Automotive Technologie in Bavaria + e-Car

GLOBAL PARTNER

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... encountering the future.

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Today's knowledge for tomorrow's innovations

Dear readers,

the entire automotive industry is currently experiencing a sea change that is radically changing our business model. Megatrends such as digitalization and electric mobility are bringing brand new players into the game, including some from other industries. Our aspiration is to set the trend and bring innovations to the market at a rapid pace. For the procurement function of a car company, this means looking outside of the core business to find partners for collaboration on key technologies. We have there fore introduced a new innovation process, the FAST program, to integrate our strategic partners into our future plans earlier than ever. We are engaged in an intense dialogue with our service partners, exchanging ideas and concepts that we then develop to market maturity in collaboration with them.

In 2018, Audi will be launching its first fully battery-powered electric SUV. With a range of 500 kilometers, it will be fully suitable for everyday use. Piloted parking and piloted driving at speeds up to 65 km/h will make their production vehicle debut with the next generation of the Audi A8.

What exactly do these trends mean for us? Electrification is changing the automobile at its core and calls for entirely new technical concepts. If the Audi of tomorrow offers automated driving, we can completely rethink the interior concept and operating logic. And as innovators, our suppliers play a tremendously important role here. We want to reinterpret the automobile and shape the future of mobility in collaboration with our partners.

We are also banking heavily on the ideas of suppliers in our home region, which we greatly appreciate for its tremendous power of innovation. It is not without reason that our experts are working on such future topics as electrification and digitalization at our headquarters in Ingolstadt, at the very heart of the high-tech location Bavaria.

We are constantly searching for capable and innovative suppliers. We want the best partners at our side so that together we can create *Vorsprung*.

Dr. Bernd Martens

Member of the Board of Management
of AUDI AG,
Procurement

Automobiltechnikum Bayern GmbH in Hof

Founded by the Bavarian Ministry of Economic Affairs, Infrastructure, Transport and Technology, the test laboratory is accredited according to EN 17025 and situated within the Automobilzulieferpark (= Automotive Supplier´s Park) Pole Position at Hof-Gattendorf. It performs tests and experiments in accordance with customerspecific test instructions and requirements. As regards concepts, the tests are supervised by competent staff. Engineering services and solutions to problems as well as constructional adjustments are offered individually.

Concerning service strength, three Occubot seat test robots made by KUKA are available at ATB. Using a system for changing test dummies does not only provide an automated programme process, but a continuous picture documentation as well. At the same time the test loads are constantly observed and readjusted. The area of service strength comprises as well four spring testing machines, versions "Schenck" and "Reicherter Short and Long Stroke".

The servo-hydraulic testsystem with a total of 8 hydro-pulse cylinders operates with loads of up to 40 kN and mximum strokes of 400 mm.

Two electric stroke cylinders with loads of up to 20 kN and maximum strokes of up to 350 mm can also be operated in connection with a climate chamber of 1,5 m^3. Tests with lower loads may be run by using various pneumatic stroke cylinders.

The area environmental simulation disposes of 14 climate chambers with sizes ranging from 240 litres to 30 m3, the latter being accessible by vehicles. Temperature ranges lie between -70 °C and 180 °C, the relative humidity can be programmed continuously between 10 % and 97 %.

Forschung und Entwicklung

The two heating furnaces with a volume of up to 720 litres allow tests up to 300 °C. The salt spray fog chamber with a test volume of 2 m³ complies with all established test standards, also for condensation tests.

The measuring laboratory contains a material testing machine for tensile and pressure tests, several digital tracers by HBM with up to 8 measuring channels per system, an infrared camera and a digital light optical microscope with up to twohundredfold enlargement. Furthermore, photogrammetric surveys are offered, thereby using a system produced by AICON respectively a stripe light scanner produced by Steinbichler.

The 90 kN shaker is fitted with a Head expander measuring 150 cm x 150 cm. The frequency range goes from 5 Hz to 3000 Hz. Maximum acceleration is achieved at 150 g. In addition, the control system enables tests in multisinus mode.

In addition, a climate chamber of 15 m³ may be positioned over the support plates.

