. The coolant circuit is comprised of:

- battery modules
- a coolant reservoir/pump
- coolant lines
- air to liquid cooler
- liquid to A/C refrigerant chiller

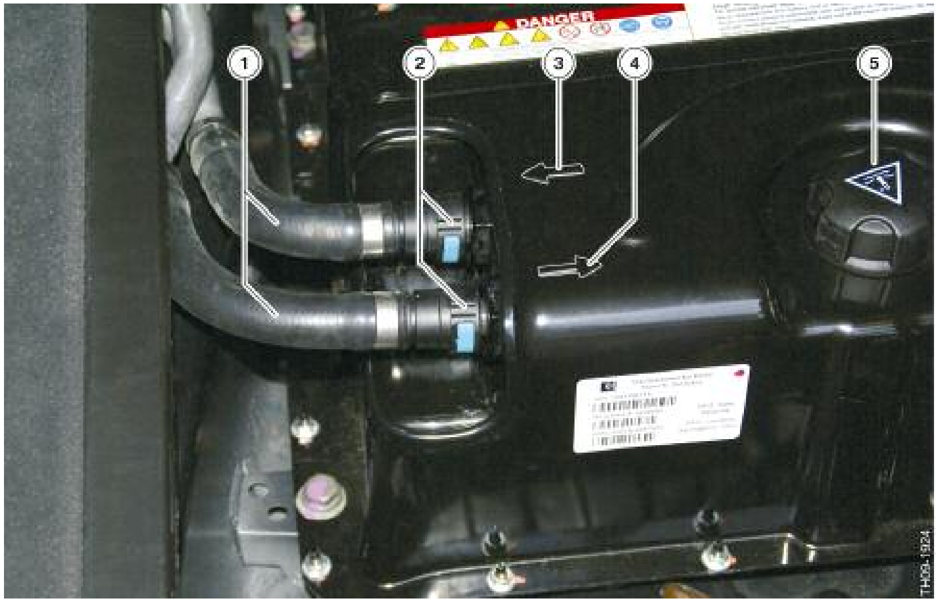
The cooling circuit utilizes the same type of fluid mixture known from the engine cooling system a (50% water and 50% glycol).

Battery Modules

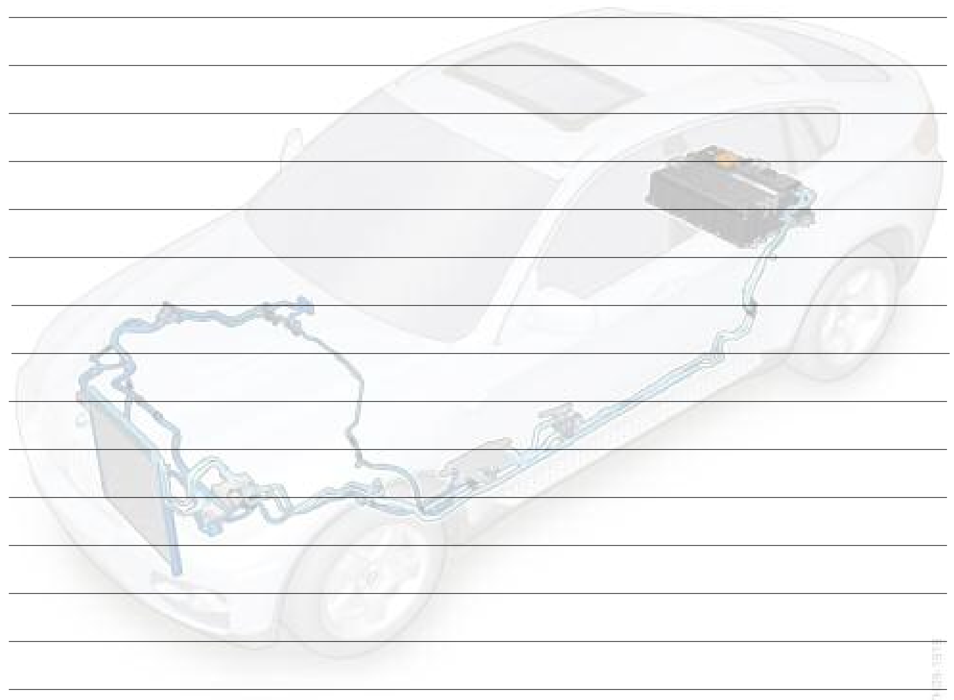
The battery modules have been designed with internal coolant passages built in. These passages allow the coolant to run through the inside of the battery for more efficient cooling.

This is a major advantage over other manufacturers that require air vents in the passenger compartment for cooling. Those vents can be blocked by bags, clothing or any item left in the vehicle and cause the batteries to overheat. The E72 will not face this situation because of direct liquid cooling of the batteries.

Connections to the High Voltage Battery

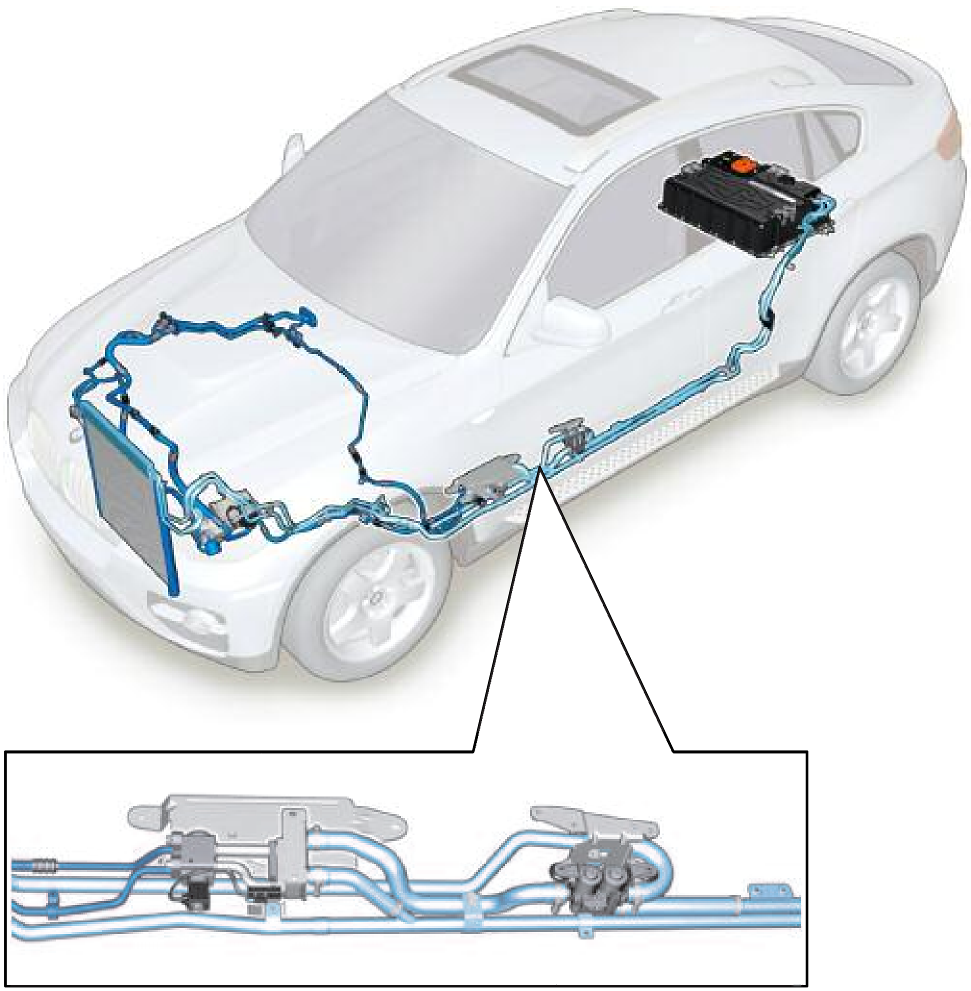


Index	Explanation
1	Coolant lines
2	Quick connect coolant lines
3	Outlet line
4	Inlet line
5	Coolant reservoir cap



E72 Complete Vehicle.

High voltage battery unit > Cooling system



By which means can the high voltage battery be cooled?

How can the cooling system switch between the two cooling sources?

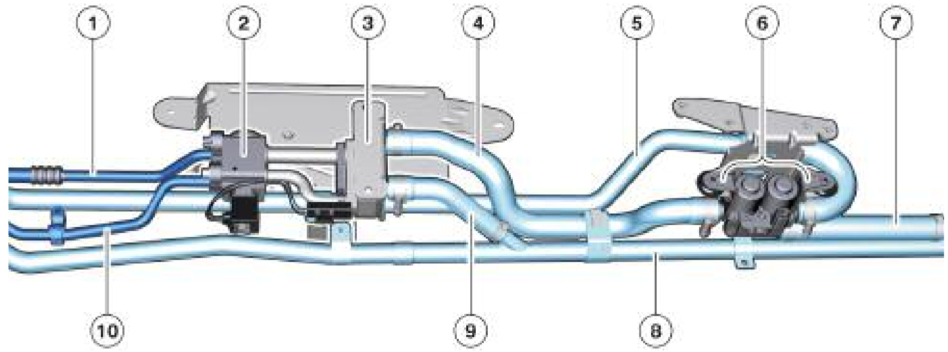
Notes:

In order to start the cooling system functions, multiple communication steps are required, which are listed briefly here:

- BCM => IHKA: cooling power request (bus signal)
- IHKA => EKK: switch on air conditioning compressor (bus signal)
- IHKA => HIM: request to switch bypass valve, switch solenoid valve of the cooling unit, switch shut-off valve where applicable (bus signals)
- HIM => Bypass valve: the bypass valve in the cooling circuit is supplied with current in order to redirect the cooling circuit from the coolant/air heat exchanger to the coolant/refrigerant heat exchanger
- HIM => Solenoid valve in the cooling unit: the solenoid valve is activated so that refrigerant flows through the cooling unit
- HIM => Shut-off valve: if the driver does not want any climate control of the passenger compartment, the shut-off valve must be triggered so that no refrigerant flows to the heat exchanger for the passenger compartment.

Thus the hybrid interface module activates the valves. However, the nominal values for this purpose come from the integrated automatic heating / air conditioning system via bus signals. By using the refrigerant circuit, regardless of the ambient temperature, a cooling power of multiple hundred watts can be dissipated.

Exploded view of Connection between cooling and refrigerant circuits



Index	Explanation
1	Refrigerant line from the cooling unit (return line)
2	Combined expansion and shut-off valve in the refrigerant circuit
3	Cooling unit (coolant/refrigerant heat exchanger)
4	Coolant line to the cooling unit (feed line)
5	Coolant line to the coolant/air heat exchanger
6	Bypass valve
7	Coolant line from the high voltage battery unit
8	Coolant line to the high voltage battery unit
9	Coolant line from the cooling unit (return line)
10	Refrigerant line to the cooling unit (feed line)

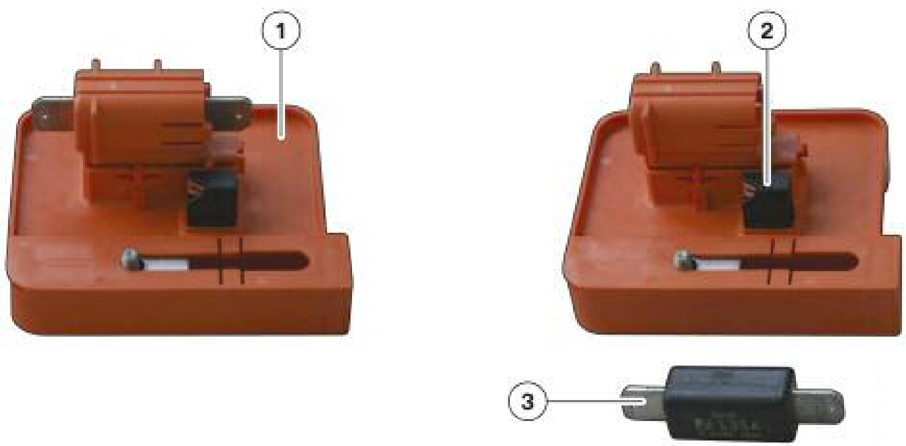
Service Disconnect

The high voltage safety connector of the E72 is installed on the top of the housing of the high voltage battery unit.

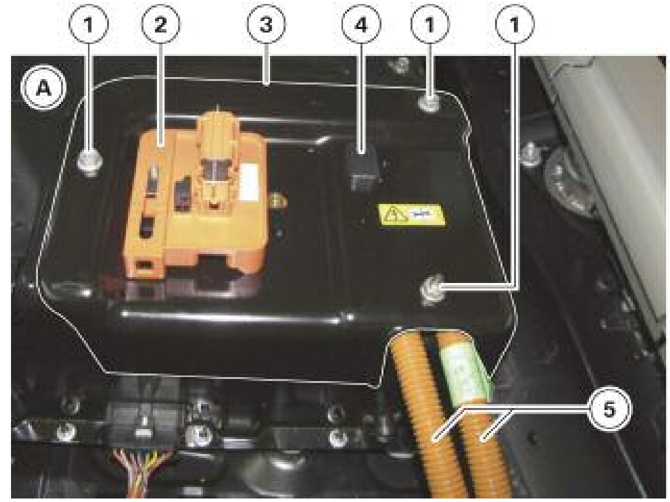
The high voltage safety connector fulfils multiple tasks:

- De-energizing the high voltage system
- Securing the system against being switched on again
- Holding the high voltage fuse of the high voltage battery

The fuse in the high voltage safety connector is plugged in directly between the battery cells switched in series and thus is a high voltage component. For this reason, it is identified by its orange color.



Index	Explanation
1	Housing of the high voltage battery unit
2	High-voltage safety connector (in plugged-in state)
3	Fuse

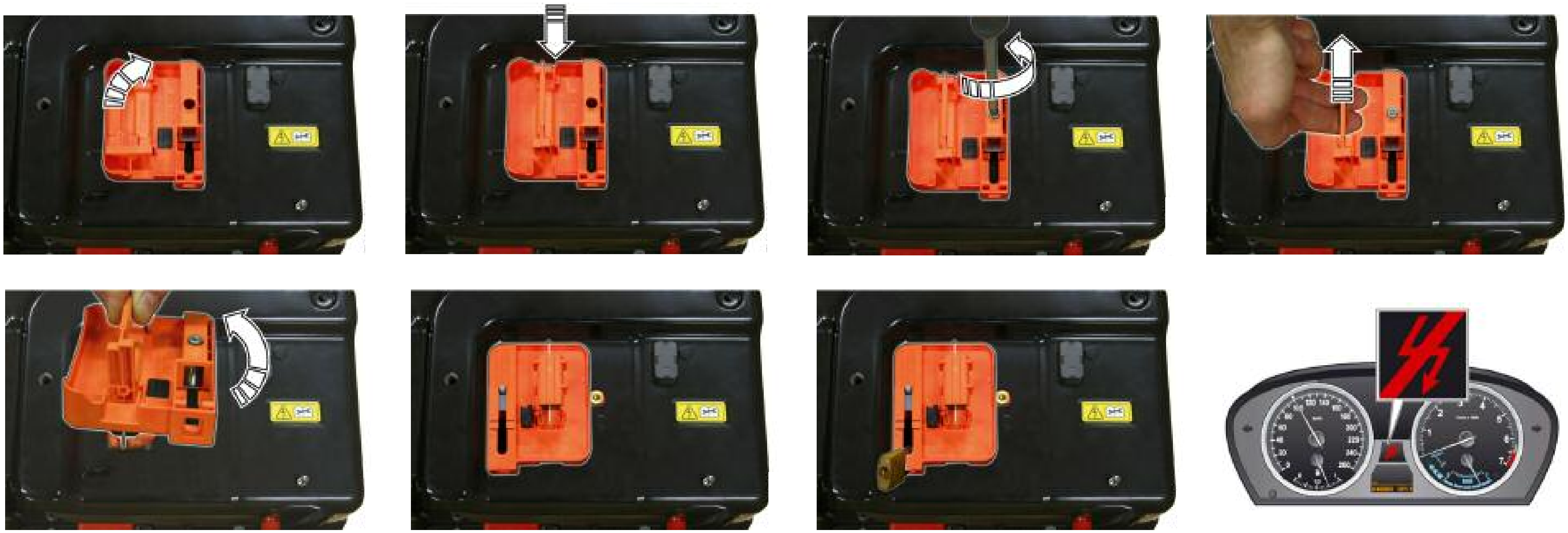


Index	Explanation
1	Screws and nuts for mounting the high voltage safety cover
2	High-voltage Service Disconnect (inserted the opposite way)
3	High-voltage safety cover
4	Bridge for the circuit of the high voltage interlock loop in the high voltage safety cover
5	High-voltage cables

E72 Complete Vehicle.

High voltage battery unit > Manual shutdown using the high voltage safety connector

Perform a manual shutdown of the high voltage system, secure it and verify, that high voltage is off.



Notes:

Functions

Starting the High-voltage System

The start of the high voltage system is requested by the hybrid master control unit via messages on the hybrid CAN and via an additional separate signal line (PWM-encoded). The execution of the start is then controlled by the battery monitoring module. The start takes place in three steps, each of which takes place only if the previous step has been completed successfully.

The three steps are:

1. Testing the high voltage electrical system
2. Raising the voltage
3. Closing the contacts of the switch contactors.

In the first step, testing the high voltage system, the system checks the following:

- Whether the high voltage cables are connected to the high voltage battery unit and a connection to the power electronic box has been made.
- Whether the circuit of the high voltage interlock loop is closed.
- Whether the high-current circuit breaker is intact.
- Whether the high voltage battery is operational.

Even after the tests have been completed successfully, the contacts of the switch contactors still cannot be closed. Due to the capacitance values in the high voltage circuit (link capacitor), a very high switch-on current flow would result that would damage both the capacitors and the switch contactors over the long term. Therefore, the voltage is raised slowly beforehand. To do so, the contact of the switch contactor for the negative lead is initially closed. Via a relay with clock activation and a dropping resistor in the positive wire, the voltage in the high voltage system is increased slowly. Whenever the relay contact is closed, a current flows, which is limited by the dropping resistor and charges the capacitors in the high voltage electrical system. After approximately 300 ms, the voltage in the high voltage electrical system is only slightly below the battery voltage. Then, the contact of the switch contactor for the positive wire of the start is also closed.

The battery monitoring module communicates the successful start to the other hybrid components via the hybrid CAN, and particularly to the hybrid master control unit. In the same way, fault states are signalled if the start was not successful.

Shutting Down the High Voltage System

When shutting down the high voltage system, we distinguish between the regular shut-off and the fast shut-off. The regular shut-off described here protects the electrical components. In addition, monitoring functions are carried out to check safety-related components and characteristics of the high voltage system. The steps during the regular shut-off are as follows:

1. Terminal 15 is switched off.
2. The current levels in the high voltage electrical system are reduced to null (by the control units in the power electronic box).
3. The hybrid master control unit sends a request to open the switch contactors in the high voltage battery unit via a bus signal on the hybrid CAN and via a separate line (PWM signal).
4. The battery monitoring module opens the contacts of the switch contactors in the high voltage battery unit.

5. Controlled by the battery monitoring module, the insulation resistance of the high voltage cables is measured and monitored to ensure that the values fall within the permitted range. If an unacceptably low insulation resistance is detected, an entry is stored in the fault memory. The driver is informed about this fault status by a Check Control message. Despite this status, the high voltage system can usually be restarted, as there is no direct danger to any person.
6. The battery monitoring module checks whether the contacts of the switch contactors have actually been opened. This ensures that hazardous voltage is no longer present at the high voltage connections of the high voltage battery unit. If the system detects that the contacts have not been opened properly, the high voltage system is prevented from restarting. Otherwise, safe operation of the high voltage system would no longer be guaranteed.
7. After successfully checking that the contacts of the switch contactors have been opened, the battery monitoring module communicates this state of the switch contactors.
8. The high voltage circuit is actively discharged and the coils of the electric machines are short-circuited. This is controlled by the control units of the power electronic box.

This regular shut-off can take up to two minutes. In particular, measuring the insulation resistance and checking the opened contacts take a certain amount of time, which is responsible for this lengthy period. The shut-off is interrupted if a start up is initiated in the mean time (e. g. because the driver switches terminal 15 back on). The regular shut-off is also interrupted if a situation arises that requires a fast shut-off of the high voltage system.

Fast Shut-off of the High Voltage System

The fast shut-off of the high voltage system is carried out whenever states arise in which, for safety reasons, the voltage in the high voltage system must be reduced to a safe value as quickly as possible. The following list describes these states and the consequences for the shut-off of the high voltage system:

- High-voltage interlock loop: if an interruption of the circuit of the high voltage interlock loop is detected and there is a possibility that a person is touching active parts of the high voltage system, the contacts of the switch contactor are opened immediately. Such a possibility is assumed if the vehicle is at a standstill or the engine compartment lid or tailgate are open. The contacts of the switch contactor are opened immediately without first reducing the current to null. This places a high load on the contacts of the switch contactors; as a result, this process must be carried out as rarely as possible. Simultaneously, the high voltage circuit is actively discharged and the coils of the electric machines are short-circuited.
- Accident: if the crash safety module detects an accident of corresponding severity, the safety battery terminal is disconnected from the positive terminal of the 12 V battery. In the E72, the electromechanical switch contactors are supplied by terminal 30 of the safety battery terminal. Therefore, the contacts of the switch contactors are opened at the same time as the safety battery terminal is disconnected. The battery monitoring module and the hybrid master control unit also evaluate the status of terminal 30 of the safety battery terminal. If both of these control units detect that the safety battery terminal has been disconnected, they carry out additional measures to switch off the high voltage system (active discharge, short-circuiting the coils).

- **Short circuit monitoring:** if the current sensors detect that the current level in the high voltage cables is too high, the battery monitoring module also triggers a fast shut off to protect the components. In extreme cases, the fuse (in the high voltage safety connector) is also tripped, thus causing a hard interruption of the high voltage circuit. The battery monitoring module monitors the state of the fuse. In the event of a switch-off due to short circuit, the battery monitoring module communicates this state, so that active discharge can take place and the coils can be short-circuited.
- **Failure of the 12 V voltage supply of the high voltage battery unit:** as in all other high voltage components, the control electronics (battery monitoring module) are supplied with 12 V. To ensure the maximum possible safety, a fast shut-off of the high voltage system takes place if the 12 V voltage supply fails, as in this case the battery monitoring module is also no longer working. Therefore, the fast shut-off in this case is also carried out by means of a hardware switch-off and not by software functions.

High Voltage Interlock Loop

Many monitoring functions exist in which the high voltage battery unit and/or the battery monitoring module play a critical role. They include:

- 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 principle of the high voltage interlock loop is familiar from the "Basics of hybrid technology" information bulletin. In the E72, the high voltage interlock loop consists of high voltage components shown.

The electronics for controlling and generating the test signal for the high voltage interlock loop are integrated into the battery monitoring module in the E72. 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. As the test signal, the battery monitoring module generates a square AC signal and feeds it 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 power electronic box and at the very end of the ring, in the battery monitoring module. The signal must have a current level between 12 mA and 35 mA. If the current level is outside this range, an interruption of the circuit or a short circuit in the test lead is detected. As described above in the section on "fast shut-off of the high voltage system," high voltage system is shut down immediately whenever a situation is present in which a person can touch active, electrically live parts. Both the power electronic box and the battery monitoring module can initiate this shut-off.

Insulation Monitoring

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. Therefore, the high voltage system of the E72 has a fully automatic insulation monitoring system. It is divided into two high voltage components:

- Battery monitoring module: there are precision resistors between the two high voltage cables and the housing of the high voltage battery unit. These can be activated individually for insulation monitoring. The voltages at the precision resistors are measured electronically. The insulation resistance values of the high voltage cable to the housing can be calculated from the voltage values. By doing so, it is possible to determine whether one or both high voltage cables have an unacceptably small insulation resistance. This process can be carried out only if the high voltage system is not active.
- Power electronic box: based on voltage measurements that are carried out continuously when the high voltage system is active, the power electronic box likewise measures the insulation resistance values between the high voltage cables and the housing. More precisely, the ratio of the insulation resistance values to each other is calculated. This means that the insulation monitoring system in the power electronic box can detect insulation faults of one high voltage cable only. Thus an insulation fault of both wires cannot be identified.

As described here, the insulation monitoring takes place via voltage measurement, using the potential of the housing of a high voltage component as a reference. Without additional measures, only local insulation faults can be identified in the battery monitoring module and the power electronic box. However, it is equally important to identify insulation faults from the high voltage cables in the vehicle to earth. For this reason, all electrically conductive housings of high voltage component are galvanically connected to earth. Thus insulation faults in the entire high voltage electrical system can be identified by insulation monitoring at two central points.

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

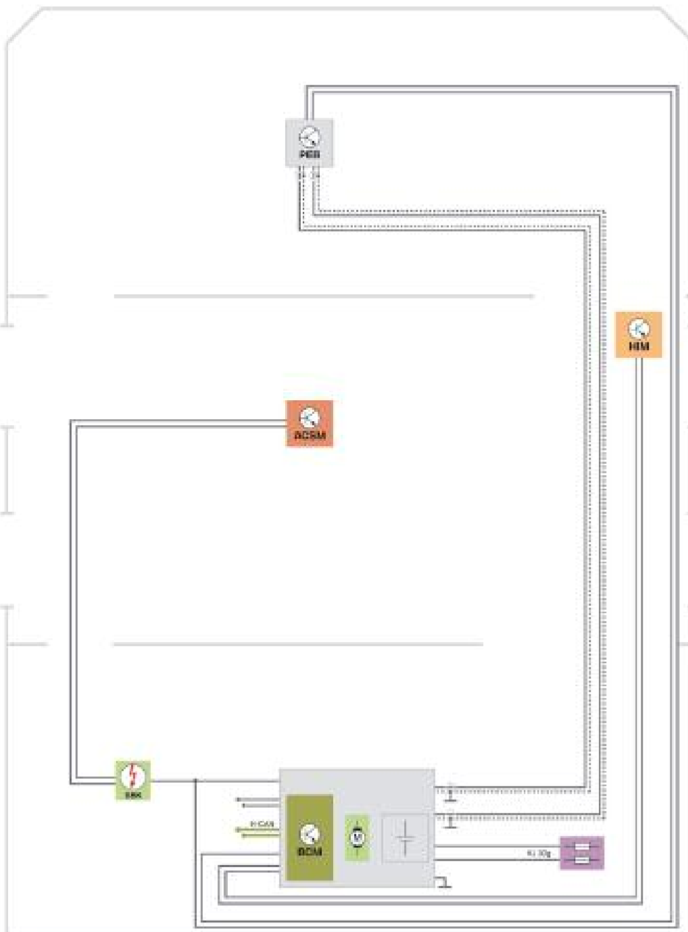
Additional monitoring functions in the high voltage battery ensure that the voltage, the state of charge and the temperature of the battery cells are in the range that enables optimum power development and maximum service life of the high voltage battery.

E72 Complete Vehicle.

High voltage battery unit > Powering up and powering down the high voltage system

Several actions are carried out while powering up and powering down the high voltage system. Please sort the actions in the correct order.

Powering up	
No.	**Action**
	Precharge the high voltage circuit (by BCM)
	Check if high voltage interlock loop is intact?
	Check if fuse is ok?
	Cable-off check
	Close electromechanical switch contactors
	Check if high voltage battery is "healthy"
	Hybrid Controller Processor requests power up
	BCM reports "power up succesful"



Powering down	
No.	**Action**
	Discharge the high voltage circuit (by PEB)
	Hybrid Controller Processor requests opening of the switch contactors
	BCM double-checks if switch contactors are open
	Current in the high voltage wires "is controlled to be zero" (by PEB)
	BCM reports "switch contactors open"
	BCM opens switch contactors
	BCM measures and checks the insulation resistance

E72 Complete Vehicle.

High voltage battery unit > Regular or fast shutdown of the high voltage system

No shutdown	Regular shutdown	Fast shutdown
		

Terminal 15 off

Driver‘s seatbelt unbuckled and driver‘s door opened

High voltage interlock loop interrupted

Short circuit detected

Crash detected

12 V power supply gone from BCM

Draw lines and hereby match the conditions in the boxes to the shutdown variants above.

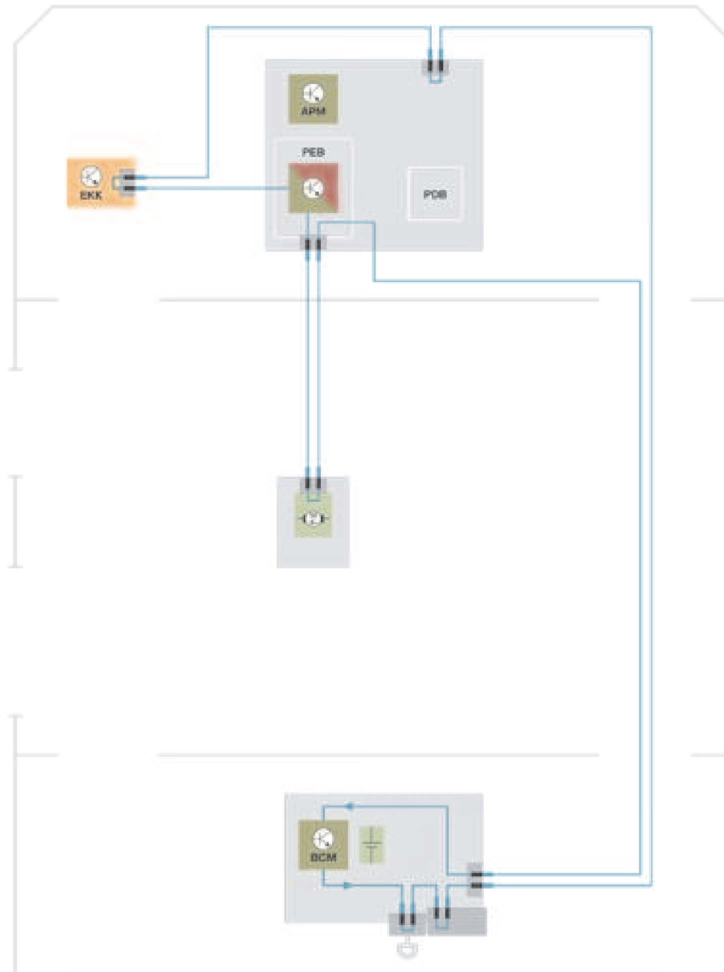
What are the consequences of a fast shutdown?

E72 Complete Vehicle.

High voltage battery unit > High voltage interlock loop

Where are the jumpers of the high voltage interlock loop located on the E72?

Which control unit generates the interlock signal and at which control unit is it evaluated on the E72?



E72 Complete Vehicle.

High voltage battery unit > Replacement > Removing

Please note the necessary steps, when you remove the high voltage battery from an E72 below.

The electrical safety rules must be observed and implemented before any work is carried out on high voltage components of the E72:

1. **The high voltage system must be de-energized.**
2. **The high voltage system must be secured against being switched on again.**
3. **The de-energized state of the high voltage system must be verified.**

Charging Strategy and Operational Strategy

The objectives of the charging strategy for the high voltage battery are to maximize the service life of the high voltage battery and to maintain reserves, both in terms of additional energy consumption (brake energy recovery) and energy output (e.g. boost function). The primary goal of the operational strategy of the hybrid drive is to use the hybrid drive to increase efficiency and dynamics in as many situations as possible. Whether boost function, driving in electric mode, automatic engine start-stop function or brake energy recovery – all of these functions are to be provided over the widest possible range of the state of charge of the high voltage battery. As the following graphic shows, this has also been implemented technically in the E72. The individual functions have to be restricted only if the limits of the state of charge are exceeded such that the service life of the high voltage battery would be decreased.