For further informations please see our homepage:

www.atbayern.de

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quattro with ultra technology – all-wheel drive for the future

Audi opens a new chapter in the history of quattro: The new quattro with ultra technology combines driving dynamics and safety with highefficiency, making the all-wheel drive system fit for the future. The system is designed for numerous Audi models with longitudinally mounted front engines. An initial variant will debut in the new Audi A4 allroad quattro in mid-2016.

With quattro permanent all-wheel drive, Audi has extended its lead over a period of more than three decades. Now it‘s time for the next big step: quattro in combination with ultra technology.

The development goal of quattro with ultra technology is an all-wheel drive system optimized for efficiency with no discernible differences to permanent systems with respect to traction and driving dynamics.

The system should set benchmarks in its class for fuel consumption and CO_2 emissions, particularly under everyday conditions. With correspondingly equipped test vehicles, Audi developers used on average 0.3 liters/100 kilometers less fuel than with conventional all-wheel drive. The tests were conducted on a route throughout the Ingolstadt area and in normal traffic.

At first glance, these requirements hardly appear to be reconcilable. But through the interaction of the newly developed all-wheel drive components and a sophisticated operating strategy, the Audi developers were able to achieve this goal. The results: The all-wheel drive system‘s intelligent control works predictively, always looking ahead by means of a comprehensive array of sensors and the continuous analysis of the driving dynamics, road condition and driver behavior data collected. Consequently, the quattro all-wheel drive system is always ready when needed. During standard operation at low loads without the risk of wheel slip, the new quattro taps into all the advantages of front-wheel drive.

All-wheel drive is always deactivated when it is not needed, but remains permanently available, significantly reducing the potential fuel consumption difference between front-wheel drive and permanent all-wheel drive. ■

Audi A4 allroad quattro – front view ■

The strategy

The all-wheel drive system is activated before the driver needs it. In fact, all activations and deactivations follow a highly differentiated strategy.

The quattro electronics are networked with a number of other control units. Every ten milliseconds, the system acquires and analyzes a wide variety of data, such as steering angle, lateral and longitudinal acceleration and engine torque to name just a few.

Activation of the all-wheel drive system follows a three-stage strategy: proactive, predictive, i.e. forward-looking, and reactive.

Audi quattro with ultra technology – Front-wheel-drive mode ■

On the proactive level, the focus is on the data delivered by the networked systems in the car. The control unit uses these data to, for example, compute the point when the inside front tire will reach the limit of grip during fast cornering.

The calculation is completed roughly 0.5 seconds prior. If the wheel approaches the limit of grip to within a defined threshold, the all-wheel drive system is activated.

With predictive activation, the quattro control unit orients primarily on the driver's style, the status of the ESC and the mode selected in drive select, and on the trailer detection system.

With reactive activation, which rarely occurs in practice, the system reacts to sudden changes in the coefficient of friction. These occur, for example, when the wheels go from dry asphalt to a sheet of ice.

quattro all-wheel drive is more frequently active in winter than in summer because the coefficients of friction are lower then. The need for all-wheel drive is generally higher at low and moderate speeds with acceleration phases than when driving fast at a constant speed. Use of quattro all-wheel drive is therefore lower on the highway, in particular.

However, the car can also be driven safely on a snow-covered road with just front-wheel drive if the road is straight and speed remains constant. On the other hand, if the car is being driven dynamically on a winding road, all-wheel drive remains active at all times, even on dry, grippy asphalt.

The optimal distribution of power between the front and rear axles is computed continuously when the system is active. The control strategy considers ESC data, ambient conditions, the driving situation and the wishes of the driver. The power can be optimally distributed between the two axles at all times as a function of these factors.

There is generally sufficient time available for deactivation of the all-wheel drive system. In contrast, operational requirements determine the speed at which the clutches close to activate the system. In certain driving situations, this has to occur in just fractions of a second.