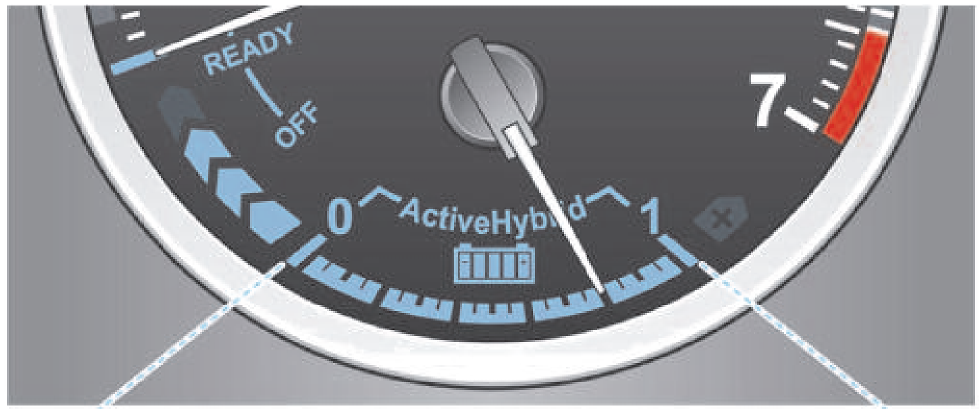
If the combustion engine is running anyway (e.g. at a driving speed of over 60 km/h), the high voltage battery is charged to the marked optimum level. At this state of charge, there is a sufficient reserve so that if, for example, the driver exits a highway, additional energy can be stored in the high voltage battery during the ensuing braking. However, the distinguishing feature of this optimal state of charge is primarily that the battery has enough energy to provide support from the electric machine or driving in pure electric mode.

The automatic engine start-stop function is not available all the way down to the very lower limit of the state of charge. An example to illustrate this: when the vehicle decelerates all the way to a standstill, the combustion engine is usually shut off while driving and the high voltage battery charged during deceleration. While the vehicle is at a standstill, energy is drawn from the high voltage battery to operate the electric A/C compressor and supply power to the 14 V vehicle electrical system. The combustion engine remains shut off almost all the way down to the lower limit of the state of charge. Once the limit is reached, the combustion engine has to be started to again provide electrical energy via the electric machines. This is then used to supply power to the consumers and to charge the high voltage battery. To prevent continuous starting and stopping of the combustion engine, the high voltage battery must reach a higher state of charge before the combustion engine can be shut down again.

Therefore, a hysteresis ensures that the energy reserve will be sufficient while the combustion engine is at a standstill.

E72 Complete Vehicle.

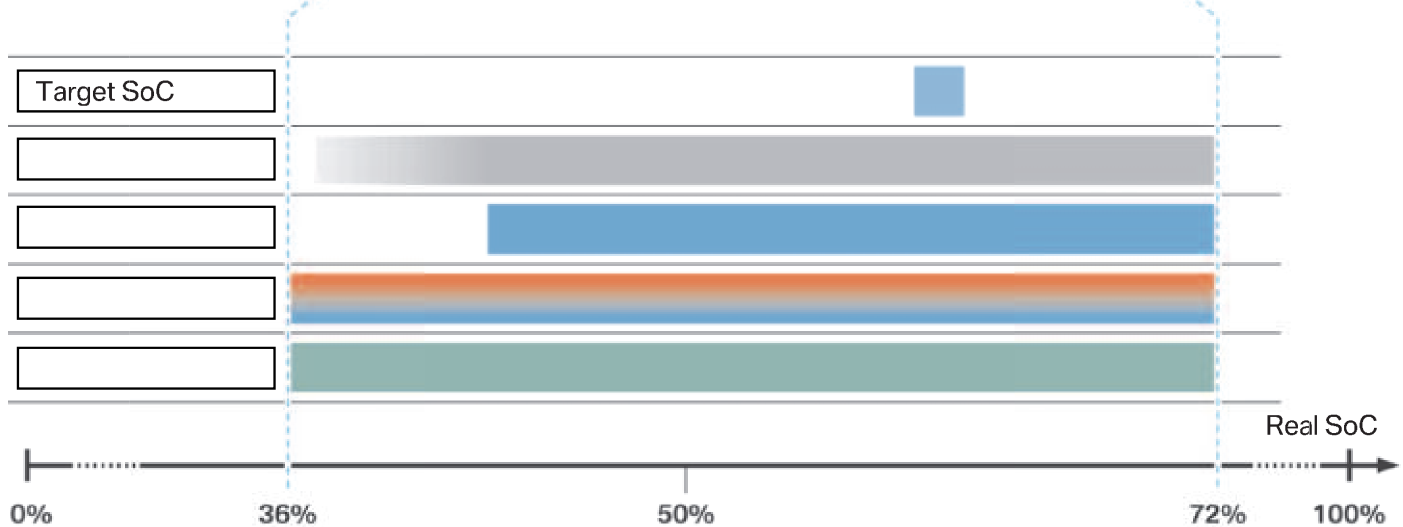
High voltage battery unit > Charging and discharging while driving



The bars show, at which state of charge (SoC) a hybrid function is available.

Please select the hybrid functions from the list below and assign them to the bars.

- CHARGE
- eBOOST
- eDRIVE
- Engine start/stop



Active Transmission

The active gearbox of the E72 was developed in a co-operative effort between General Motors, Daimler Chrysler (currently Daimler) and BMW. Like a conventional automatic transmission, it makes different ratios between the gearbox input and gearbox output available.

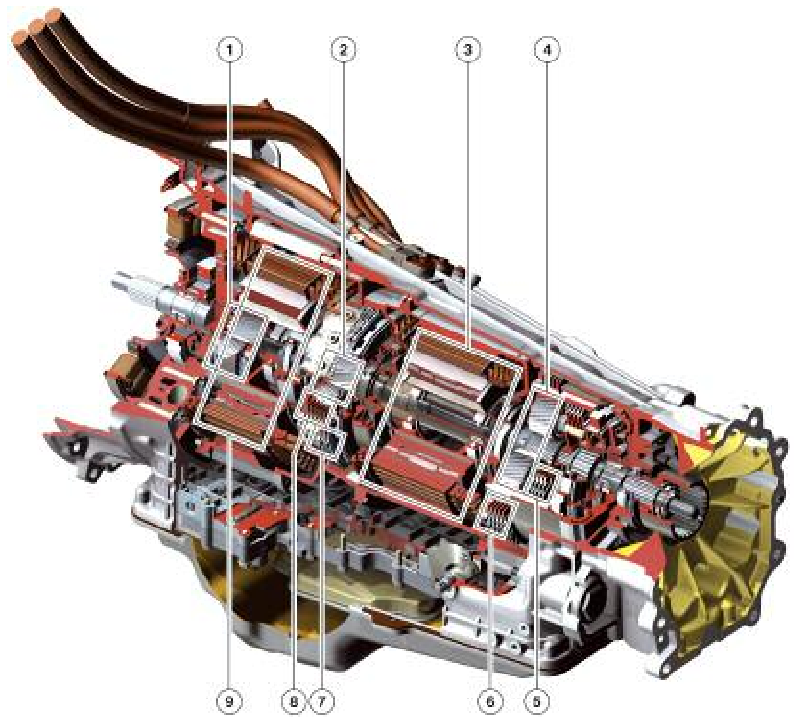
From the driver's perspective, there are seven forward gears. Within the transmission, these seven forward gears are implemented by means of four fixed basic gears and two modes with variable gear ratio. In the four fixed basic gears, the speed of the combustion engine and transmission output shaft are in a fixed relationship to each other. This is not true of the modes with variable gear ratio: in these modes, the ratio between the speed of the combustion engine and the transmission output speed can be adjusted continuously, which is why the abbreviation "CVT" (for "continuously variable transmission") is used for these modes.

Because the active gearbox in the E72 provides two CVT modes, it is frequently also referred to as "two-mode active transmission" in the literature. The gear ratio is adjusted electrically using two electric machines integrated into the active gearbox. Therefore, these two modes are also referred to as "ECVT", where the "E" stands for electrical. As an integral part of the hybrid drive, the electric machines also serve to support the combustion engine and to recover the brake energy. The four fixed basic gears and the two ECVT modes are implemented and switched using three planetary gear trains and four multidisc clutches.

Therefore, the active gearbox in the narrower sense consists of:

- Two electric machines
- Three planetary gear sets
- Four multidisc clutches

Sectional view of E72 active gearbox



Index	Explanation
1	Planetary gear set 1
2	Planetary gear set 2
3	Electric machine B
4	Planetary gear set 3
5	Multidisc clutch 2
6	Multidisc clutch 1
7	Multidisc clutch 3
8	Multidisc clutch 4
9	Electric machine A

A dual-mass flywheel is used as the torsional vibration damper. It is located between the combustion engine and active gearbox. It has a similar design to those in vehicles with a manual transmission. The combustion engine of the E72 is not started via a conventional starter motor. Despite this, the toothed ring gear on the flywheel is present only for measuring the crankshaft speed.

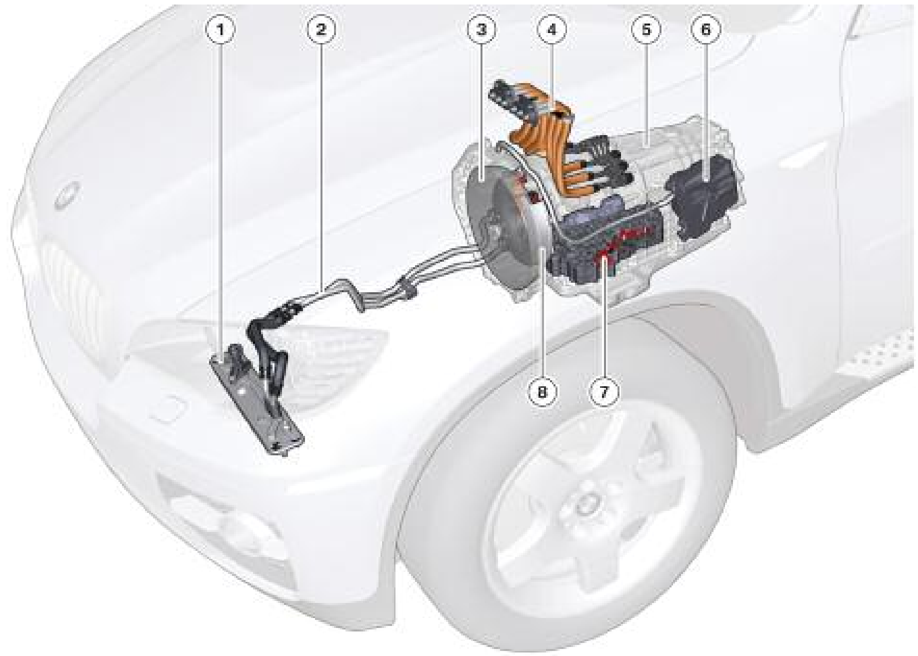
Despite the fact that the active gearbox does not have a hydrodynamic converter, the gearbox components naturally have to be lubricated. Because of this, and to actuate the multidisc clutches, there is an oil pump on the gearbox input, which can be driven either by the combustion engine or by the electric motor installed specifically for this purpose. The oil circuit is also used to cool the gearbox components. The cooling circuit for the transmission oil in the E72 is the same as in the E71 xDrive 50i.

The electronic hybrid gearbox control unit – as in other current automatic transmissions – is part of the electro-hydraulic control module and is housed in the transmission oil sump. The electronic hybrid gearbox control unit in E72 is referred to using the abbreviation "TCM", derived from the "Transmission Control Module" designation used in the development co-operation.

The active gearbox also does not include an automatically actuated clutch, as in a sequential manual gearbox (SMG). The electric machines can compensate for this by creating a speed differential between the input and output shafts. When driving off with the combustion engine, the combustion engine initially powers only one of the two electric machines. This generates electrical energy with which the second electric machine is operated and generates a torque at the transmission output shaft. This ultimately sets the vehicle in motion.

The electric machines are also used when changing gears, for example to support the torque of the combustion engine and provide a comfortable shifting sequence while the multidisc clutches are opened and closed.

Overview of active gearbox components



Index	Explanation
1	Transmission fluid-to-coolant heat exchanger
2	Transmission oil lines
3	Dual-mass flywheel
4	High-voltage cables
5	Housing of the active gearbox
6	Hybrid parking lock (direct shift module)
7	Electro-hydraulic control module
8	Electrically/mechanically driven transmission oil pump

Parking Lock and Direct Shift Module

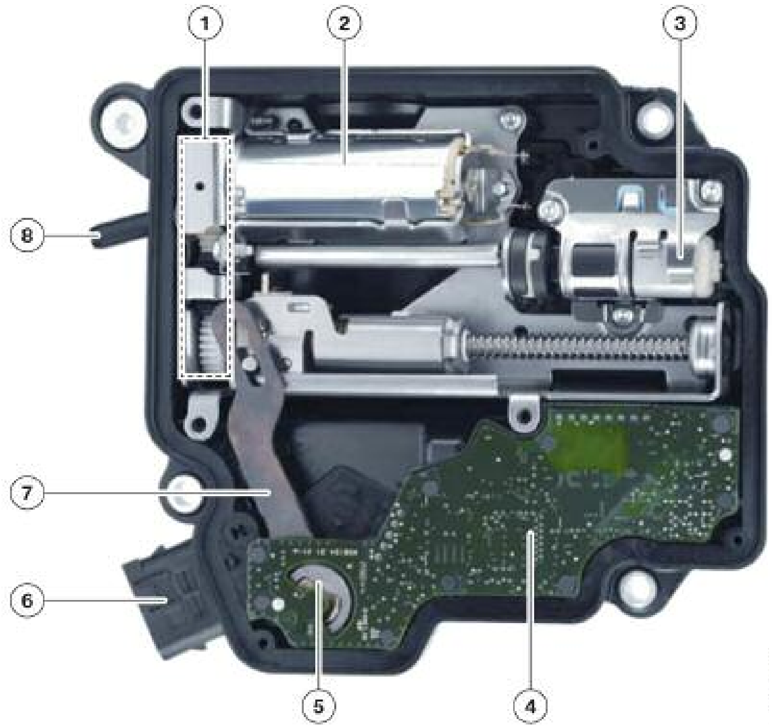
The hybrid parking lock of the active gearbox is not hydraulically actuated. Instead, it is actuated via an electric motor. This motor and the associated control unit are combined in one housing and called the "Direct Shift Module" (DSM). It is on the outer side of the transmission housing.

The parking lock mechanism is similar to that used in other automatic transmissions in BMW vehicles: the parking lock blocks the transmission output shaft via a parking lock pawl that meshes with the gearing of the parking lock gear.

In conventional automatic transmissions, the parking lock is engaged by spring force and disengaged hydraulically. This proven concept could not be implemented in the active gearbox, as the requirements that apply for engaging the parking lock could not have been fulfilled in this way. Therefore, the active gearbox of the E72 has an electromechanical actuator for engaging and disengaging the parking lock. This actuator and the corresponding control unit are integrated into one housing. This unit is called the "Direct Shift Module", or "DSM" for short.

The direct shift module, which is installed on the outside of the transmission housing, is connected to the parking lock mechanism in the active gearbox via a splined shaft. Using this shaft, the direct shift module can turn a notched disc inside the active gearbox, as is familiar from automatic transmissions with a mechanical selector lever. In the active gearbox of the E72, the notched disc is used only to distinguish between the engaged and disengaged parking lock. Accordingly, only the "park" (P, parking lock engaged) and "neutral" (N, parking lock not engaged) positions are used. The rotation of the notched disc moves the parking lock lever in the longitudinal direction. When the parking lock is engaged, the parking lock lever pushes the parking lock pawl into the parking lock gear via a conical sleeve. When the parking lock is disengaged, the parking lock lever is retracted and the parking lock pawl is released. A spring pulls the parking lock pawl out of the parking lock gear.

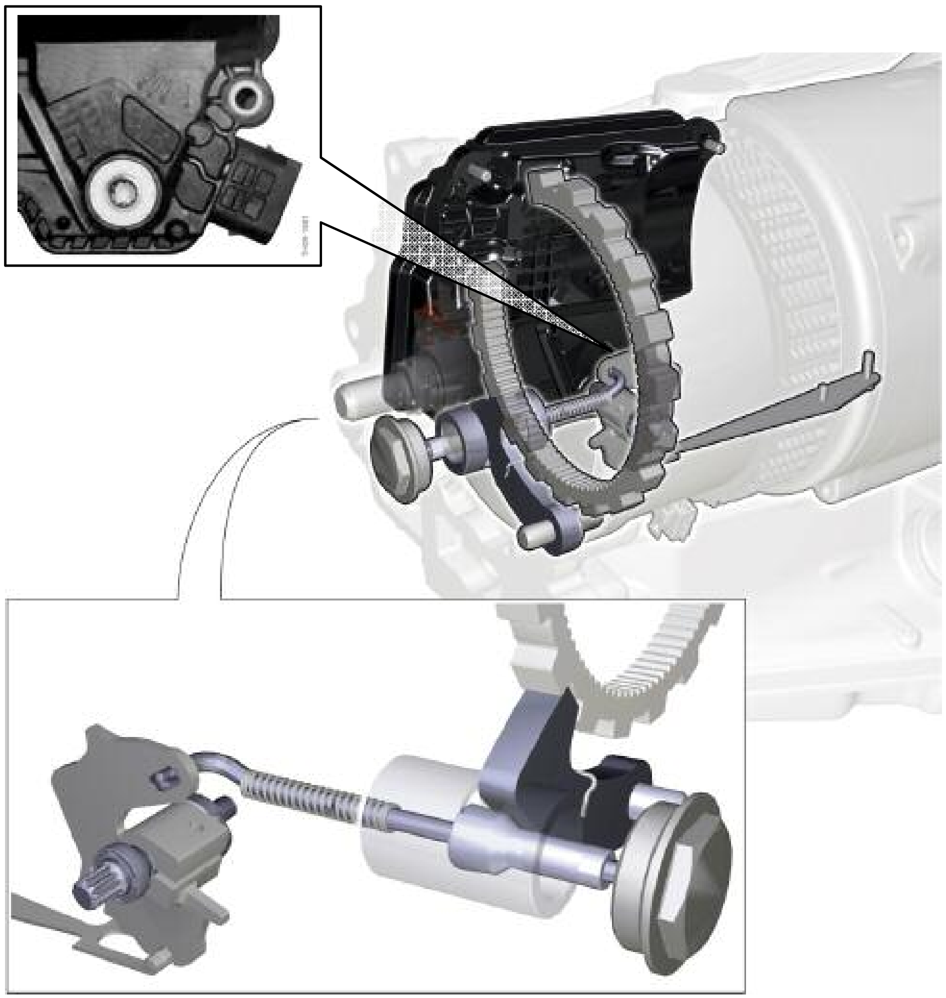
Direct Shift Module (interior view)



Index	Explanation
1	Belt drive
2	Electric motor
3	Additional electric motor (Not used on E72)
4	Printed circuit board of the control unit
5	Mechanical connection to the active gearbox
6	Connector
7	Adjusting mechanism
8	Connection for tank ventilation line

Note: BMW does not use the additional motor (3). The additional motor is used by Diamler in their application as a backup.

Active transmission > Parking lock



How is the parking lock in the E72 actuated?

Take notes about the components of the parking lock below.

How is the Direct Shift Module connected to the transmission?

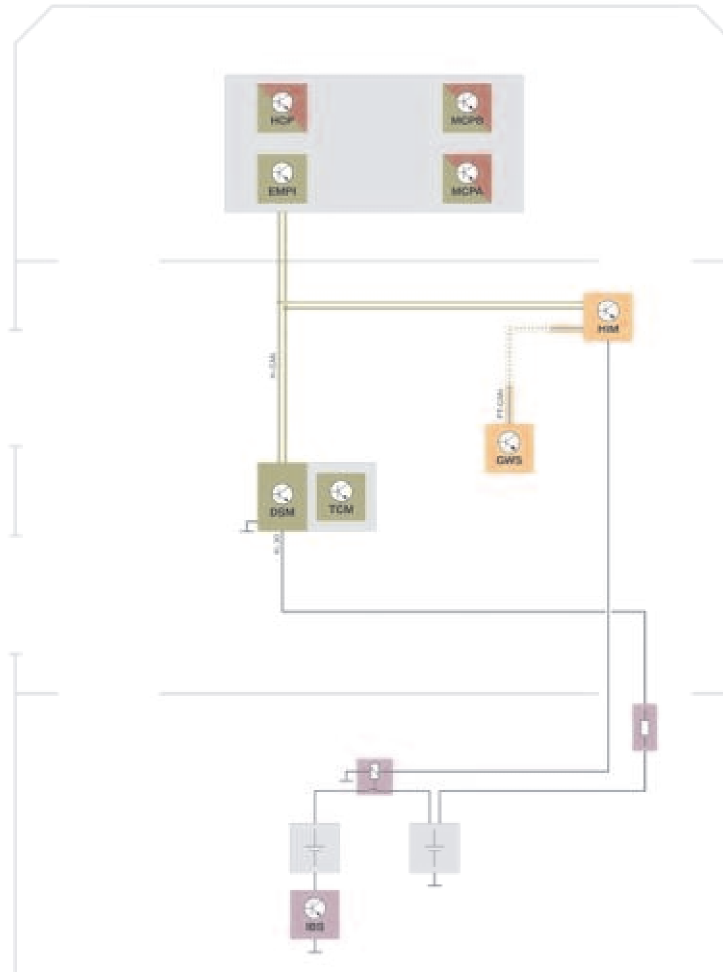
Why does the Direct Shift Module need a venting line?

E72 Complete Vehicle.

Active transmission > Direct Shift Module DSM

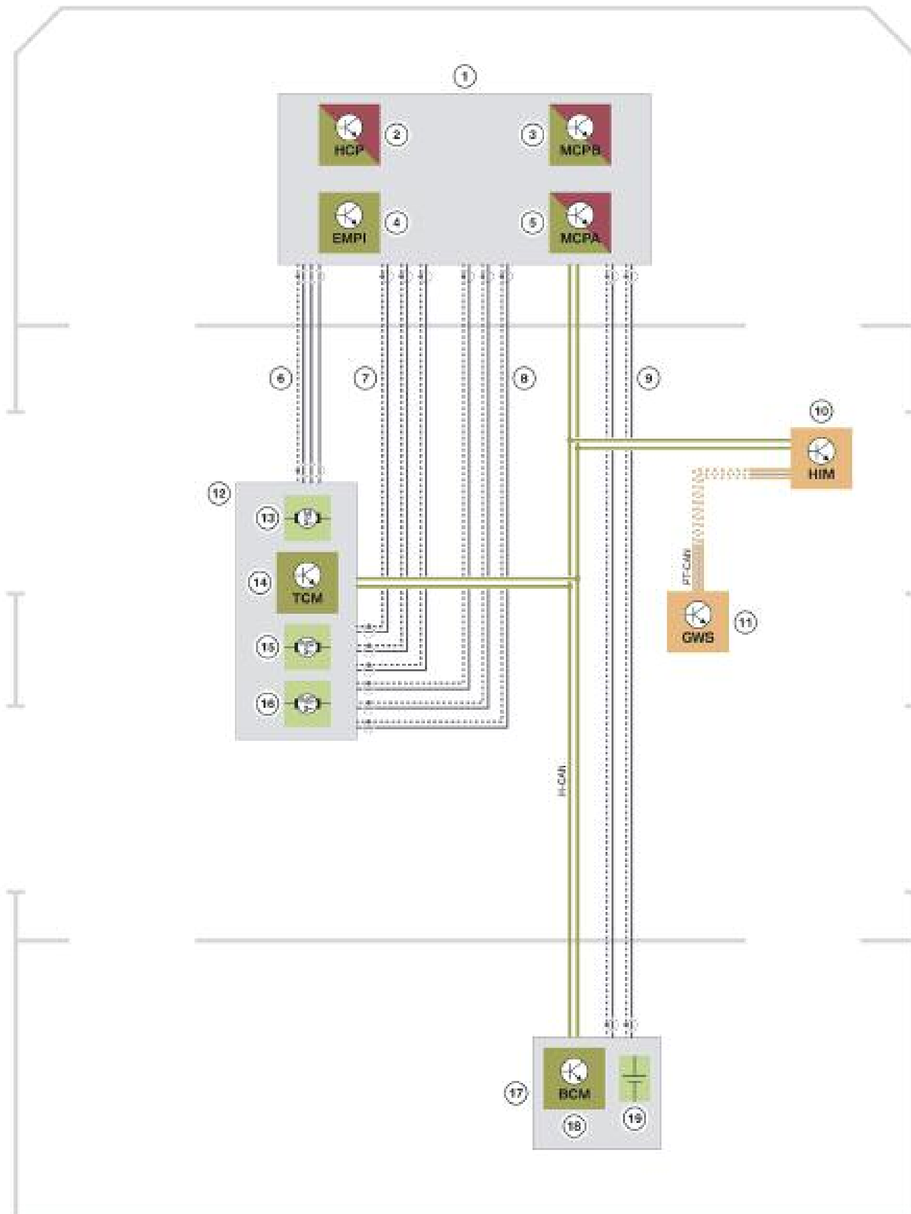
How is the Direct Shift Module supplied with electrical power?

How can you perform an emergency release of the parking lock?



System Wiring Diagrams

The electrical networking of the active gearbox and the hybrid parking lock is shown in the system wiring diagrams.



Index	Explanation
1	Power electronic box (PEB)
2	Hybrid master control unit (HCP)
3	Hybrid electric machine control unit B (Machine Controller Pack B, MCPB)
4	Hybrid oil pump control unit (Electrical Motor Pump Inverter, EMPI)
5	Hybrid electric machine control unit A (Machine Controller Pack B, MCPB)
6	High-voltage cables from PEB – hybrid oil pump, shielded
7	High-voltage cables from PEB – electric machine A, individually shielded
8	High-voltage cables from PEB – electric machine B, individually shielded
9	High-voltage cables from PEB – high voltage battery, individually shielded
10	Hybrid Interface Module (HIM)
11	Electronic gear selector switch (GWS)
12	Hybrid active gearbox
13	Hybrid oil pump
14	Transmission Control Module (TCM)
15	Electric machine A
16	Electric machine B
17	High-voltage battery unit
18	Battery monitoring module (BCM)
19	High-voltage battery

Distributed Functions

Because parts of the hybrid active gearbox and its functions have been developed by the co-operation partners, BMW had to agree to compromises regarding distributing the gearbox functions to the control units.

In previous BMW vehicles, the electronic transmission control (EGS) has authority over most gearbox functions, such as gear selection, engaging and disengaging the parking lock or selecting the shift program. Important input signals here are those from actuation of the accelerator pedal or brake pedal, information about the movement of the vehicle (speed, acceleration etc.), the engine speed and the operation of the gear selector switch. Based on this, the suitable shift program is used and the correct gear for the driving situation determined and engaged.

Hybrid Control Processor

As the name indicates, the hybrid master control unit (Hybrid Controller Processor, HCP) plays a central role in the controlling the hybrid drive and thus also in controlling the active gearbox. The following is a list of the functions of the hybrid master control unit that are relevant for the active gearbox:

- Evaluating the driver's choice and determining the gear (P, R, N, D, S, M)
- Selecting the shift program
- Determining the correct gear
- Adaptive transmission control
- Calculating the necessary torque at the internal multidisc clutches
- Calculating the setpoint torque at the gearbox output

Transmission Control Module

The hybrid gearbox control unit translates the nominal values of the hybrid master control unit (setpoint torque at the clutches and at the gearbox output). Thus the hybrid gearbox control unit, unlike the electronic transmission controls of other automatic transmissions, is no longer the primary controller for the gearbox functions, but an intelligent actuator control unit.

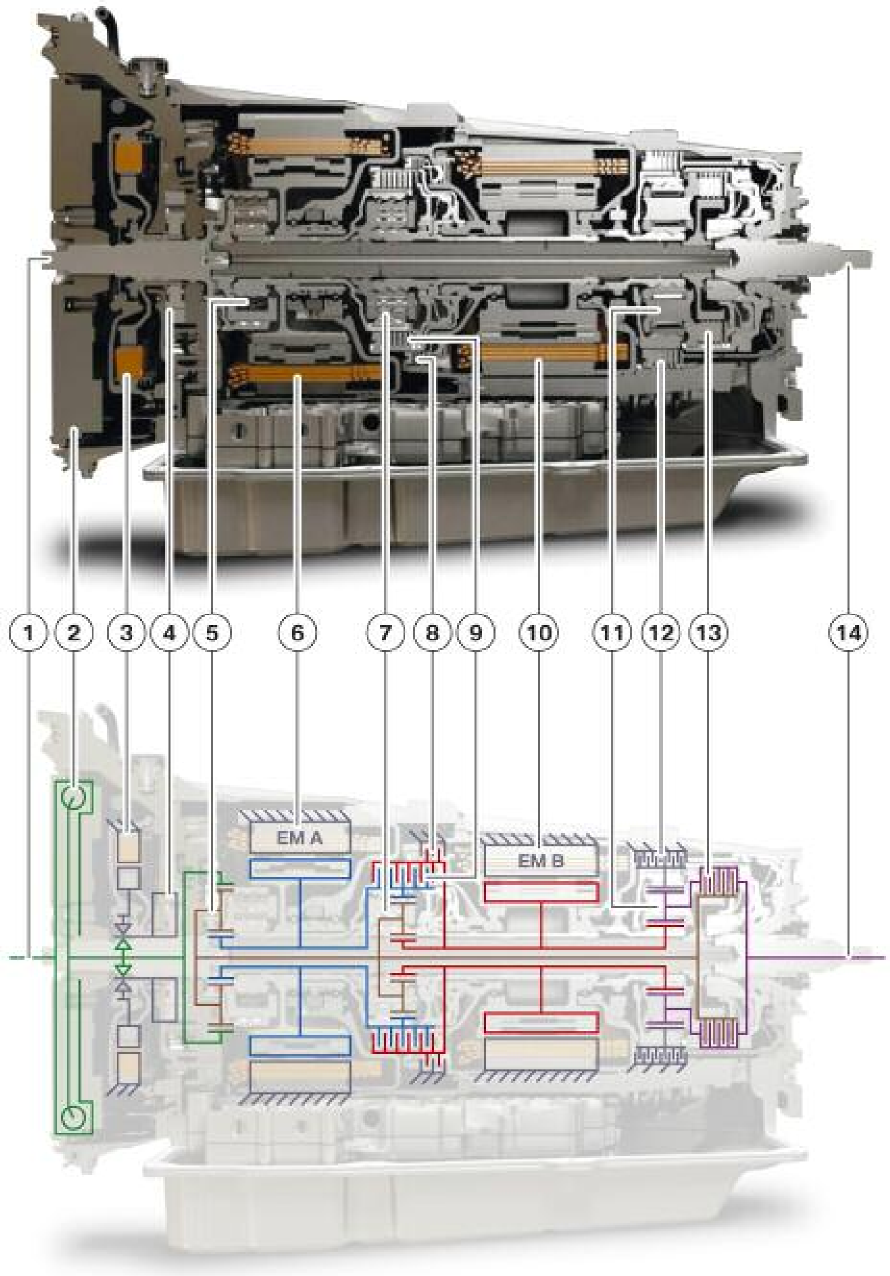
Some of responsibilities of the hybrid gearbox control unit are:

- Controlling the transmission oil circuit
- Operating and monitoring the multidisc clutches
- Ensuring cooling of the electric machines
- Reading sensor signals (output speed, transmission oil temperature and position of the parking lock)
- Monitoring the gearbox status and activating emergency programs if necessary
- Electronic immobilizer

Assign the transmission related functions to the control units.