By networking quattro drive with Audi drive select, the driver can adjust the all- wheel-drive properties to suit his or her individual requirements. The auto mode in drive select provides the best possible traction and balanced driving dynamics. In dynamic mode, power is sent to the rear axle sooner and to a larger degree, improving the driving dynamics particularly at low coefficients of friction. Wheel-selective torque control – a software function of the ESC – smooths out the handling as needed by minimally braking the inside wheels. ■

Two clutches – the technology

The enhanced efficiency is made possible by two clutches in the drivetrain. When the system changes to front-wheel drive, the

Audi quattro with ultra technology ■

Audi A4 allroad quattro ■

front clutch – a multi-plate clutch at the transmission takeoff – disconnects the propshaft. An integrated decoupler in the rear-axle differential also opens, shutting down the primary cause of drag losses in the rear section of the drivetrain.
At the same time, the quattro drivetrain is nearly four kilograms (8.8 lb) lighter than the previous system despite the new technical components. That, too, saves fuel and benefits handling. ■

The multi-plate clutch

The all-wheel drive clutch is located at the rear end of the transmission.
An electric motor integrated into the quattro control unit powers a spindle drive that actuates the multi-plate clutch. Depending on the model, the clutch comprises a package of five or seven pairs of plates that rotate in an oil bath. The friction rings are arranged behind one another in pairs. The first is permanently meshed with the clutch basket, which rotates with the input shaft. The next ring is meshed with the output shaft to the rear axle differential. When the plates are pressed together, the all-wheel drive system is activated. The contact pressure of the plates is used to distribute the drive torque variably and dynamically between the axles. ■

The integrated decoupler

The decoupler integrated into the rear-axle differential works according to a different principle. The shaft to the right rear wheel is divided into two parts beyond the point where it exits the differential. The left sub-shaft with the axle bevel gear in the differential and the right sub-shaft are each connected to a claw element. Both can be positively coupled.
The claw clutch is opened electromechanically and closed via pretensioned springs. If both the all-wheel drive clutch and the decoupler are open, the large components in the rear-axle differential relevant for friction and drag losses as well as the propshaft stop. Only the axle bevel gear and the compensating gears in the differential, which compensate for differences in the speed of rotation of the vehicle‘s drive wheels during cornering, continue to rotate under zero load.
However, they cause only very slight drag losses.
To activate the all-wheel drive system, the stationary components are accelerated in fractions of a second via the controlled multi-plate clutch.
The claw clutch closes as soon as the propshaft and thus the differential housing are rotating at the necessary speed. An electromagnetically actuated metal pin then disengages the locking lever. The springs relax and the claw clutch closes.
The use of pretensioned springs when closing the claw clutch allows for very short shift times. ■

quattro with ultra technology – the transmission

The key to achieving a significant efficiency gain in single-axle operation is a directly driven axle with optimal efficiency. The new generation of manual and S tronic transmissions ideally fulfill all the prerequisites, as efficiency was also a primary focus during their development.

The first model with the next-generation quattro will be the new A4 allroad quattro with S tronic in the second quarter of 2016. The technology will then gradually roll out to additional models with longitudinally mounted front engines and manual or S tronic transmissions. ■

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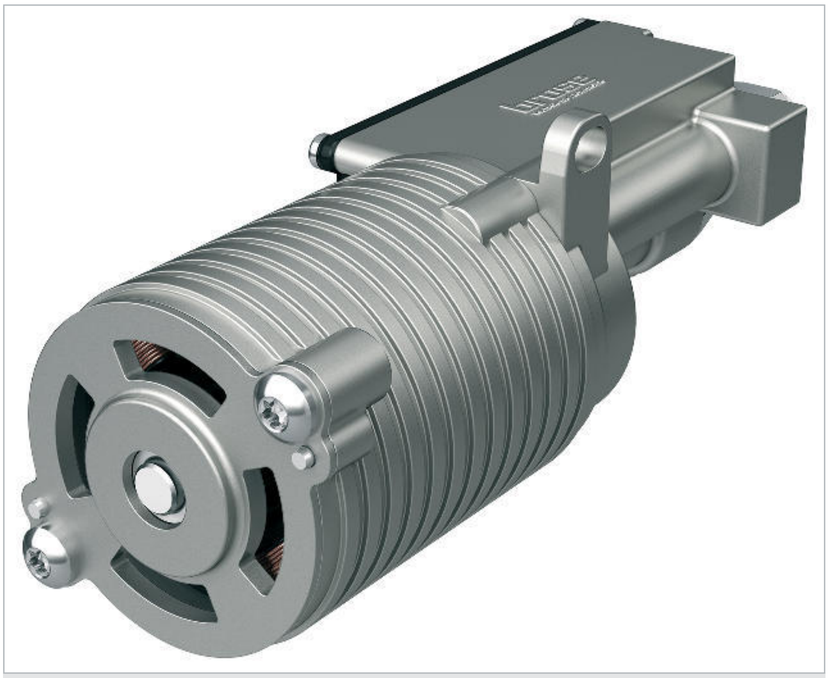
Comfort meets economy

Lightweight design alone is not enough: in order to meet legal CO_2 requirements, OEMs must constantly improve the efficiency of their vehicles. Despite all their efforts, manufacturers should never forget that car buyers want an exciting driving experience. The electric oil pump from Brose provides all of the comfort, convenience and dynamics drivers have grown accustomed to while boosting fuel economy in start-stop and coasting mode – and it is further proof of the automotive supplier's system expertise.