Function	**HCP** Hybrid Controller Processor	**TCM** Transmission Control Module	**DSM** Direct Shift Module	**GWS** Gear selector switch
Operation and evaluation of gear selector switch				
Determine the gear position (P, N, R, D, S, Mx)				
Adaptive transmission control				
Select the required gear (1…7)				
Calculate the output torque of the transmission				
Calculate the torque command value of the electric machines				
Control the transmission oil circuit				
Actuate the multidisc clutches				
Read and communicate transmission related sensor signals				
Monitor the transmission state and activate emergency programs if necessary				
Engage and disengage the parking lock				

Sectional view and skeleton view of the active gearbox in the E72



Index	Explanation
1	Transmission input shaft
2	Dual-mass flywheel
3	Electric motor for driving the transmission oil pump
4	Transmission oil pump
5	Planetary gear set 1
6	Electric machine A
7	Planetary gear set 2
8	Multidisc clutch 3
9	Multidisc clutch 4
10	Electric machine B
11	Planetary gear set 3
12	Multidisc clutch 1
13	Multidisc clutch 2
14	Transmission output shaft

Modes of Operation

The Advance Hybrid System - Car variant (AHS-C) contains three planetary carriers that provide four fixed forward gears (4-spd transmission) that with the aid of two electric machines (E-Machine A and E-Machine B provides an additional three virtual gears. For the driver, the indicator on the cluster displays 7 forward gears.

A mechanical reverse does not exist in the transmission. Reverse is only possible by electrically energizing E-Machine B.

The E72 is not equiped with a conventional starter motor. E-Machine A is used as the ICE (Internal Combustion Engine) starter.

Technically the Active transmission is capable of the following modes of operation:

- Electric Continuous Variable Transmission Mode 1 (ECVT 1)
- Electric Continuous Variable Transmission Mode 2 (ECVT 2)
- Fixed Gear 1
- Fixed Gear 2
- Fixed Gear 3
- Fixed Gear 4
- Neutral
- Reverse

ECVT 1 Mode

The first mode with variable ratio (ECVT 1 mode) is designed for low speeds and maximum tractive force. In this mode, the vehicle can be powered in the following ways:

- Solely by electric machine B
- Solely by the combustion engine
- By electric machine B and the combustion engine.

The gear ratio for powering the vehicle using the combustion engine can be calculated as follows:

i = speed of the combustion engine / speed of the transmission output shaft

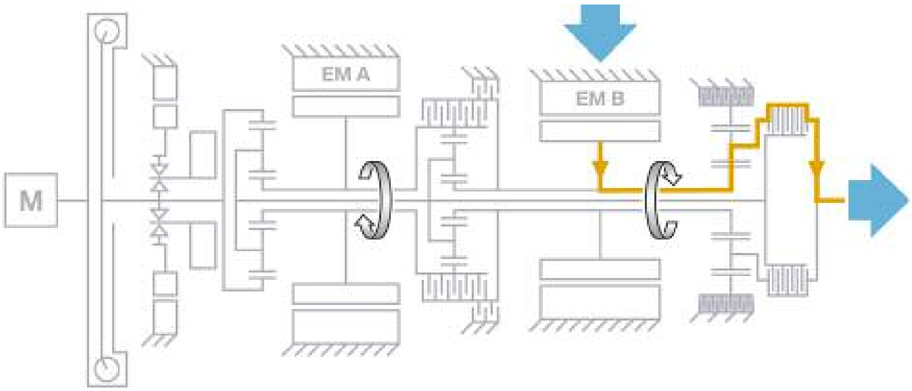
This gear ratio ranges from infinite to 1.800. The value "infinite" indicates that the combustion engine can run, despite the fact that the transmission output shaft is not moving. Thus driving off is reproduced in a similar manner as with a hydrodynamic torque converter. The gear ratio can be adjusted by controlling the speeds of the two electric machines: the higher the speed of electric machine A, the greater this gear ratio will be.

Electric machine B is connected to the transmission output shaft with a ratio of approximately four.

To implement ECVT 1 mode, only the multidisc clutch 1 in the active gearbox is closed; all others are opened.

When the vehicle is powered purely electrically, the electric machine A rotates without load, at the same time and in the opposite direction as electric machine B. This allows the transmission input shaft and thus the combustion engine to remain at a standstill.

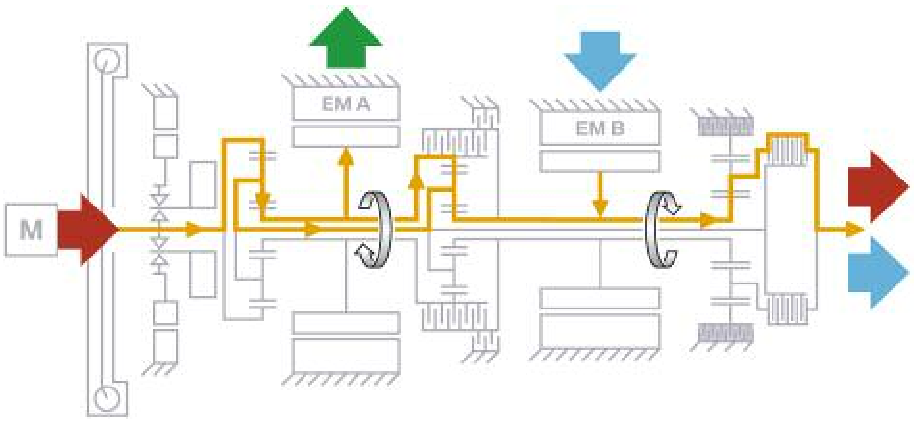
Power flow while driving in pure electric mode in ECVT 1



When the vehicle is powered by a combination of the combustion engine and electric machine B, the power of the combustion engine is divided into two portions. One could say that the power of the combustion engine branches off or "splits." This is the origin of the term "power-split hybrid drive." The two portions are:

- A mechanical portion, which is used to propel the vehicle.
- An electrical portion, because electric machine A works as a generator and generates electrical energy.

Power flow when the vehicle is powered by a combination of the combustion engine and the electric machine in ECVT 1 mode



Some or all of the electrical energy generated in generator mode can be stored in the high voltage battery. Electric machine B consumes electrical energy as a motor. Some or all of this comes from electric machine A or from the high voltage battery. How large the individual amounts of energy are depends on a number of factors and is recalculated and reset by the hybrid master control unit at all times.

The characteristic feature of both ECVT modes is that in addition to the mechanical drive path of the combustion engine, there is also an electrical drive path. This electrical drive path is identified by the fact that the combustion engine generates electrical energy using a generator, some or all of which is used by an electric machine to power the vehicle. The arrangement of this electrical drive path corresponds to that of a serial hybrid drive.

If we consider the sum of the energy flows, the electric machine can support the combustion engine. However, it is also possible to charge the high voltage battery in this mode. In this case, the combustion engine must provide a higher output and uses somewhat more fuel. However, this only appears to be a disadvantage. The hybrid operational strategy carries out this "load point increase" primarily when doing so increases the efficiency of the combustion engine. For example, the efficiency is better under full load than under partial load. Thus the energy stored in this way is obtained with a relatively low extra energy input and can be used later, for example for driving in pure electric mode.

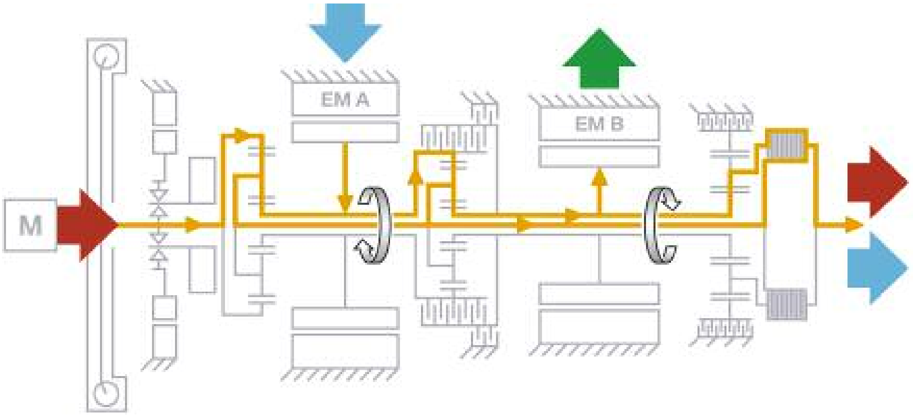
ECVT 2 Mode

Unlike the first ECVT mode, the second is designed for higher driving speeds. In ECVT 2 mode, both driving in pure electric mode and driving with the combustion engine switched on are possible. The gear ratio for the combustion engine can be adjusted in a range from 1.800 to 0.723. As in ECVT 1 mode, the electric machine speeds are the control variables used here. Based on the numerical values, we see a longer ratio than in ECVT 1 mode and thus the suitability for higher speeds. However, the electric machines also have a longer ratio. This means that their usable speed range is shifted towards higher speeds.

The electric machines can support the combustion engine or be used to charge the high voltage batteries. As in the first ECVT mode, one electric machine is typically operated as a motor (here, electric machine A), the other as a generator (here, electric machine B).

In ECVT 2 mode, multidisc clutch 2 is closed; all others are opened.

Power flow in ECVT 2 mode



In the second ECVT mode, the electrical energy flow can be controlled such that when the sum is considered, the high voltage battery is charged (load point increase of the combustion engine) or discharged (support of the combustion engine). The operational strategy sets the suitable energy flow that will attain the best possible efficiency.

Fixed Basic Gears

Unlike the two ECVT modes, the fixed basic gears of the active gearbox are characterized by a fixed gear ratio of the transmission input shaft to the transmission output shaft. Thus a change in speed of the combustion engine results in a proportionate change in driving speed. This fixed gear ratio would be a disadvantage only if the combustion engine were not in the optimum efficiency range. However, it is selected by the operational strategy specifically when a high torque of the combustion engine is required anyway. In that case, its efficiency is already very good. Compared to the ECVT modes, the advantage of the fixed gears is that the double energy conversion in the electric machine is omitted. Losses are also associated with the generation of electrical energy by the one electric machine and the use of electrical energy by the other.

In all fixed basic gears, the electric machines can do the following (with the exception of basic gear four):

- Rotate without load
- Be operated as a motor to support the combustion engine
- Be operated as a generator to charge the high voltage battery

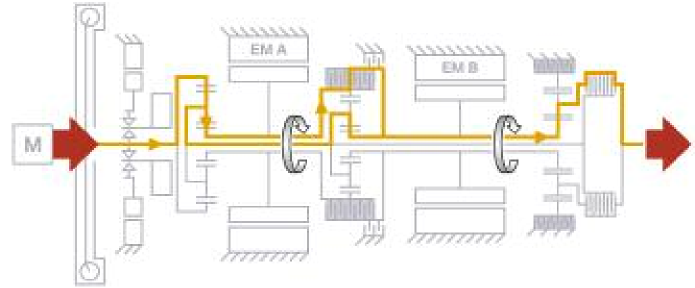
Exception: in fixed basic gear four, electric machine B is at a standstill, so that only electric machine A can be used as flexibly as described.

The generator mode is used particularly in overrun phases or when decelerating the vehicle in order to convert the kinetic energy into electrical energy and store it in the high voltage battery.

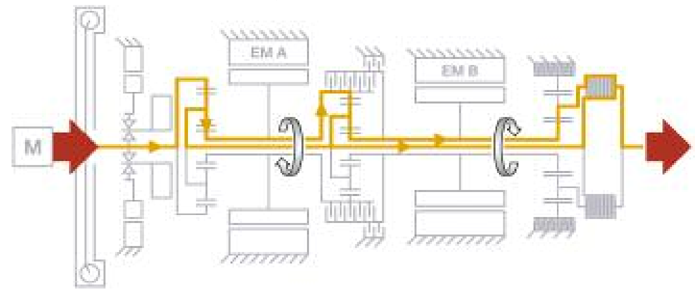
If we ignore for a moment the different ratios in the fixed basic gears, the active gearbox acts as if the electric machines and the combustion engine were installed on the same shaft. This arrangement corresponds exactly to that of a parallel hybrid drive.

All fixed basic gears are implemented in the active gearbox by closing two multidisc clutches.

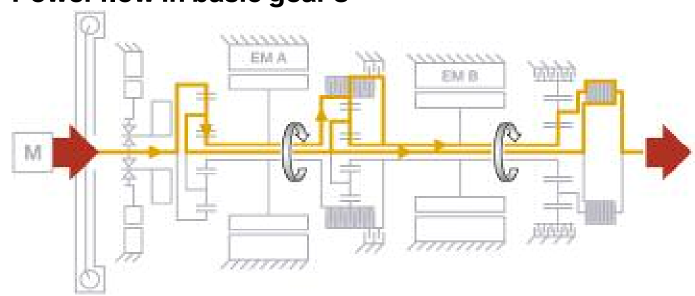
Power flow in basic gear 1



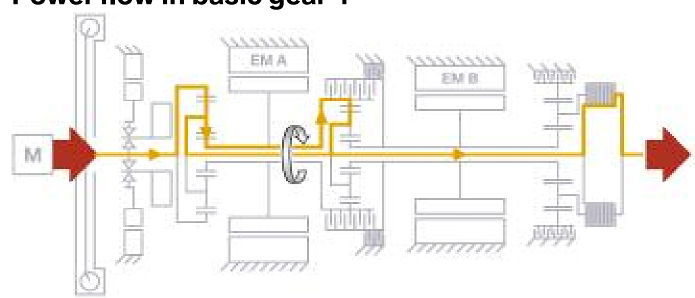
Power flow in basic gear 2



Power flow in basic gear 3



Power flow in basic gear 4



E72 Complete Vehicle.

Active transmission > Modes and fixed gears

Mode / fixed Gear	Characteristics	Transmission ratio
Electric Continuous Variable Transmission Mode 1 (ECVT 1)		Infinite … 1.800
Electric Continuous Variable Transmission Mode 2 (ECVT 2)		1.800 … 0.723
Fixed gear 1		3.889
Fixed gear 2		1.800
Fixed gear 3		1.000
Fixed gear 4		0.723
Neutral		0.000

No Power Transmission

Because there is no central clutch between the combustion engine and active gearbox, the active gearbox must offer a state in which there is no power transmission between the transmission input shaft and transmission output shaft. This makes it possible, for example, for the combustion engine to rotate freely without moving the vehicle. Conversely, the vehicle can roll freely without torque being output or absorbed by the combustion engine.

The "no power transmission" state is attained by opening all four multidisc clutches. When the combustion engine is running the electric machines also rotate at the same time, in this case without load, thus operating as neither a generator nor as a motor. At a combustion engine speed of 4000 rpm or higher, the electric machines would reach speeds higher than those for which they are designed. Therefore, in this transmission state, the speed of the combustion engine is regulated electronically to a value below 4000 rpm.

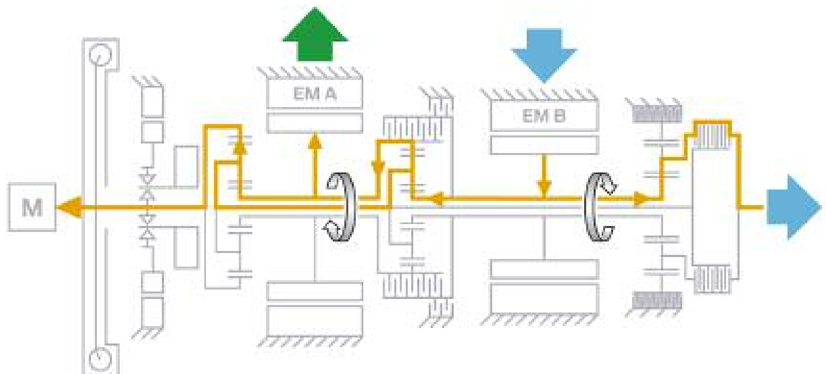
Reverse Gear

The active gearbox does not have a mechanical reverse gear. Instead, reverse is made possible in ECVT 1 mode. To do, the electric machine B is activated as a motor, in the opposite direction of rotation as for forward driving. Depending on the state of charge of the high voltage battery, driving backwards in pure electric mode is possible. If necessary, the combustion engine can also be activated to provide, with the help of electric machine A, sufficient electrical energy for electric machine B. During reverse, there is also a mechanical drive path from the combustion engine to the gearbox output. However, the torque of the combustion engine transmitted through this path would propel the vehicle forwards. Therefore, it is compensated for by electric machine B. Thus during reverse with the combustion engine switched on, the active gearbox behaves like a power-split hybrid drive.

Starting and stopping the combustion engine

When the prerequisites for driving in pure electric mode are no longer met, for example because the driver presses down harder on the accelerator, the combustion engine must be started. To accelerate it to the starting speed, electric machine A is braked and thus works as a generator. In the meantime, electric machine B continues to power the vehicle and also has to supply extra torque: this additional torque compensates for the torque generated by electric machine A to start the combustion engine. During the start while driving, the power flow in the gearbox skeleton looks like this:

Power flow while starting the combustion engine



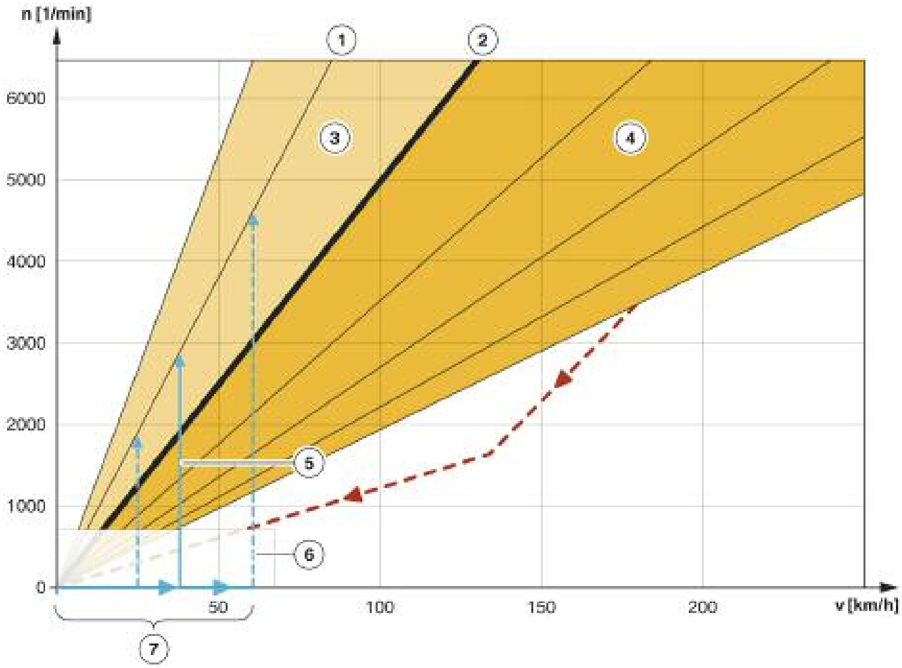
If the combustion engine is to be started while the vehicle is at a standstill, electric machine A is activated as a motor. Electric machine B supports the torque. However, for this purpose, the transmission must be in the "no power transmission" state, as only then is the transmission output shaft torque-free.

As soon as the combustion engine reaches the starting speed, the ignition and fuel injection are activated. Of course, the engine then no longer absorbs any torque, but feeds torque into the active gearbox. As described earlier in the chapter on "ECVT 1 mode", both the combustion engine and electric machine B power the vehicle.

The combustion engine does not have to be started at a certain driving speed. It can be started throughout the entire speed range at which driving in electric mode is possible.

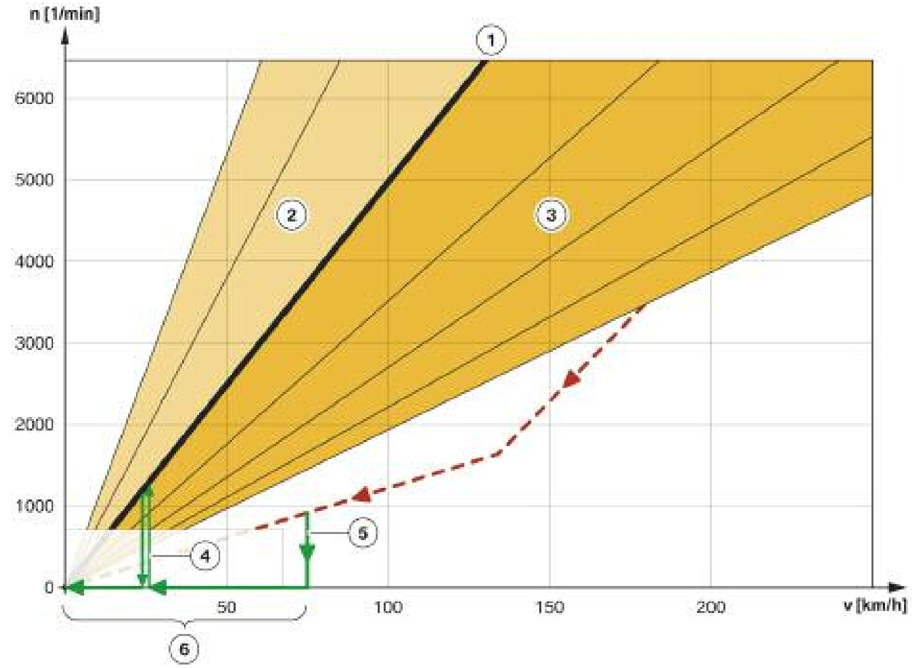
The combustion engine can be shut off not only when the vehicle is at a standstill, but also while driving. After the fuel injection and ignition are shut off, the combustion engine is brought to zero speed, controlled by electric machine A.

Starting the combustion engine



Index	Explanation
1	2nd gear
2	3rd gear, border between ECVT modes 1 and 2
3	Possible engine speed-vehicle speed range for ECVT mode 1
4	Possible engine speed-vehicle speed range for ECVT mode 2
5	Example for starting operation at driving speed of approx. 40 km/h
6	Maximum driving speed at which the combustion engine must be started
7	Speed range in which the combustion engine can be started

Stoping the combustion engine



Index	Explanation
1	3rd gear, border between ECVT modes 1 and 2
2	Possible engine speed-vehicle speed range for ECVT mode 1
3	Possible engine speed-vehicle speed range for ECVT mode 2
4	Short-term spike in the speed of the combustion engine while changing from ECVT mode 2 to ECVT mode 1
5	Example of shutting off the combustion engine during deceleration phase
6	Speed range in which the combustion engine can be shut off

Oil Supply

To lubricate and cool the components of the active gearbox and to actuate the multidisc clutches, sufficient pressure and volumetric flow of the transmission oil must be provided in each operating state. The transmission oil supply must be ensured even when the combustion engine is at a standstill.

Therefore, the transmission oil pump is driven in two ways:

- Mechanically by the combustion engine via the transmission input shaft
- Electrically by an electric motor installed specifically for this purpose

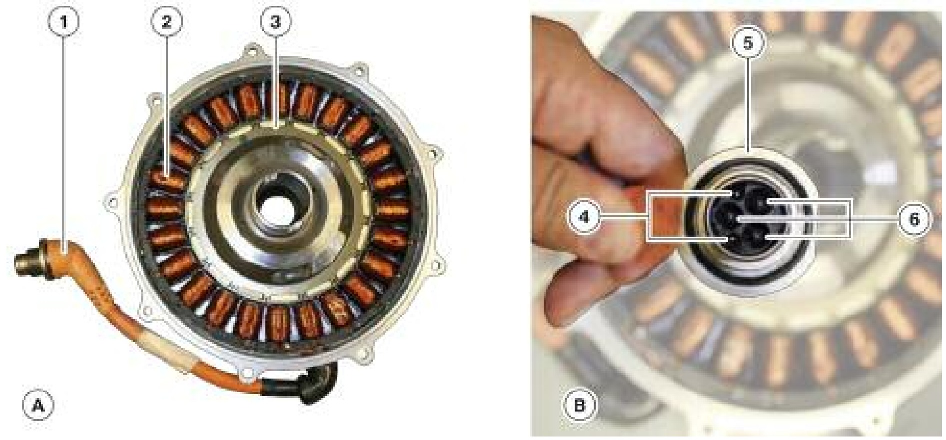
The actual transmission oil pump is connected to the transmission input shaft via a freewheel. When the transmission input shaft rotates (while the combustion engine is running), the transmission oil pump is also driven. If the speed of the combustion engine is sufficient, this type of drive is adequate. However, it must be driven by the electric motor if the speed of the combustion engine is not adequate or the combustion engine is at a standstill. The electric motor is connected to the actual transmission oil pump via a free-wheel. When the transmission input shaft rotates (while the com-bustion engine is running), the electric motor also rotates. However, in this case, it is activated such that it can rotate without load. If the transmission input shaft is at a standstill (when the combustion engine is also at a standstill), the electric motor must power the transmission oil pump. The electric motor is then activated such that the transmission oil pump rotates at an adequate speed and the transmission oil supply is ensured.

The maximum speed of the electric motor corresponds to that of the combustion engine (6500 rpm), but it is operated actively only at a significantly lower speed range (approx. 0 to 2000 rpm). At higher speeds, the combustion engine drives the transmission oil pump and the electric motor only has to rotate at the same speed.

The electric motor of the transmission oil pump does not have any sensors (such as motor position sensors or temperature sensors).

"Dexron-VI" is used as the transmission oil.

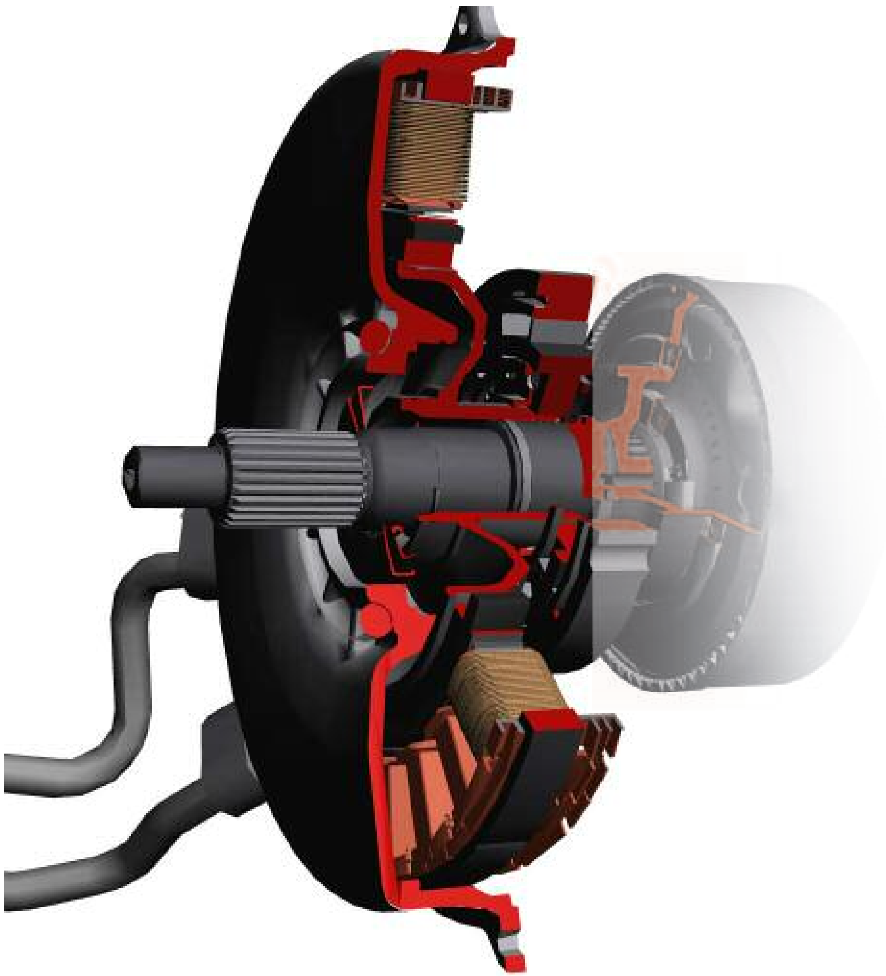
Electric motor for driving the oil pump



Index	Explanation
A	EMPI
B	Detailed view of the electrical connection
1	Electrical connector
2	Coils of the stator
3	Rotor equipped with permanent magnets
4	Contacts of the high voltage interlock loop
5	Housing of the connector for connection to the power electronic box
6	Contacts for three phases

E72 Complete Vehicle.

Active transmission > Transmission oil supply



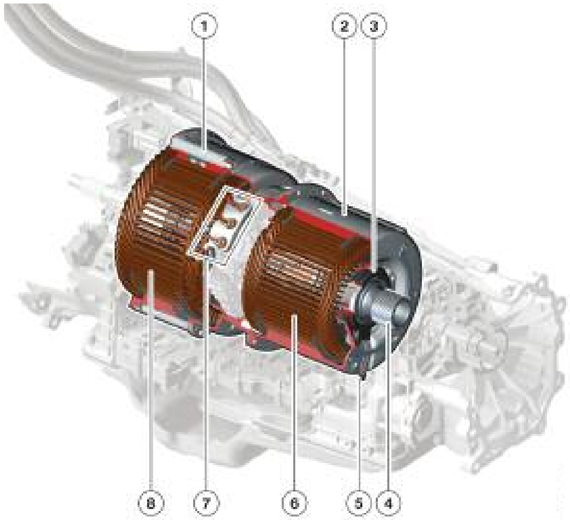
For which purposes is oil flow and/or oil pressure used in the active transmission?

How is the transmission oil pump driven, especially when the internal combustion engine is off?

Electric Machines

Electric machines A and B together make up the electrical part of the hybrid drive in the E72. They are both integrated into the active gearbox and are not accessible for Service employees. To make the operating principle of the active gearbox and the hybrid drive easier to understand, we will describe a few characteristics of these electric machines here.

Sectional view of active gearbox with highlighted electric machines



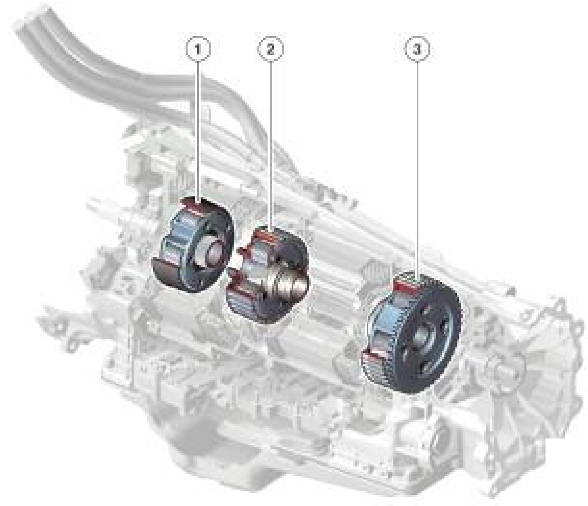
Index	Explanation
1	Electric machine A
2	Electric machine B
3	Rotor of electric machine B
4	Main shaft of the active gearbox
5	Connection for the position sensor of electric machine B
6	Coils on stator of electric machine B
7	High-voltage connection for three phases of electric machine A
8	Coils on stator of electric machine A

Variable	Value for E-Machine A	Value for E-Machine B
Maximum power	67 kW at 3000 rpm	63 kW at 2500 rpm
Maximum torque	260 Nm at 0 to 2500 rpm	280 Nm at 0 to 2000 rpm
Maximum speed	10,500 rpm	13,500 rpm
Nominal voltage	300 V	300 V
Nominal current level	300 A	300 A

Planetary Gear Sets

The active gearbox contains three planetary gear sets, which likewise move in the transmission oil. The planetary gear sets serve to generate the various basic gears and states in the active gearbox.

Sectional view of active gearbox with highlighted planetary gear sets



Index	Explanation
1	Planetary gear set 1
2	Planetary gear set 2
3	Planetary gear set 3

Modifications to the N63

There are few changes to the N63 engine primarily to the cooling system and belt drives.

Belt Drive

One of the most outstanding characteristics of the E72 is driving in pure electric mode. Functions like hydraulic steering and air conditioning are also to be available in this case. Since the combustion engine does not run during this operating condition, it cannot drive the power steering pump and the air conditioning compressor.

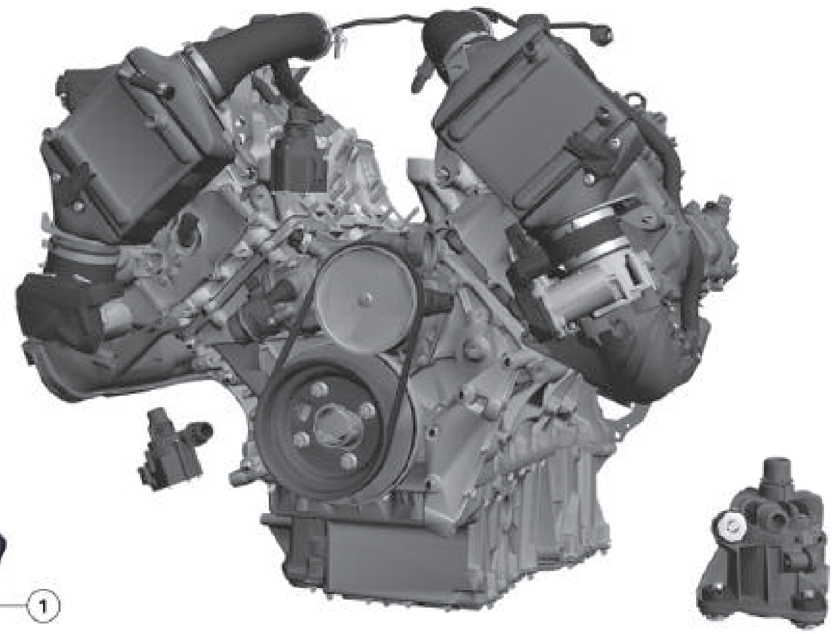
Consequently, both of these systems are operated electrically and omitted from the belt drive. Since the E72 also has no conventional alternator on the engine, this is also omitted from the belt drive.

Thus the belt drive is designed with the highest possible simplicity. Only the coolant pump required for the electric machines is driven. A tensioning pulley is not required since an elastomer belt is used, which is installed using the "turret clamping system" known since the N63. The elastomer belt is, as usual, a poly-V belt with 4 ribs.

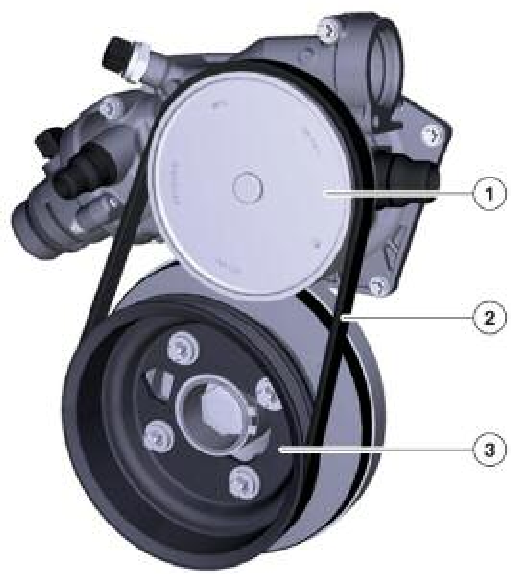
E72 Complete Vehicle.

N63 engine modifications > Overview and belt drive

What are the major modifications of the N63 engine used on E72?



What is special or different about the belt drive in comparison to the E71?



1

2

3

Cooling System

Also in the E72, the N63 engine has two separate cooling circuits. One takes care of engine cooling, the second charge air cooling. The vehicle also has a third cooling circuit for the high voltage battery. It will be discussed in the corresponding chapter, since it does not belong to the engine.

Engine Cooling

The cooling circuit for engine cooling also supplies the bearing seats of the exhaust turbocharger with coolant. The electric auxiliary water pump with a power of 20 W supports the mechanical main coolant pump and ensures cooling of the exhaust turbocharger even after the engine has been stopped.

The electric auxiliary water pump is arranged in the engine cooling circuit so that when the combustion engine is at a standstill, coolant flows through the transmission fluid-to-coolant heat exchanger. This guarantees that the gearbox and its two electric machines are cooled when driving in pure electric mode.

As with the other models with an N63 engine, this pump also continues running after the combustion engine has been stopped in order to dissipate the residual heat away from the exhaust turbocharger (this can be for 15 to 20 minutes).

Charge Air Cooling

In the E72, the engine control unit is not cooled by coolant, but by two additional control units, the Power Electronic Box (PEB) and the Auxiliary Power Module (APM). This led to other changes in the low temperature cooling circuit.

Electric Coolant Pumps

Due to the additional components that have to be cooled and the associated pressure loss, a second electric coolant pump connected in series with a power of 50 W is used. Only one 50 W pump would not be able to maintain the required volumetric flow.

Additional 20 W Coolant Pump

An additional electric coolant pump with a power of 20 W balances the different pressure losses between the APM and PEB. Coolant flows through the APM and PEB in parallel with one another but because the PEB generates more heat than the APM, this means that a larger cooling surface needs to be made available in the PEB, which brings with it a higher flow resistance and higher pressure losses. Without special measures, the coolant would mainly flow via the lower flow resistance of the APM. A restriction in the APM partly balances this, but not completely. The additional 20 W coolant pump is responsible for the rest.

Bypass

Another task of the 20 W coolant pump is to generate a small "bypass". At low ambient temperatures, the two 50 W pumps can be shut down, since e.g. cooling output is not required. Downstream of the PEB, there is a temperature sensor which is used to control this. However, the temperature sensor in the PEB is also accessed.

Electrical Connection

The two electric 50 W coolant pumps are connected to the digital engine electrical system via a LIN bus, while all 20 W pumps in the vehicle are activated by a pulse-width modulated signal.

After-run

To enable the heat from the PEB and APM to be dissipated even after parking, now there is also an after-run function for the low temperature cooling circuit. All three coolant pumps always continue running for this purpose.

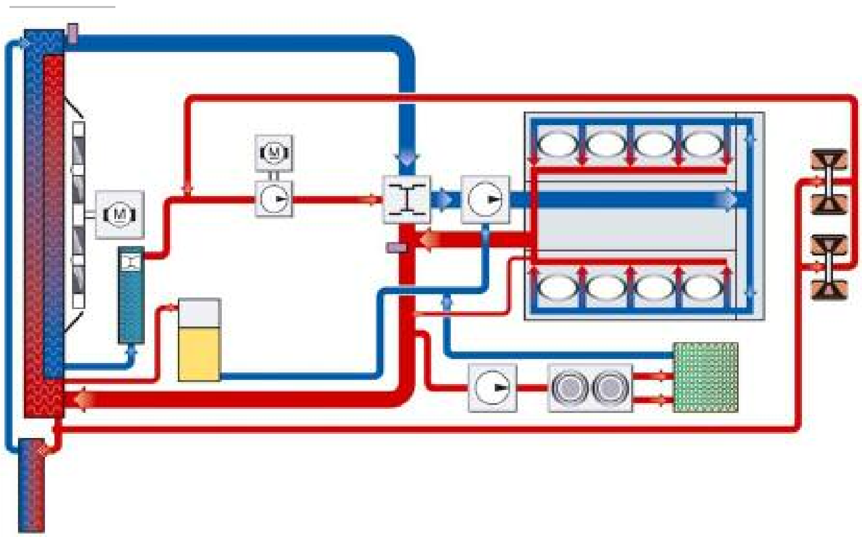
Temperatures

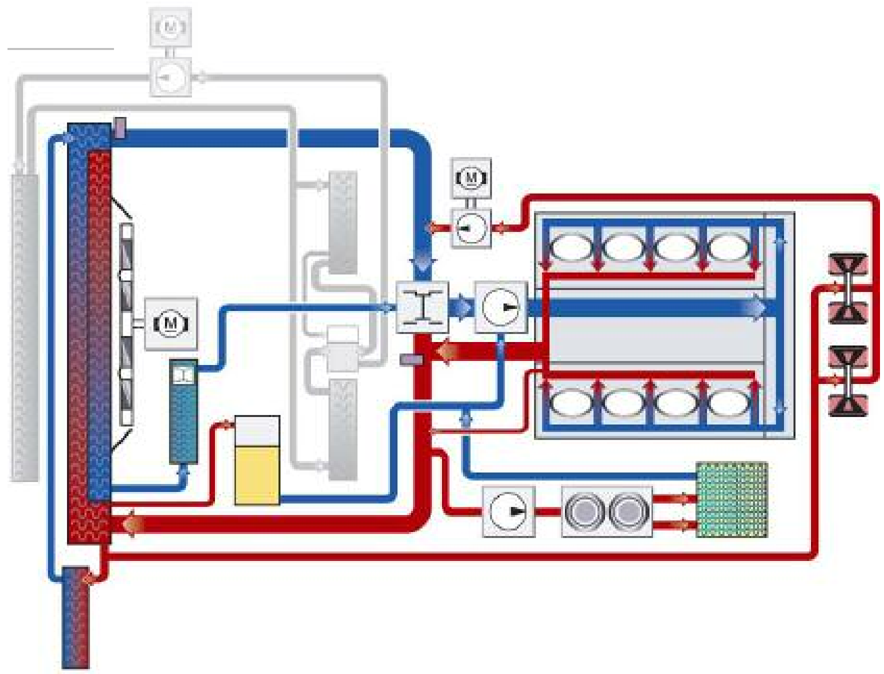
The set temperature for the low temperature cooling circuit is 65°C at the temperature sensor downstream of the PEB. As of 70°C, reduction of the controlled power in the PEB and at the APM begins in order to reduce the heat generation.

E72 Complete Vehicle.

N63 engine modifications > Engine cooling

Compare the engine cooling circuits of E71 and E72. What are the modifications and why were they made?





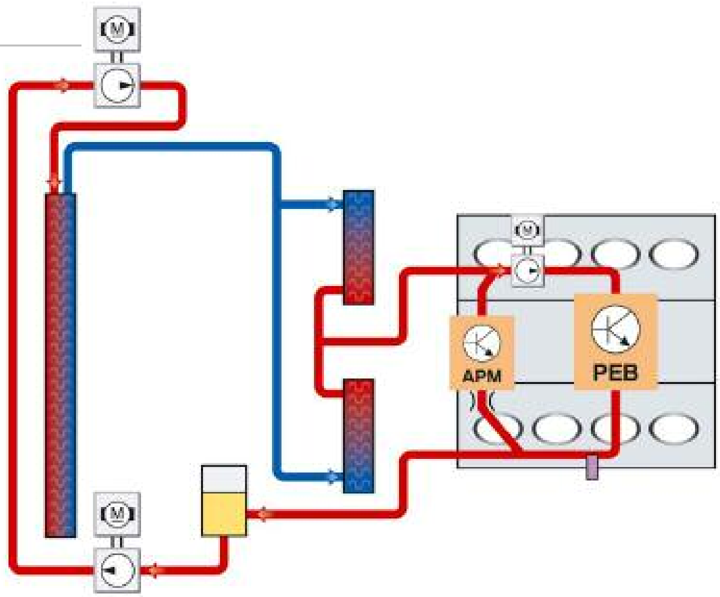
Modifications:

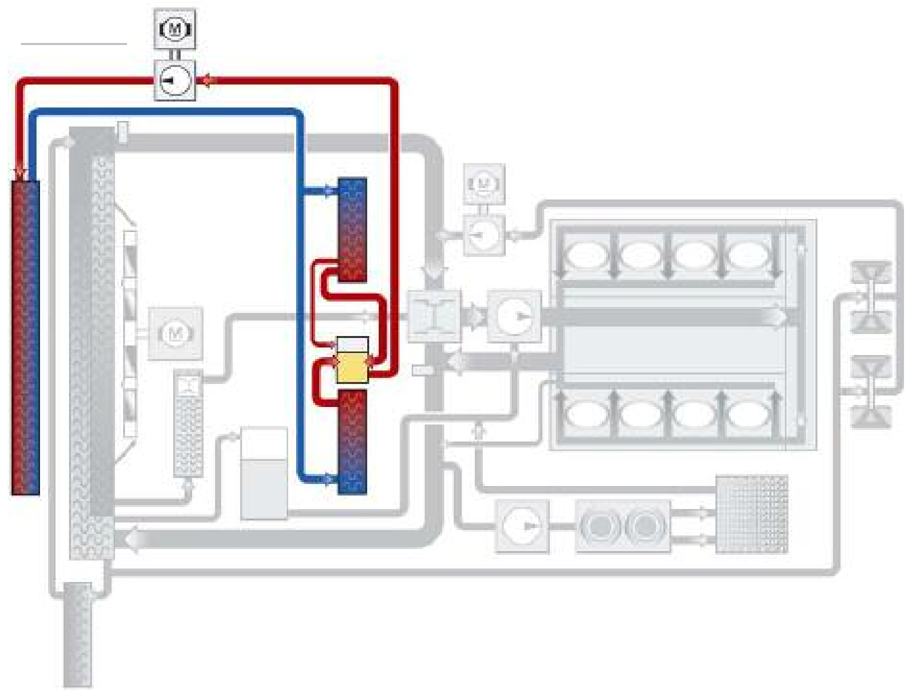
Reasons:

E72 Complete Vehicle.

N63 engine modifications > Low temperature cooling circuit

Compare the low temperature cooling circuits of E71 and E72. What are the modifications and why were they made?





Modifications:

Reasons:

Fuel Supply System

The E72 has a pressurized fuel tank made of stainless steel with two chambers and a tank capacity of 85 liters. The reasons for introducing the pressurized fuel tank are based on US legislation, which provides very strict limit values for HC emissions.

In a vehicle with a conventional tank, the fuel vapors collect in the carbon canister. While driving, fresh air is sucked through the carbon canister for purging and burned in the engine. In the E72, there are driving situations in which the combustion engine does not run (driving is supported only by the electric machines). This means that in such cases, the fuel vapors could not be guided out of the carbon canister to the combustion engine for burning. Therefore, the pressurized fuel tank is used in the E72 to prevent vapors from exiting the pressurized fuel tank. This pressurized fuel tank is designed for an excess pressure of 350 millibars while stopped and 100 millibars while driving.

Pressurized Tank

The pressurized fuel tank in the E72 has a shape similar to the fuel tank in the E71. However, the pressurized fuel tank in the E72 is not made of plastic, but of uncoated stainless steel. This way, the pressurized fuel tank can be distinguished even better from a "normal" fuel tank made of plastic. The weight of the pressurized fuel tank is approx. 25 kg and thus is 11 kg heavier than the fuel tank in the E71. The pressurized fuel tank is designed for a pressure range between –150 millibars and +350 millibars. While driving the pressure range is reduced and lies between –90 and + 100 millibars.

The fuel tank capacity has the same volume as that of the E71 and holds 85 liters.

Pressurized tank

Index	Explanation
1	Pressurized fuel tank
2	Fuel pressure sensor

Fuel Pressure Sensor

The pressure and temperature in the pressurized fuel tank are measured by a combined pressure/temperature sensor. The sensor measures the temperatures in the range from –40°C to +85°C and the pressure in the range from –150 millibars to 400 millibars. The measured values are sent to the control unit of the hybrid pressure refuelling electronic control unit via the LIN bus. The hybrid pressure refuelling electronic control unit evaluates the signals of the pressure/temperature sensor and, if necessary, activates the fuel tank isolation valve.

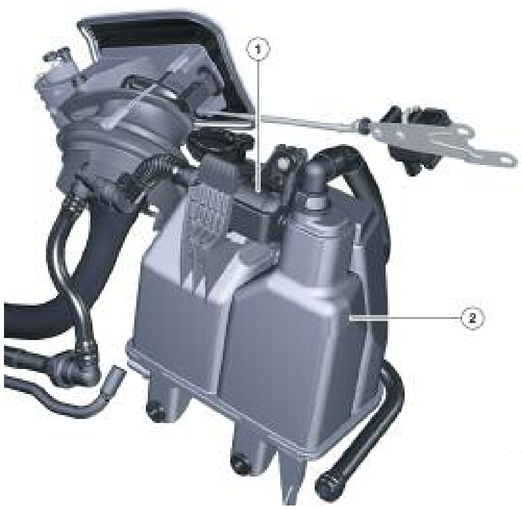
Tank Isolation Valve

The fuel tank isolation valve is installed on the carbon canister. The fuel tank isolation valve is activated by the hybrid pressure refuelling electronic control unit (TFE). The fuel tank isolation valve is normally closed when de-energized.

While driving, the pressure is limited to the permissible values by briefly activating the fuel tank isolation valve. The fuel tank isolation valve is also activated in order to relieve the pressure in the pressurized fuel tank before refuelling.

As keeping the valve open would require some power consumption, the activation time is limited depending on the fuel filler flap. The length of activation is 10 minutes if the filler flap is not opened and 15 minutes if the filler flap is opened.

During phases of standstill, the excess pressure and vacuum are limited by two non-return valves that are integrated in the fuel tank isolation valve.



Index	Explanation	Index	Explanation
1	Tank isolation valve	2	Carbon canister

Carbon Canister

The carbon canister (AKF) in the E72 has been made larger (capacity of 3.4 liters). For comparison: the volume of the carbon canister in the E71 is 2.8 liters.

TFE Control Unit

The hybrid pressure refuelling electronic control unit is installed in the luggage compartment floor to the right of the high voltage battery.

The task of the hybrid pressure refuelling electronic control unit is to limit the internal pressure of the fuel tank. To do so, the hybrid pressure refuelling electronic control unit reads in the data from the sensors and buttons, evaluates it and, if necessary, activates the fuel tank isolation valve. In addition, it controls the refuelling procedure. Information is exchanged with other control units via the PT-CAN. Power is supplied to the hybrid pressure refuelling electronic control unit via the auxiliary fuse block (terminal 30g).

Installation location of the TFE control unit

Index	Explanation
1	TFE control unit

Refuelling Button

To introduce the refuelling procedure, the button for "refuelling" must first be operated. The refuelling button is located in the area of the A-pillar on the driver's side. The control unit of the hybrid pressure refuelling electronic control unit evaluates the status of the button. The button receives the signal for the backlighting from the footwell module.

Fuel Cap

The fuel filler cap in the E72 bears the "ActiveHybrid" label. The fuel filler cap must not be exchanged with the "normal" fuel filler cap. Due to the increased pressure level in the E72 pressurized fuel tank, the opening pressure of the safety valve in the fuel filler cap is also increased.

Refuelling

The driver's desire to refuel is indicated by the refuelling button. The vehicle must be at rest.

The hybrid pressure refuelling electronic control unit receives the request from the refueling button and starts reducing the pressure in the pressurized fuel tank (via activating fuel tank isolation valve). The hybrid pressure refuelling electronic control unit gets the information about the pressure from the fuel pressure sensor.

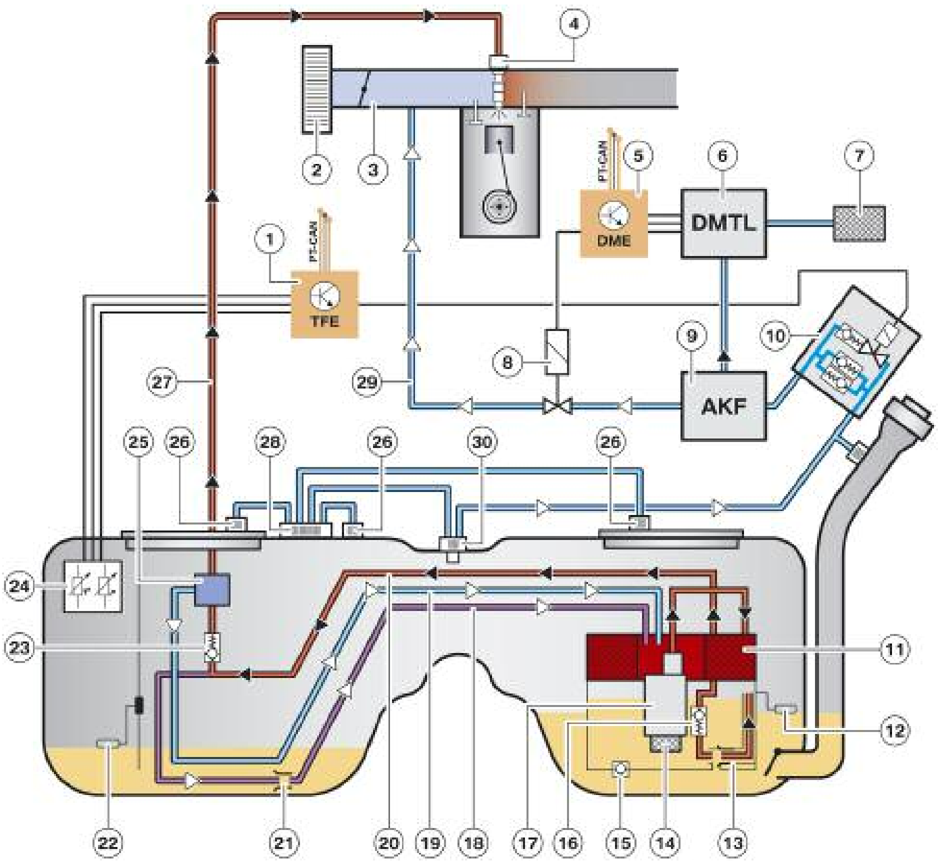
If any fuel vapors are present, they are released into the atmosphere via the carbon canister and dust filter. After the pressure has been reduced, the fuel filler flap is unlocked by the filler flap actuator.

Displays for tank readiness

Index	Explanation
1	Check Control message in the instrument panel
2	Refuelling is possible

The driver simultaneously receives information about the tank readiness status in the instrument panel as well as the CID. Then the fuel filler flap and cap can be opened and refuelling can take place. The refuelling should take place within 10 to 15 minutes. A hall effect sensor detects when the fuel filler flap is closed after refuelling. After about 2 seconds, the hybrid pressure refuelling electronic control unit activates the actuator drive for locking the fuel filler flap. The fuel tank isolation valve is no longer activated (is closed) and the displays in the instrument panel and CID disappear. This concludes the refuelling process.

Fuel supply system

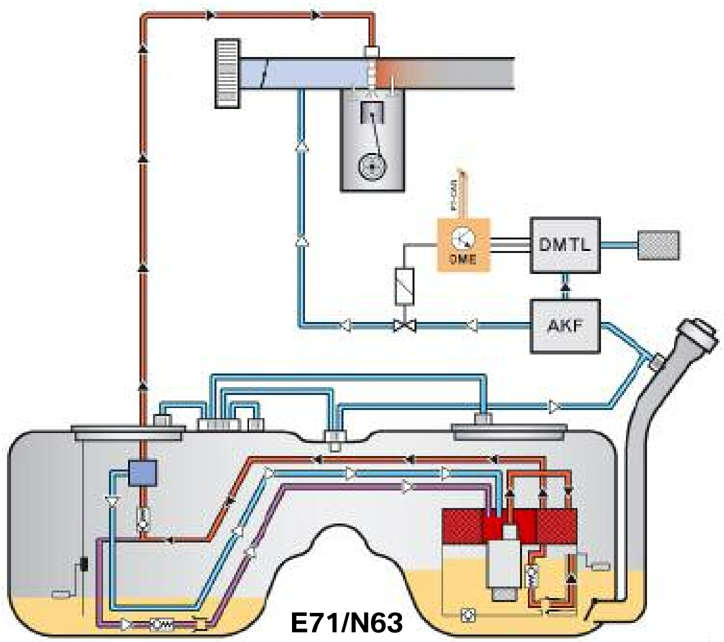


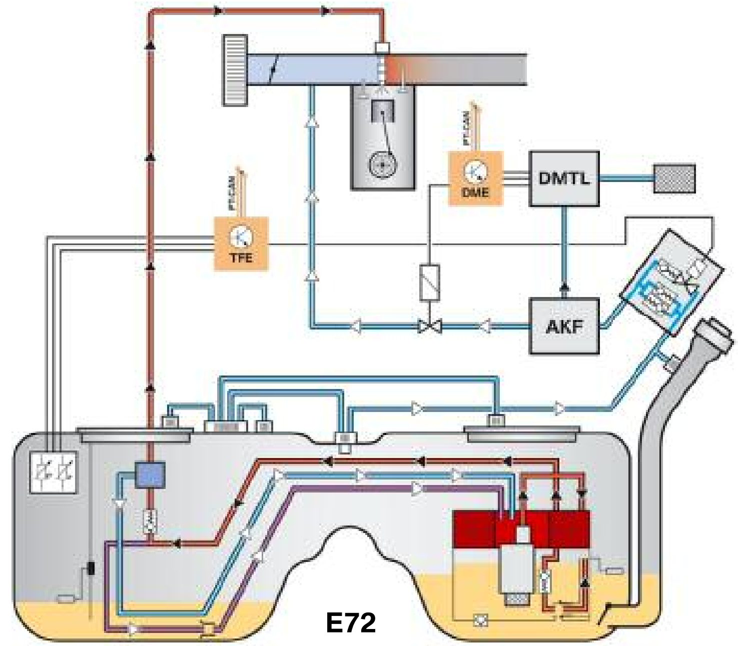
Index	Explanation
1	Hybrid pressure refuelling electronic control unit (TFE)
2	Air filter of the combustion engine
3	Differentiated air intake system of the combustion engine
4	Fuel injectors
5	Digital motor electronics (DME)
6	Diagnostic Module for Tank Leaks (DMTL)
7	Dust filter
8	Fuel tank vent valve (TEV)
9	Carbon canister (AKF)
10	Tank isolation valve
11	Fuel filter
12	Fuel level sensor
13	Suction jet pump
14	Intake mesh filter
15	First filling valve
16	Non-return valve
17	Electric fuel pump (EKP)
18	Expansion line
19	Return pipe
20	Feed line
21	Suction jet pump
22	Fuel level sensor
23	Non-return valve
24	Fuel pressure sensor
25	Pressure regulator
26	Service vent valves
27	Feed line to the combustion engine
28	Central pressure-retaining valve (Z-DHV)
29	Purge air line
30	Fuel tank vent valve

E72 Complete Vehicle.

Fuel supply system > System overview

Compare the fuel supply systems from E71/N63 to E72. Note the differences.

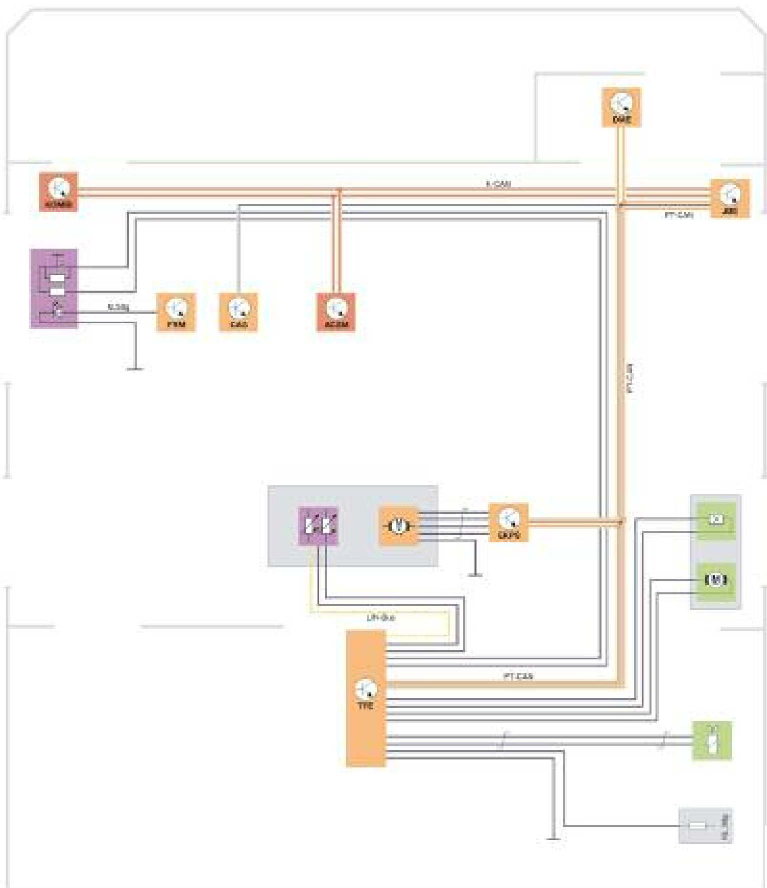




E72 Complete Vehicle.

Fuel supply system > Wiring diagram

Note the connections and functions of TFE.



E72 Complete Vehicle.

Fuel supply system > Refuelling

Note the procedure for refuelling of E72.