The continued strong demand for automatic transmissions in the United States in particular presents a challenge for car manufacturers: stricter fuel economy standards and emission reduction requirements must be met, but this should not affect the level of comfort drivers are accustomed to. Internal combustion engines with an automatic start-stop function are one way to solve this problem. Another – which will become more and more important in the future – is "coasting". This function also switches the engine off when it is not needed, such as when driving downhill.

However, implementing these two fuel-saving driving modes is not that simple because the engine powers various other hydraulic systems via belts. These systems are important for safety features such as power brakes and steering, but they also maintain oil pressure in the transmission. When the motor is switched off, the transmission is no longer supplied with hydraulic fluid and restarting following a stop or coasting phase causes the car to jerk noticeably.



Brose's electric oil pump combines the motor, electronics and pump to create a compact system. ■

This is where the Brose (auxiliary) electric oil pump comes in: it takes over when the engine stops and maintains sufficient oil pressure for hydraulic actuation until the main pump resumes operation. The product reliably lubricates and cools the clutch, bearings and gear sets. The electrically powered auxiliary system provides a far more dynamic driving experience when the engine is restarted than purely mechanical oil pressure systems. Yet another advantage: the driver also notices that the transmission works faster, smoother and quieter. In this way, the pump ensures more comfort despite lower fuel consumption – up to seven percent less with these functions in city traffic according to the driving cycle

developed by the U.S. Environmental Protection Agency (EPA). In absolute terms: using the on-demand pump in the transmission reduces CO2 emissions by up to 10 grams per kilometer driven.
Even greater savings are imaginable going forward: the main transmission oil pump can be much smaller than it is now in variable, automatic and dual clutch transmissions if the main and auxiliary pumps work optimally together. Right now, it has to deliver sufficient power even at low speeds, but a great deal of this performance is lost at higher speeds.
However, if the electric oil pump helps out at lower speeds, the main pump‘s ideal operating point can be reached at higher speeds, thereby minimizing performance loss.
In the next step, an electric oil pump that is powerful enough may even replace the standard version completely. This ensures maximum efficiency in every driving situation since only the required oil pressure is built up. ■

Advantages of the system approach

With its electric oil pump, Brose becomes a system supplier in the field of drive train actuators. The product is also a perfect example of the mechatronics specialist‘s goal of integrating more functions across all of its product ranges. In this particular case, the company‘s focus is on the further development of powerpacks, or combining the electronically commutated motor and the electronic control unit in a single housing. Adding a hydraulic pump creates a compact system. This has multiple advantages: the individual components are coordinated to ensure they work together very effectively and efficiently. At the same time, the intelligent design dispenses with a number of parts, thereby reducing the unit‘s form factor. This also greatly improves acoustics. ■

Brose drives production in Querétaro. The Mexican manufacturing location will start producing the first electric oil pumps in 2018. ■

Modular system offers flexibility

Thanks to the modular design, the system‘s pump, motor and electronics feature various power stages that can be selected based on customer requirements. The available power range is 50 to 350 watts for 12V electrical systems using ferrite or rare earth magnets. In the future it will also be possible to use the electric oil pump with 48V vehicle electrical systems. In these cases the maximum output will even reach 1.2 kilowatts. This would make it possible to build up pressures of over 60 bar and transport over 20 liters per minute. Customers who want the smallest, most efficient design possible will also find the right solution for their needs: the lightest version of the system weighs only 750 grams. Brose‘s modular system thus makes it possible to adapt the product to a wide range of vehicles, from compact cars to luxury sedans, without high development expenses and in a considerably shorter period of time. Customers can also place orders for small quantities at an affordable price. Yet another advantage of the electric oil pump‘s modular design is that it gives Brose the speed and flexibility it needs to respond to the increasing demands of the highly dynamic electrified transmission market.
Brose offers its electric oil pump in the three most important automotive markets: North America, Europe and Asia. The company‘s “global footprint” enables it to develop and manufacture products locally in these regions. Worldwide quality standards ensure reliable product quality. North American production is slated to begin in early 2018 at Brose‘s El Marqués/Mexico manufacturing location, with additional ramp-ups to follow. Brose will produce more than seven million fully electric stop-start oil pumps in the next five years. ■