Power Electronics

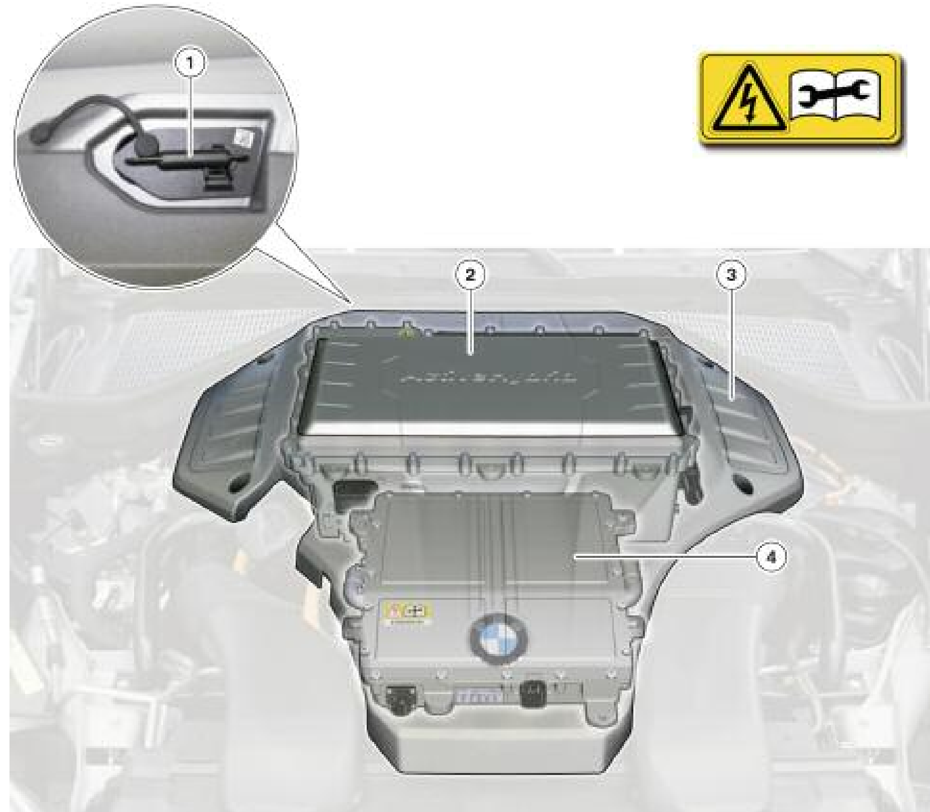
The hybrid-relevant power electronics of the E72 are divided into two control units:

- Auxiliary Power Module APM
- Power Electronic Box PEB

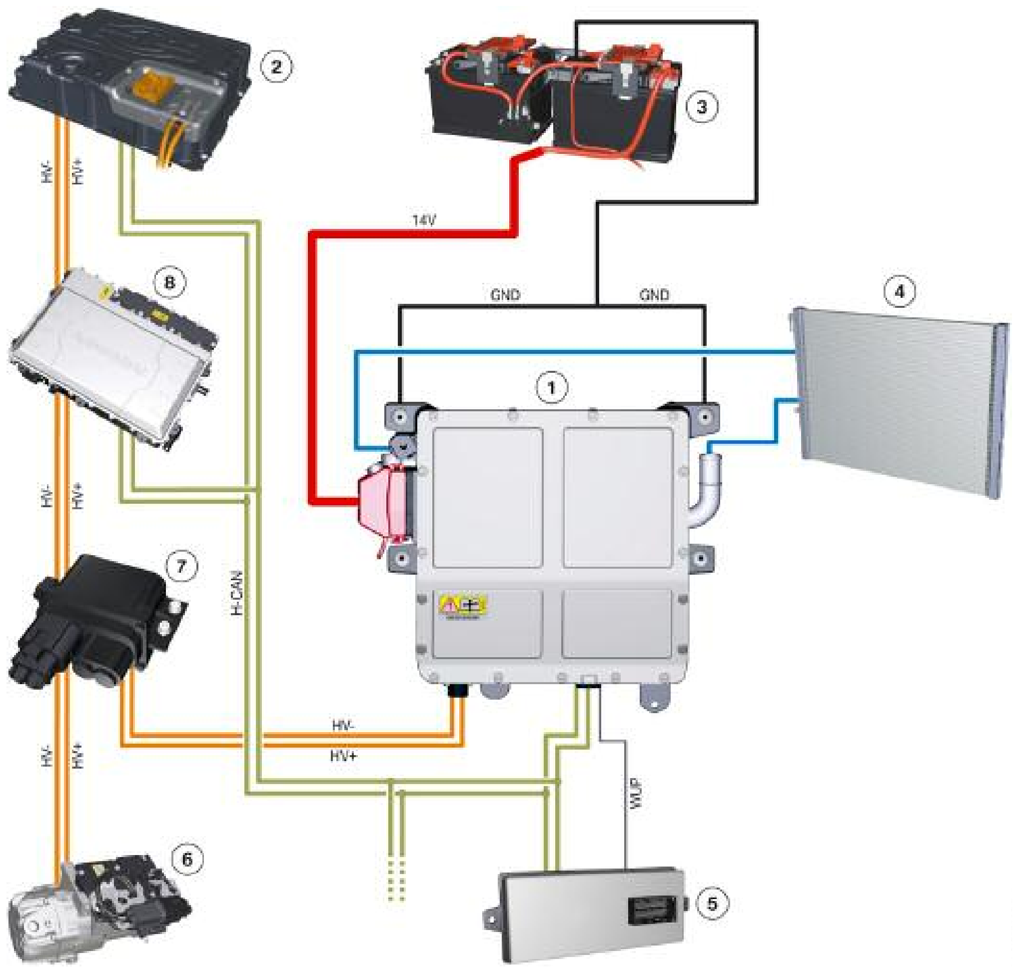
Both control units are installed above the combustion engine in the engine compartment. The safety cover protects against touching the high voltage connections directly. Both control units are high voltage components.

There is a bridge on the safety cover, which closes the circuit of the high voltage interlock loop. Four easily accessible screws must first be unscrewed in order to remove the safety cover. The safety cover is still attached via a fifth screw that cannot be seen initially. The bridge must be unlocked and pulled out so that this screw can be unscrewed. This interrupts the circuit of the high voltage interlock loop and de-energizes the high voltage electrical system. Only now, the fifth screw can be unscrewed and the safety cover can be removed.

Installation location of the APM and PEB



Index	Explanation
1	Bridge for high voltage interlock loop
2	Power Electronic Box PEB
3	Safety cover
4	Auxiliary Power Module APM



Complete the following table and explain why the APM needs the connection to these components.

1 Auxiliary Power Module

2 ____________________

3 ____________________

4 ____________________

5 ____________________

6 Electric A/C compressor

7 Power Distribution Box

8 Power Electronic Box

APM

The APM is a DC/DC converter that enables energy transfer between the two voltage levels of the hybrid car. One voltage level is the high voltage electrical system with approx. 300 V and the other is the familiar 14 V vehicle electrical system. The DC/DC converter replaces the alternator, which was previously used for the voltage supply of the 14 V vehicle electrical system. Thus the electrical voltage supply of the 14 V vehicle electrical system while driving is no longer dependent on the engine speed of the combustion engine.

The APM control unit is used in the E72 only. It is designed as a bidirectional converter. This means that the APM transfers the electrical energy in both directions between the high voltage electrical system and the 14 V vehicle electrical system. The APM has been developed as part of the hybrid co-operation along with GM, DaimlerChrysler (later Daimler and Chrysler) and is based in part on the DC/DC converter of a predecessor project in which BMW did not participate. The developer and manufacturer of APM is Delphi Electronics & Safety.

The APM is activated by the HCP, which is part of the PEB. The APM does not switch on the voltage conversion on its own.

The HCP sends the following commands to the APM:

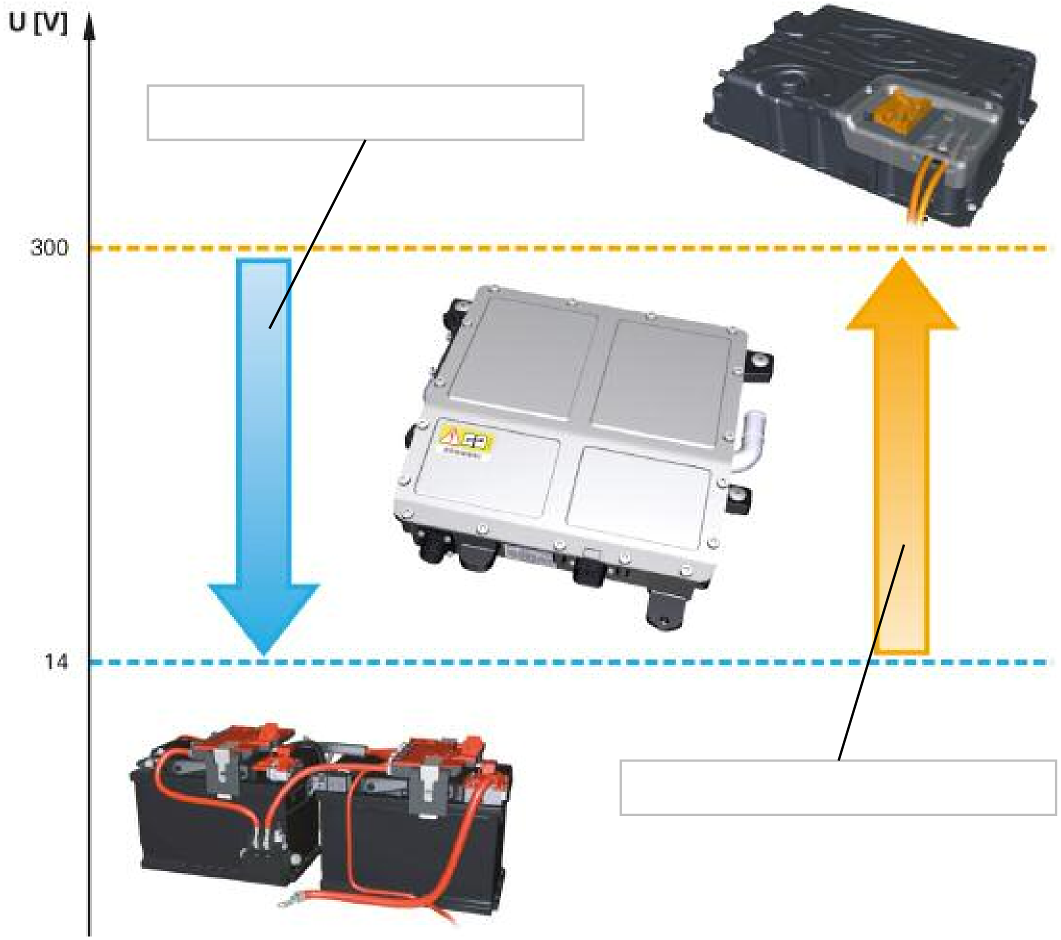
- Switch conversion on or off
- Conversion direction
  (high voltage to 14 V or 14 V to high voltage)
- The nominal voltage

The APM then decides, based on the data from the self-diagnosis and the values it has detected itself, whether the conversion can be switched on. During operation, the APM attempts to adjust the nominal voltage to the corresponding voltage level by increasing the current up to the technically possible limit value. The APM cannot decrease the voltage in the vehicle electrical system, for example by lowering the voltage in the 14 V vehicle electrical system to 11 V. However, if the current voltage in the respective voltage level is higher than the nominal voltage of the APM, the APM reduces the current to 0 A. Thus no energy transfer takes place. The APM has a passive discharge circuit that discharges the capacitors in the APM to a voltage value of less than 60 volts within five seconds. If a fault is detected, the APM switches off the conversion automatically.

Operating Modes of the APM

Depending on the direction in which the APM converts the voltage, two operating modes exist: downward conversion and upward conversion.

Although the E72 cannot be jump started, the high voltage battery can be charged via the 12 Volt side. One responsibility of the APM is to upconvert the voltage to charge the high voltage battery.



What are the two operating modes of the APM?
Fill in the Boxes.

Power Electronic Box (PEB)

The abbreviation PEB stands for Power Electronic Box and refers to the control unit used in the E72 to activate and control the hybrid-specific components.

The PEB controls the high voltage electrical system in all operating conditions, the bidirectional energy flow of the electric machines, the speed and torque of the two electric machines and the electrical hybrid oil pump control unit (electrical motor pump inverter). The PEB has been developed as part of the hybrid co-operation along with GM, DaimlerChrysler (later Daimler and Chrysler) and is based in part on the developments of a predecessor project in which BMW did not participate. The manufacturer and developer of the PEB is Hitachi, Ltd., Automotive Systems Japan.

The PEB is the central bidirectional high voltage hybrid control unit, consisting of four microcontrollers (control units). These four control units are the HCP, MCPA, MCPB and EMPI.

During diagnostics, each control unit sends its signals individually, where the fault entries of the EMPI and MCP are stored in the fault memory of the HCP. The communication of the control units in the PEB with other control units in the vehicle takes place independently via the H-CAN and the H-CAN2.

The following are the functions of the four control units in the PEB:

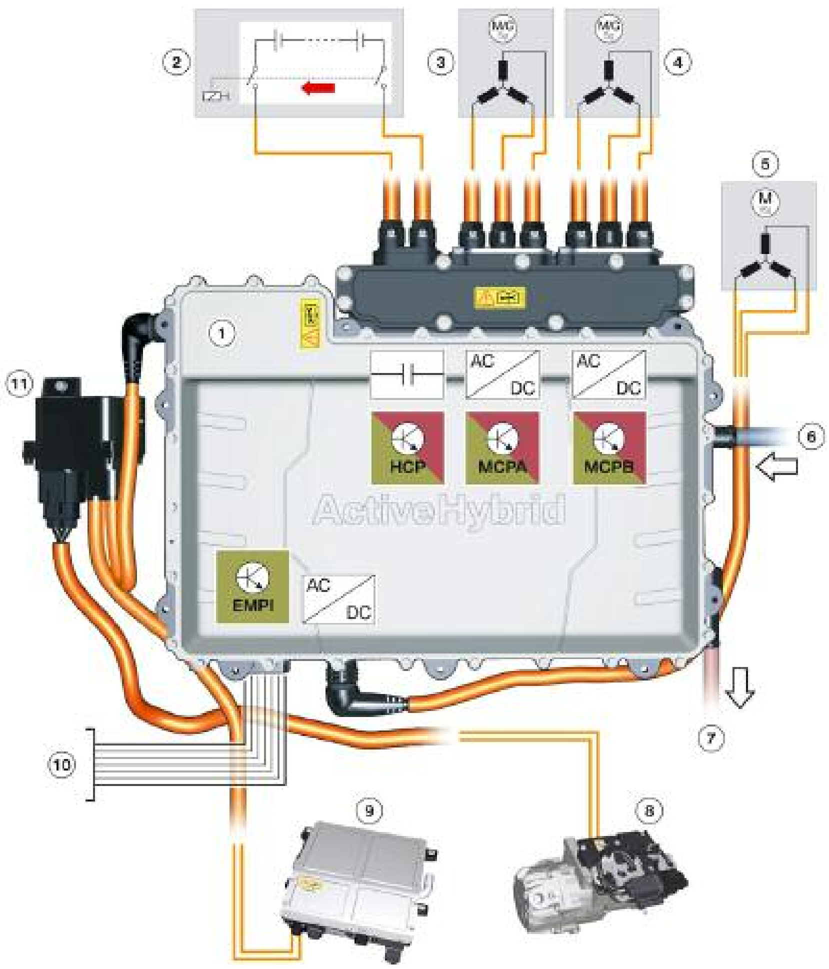
- HCP: co-ordinates all central functions of the hybrid system, selects the gear, calculates the torque distribution between the combustion engine, electric machines, chassis and suspension and monitors the complete system.
- MCPA: calculates the control of electric machine A depending on the requirement of the HCP.
- MCPB: calculates the control of electric machine B depending on the requirement of the HCP.
- EMPI: controls the electric motor of the hybrid oil pump.

In addition to these four control units, the PEB contains the power electronics of the two impulse converters (AC/DC converters) to control the two electric machines, one impulse converter (AC/DC converter) to control the electrical hybrid oil pump control unit and a capacitor (1 mF) as the intermediate voltage circuit as well as the external hardware for all four control units.

Other functions:

- Control of the high voltage electrical system
- Bidirectional distribution and transfer of the energy between the electric machines of the drive system and the high voltage system
- Controlled discharge of the high voltage in the vehicle
- Filtering of the high voltage electrical system
- Insulation and insulation monitoring of the high voltage to earth
- Diagnostic functions and self-protection of the components
- Control of the electric machines in torque, speed
- Activation and control of the hybrid oil pump
- Pre-charge mode, which allows the high voltage system to be started

The energy operational strategy in the hybrid master control unit HCP continuously adjusts the energy distribution depending on the environmental conditions, vehicle condition and driver's choice. The most important input and control variable for the operational strategy is the state of charge of the high voltage battery.



Complete the following table.

1 Power Electronic Box

2 ____________________

3 ____________________

4 ____________________

5 ____________________

6 ____________________

7 ____________________

8 ____________________

9 ____________________

10 12 V, H-CAN, H-CAN 2, ...

11 Power Distribution Box

Power Distribution Box

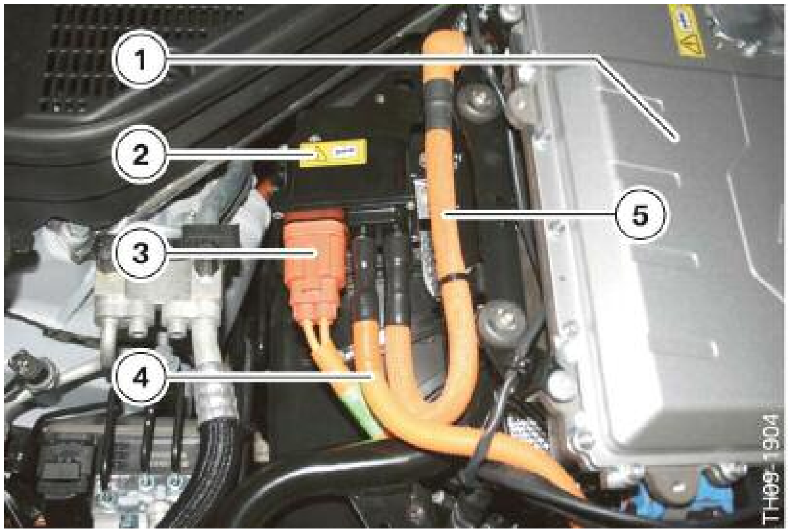
The PEB can be diagnosed and programmed. It is important that after the PEB is replaced, all four control units are programmed to bring them up to date.

The 20 A fuse serves to protect the high voltage cable to the APM and the 40 A fuse serves to protect the high voltage cable to the EKK. Each of the high voltage fuses protects the high voltage positive wire.

If the high voltage fuses are defective, the entire PDB must be replaced.

E72 Complete Vehicle.

Power electronics > Power Distribution Box



Complete the following table.

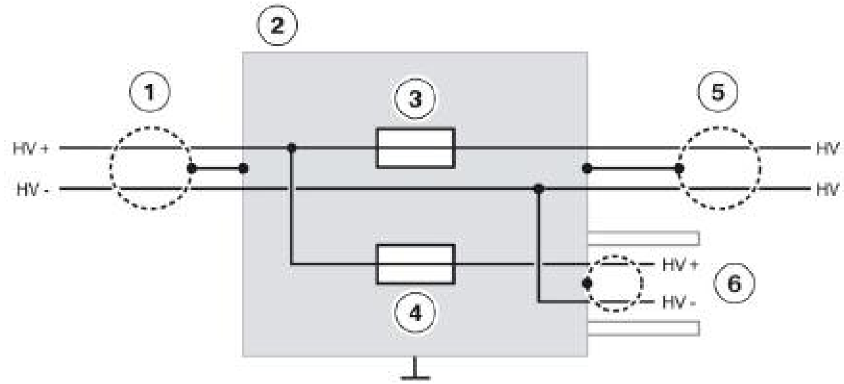
1 ______________________________

2 ______________________________

3 ______________________________

4 ______________________________

5 ______________________________



Complete the following table.

1 ______________________________

2 ______________________________

3 ______________________________

4 ______________________________

5 ______________________________

6 ______________________________

High Voltage Cables

The high voltage cables connect the high voltage components to each other and are identified by the orange cable sheath. The manufacturers of hybrid cars have agreed on uniform identification of high voltage cables using orange as a warning color.

High voltage cables can be connected in one of two ways:

- Screwed/bolted on
- Quick connector

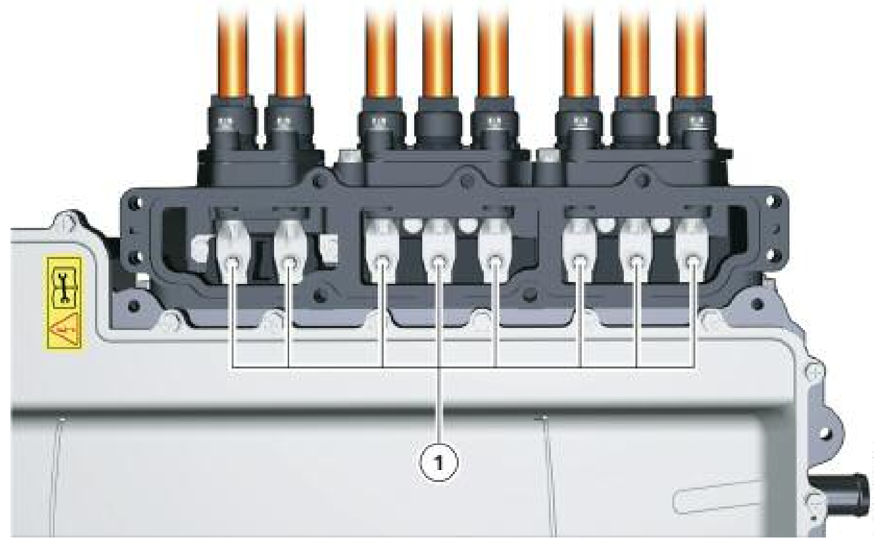
Screws/Nuts/bolts are used to connect the High Voltage cables to the high voltage battery, and PEB.

All other connections are made with round high voltage connectors with "quick-connect" locking mechanism.

These round high voltage connectors have, until now, primarily been used in military applications.

When contacting round high voltage connectors, it is particularly important to ensure correct locking. For locking, a locking ring is used, which can be pushed forwards and backwards.

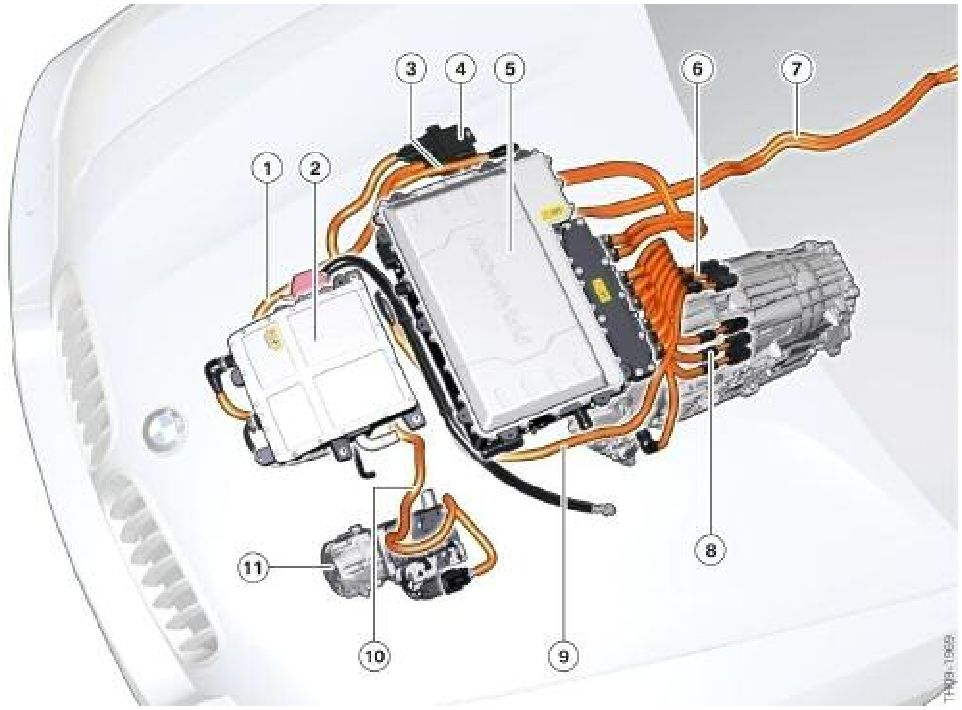
Screw type connectors at PEB



Round high voltage connectors

Index	Explanation
A	The round high voltage connector is locked when the locking ring (1) is pushed forwards.
B	The round high voltage safety connector is unlocked if the locking ring is pushed backwards. The red mark (2) is visible. Before the round high voltage connector is plugged in, the locking ring must be pushed backwards.

E72 Complete Vehicle.



Complete the following table: Identify the component and write the kind of voltage that goes accross the cable (AC/DC).

1 ______________________________

2 Auxiliary Power Module (DC)

3 ______________________________

4 ______________________________

5 Power Electronic Box (AC/DC)

6 ______________________________

7 ______________________________

8 ______________________________

9 ______________________________

10 ______________________________

11 Electric A/C compressor

Voltage Supply

The vehicle electrical system of the E72 can be divided into three areas:

- Driven with electric machines (high voltage with AC voltage)
- High-voltage electrical system with DC voltage
- 14 V vehicle electrical system.

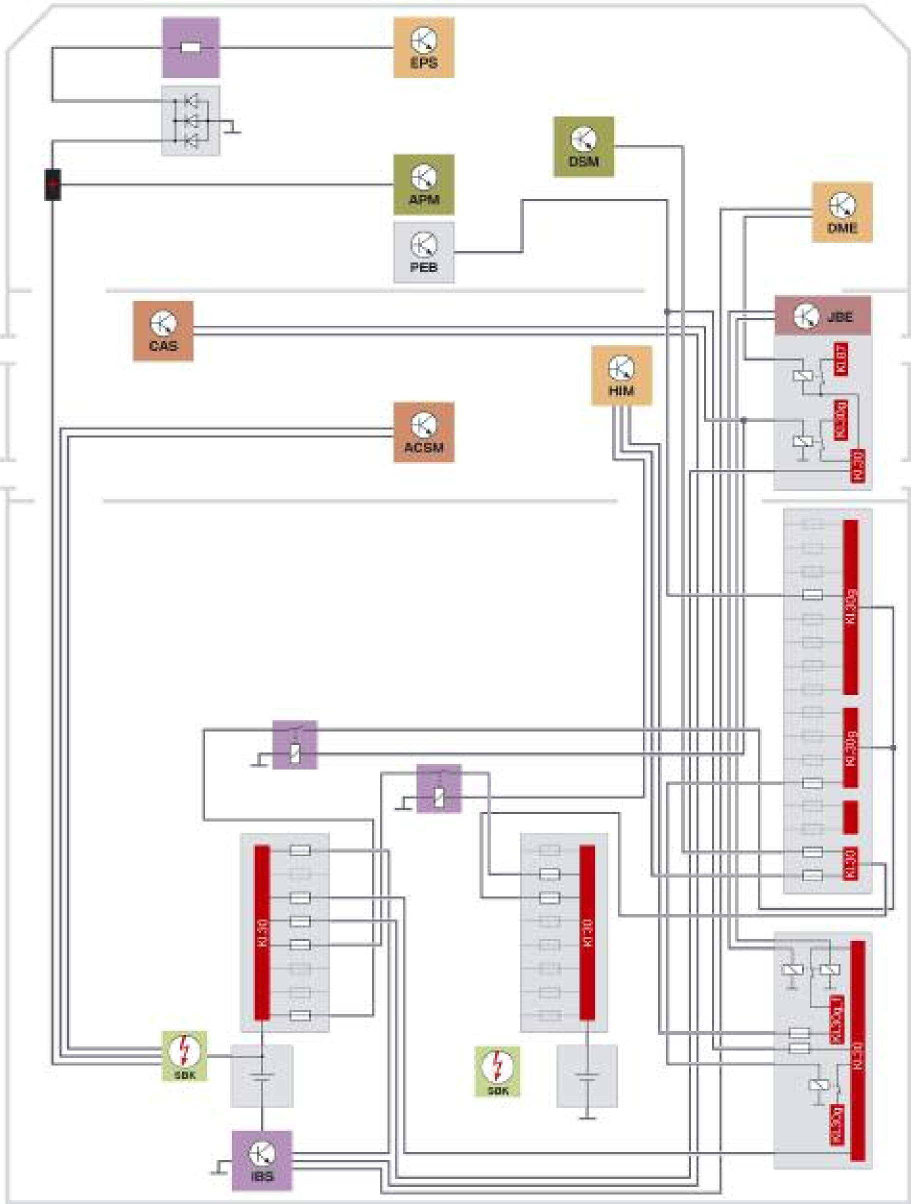
The electric drive consists of two electric machines, which can be operated as a generator (power source) or as a motor, and the power electronics (PEB). An AC/DC converter (coupling the electric drive and the high voltage electrical system) and a DC/DC converter (high voltage electrical system and 14 V vehicle electrical system) are used as coupling elements. Both converters can be operated bi-directionally.

The high voltage battery is the main element of the high voltage electrical system. In the E72, a nickel metal hydride battery (NiMH) is used for this purpose. This high voltage battery ensures, among other things, voltage supply when the vehicle is at a standstill or when "driving in electric mode". The electric A/C compressor EKK and the transmission oil pump EMPI are other vehicle electrical system components in the high voltage electrical system.

The 14 V vehicle electrical system is similar to the vehicle electrical power system in existing vehicles; however, with the DC/DC converter (APM) being responsible for its voltage supply. The DC/DC converter has replaced the generator previously used for this purpose. The electric voltage supply of the 14 V vehicle electrical system is thus no longer dependent on the engine speed of the combustion engine when driving.

For the E72, the combustion engine is started via an electric machine. As a result, the E72 does not require a conventional starter motor.

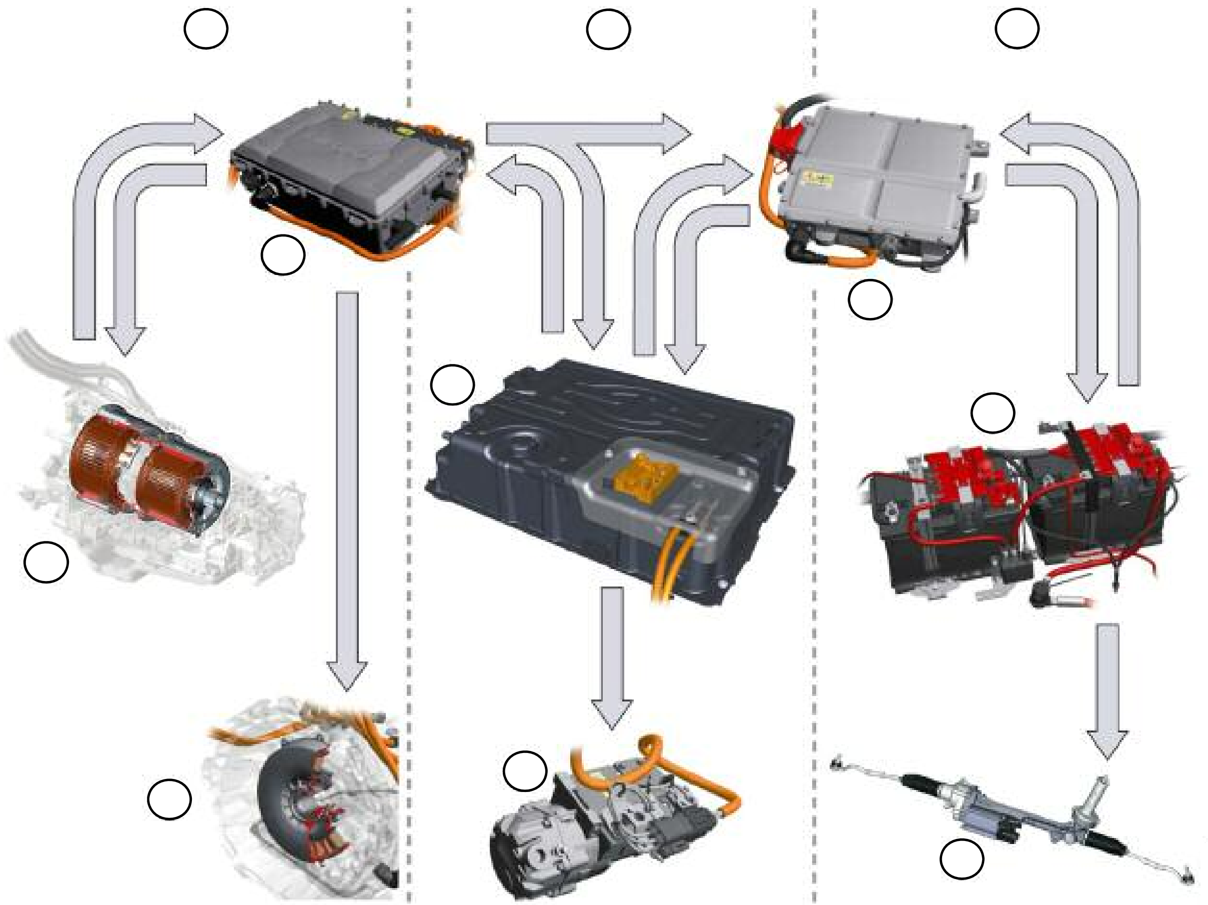
System circuit diagram for low voltage supply



E72 Complete Vehicle.