brose
Technik für Automobile

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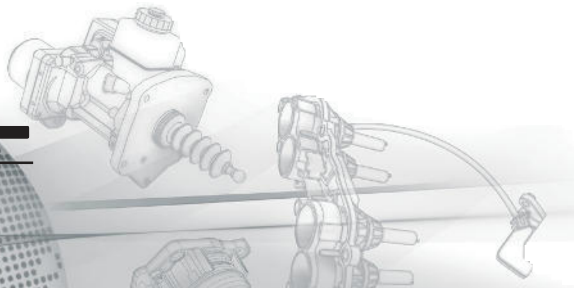
Turnover in 2015
approx. 6 billion euros

Customers
about 80 manufacturers and more than 40 suppliers

Employees in 2015
about 24.000

FTE automotive – Innovation drives



The FTE automotive Group is your competent partner in the sector of development and production of drive train and brake system applications for the automotive industry. The company is located in all important continents and one of the leading OE-suppliers for passenger cars and commercial vehicles worldwide.
With the development and production of hydraulic clutch and brake systems, FTE automotive helps increase safety and comfort in vehicles. We assume a high level of responsibility for the functionality, quality and reliability of our products. We have more than 60 years of experience to ensure a successful future.

Research and Development

The products of FTE automotive are the result of intensive research and development work. In close collaboration with leading vehicle manufacturers, we are continuously developing new technically and economically trend-setting system solutions for brakes and hydraulic clutch actuations.
To meet this challenge, the company places great emphasis on having highly qualified employees. Our engineers find new ways of making driving even more comfortable and safe – for pure driving pleasure at a high level.
In competition, it is not the big firms that assert themselves over the small firms in the long term, but the fast who stand their ground against the slow. Innovative product developments and program extensions are therefore characteristic of FTE automotive. The aim is always to be faster, more flexible, and better than the competition.

PACE Award Winner:
Gear Shift Actuator Module,
Innovative technology with several features and simplified assembly ■

Lubrication Oil Pump - Intelligent material choice for cost and weight benefits ■

Quality as a basic Requirement

Our organization, our processes, and our management system are certified according to the standards in the automotive industry and are subject to continuous further development.
High quality and durability characterize the demands of our customers with regard to our products and processes. The quality of our benefits and our products is an absolute requirement or a trusting relationship with our customers, for stability and for the long-term safeguarding of our company. ■

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FTE automotive

Patent Protection at Trade Fairs

This year there will be more than 50 trade fairs in the automotive sector in Germany, among them some long-established trade fairs, such as the 66th IAA Commercial Vehicles, but also the eCarTec which will take place for the 8th time this year and which has since developed into the world's biggest trade fair for electric and hybrid mobility.

At trade fairs, owners of intellectual property (IP) rights, in particular patent owners, unfortunately regularly observe that there are competitive products on exhibition, which at least initially are suspected of infringing a valid IP right.

Thus, the owner of the respective IP right is faced with the questions of how to effectively proceed against the presumed infringer and what options he has for stopping the alleged infringement, while the trade fair is still on.

Furthermore, the public perception should not be underestimated when active measures are taken against the infringer already during the trade fair, such as seizing infringing products at exhibition stands, in order to secure evidence.

Depending on the specific case, the following options are available to the owner of an IP right:

- Preliminary injunctions against the infringer with the aim of stopping the infringement and seizing the infringing product;
- Seizure of allegedly infringing products for the purpose of initiating criminal proceedings;
- Enforcement of a claim for inspection for the purpose of collecting evidence for civil infringement proceedings;
- Serving of the statement of claim for an infringement action on the already known infringer; and
- Enforcing an already issued court order.

Seizure of allegedly infringing goods at a trade fair

The majority of infringers regard the seizure of allegedly infringing goods by the competent public prosecutor's office, in collaboration with custom officials and the connected negative publicity, as larger risk than the "mere" enforcement of civil law claims.