14 V system > Voltage levels in E72

Assign the components to the terms in the legend. Write the related numbers/letters in the graphic.



A HV system, alternating current (AC)

B HV system, direct current

C 14 V system, direct current

1 Power Electronic Box

2 High-voltage battery

3 Auxiliary Power Module

4 Two 12 V batteries

5 Electric Power Steering

6 Electric A/C compressor

7 Electrical Motor for transmission oil pump

8 Electrical machines A / B

12 V Batteries

To ensure the stability of the vehicle voltage and the redundant voltage supply of the hybrid parking lock (DSM), the E72 has an auxiliary battery which is connected in parallel to the 12 V battery present in the E70 and E71. In addition to ensuring vehicle voltage stability, the auxiliary battery is also used for the redundant supply of the DSM control unit. Both 12 V batteries are AGM batteries with 70 Ah.

The use of auxiliary batteries reduces the internal resistance of the "standard battery". This allows current output on short notice. In order to prevent equalizing current while the vehicle is immobilized, both 12 V batteries are disconnected via a cut-off relay after the "ready to drive" mode has been switched off. While the vehicle is at a standstill, the 14 V vehicle electrical system is supplied by the "standard battery" only. The Hybrid Interface Module (HIM) controls a cut-off relay and monitors the battery condition through voltage measurements at the positive terminal of the auxiliary battery.

Cut-off Relay

The cut-off relay is opened 5 s after the vehicle is parked and the high voltage system is switched off.

The cut-off relay is closed under the following conditions:

- The vehicle is "ready to drive" (CAN message from hybrid master control unit HCP)
- The hybrid DC/DC converter has set the vehicle supply voltage of the 14 V vehicle electrical system close to the battery voltage of the auxiliary battery
- The difference between the battery voltage of the system battery and the auxiliary battery is smaller than the threshold value of 1.2 V (preventing high currents to protect the cut-off relay).

Charging the Auxiliary Battery

The cut-off relay can only be closed if a charger is connected to the jump start terminal point of the vehicle. In order to recharge the auxiliary battery, first connect the charger to the jump start terminal point and then close the cut-off relay using the corresponding service function.

The following service function for the auxiliary battery (second 12 V battery) is available via the BMW diagnosis system:

- Charge second 12 V battery.

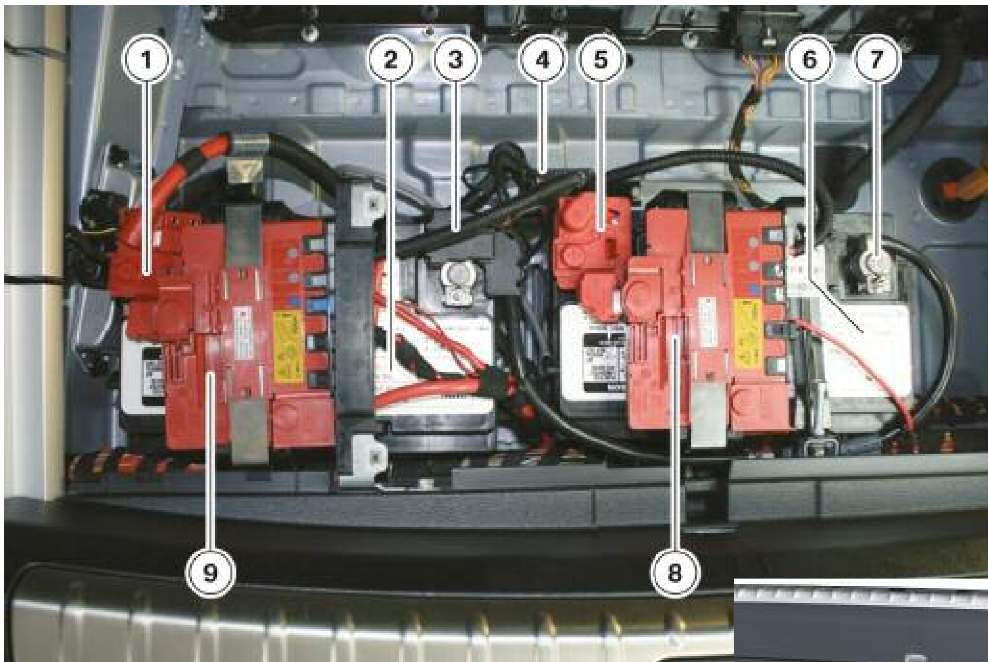
Path: service functions > Body > Voltage supply > Hybrid car > 12 V battery

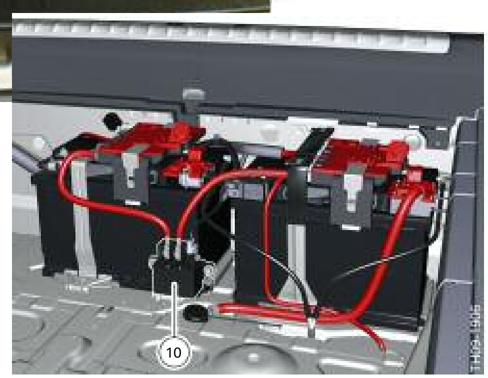
The auxiliary battery must be charged by activating the service function in order to prevent a timed cutoff of terminal 15.

E72 Complete Vehicle.

14 V system > Two 12 V batteries

Write the names of the numbered components.





Index	Explanation
1	
2	
3	
4	
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7	
8	
9	
10	

Reverse Polarity Protection

Reverse polarity protection is used to prevent the subsequent damage to the vehicle electrical system and electronic components connected to it which would result from a polarity reversal on the customer side during an external start. The diodes in the alternator are generally used to fulfil this task. Since the E72 does not have the conventional alternator (electric machine in the transmission), reverse polarity protection must be provided via a new component (reverse polarity protection module).

The reverse polarity protection module is installed in the engine compartment near the jump start terminal point. The module is connected to the positive battery wire on one side and to earth on the other side. There are three Zener diodes inside the reverse polarity protection module; they limit the applied reversed voltage for at least six seconds to below -3.2 V. A polarity reversal that lasts a longer period of time may damage the module without causing damage to the neighboring components. The current carrying capacity is 650 A.

Auxiliary Fuse Block

A rear auxiliary fuse block with slots for 16 fuses supplies the following control units and components with 14 V vehicle supply voltage:

- Hybrid brake actuation changeover SBA
- Power electronic box
- Hybrid pressure refuelling electronic control unit TFE
- Hybrid Interface Module HIM
- Electronics for the electric A/C compressor EKK
- Direct Shift Module DSM
- Transmission Control Module TCM
- Coolant pump for the high voltage battery
- Electrical vacuum pump
- Electric coolant pump for PEB/APM

The terminal 30g for the auxiliary fuse block is switched via the hybrid load relay. The hybrid load relay is controlled by the CAS.

E72 Complete Vehicle.

14 V system > components in engine / luggage compartment

Write the names of the numbered components.

1 ______________________________

2 ______________________________

3 ______________________________

4 ______________________________

1 ______________________________

2 ______________________________

Terminal Control

The terminal assignments for all components taken over from the E71 have remained the same. The following terminal assignments are defined for the hybrid components:

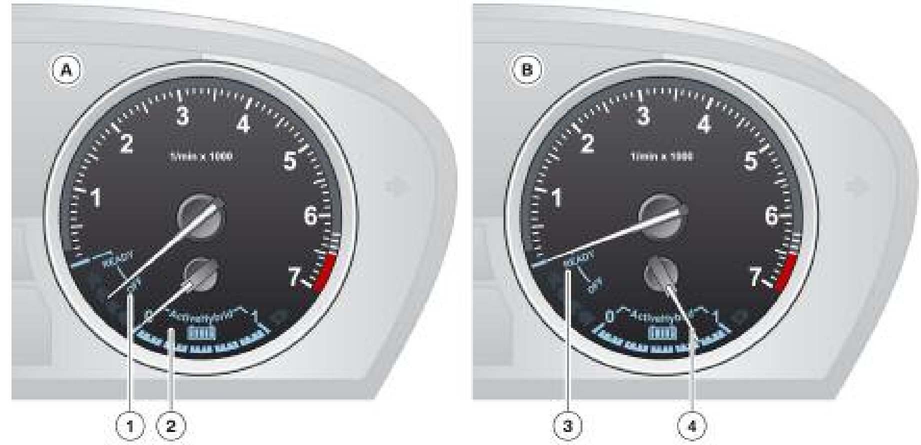
- Terminal 30: APM, EPS and DSM
- Terminal 30g: BCM, EKK, HIM, PEB, SBA, TCM, TFE
- Terminal 30g_f: HIM

"Ready to drive" Mode

"Ready to drive" is a vehicle mode in which wheel torque is provided by selecting a gear and actuating the accelerator pedal. Unlike in conventional vehicles, "ready to drive" mode in hybrid cars cannot be identified by a running combustion engine.

The "ready to drive" mode is managed by the HCP. The vehicle is put into "ready to drive" mode as soon as terminal 50 is switched on. The information "Terminal 50 = ON" is generated by CAS and transmitted to the HCP by the HIM via H-CAN. The logic in the CAS for controlling terminal 50 corresponds to the logic in the E72 for a conventional starter control. Depending on various parameters (state of charge of the high voltage battery, temperature of the combustion engine, etc.), the HCP decides whether the subsequent journey is driven with support of the combustion engine or the electric machines.

In the E72, the voltage supply of the 12 V vehicle electrical system during "ready to drive" mode is ensured by the DC/DC converter (APM).



A: display indicating "ready to drive" is deactivated

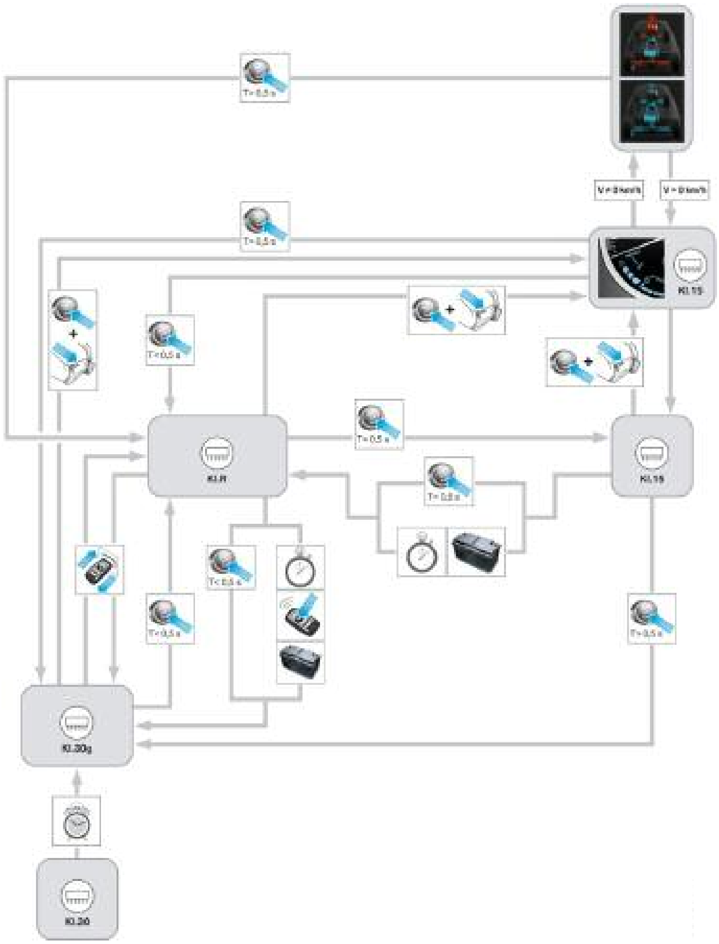
B: display indicating "ready to drive" is activated

Index	Explanation
1	Needle of the engine speed display is in "OFF" position —> "ready to drive" is not activated.
2	Needle for state of charge of the high voltage battery points to null.
3	Needle of the engine speed display is in "READY" position —> "ready to drive" is activated.
4	Needle for state of charge of the high voltage battery indicates the current state of charge

E72 Complete Vehicle.

14 V system > Energy management > Terminal control

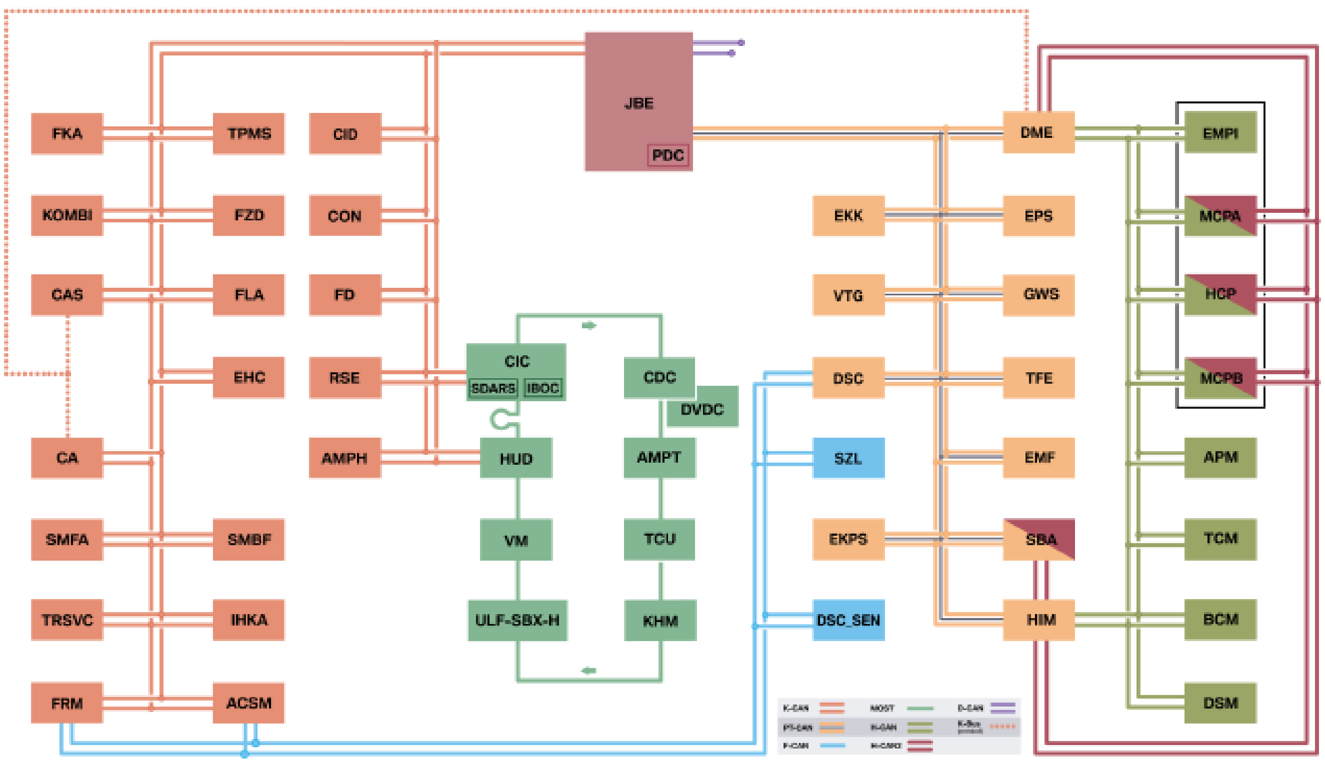
Note the changes with regard to the terminal control for the E72.



E72 Complete Vehicle.

Bus systems > Bus overiew

Compare the E72 and the E71 bus systems. Try to answer following questions: Which bus systems are new? Which control units are new? Which control units and bus system are not in E72? Which control units are in your opinion changed?



E72 Complete Vehicle.

Bus systems > Bus overiew

Compare the E72 and the E71 bus systems. Try to answer following questions: Which bus systems are new? Which control units are new? Which control units and bus system are not in E72? Which control units are in your opinion changed?

H-CAN and H-CAN2

As additional bus systems, the E72 uses two additional CAN buses for networking the hybrid components together and directly connecting to BMW control units with a high communication overhead (DME and SBA).

The HIM ensures that these two bus systems connect to the remaining BMW bus systems. These hybrid bus systems are designated H-CAN and H-CAN2. They have been taken over from the development co-operation and are specified by it.

Both data buses have a data transfer rate of 500 kilobits per second. As with previously used CAN bus systems, H-CAN and H-CAN2 are also designed as twisted two-wire connections. Using twisted two wire connections achieves better electromagnetic compatibility of the bus systems.

The signal levels on the H-CAN and H-CAN2 with an active data bus are:

- CAN-H: 3.5 V
- CAN-L: 1.5 V.

In an inactive data bus, the low and high bus level is 2.5 V (logical zero). A logical 1 is transmitted with a voltage difference of 2 V.

Both data buses have emergency running properties, i.e. if one of the two bus wires (CAN-H, CAN-L) has been interrupted, the data are then transmitted over the remaining intact wire. Some control units are connected to both the H-CAN and the H-CAN2. In this respect, the data buses are not redundant. Different messages are transmitted on both data buses.

The terminating resistors on the H-CAN are in the BCM and DME (each 120 ohms). On the H-CAN2, the terminating resistors are installed in the PEB connector and in the DME (also each 120 ohms). The total resistance, which comes from the parallel circuit of two 120-ohm resistors, is therefore 60 ohms. This resistance can be measured between two bus wires. Both bus systems are event-driven, i.e. messages are transmitted only if there is something to report.

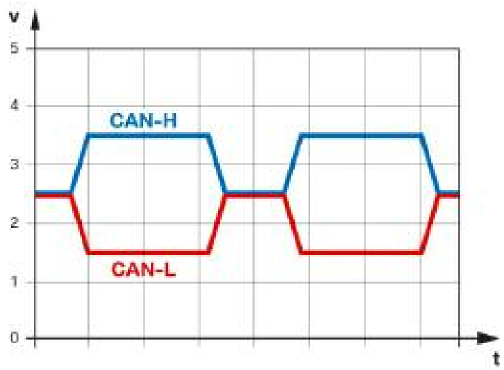
These two CAN buses have the following characteristics, which deviate from the BMW standards:

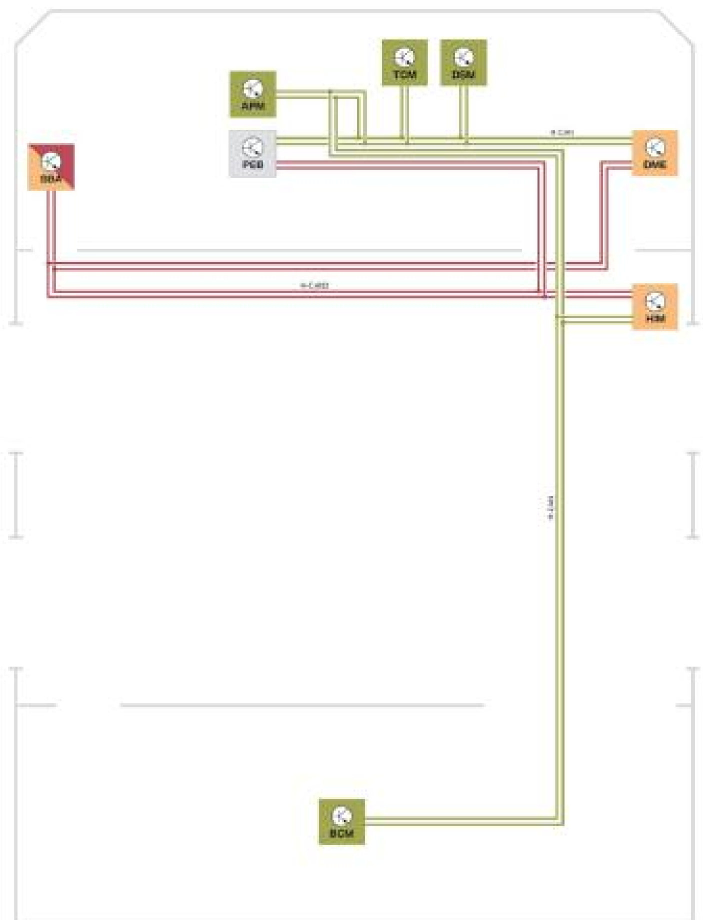
- No network management is implemented. This means that the H-CAN and H-CAN2 cannot be wakened. The control units on these data buses are wakened via a separate wake-up line.
- "Normal addressing" for diagnosis reports. The BMW standard is "extended addressing". With extended addressing, the amount of user data for each CAN message is 1 byte smaller than with normal addressing. Therefore a "translator" is required to correctly format the CAN messages from the H-CAN and H-CAN2 to the PT-CAN and vice versa. This task is assumed by the HIM as gateway.
- 1-bit signals, no invalid signal detection. At BMW, the signals on the PT-CAN are safeguarded with a checksum. The corresponding signals on the H-CAN and H-CAN2 are either not safeguarded or are safeguarded differently. The checksum is not recalculated in the HIM.
- Varying cycle times. The message format on the H-CAN and H-CAN2 is that from Motorola. The BMW standard is that from Intel.

E72 Complete Vehicle.

Bus systems > Hybrid-CAN

What is the voltage level on the Hybid-CAN? What are the characteristics of H-CAN / H-CAN2? Which control units are connected to H-CAN / H-CAN2?





Hybrid Interface Module (HIM)

The HIM has a gateway function between the control units of the BMW vehicle electrical system and the control units that have been developed as part of the co-operation. Thus the control units known from the E71 vehicle electrical system can be used in the E72 and the control units from the co-operation can also be integrated into the newly developed vehicle electrical system. Here, the HIM acts a "translator" and enables the control units on the PT-CAN to exchange information with the control units on the H-CAN and H-CAN2.

The installation location and the dimensions of the HIM are exactly the same as those of the ARS control unit in the E71. The ARS is omitted in the E72.

In addition to the gateway function, the HIM has the following functions:

- Waking up the co-operation control units
- Evaluating the temperature sensor for the cooling circuit of the hybrid components (PBM and APM)
- Activating the valves for cooling the high voltage battery
- Reading in the shift paddles on the steering wheel
- Measuring the voltage of the auxiliary battery
- Controlling the cut-off relay for the auxiliary battery

Waking up the Co-operation Control Units

Since the H-CAN and H-CAN2 have no network management, the HIM has to control the activation and going to sleep of both data buses as master by activating wake-up lines. To do so, the HIM has two wake-up lines and itself is connected to terminal 15.

If the HIM is woken up via the PT-CAN network management (once the bus is active), the HIM activates the wake-up lines for the H-CAN and H-CAN2. If a co-operation control unit does not wake up after a defined waiting period when the corresponding wake-up line is activated, a fault entry is made in the HIM. This wake-up mechanism is unidirectional. It is not possible to wake up the HIM via the co-operation control units.

The HIM wakes up the following control units: APM, BCM, HCP, MCPA, MCPB, TCM and EMPI. Terminal 15 is controlled as usual by the CAS.

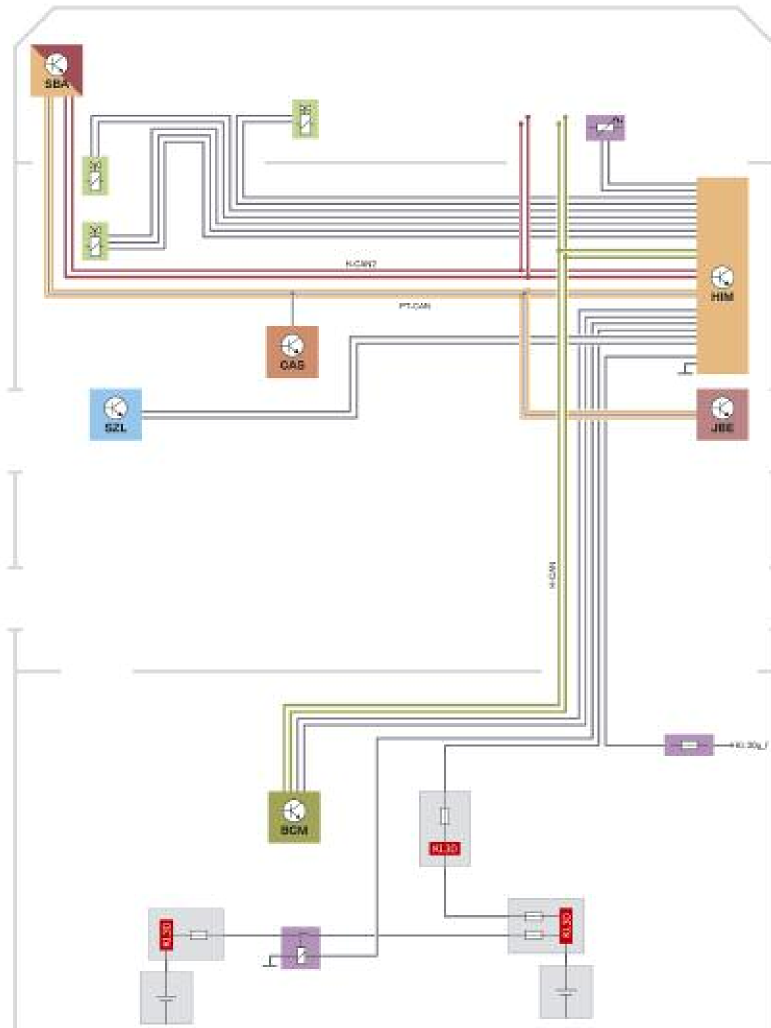
The only exception relating to waking up the data buses or the control units is the DSM control unit. The DSM (Direct Shift Module) is a control unit taken over from Daimler and, unlike other control units on the H-CAN / H-CAN2, does not have a wake-up line, but a CAN transceiver that can be wakened. i.e. the DSM is woken up as soon as the H-CAN is active.

Since there is no network management on the H-CAN, the DSM has to evaluate certain messages for identifying the bus sleep mode. The wake-up mechanism described has been selected to integrate the DSM into the vehicle electrical system without a hardware change and may be used only by the DSM. If another control unit on the H-CAN were to use the same wake-up mechanism, the control units could never go to sleep due to the absence of network management.

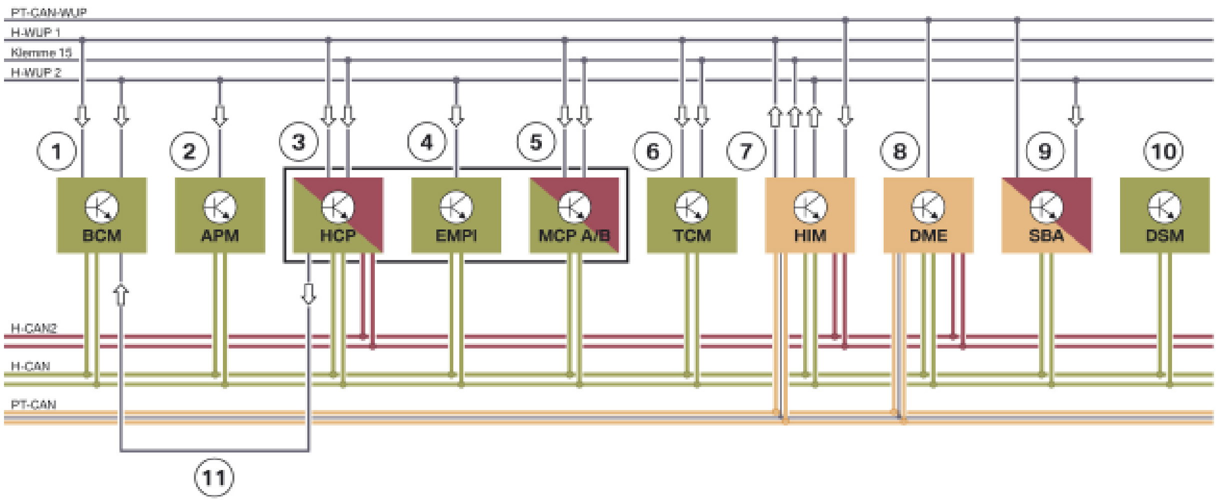
E72 Complete Vehicle.

Bus systems > Hybrid-Interface-Module

What is the installation location of the HIM? What are the functions of the HIM?



Wake-up mechanism of the co-operation control units



Index	Explanation	Index	Explanation
1	BCM battery monitoring module	7	HIM Hybrid Interface Module
2	APM Auxiliary Power Module	8	DME Digital Motor Electronics
3	HCP Hybrid Controller Processor	9	SBA Sensotronic Brake Actuation
4	EMPI Electrical Motor Pump Inverter (hybrid oil pump control unit)	10	DSM Direct Shift Module
5	MCP A/B Machine Controller Pack A/B	11	Direct connection between the HCP and BCM for closing and opening the contacts of the switch contactors
6	TCM Transmission Control Module		

E72 Complete Vehicle.

Chassis and Drive Dynamics > Overview

Please fill in the available features.

Feature	**E71** X6 xDrive 50i		**E72** ActiveHybrid X6	
	Standard	Option	Standard	Option
xDrive all wheel drive	X		X	
Dynamic Performance Control				
Power Steering				
Power Steering with Servotronic function				
Active Steering		X		
Integral Active Steering (incl. rear wheel steering)				
Dynamic Drive		X Package "Adaptive Drive"		
Vertical Dynamic Control (Electronic Damper Control)				
Self-levelling air suspension			X	
Flat tire monitor (RPA)	X (ECE)			
Tire Pressure Monitor (TPM/RDC)	X (US)			

Electronic Power Steering

The optional equipment "active steering" is not offered for the E72. The E72 is only available with electromechanical power steering. This is also referred to as "Electric Power Steering EPS".

Since power steering must also be available while the vehicle is driven in pure electric mode it was decided in development that the E72 would use electromechanical power steering instead of hydraulic steering.

The electric motor which generates the steering servo is arranged axially parallel to the rack and pinion power steering gear. The design principle and the functions of the electromechanical power steering in the E72 are largely identical to the steering implemented in the E89.

The most important changes are:

- Design adaptation to the axle geometry of the E72
- Increase in power of the electric motor based on greater track-rod forces
- Integration into the on-board communication system and the onboard energy system of the E72.

Although a power increase was necessary for the electromechanical power steering for the E72, it is not a high voltage component, but rather a 14 V component. This is the primary purpose for the second 12 Volt battery.

The general characteristics of electromechanical power steering systems are as follows:

- Damping disturbances which originate from the road surface (increased ride comfort)
- Active steering wheel return (increased ride comfort)
- Speed-dependent steering servo "Servotronic" (increased ride comfort and improved driving safety)
- No hydraulic circuit (easier vehicle integration and improved environmental compatibility)
- Requirements-based activation of the electric motor (contribution to lower fuel co sumption)
- Steering servo independent of the speed of the combustion engine.

The EPS steering system consists of the following main components:

- Steering-torque sensor
- EPS control unit
- Electric motor with motor position sensor
- Speed reducer
- Rack-and-pinion steering box

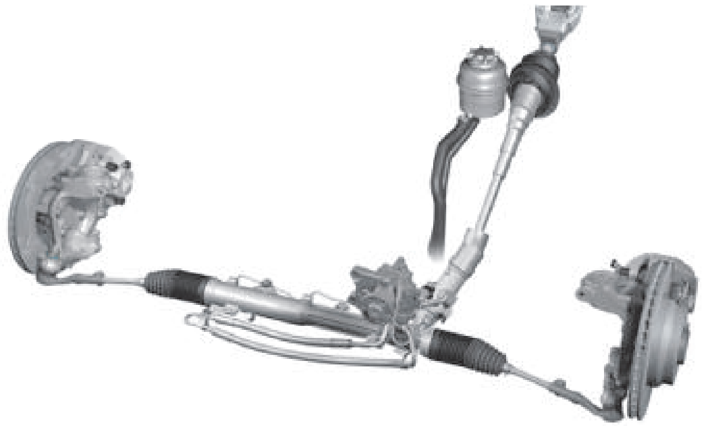
These components form a unit (the "EPS rack-and-pinion steering box") which can only be replaced as a complete assembly during service.

After a new EPS rack-and-pinion steering box is installed, a wheel alignment with toe adjustment must be carried out. In the course of the start-up, a service function must be run to teach in the end stops.

E72 Complete Vehicle.

Electric Power Steering EPS > Overview

Please compare a Hydraulic Power Steering (HPS) with an Electric Power Steering (EPS) system.



Hydraulic power steering	Feature	Electric power steering
	Driven by	
	Energy source	
	Power consumption (peak)	
	Power consumption (combustion engine at idle speed, but no steering)	
	Power consumption (combustion engine at max. speed, but no steering)	

E72 Complete Vehicle.

Electric Power Steering EPS > Interfaces

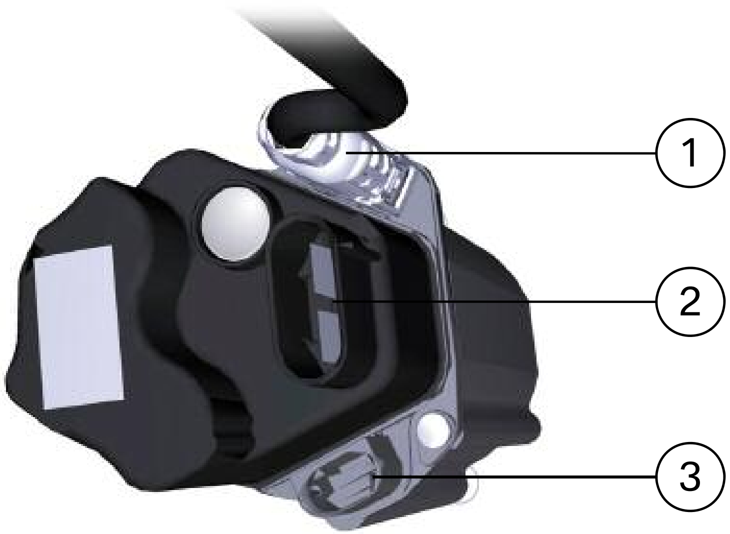
The mechanical interfaces of an HPS and an EPS are basically the same. Which electrical interfaces does the EPS have?

Where are the power lines for the EPS connected?
Do the power lines need "special treatment"?

___

___

___



Write down the electric connections at the EPS motor.

1 ___

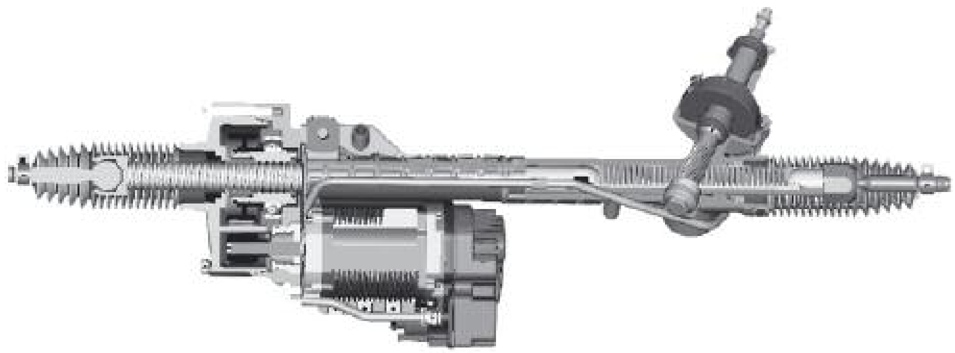
2 ___

3 ___

E72 Complete Vehicle.

Electric Power Steering EPS > Repairs

Which parts of the EPS can you replace separately?



What do you have to do after replacing the EPS rack?

Write down the necessary steps in the correct order below.

1 ____________________

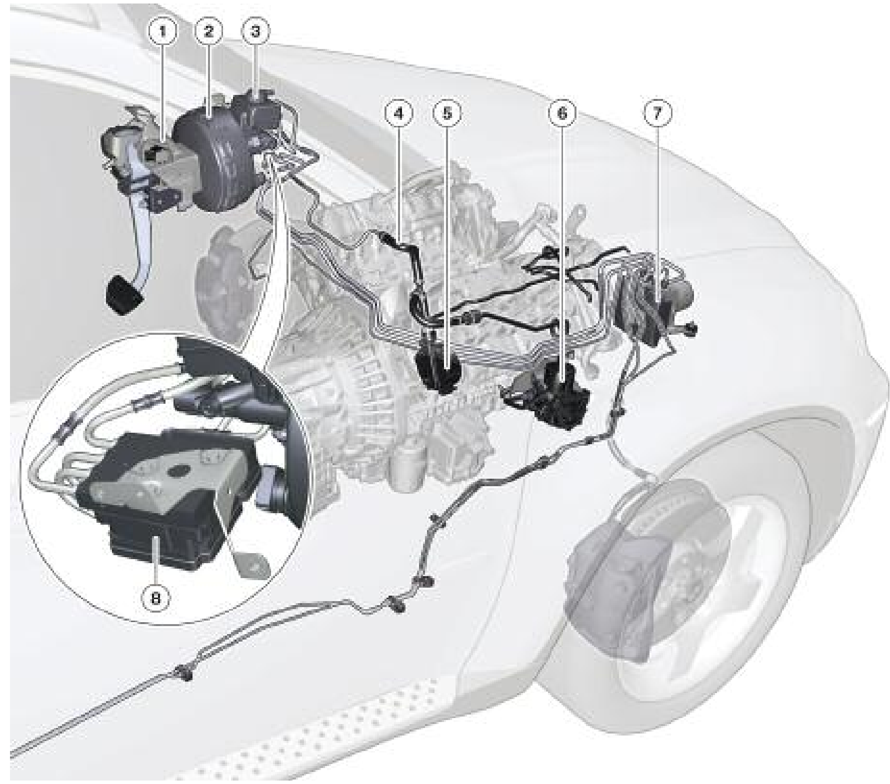
2 ____________________

3 ____________________

Sensotronic Brake Actuation

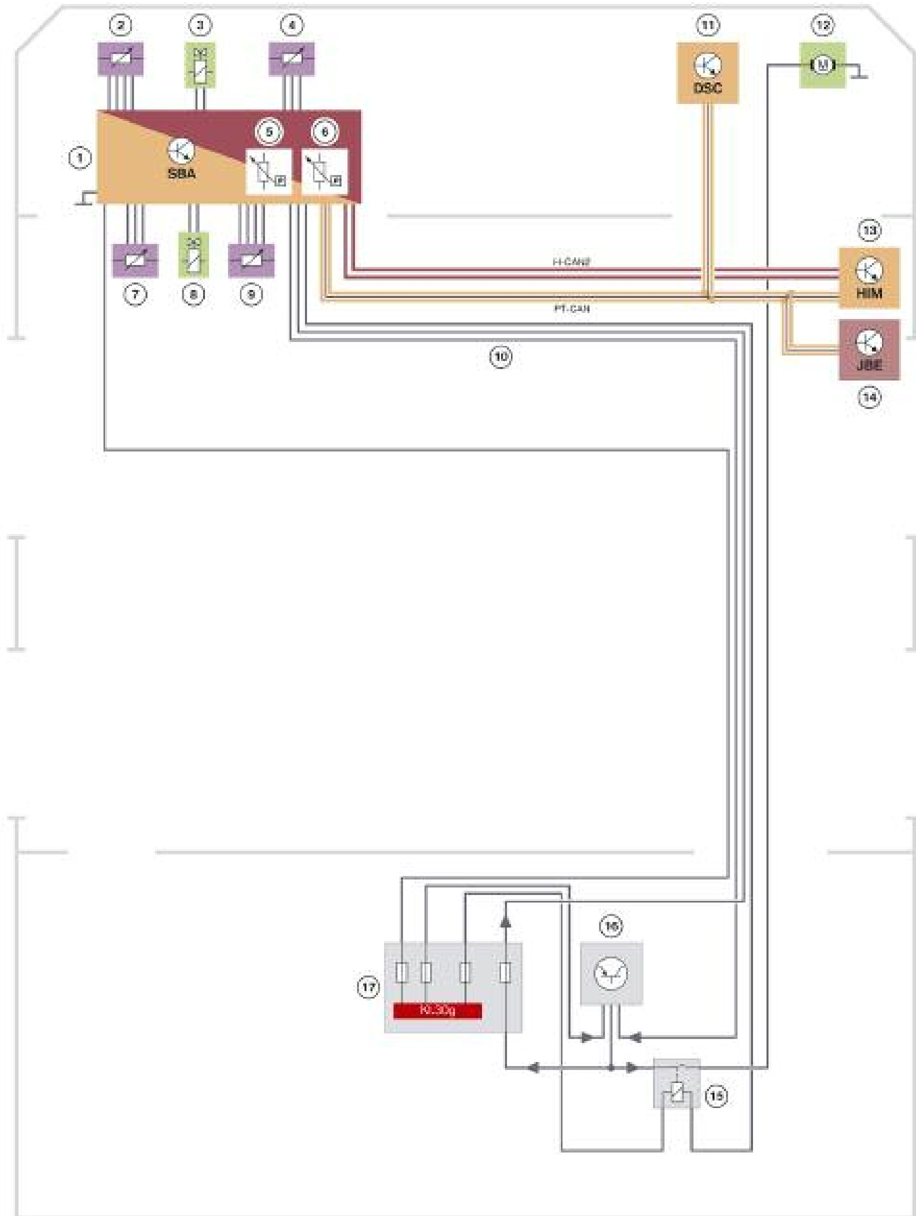
The brake system of E72 serves not only to decelerate the vehicle in a safe and stable manner. It also enables the braking energy of the vehicle to be not converted into heat, but instead recovered and converted into electrical energy using the electric machines in the active gearbox. To attain maximum fuel economy in conjunction with the full hybrid drive of the E72, the brake system must be able to recover as much brake energy as possible. At the same time, the customer has the right to expect the typical BMW brake pedal feeling, exact controllability of the brake force and, of course, outstanding deceleration values in all speed ranges and driving situations. Of course, the hybrid brake system of the E72 meets all of these requirements, thus proving the technological expertise of the BMW Group in this area.

To meet these requirements, a brake system has been developed in which there is not a permanent mechanical connection between the brake pedal and the rest of the brake system (brake servo). Instead, it is a brake-by-wire system, which detects the driver's braking request electronically. Then, the braking request is split into an electrical portion and a hydraulic portion. The electrical portion is converted to electrical energy by the electric machines of the active gearbox and stored in the high voltage battery. The hydraulic portion generates deceleration via the conventional service brake. The braking request is split according to its strength, the driving situation and the state of the hybrid components. In this way, the hybrid brake system can implement decelerations of up to 3 m/s² in pure electric mode. However, a much more important parameter is the percentage of brake energy that can be recovered, across all driving situations. Here, the complex brake system of the E72 attains a very high value of between 80% and 90% – conversely, this means that only 10% to 20% of the entire brake energy is converted into useless heat via the service brake.



Index	Explanation
1	Brake pedal
2	Active brake servo
3	Brake fluid expansion tank
4	Vacuum line
5	Mechanical vacuum pump
6	Electrical vacuum pump
7	Dynamic stability control
8	Hybrid brake actuation changeover (Sensotronic Brake Actuation SBA)

System wiring diagram of hybrid brake system



Index	Explanation
1	Hybrid brake actuation changeover (Sensotronic Brake Actuation SBA)
2	Sensor for brake vacuum
3	Solenoid valve for activating the active brake servo
4	Sensor for diaphragm travel
5	Brake pressure sensor, pressure chamber
6	Brake pressure sensor, floating circuit
7	Pressure sensor of the shut-off unit
8	Valve in the shut-off unit
9	Sensor for brake pedal angle
10	Lines for controlling and monitoring the electrical vacuum pump
11	Dynamic Stability Control (DSC)
12	Electrical vacuum pump
13	Hybrid Interface Module HIM
14	Junction box electronics
15	Electromechanical relay for activating the electrical vacuum pump
16	Semiconductor relay for activating the electrical vacuum pump
17	Hybrid fuse block

Distributed Functions

The SBA control unit is the primary control unit of the hybrid brake system. It controls all processes, from detecting the braking request to activating the actuators of the brake system.

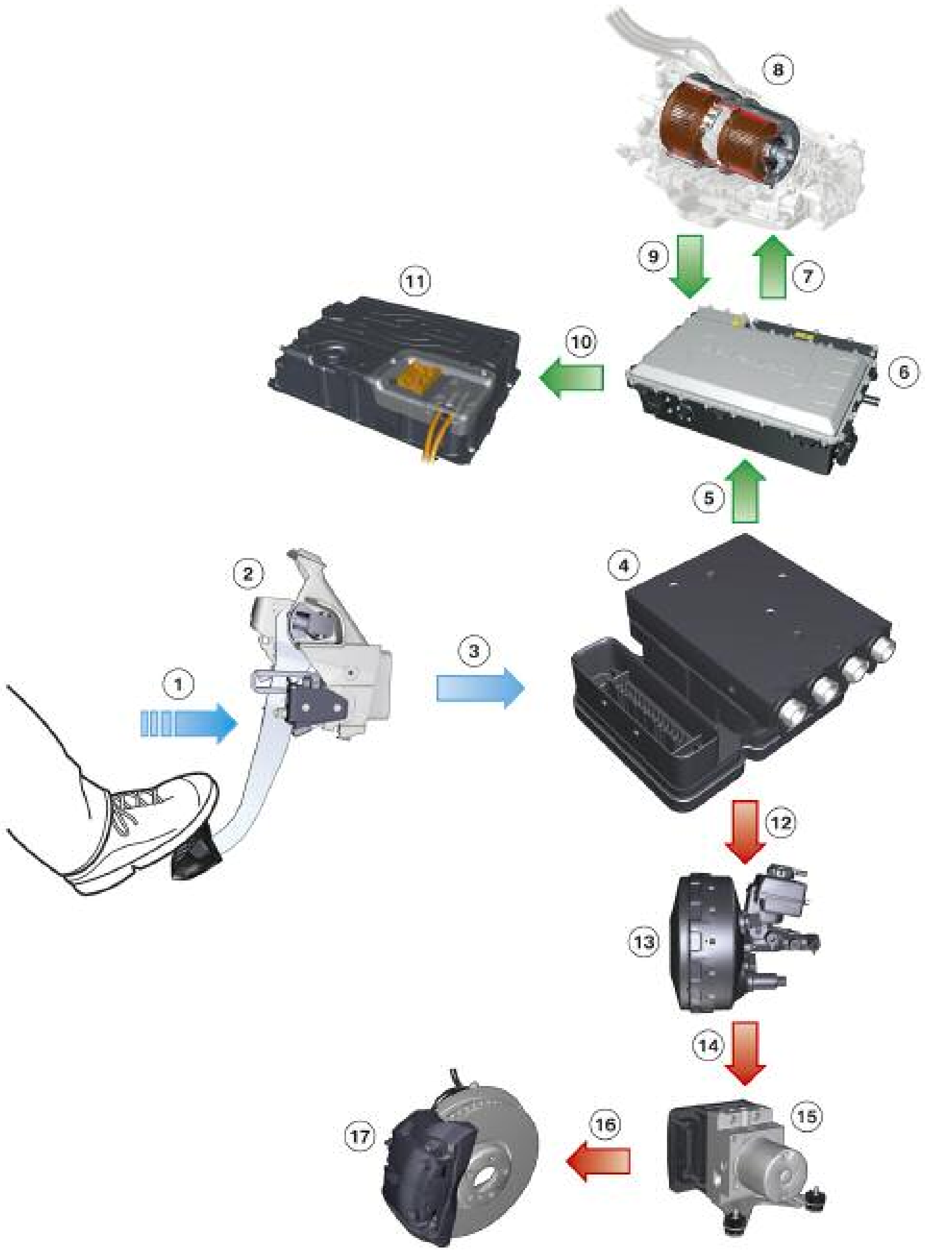
The actuator for regenerative braking is the drive train: using the power electronic box, the electric machines are activated such that they work as generators. So that they can generate electrical energy, they have to be driven mechanically. Thus they absorb torque, which acts as braking torque on the drive train. Therefore, with the possible decelerations of up to 3 m/s², unstable driving situations could result if the braking torque acted on the rear axle only. Therefore, in regenerative braking, the multidisc clutch in the transfer box is also closed. Then, the speeds at the front axle and rear axle are the same, which is the prerequisite for splitting the braking torque almost equally between the two axles.

In this "by-wire" mode, as much brake energy as possible is recovered, i.e. fed to this first, electrical path. The conventional service brake is used for the remaining amount of energy only for decelerations greater than 3 m/s² or if the hybrid drive cannot convert the full brake energy. For this purpose, the SBA control unit activates the active brake servo. The servo generates the brake pressure for both brake circuits, which is distributed to the four wheel brakes by the dynamic stability control.

Only in fault situations or special situations are there emergency functions in which the SBA control unit does not assume the master role. For example, in situations with unstable dynamic handling characteristics, the dynamic stability control assumes the master role, taking higher priority in order to stabilize the vehicle. In that case, regenerative braking is no longer possible.

If one of the components required for regenerative braking fails or the power supply is interrupted, the hybrid brake system switches from "by-wire" mode to a conventional mode. In conventional mode, the mechanical connection between the brake pedal and service brake is once again made. This allows the vehicle to be decelerated safely using the conventional hydraulic brake system.

Implementation of the brake request by the hybrid brake system



Index	Explanation
1	Pressing the brake pedal (force, distance)
2	Brake pedal unit
3	Electrical transmission of the braking request
4	Hybrid brake actuation changeover (Sensotronic Brake Actuation SBA)
5	Nominal value of the regenerative portion
6	Power electronic box
7	Activation of the electric machines as a generator
8	Electric machines in the active gearbox
9	Electrical energy generated by the electric machines
10	Electrical energy to be stored
11	High-voltage battery
12	Electrical activation of the solenoid valve in the brake servo
13	Active brake servo
14	Hydraulic pressure in the two brake circuits
15	Dynamic stability control
16	Hydraulic pressure in the brake lines to the wheel brakes
17	Four wheel brakes

Conventional Mode

The conventional mode is the mechanical fallback level of the hybrid brake system. In this mode, there is again a mechanical connection between the brake pedal and brake servo. Thus the driver can generate a brake pressure in the hydraulic brake system just as in conventional vehicles with brake power assistance, safely decelerating the vehicle. In conventional mode, regenerative braking is no longer possible. Instead, the full braking power is provided by the hydraulic brake system.

If the driver presses the brake pedal in conventional mode, the solenoid valve in the active brake servo is not activated. Thus the push rod initially does not move. As a result, when the brake pedal is pressed, the gap between the bolt and limit position at the end of the push rod is closed, and the mechanical connection mentioned above is created.

From the driver's perspective, this manifests itself as an increase in the free travel. The driver feels hardly any counterforce until the bolt touches the limit position. In conventional mode, the solenoid valve in the shut-off unit is open. Thus the brake fluid in the shut-off unit can flow upwards into the chamber. There, a moving piston is located that can move upwards against a spring force. The spring in the shut-off unit generates a significantly lower counterforce than that in the pedal force simulator. Thus in this case, the spring in the pedal force simulator is barely compressed at all. One could also say that the pedal force simulator is not relevant here. The only remaining counterforce is the spring force of the spring in the shut-off unit, which is very low.

Brake by Wire Mode

After the voltage supply is switched on, the hybrid brake system carries out a self-test of all system components required for proper function of the by-wire mode. If this self-test is completed successfully, by-wire mode is activated. Otherwise, the hybrid brake system remains in conventional mode.

In by-wire mode, the brake pedal is mechanically decoupled from the brake servo. The driver's brake request is evaluated by the SBA control unit using the brake pedal angle sensor. Depending on the driving situation and the state of the hybrid components, this braking request is split into a regenerative portion and a hydraulic portion. To do so, the SBA control unit sends a nominal value to the hybrid master control unit to implement the regenerative portion. The hybrid master control unit then implements this nominal value via the hybrid electric machine control unit A and B control units. The electrical energy generated by the electric machines in this way is stored in the high voltage battery. Here, too, the control units of the power electronic box are involved (converting voltage and current level).

To transmit the hydraulic portion, the SBA control unit supplies current to the solenoid valve in the active brake servo. This allows air to flow into the work chamber, and due to the prevailing vacuum, a force is generated on the pistons in the tandem brake master cylinder. Thus pulls the push rod into the brake servo. As a result, the bolt of the brake pedal, which is plugged through the fork-shaped end of the push rod, cannot reach the mechanical limit position. Thus there is no counterforce when the brake pedal is actuated.

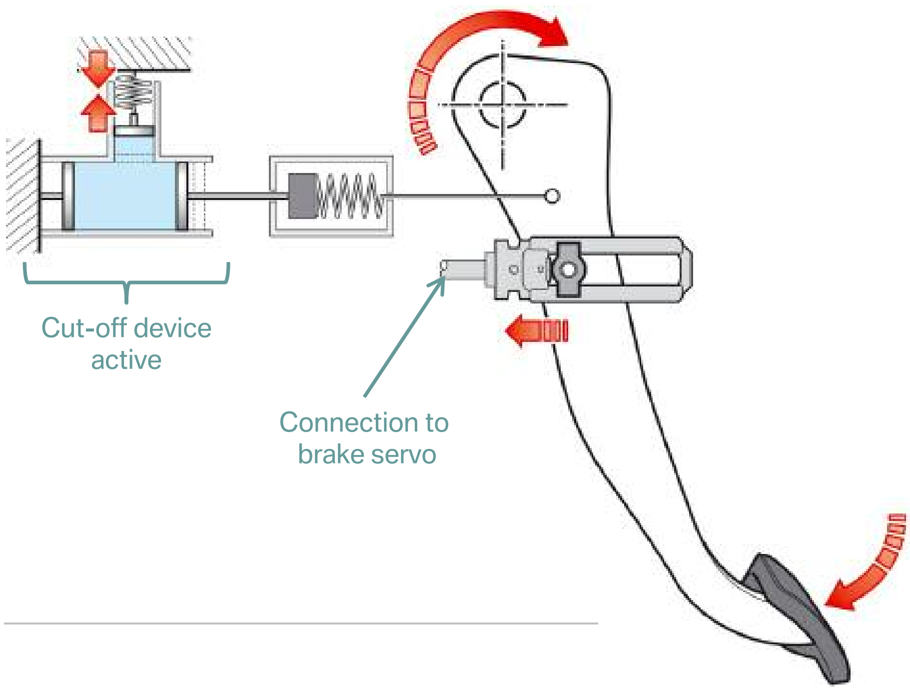
Instead, the counterforce is generated by the pedal force simulator. A force curve has been implemented that is practically identical to that of a conventional brake system. The shut-off unit acts as a rigid element in by-wire mode. The enclosed brake fluid cannot be compressed. Here, it cannot escape into the expansion chamber with the spring, as the chamber is blocked by a solenoid valve.

E72 Complete Vehicle.

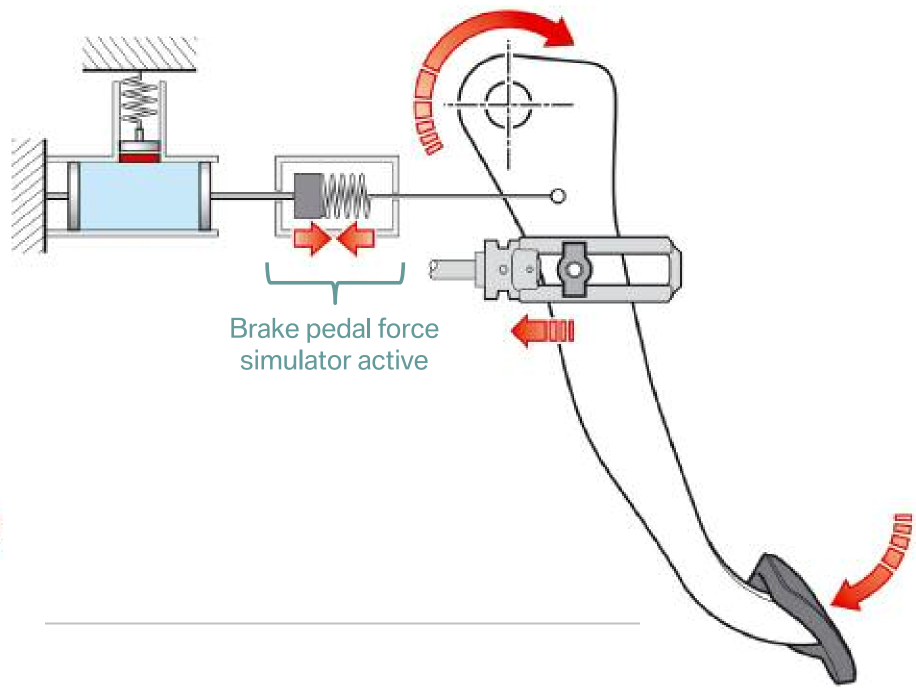
Hybrid braking system > Operation modes

Compare the operation modes. How is the brake force created in each mode?

Conventional mode



Brake-by-wire mode



Active Brake Servo

In the E72, a brake servo with dimensions of 9.5 inches is used. The outwardly visible special feature is the fork-shaped end of the push rod, which holds the bolt of the brake in an elongated hole. The movement of the bolt in the elongated hole reproduces the decoupling of the brake pedal from the hydraulic brake system. This is used in by-wire mode. At the same time, however, a mechanical connection between the brake pedal and hydraulic brake system is also possible, as is necessary for conventional mode.

During service, the components listed below can be replaced individually:

- Active brake servo with push rod and fork
- Brake vacuum-pressure sensor incl. gasket
- Diaphragm travel sensor

Solenoid Valve
The active element of the brake servo is the solenoid valve, which is supplied with current by the SBA control unit in by-wire mode. The activation of the solenoid valve allows air to flow into the work chamber of the active brake servo, which moves the linkage and exerts a force on the tandem brake master cylinder. Thus brake force can be built up in the hydraulic brake system without mechanical actuation by the driver.

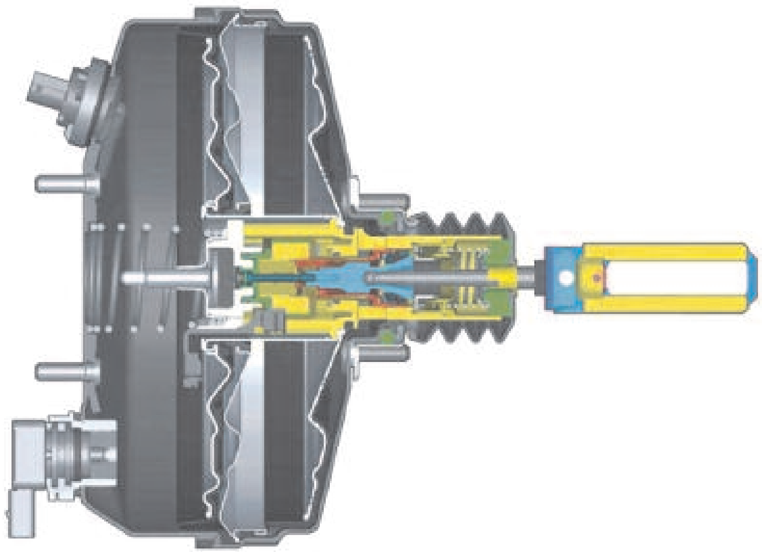
Diaphragm Travel Sensor
To enable continuous monitoring of the function of the electrical activation of the active brake servo, it has a diaphragm travel sensor. This is a tracer pin that follows the movement of the diaphragm. Specifically, this sensor signal enables air pockets in the brake fluid to be found and leaks in the hydraulic system to be discovered. In the case of these problems, the travel distance of the diaphragm is less than expected for the corresponding supply of current to the diaphragm valve. The SBA control unit evaluates the signal of the diaphragm travel sensor and carries out the monitoring. If a fault is detected, the SBA control unit exits by-wire mode and changes to conventional mode. At the same time, it triggers the output of a Check Control message.

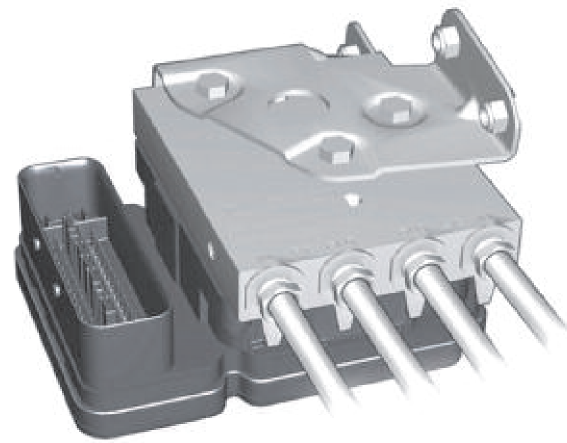
Brake Vacuum-pressure Sensor
In both by-wire mode and conventional mode, a brake vacuum is required to reinforce the brake pressure. Therefore, the brake servo has a redundantly designed brake vacuum-pressure sensor. The SBA control unit uses these signals to continuously monitor the available brake vacuum. If the brake vacuum is too low, the electrical vacuum pump is activated. If the SBA control unit determines a fault in the brake vacuum supply, it sends a command to the digital motor electronics to start the combustion engine. When the combustion engine runs, the mechanical vacuum pump also works, thus ensuring the brake vacuum supply.

E72 Complete Vehicle.

Hybrid braking system > Active brake servo and SBA unit

Take notes about sensors in and connectors at these units below.





Hybrid Brake Actuation Changeover

The "hybrid brake actuation changeover" designates the unit composed of the control unit and hydraulic unit. It is also referred to as the Sensotronic Brake Actuation SBA. The installation location of the SBA unit is to the left of the brake servo. It can only be replaced as a complete unit.