A practical and non-bureaucratic enforcement of a seizure based on criminal law is offered by the so-called "Darmstädter Modell". This is used, for example at the "Automechanika". According to the "Darmstäder Modell" the competent public prosecutor's office unbureaucratically makes the seizure together with officials of the competent customs office and lawyers of the owner of the respective IP right. When one of the IP right owners' lawyers discovers an allegedly infringing product at an exhibition stand, a customs official will confront the stand holder with the charge of infringement and the accompanying public prosecutor will ultimately decide whether the reasonable suspicion of an infringement justifies the initiation of criminal proceedings.

Initiating infringement proceedings against patent-infringing exhibitors

The patent owner can seize the opportunity of a trade fair to submit a warning letter to apply for and enforce a preliminary injunction or to serve a statement of claim on the infringer.

A warning letter presented during a trade fair informs the alleged infringer of the infringement, requesting him to cease and desist from the infringement, as well as to acknowledge claims for damages for the infringement.

In that way, the patent owner avoids the risk of having to bear the costs of any legal action should the alleged patent infringer readily admit the patent infringement in subsequent court proceedings.

Preliminary injunctions are generally only granted in exceptional cases. The exhibition of an allegedly infringing product at a trade fair may justify such an exceptional situation and cause the competent court to grant a preliminary injunction at short notice.

The grant of a preliminary injunction in patent matters is subject to the following conditions:

- The technical facts underlying the patent must be readily understandable and not require a complex technical background;
- The Patent infringement has been clearly established;
- The patent owner is able to sufficiently substantiate urgency for the grant of a preliminary injunction; and
- There is a sufficient degree of certainty with respect to the legal validity of the patent.

In particular, the short duration of a trade fair may significantly increase the chance for a successfully granted preliminary injunction.

Usually, a court will only grant a preliminary injunction after hearing the alleged patent infringer. However, in specific circumstances, the exhibition of allegedly infringing products at a trade fair constitutes an exceptional situation justifying the grant of a preliminary injunction without previously hearing the alleged patent infringer.

In cases where the alleged patent infringement is technically too complex for a preliminary injunction or where the legal validity of the patent cannot be clearly shown, a legal action may be served at the trade fair.

In the case of a foreign-domiciled alleged patent infringer this option obviates the need for service of the legal action abroad, which is frequently associated with high costs and obstacles. After the statement of claim has been served, the court will set a trial date and summon the alleged infringer for the trial.

Enforcement of a claim for inspection for securing evidence in civil proceedings

The enforcement of claims for inspection is useful for finding out, already at an early stage, whether the allegedly infringing product really infringes the patent. International trade fairs are particularly suitable for such inspections as they allow fast access to potentially patent-infringing products.

The court ordered inspection may be carried out according to the "Düsseldorfer Modell", where in a so-called "selbständigen Beweisverfahren", i.e. in independent proceedings for securing of evidence, an expert appointed by the court will make the inspection with the help of a bailiff. A simultaneous preliminary injunction orders the alleged infringer to permit the inspection to take place. It is generally possible that the patent owner's lawyers attend the inspection.

Summary

German trade fairs, in particular in the automotive sector, offer the patent owner a platform for efficient enforcement of his IP rights. Depending on the actual specific scenario, the patent owner may choose between different options. For example, an easily verifiable infringing act can be stopped by means of criminal law measures or a preliminary injunction. In the case of more complex patent infringements, it is possible to serve a legal action at a trade fair, thereby avoiding the usual obstacles connected with service of the statement of claim abroad.

Thus, an enforcement of IP rights at trade fairs offers quick results with a high level of publicity. ■