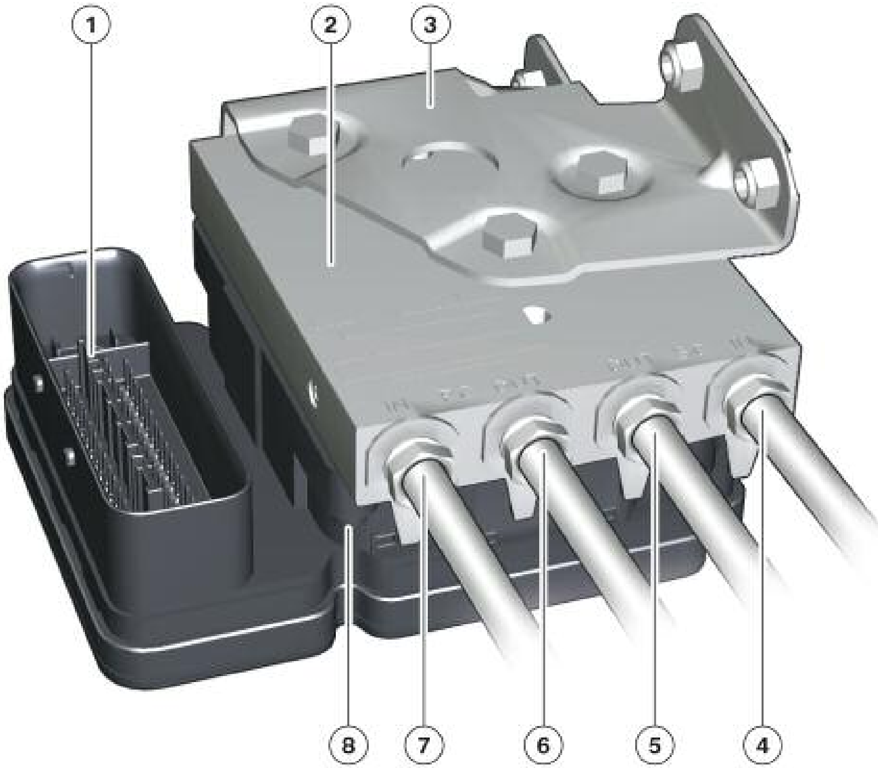
The SBA control unit assumes the master role for brake activation. It measures the driver's braking request and splits this total braking torque into a regenerative portion and a hydraulic portion. For this purpose, the SBA control unit has the following electrical interfaces:

- Brake pedal angle sensor
- Shut-off valve of the shut-off unit
- Pressure sensor of the shut-off unit
- Solenoid valve in the brake servo
- Diaphragm travel sensor in the brake servo
- Brake vacuum-pressure sensor in the brake servo
- Electrical vacuum pump (activation and monitoring)
- Voltage supply
- PT-CAN and H-CAN 2 bus systems

To implement the regenerative portion, the SBA control unit communicates with the hybrid master control unit via the hybrid CAN 2, hybrid interface module and hybrid CAN. The SBA control unit transmits the hydraulic portion by directly activating the solenoid valve in the brake servo. Here, as with all interventions into the hydraulic brake system, the DSC control unit is an important communication partner for the SBA control unit. The following is a summary of important input and output variables of the SBA control unit that are transmitted via bus systems:

Information	Direction	Source/sink
Request regenerative braking torque	Output	SBA > HCP, SBA > DSC > VTG
Request hydraulic brake power assistance	Output	SBA > DSC
Maximum possible regenerative braking torque	Input	DSC > SBA, HCP > SBA
Driving speed and wheel speeds, longitudinal acceleration	Input	DSC > SBA
Stability of the driving situation	Input	DSC > SBA
Status of operating readiness	Input/output	DSC > SBA, HCP > SBA, DME > SBA SBA > DSC, SBA > HCP, SBA > DME

SBA unit



Index	Explanation
1	Electrical connector
2	Hydraulic part
3	Bracket
4	Connection for rear brake circuit brake line, input from tandem brake master cylinder
5	Connection for rear brake circuit brake line, output to DSC unit
6	Connection for front brake line, output to DSC unit
7	Connection for front brake line, input from tandem brake master cylinder
8	Control unit

Electrical Vacuum Pump

During phases of driving in pure electric mode, the combustion engine is at a standstill and thus does not power the mechanical vacuum pump. To ensure the brake vacuum supply even during these phases, the E72 has an additional electrical vacuum pump. It is installed in the engine compartment, on the right as seen in the direction of travel, on the front end of the crankcase.

The pump element is a double diaphragm pump. The inner structure is almost symmetric, so that one intake valve and one discharge valve are installed on each of the two end faces. The two valves can be identified by the shape of the housing cover. The pump input is connected to the vacuum line. The pump draws in air at the input, thus generating a vacuum. The air that is drawn in is fed to the outside via discharge holes on one housing cover.

The electrical vacuum pump can be replaced during service only as a complete unit.

The motor of the electrical vacuum pump is supplied with current using the SBA control unit and two relays. The relays are:

- One electromechanical relay installed in the spare wheel well just to the right of the second 12 V battery.
- One semiconductor relay installed in the area of the right rear light.

The two relays for activating the electrical vacuum pump are switched in series. In normal operation, the SBA control unit switches on the electromechanical relay as soon as terminal 30g is switched on. However, the actual switching on and off of the electrical vacuum pump is carried out by the semiconductor relay. This provides the advantage of a gear shift that is free of wear and noise.

Activation of the Electrical Vacuum Pump

Of course, the semiconductor relay used here is also designed to last the service life of the vehicle. If, despite this, there should be a component defect of the semiconductor relay, measures must be taken so that the hybrid brake system still functions reliably.

If, after the combustion engine is started, the brake vacuum supply from the mechanical vacuum pump is working properly, the hybrid brake system remains in by-wire mode even in the event of a fault of the electrical vacuum pump. Otherwise, the hybrid brake system switches to conventional mode.

The SBA control unit can identify any component defects using the monitoring line, which branches off between the output of the semiconductor relay and the switching contact of the electromechanical relay. The SBA control unit measures the current at this monitoring line and compares it to the expected value, which depends on the required switching modes (relay on or off).

The SBA control unit controls the demand-based switching on and off of the electrical vacuum pump based on the information regarding whether the combustion engine is running and the brake vacuum, measured at the brake servo. If the brake vacuum is too low, it activates the electrical vacuum pump.

Dynamic Stability Control

With regard to its hardware, the dynamic stability control has the same structure as that of the E70 or E71. However, the range of functions of the software had to be adapted to the system network of the hybrid brake system.

Following is a brief list of these changes:

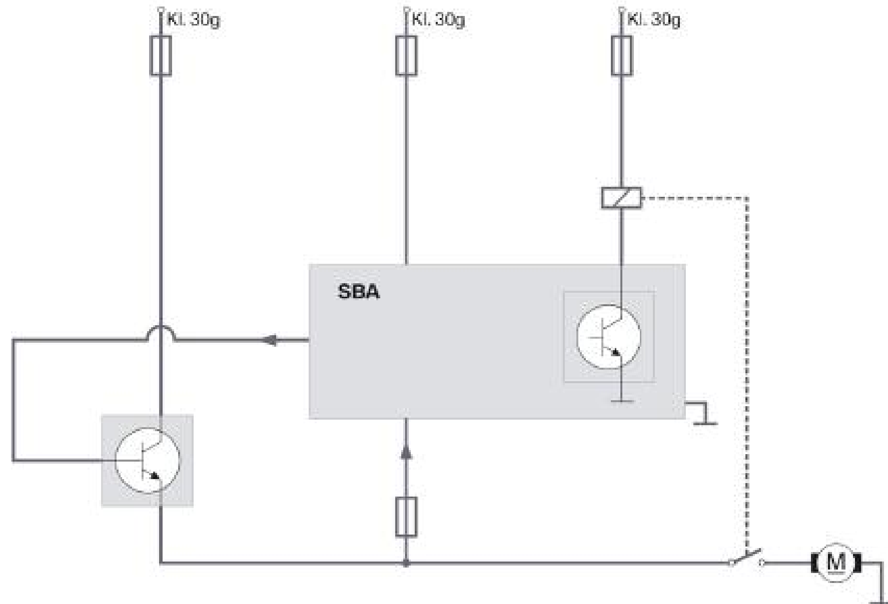
- Providing the hydraulic brake power assistance
- Activating the multidisc clutch in the transfer box for regenerative braking
- Evaluating the stability of the driving condition and providing it as a bus signal

E72 Complete Vehicle.

Hybrid braking system > Electric vacuum pump

Mark the inlet and the outlet of the electric vacuum pump at the graphic.

In which driving situations will the electric vacuum pump be activated?



What is the purpose of the electromechanic relay and the semiconductor relay in terms of the electric vacuum pump?

Where are the relays located in the car.

Displays

The hybrid-specific operating conditions and the charge state of the high voltage battery are displayed in the instrument panel and, if desired, in the central information display. The following hybrid-specific operating conditions are displayed:

- "Ready to drive" display
- Display for driving in electric mode
- Display for boost function
- Energy recovery

They are displayed in the instrument panel at all times in the bottom section of the engine speed display. The display for hybrid is called up in the CID via the "Vehicle info > Hybrid" menu. Both the display in the CID and in the instrument panel are activated when terminal 15 is switched on.

Instrument Panel

If terminal R is switched off, the needle of the engine speed display points to "OFF". This signals to the driver that both the combustion engine and the electric machines are switched off. The needle for the state of charge of the high voltage battery likewise points to null.

Index	Explanation
A	Display indicating "ready to drive" is not activated
B	Display indicating "ready to drive" is activated
C	Display for driving in electric mode
D	Display when the vehicle is powered solely by the combustion engine
E	Display during the boost function
F	Display during coasting (overrun) mode or braking (energy recovery)

E72 Complete Vehicle.

Displays, Indicators and Controls > Instrumentcluster

Write the terms for the display of hybrid functions in the boxes below. Which driving situation is displayed?

Indicators in the Central Information Display

In all operating conditions of the vehicle, the energy/power flows and the state of charge of the high voltage battery can be shown in the CID. This allows the driver to have an overview of the operating principle of the hybrid system in various driving conditions. The displays for hybrid are called up in the CID via the "Vehicle info > Hybrid" menu.

The display of the energy/power flows works according to the following principle:

- Blue: electrical energy
- Red: energy of the combustion engine
- Arrow: direction of the energy/power flow

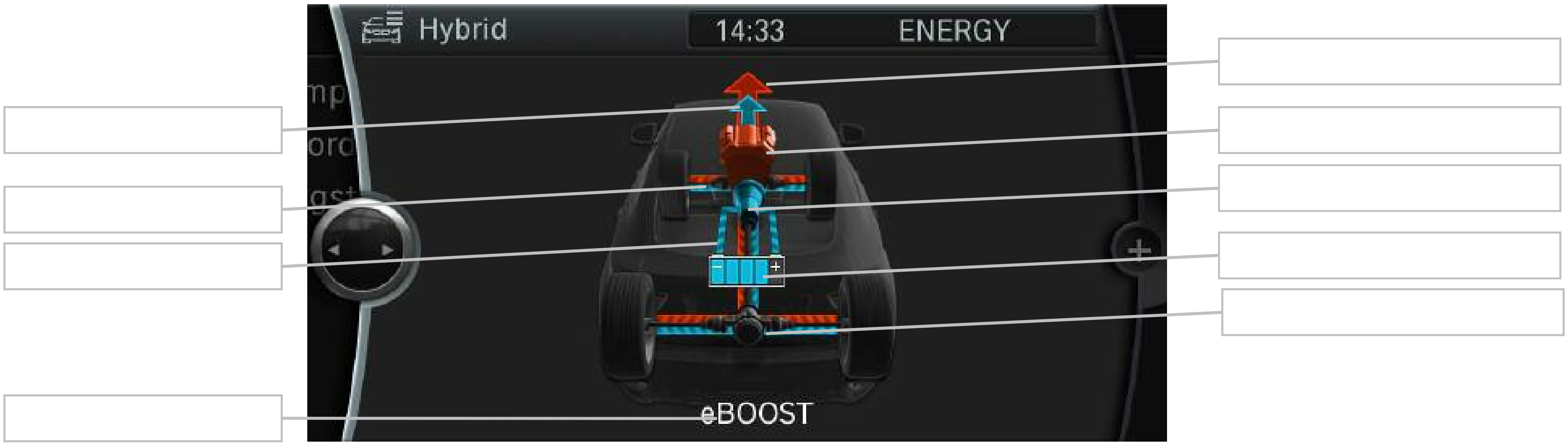
During sharp acceleration (boost function), power for the vehicle is drawn simultaneously from the combustion engine and both electric machines. This is indicated by a red arrow (portion drawn from the combustion engine) and a slightly smaller blue arrow (portion drawn from the electric machines). When the combustion engine is activated, it appears in red (otherwise, it is gray). The activity of the electric machines in the active gearbox is signalled by a blue color of the gearbox. The five segments symbolize the state of charge of the high voltage battery. In the example above, 4 segments are filled. This corresponds to a state of charge of 80%.

Because the power is drawn from both the combustion engine and the electric machines, the power flow to the output shaft is divided in two and indicated in two colors. Red corresponds to the portion drawn from the combustion engine and blue, the portion drawn from the electric machines. The arrow points in the direction of the drive gears. In the same way, the power flow to the front and rear axle is displayed. The energy flow from the high voltage battery to the electric machines is indicated by two blue lines.

Hybrid menu on Central Information Display

E72 Complete Vehicle.

Write the terms for the display of hybrid functions in the boxes below. Which driving situation is displayed?

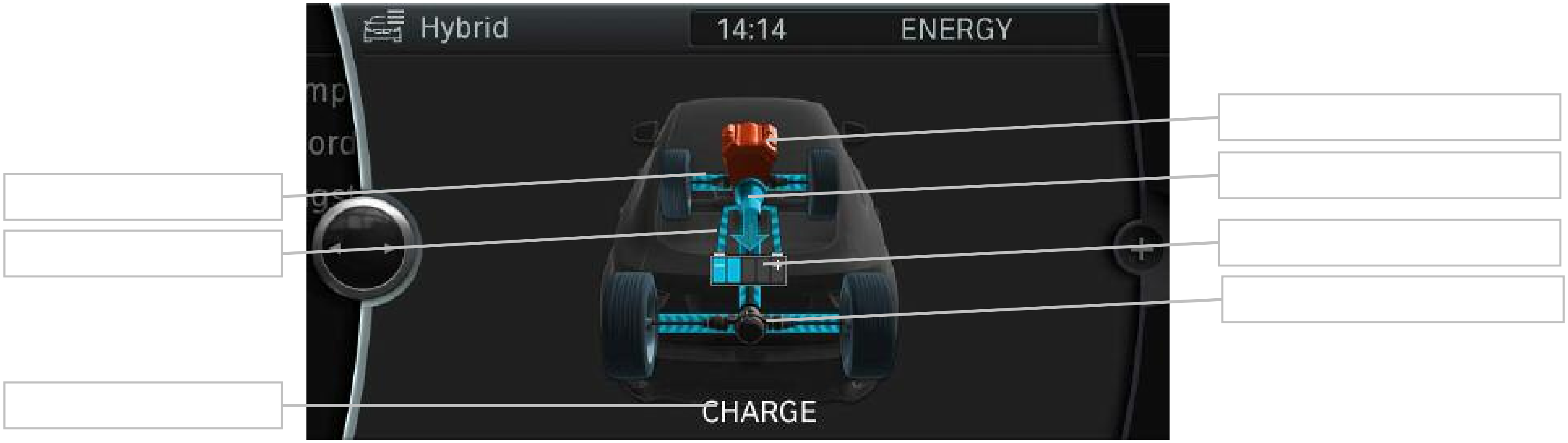


Notes:

E72 Complete Vehicle.

Displays, Indicators and Controls > Central Information Display

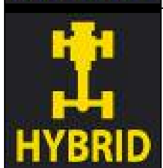
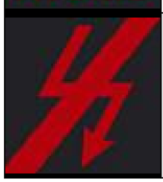
Write the terms for the display of hybrid functions in the boxes below. Which driving situation is displayed?



Notes:

Hybrid-specific Check Control Messages

If faults occur in the E72, the driver is informed of these by means of the Check Control messages. The following table summarizes the hybrid-specific Check Control messages.

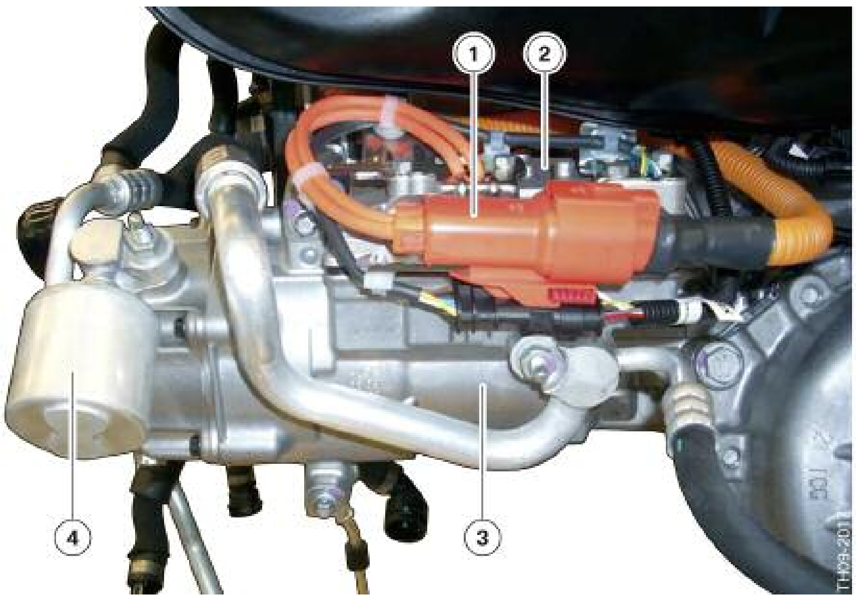
Display	Meaning	Cause
	Refuelling is possible in… s	Hybrid pressurized fuel tank Refuelling request detected
	Hybrid battery is charging, charging procedure finished, etc.	These Check Control messages can have various causes, such as charging source connected, driver must switch on ignition, charging procedure in progress, etc.
	Engine malfunctioning Power loss or Engine Engine does not shut off or hybrid system malfunctioning. Engine malfunctioning	E-machine fault, BPCM fault, TCM fault, E-machine has failed, ELUP fault, vehicle can only be driven conventionally using combustion engine
	Engine Cannot continue driving	Hybrid system shut down
	Hybrid system malfunctioning	Insulation fault, HV interlock fault or HV battery fault
	Hybrid system shut down.	HV system shut down

Although there are two different power sources and two different energy accumulators, there are no differences in operating an ActiveHybrid X6 compared to a conventional vehicle. Depending on various parameters, the hybrid system automatically configures the best settings for driving dynamically and effectively.

Climate Control

The E72 is the first BMW production vehicle to use an electrically driven air conditioning compressor. Because the air conditioning 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.

Electric A/C Compressor EKK



Index	Explanation
1	High-voltage connector for EKK
2	EKK control unit and DC/AC converter
3	Electric A/C compressor
4	Silencer

Note: The electric A/C compressor is a high voltage component!

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 an extra safety precaution is implemented as a means of imposing an automatic shutdown of the high voltage system. The plug connections on the electric A/C compressor are designed such that the 12 V connector always has to be disconnected first. Only then is it possible to disconnect the high voltage connector.

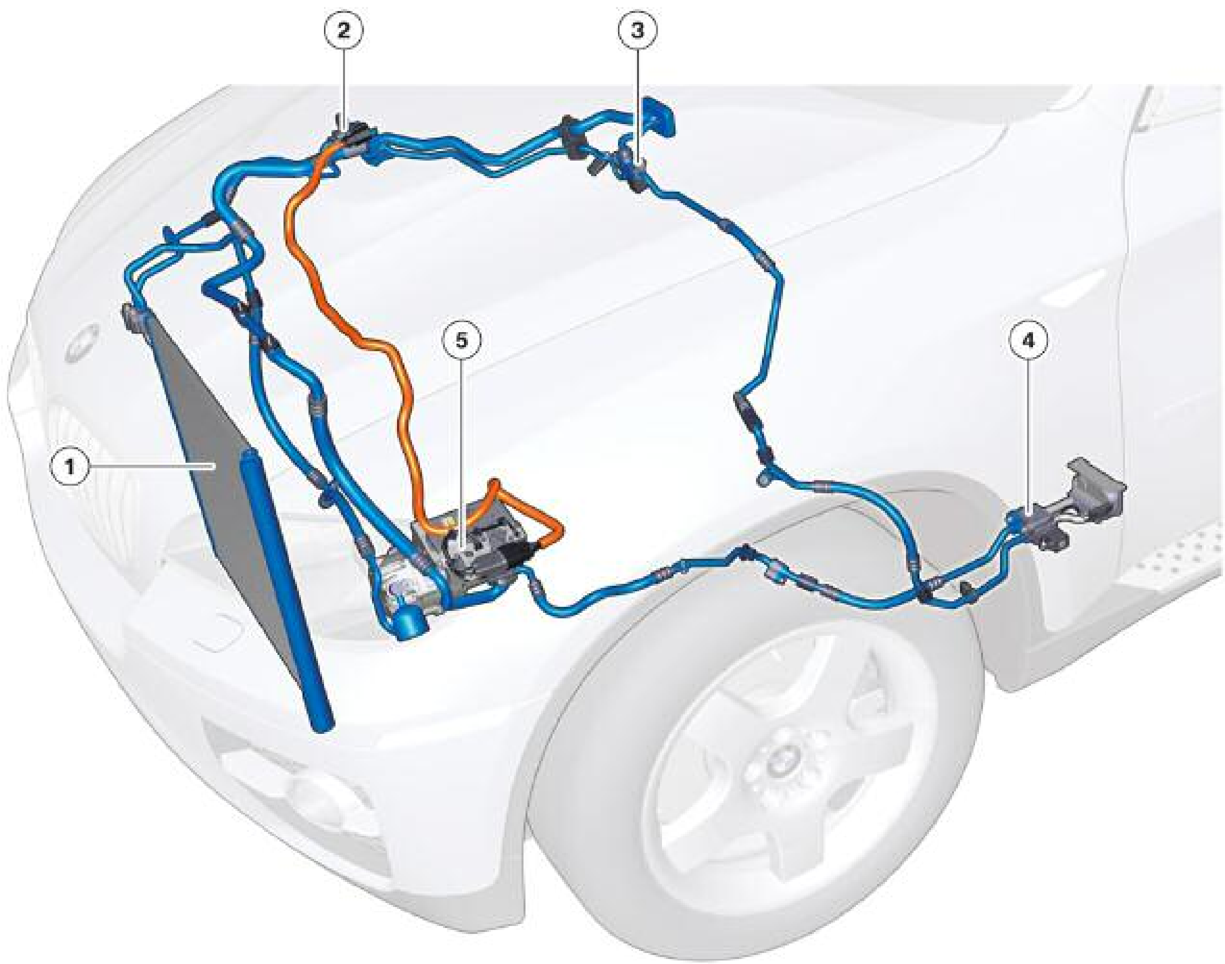
Disconnecting the 12 V connector interrupts the circuit of the high voltage interlock loop (HVIL) and de-energizes the high voltage electrical system.

The electric A/C compressor in the E72 is installed in the same location as the belt-driven air conditioning compressor of the E71. Because the electric A/C compressor in the E72 is not driven via the drive belt, it could theoretically have been installed anywhere in the vehicle, but for space reasons and to use the existing connections to the condenser, the installation location has not changed.

Note: The only Service employees permitted to work on the high voltage components identified in this way are those who satisfy all the requirements for undertaking work of this nature: qualification, compliance with the safety rules, procedure strictly in accordance with the repair instructions.

E72 Complete Vehicle.

Climate Control System > Overview



Write the new components of the climate control system below.

1 ______________________________

2 ______________________________

3 ______________________________

4 ______________________________

5 ______________________________

Notes:

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EKK Control Unit and DC/AC Converter

The EKK control unit controls the speed of the air conditioning compressor depending on the requirements of the IHKA (integrated heater and air conditioner). In addition, it carries out the diagnostics for the EKK and communicates with other control units via PT-CAN. The DC/AC converter converts the direct current voltage into the alternating current that is required to operate the three-phase motor.

The control unit and the DC/AC converter are integrated into the aluminum housing of the entire air conditioning compressor and are cooled by the flow of gaseous refrigerant. If the temperature of the DC/AC converter exceeds 110°C, it is shut off by the EKK control unit. Various measures, such as increasing the speed for self-cooling, are implemented to prevent the temperature from reaching such a level where possible. The temperature is monitored by the EKK.

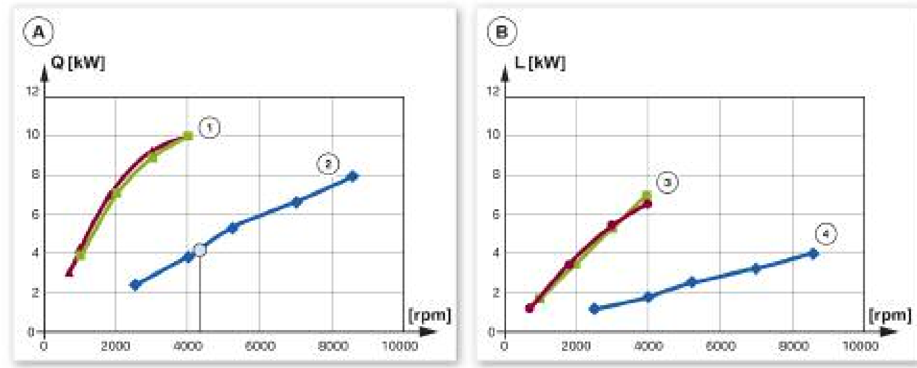
Three-phase Motor

A three-phase synchronous motor is used as the drive for the air conditioning compressor. It is an internal rotor motor. The magnetic field of the rotor is provided by six permanent magnets. The synchronous motor is operated in the speed range between 2000 and 9000 rpm and is infinitely variable. It consumes up to 5 kW of electric power.

Compression Mechanism

To compress the refrigerant, the spiral compressor (also known as the scroll compressor) is used.

After three revolutions, the refrigerant drawn in is compressed and heated and can escape in a gaseous state through an opening in the center of the outer disk. From here, gaseous refrigerant with high temperature and high pressure escapes via an oil separator at the connection of the air conditioning compressor towards the condenser.



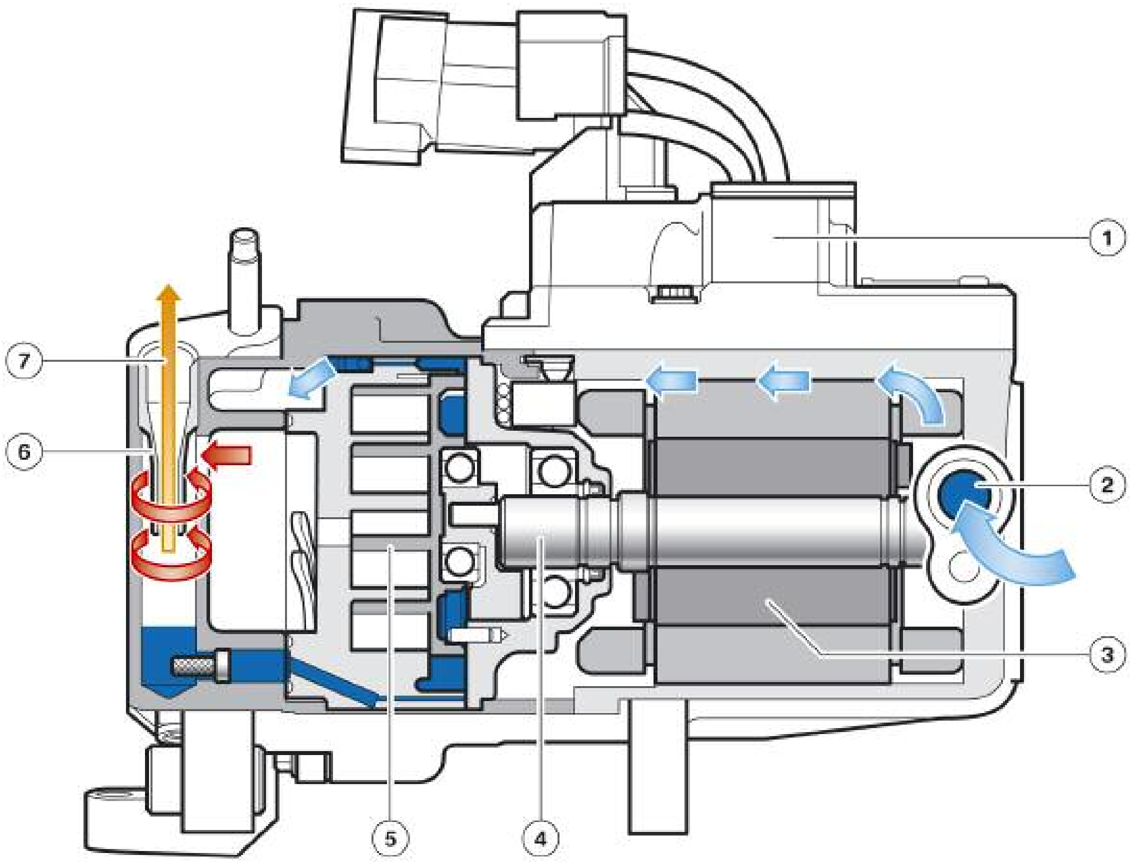
A: Comparison of the cooling power of a belt-driven and an electric A/C compressor

B: Comparison of the mechanical and electrical power consumption of a belt-driven and an electric A/C compressor

Index	Explanation
1	Cooling power of a belt-driven air conditioning compressor as a function of the speed of the combustion engine
2	Cooling power of an electric A/C compressor as a function of the speed of the electric motor
3	Mechanical power consumption of a belt-driven air conditioning compressor as a function of the speed of the combustion engine
4	Electrical power consumption of the electric air conditioning compressor as a function of the speed of the synchronous motor

E72 Complete Vehicle.

Climate Control System > Electric A/C compressor

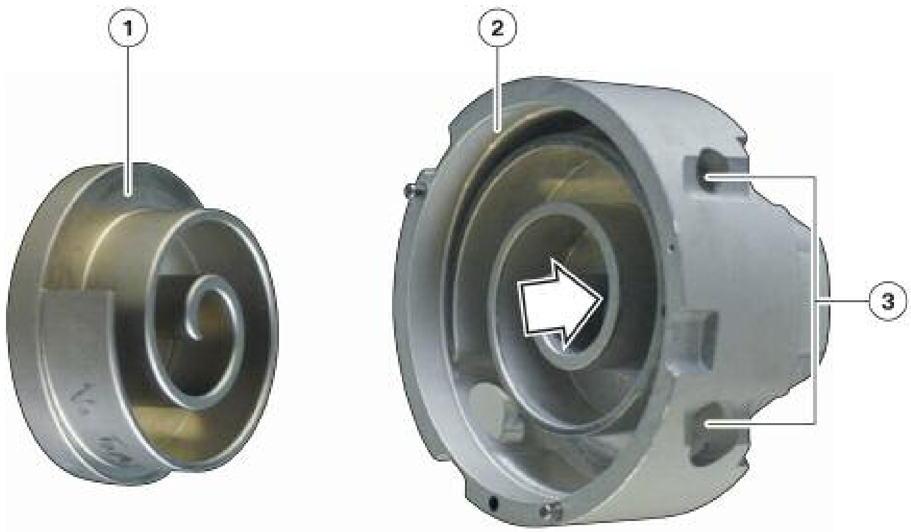


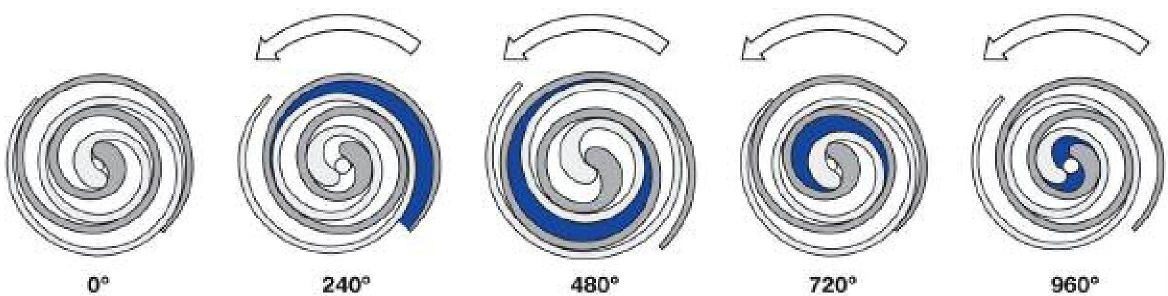
Fill out the following table with the information provided by the facilitator.

Index	Explanation
1	
2	
3	
4	
5	
6	
7	

E72 Complete Vehicle.

Climate Control System > Electric A/C compressor > Function





Index	Explanation
1	Inner disk with spiral profile
2	Outer disk with spiral profile
3	Intake openings for the refrigerant

Explain the scroll-principle.