VOSSIUS & PARTNER

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Special e-Car

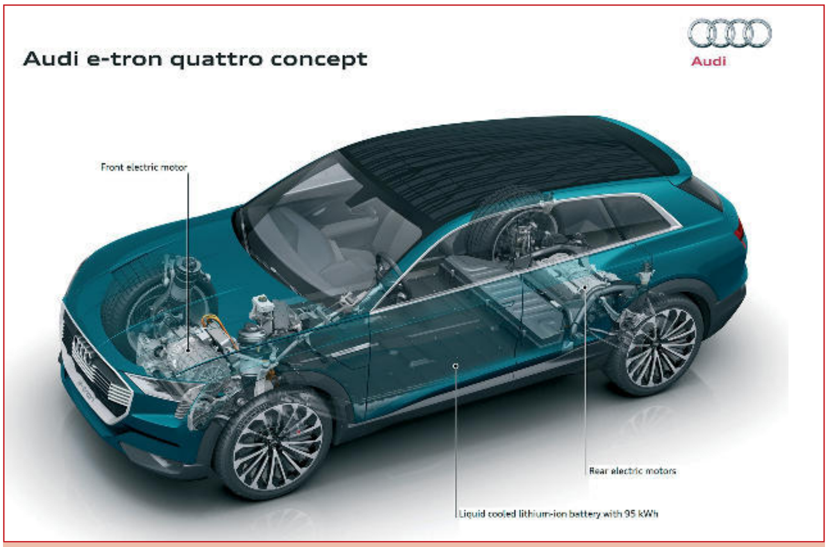
The Audi e-tron quattro concept

Aerodynamically-optimized design with a drag coefficient of 0.25, a purely electric e-tron quattro drivetrain with up to 370 kW of power output – the Audi e-tron quattro concept is an all-electric, full-size class sport SUV. The technology study provides a firm glimpse at the production model to follow in 2018. And it is a statement about the future of electric mobility: It is sporty, efficient and suitable for everyday use.

Pure performance: Three electric motors

The Audi e-tron quattro concept uses the power of three electric motors: One electric motor drives the front axle, the two others act on the rear axle. Together they produce 320 kW. During boosting, the driver can even draw temporarily on 370 kW and more than 800 Nm (590.0 lb-ft) of torque. The concept study offers sports car-like performance. When the driver floors the right pedal, the Audi e-tron quattro concept sprints from a standstill to 100 km/h (62.1 mph) in 4.6 seconds and quickly reaches the electronically governed top speed of 210 km/h (130.5 mph).

The concept with three electric motors which Audi is presenting for the first time makes the technology study an e-tron quattro. An intelligent drive management system controls the interplay between them as appropriate for the situation, while also maximizing efficiency. The driver decides on the degree of recuperation, the driving program S or D and the mode of the Audi drive select system. During sporty driving on a winding road, the Torque Control Manager actively distributes the power between the rear wheels as necessary. This torque vectoring provides for maximum dynamics and stability.



Audi e-tron quattro concept – Electric drivetrain with up to 370 kW ■

The large lithium-ion battery is integrated into the floor of the passenger compartment. It gives the Audi e-tron quattro concept a balanced axle load distribution and a low center of gravity – prerequisites for dynamic handling. The battery's capacity of 95 kWh enables a range of more than 500 kilometers (310.7 mi).

The Combined Charging System (CCS) enables charging with DC or AC electrical current. A full charge with DC electrical current at a charging column with an output of 150 kW takes just around 50 minutes. The study is also designed for use with Audi Wireless Charging (AWC) technology for contactless inductive charging. The charging process is very convenient. The Audi e-tron quattro concept uses a system for piloted parking that guides it to the proper position on the charging plate. When the sun is shining, a large solar roof provides electricity for the drive system battery.

The chassis also expresses the high-tech character of the concept study. The adaptive air suspension sport, which features controlled damping, lowers the body at higher speeds and thus reduces drag. The dynamic-all-wheel steering combines a dynamic steering system on the front axle with a steering system for the rear wheels. ■

Aerodynamic: the exterior design

The Audi e-tron quattro concept harmoniously combines the design with aerodynamics and the all-electric drivetrain. The five-door technology study is 4.88 meters (16.0 ft) long, 1.93 meters (6.3 ft) wide and just 1.54 meters (5.1 ft) high. Its coupe-like silhouette with the extremely flat greenhouse that tapers strongly toward the rear lends it a very dynamic appearance. The drag coefficient of 0.25 is the new benchmark in the SUV segment, where figures well over 0.30 are typical.

At speeds from 80 km/h (49.7 mi), electrically actuated aerodynamic elements on the engine hood, the flanks and at the rear end direct the flow of air as needed to improve the flow through and around the vehicle. The vertical separating edges on the side panels and the fully enclosed floor plan with its newly designed microstructures also help to reduce drag. Cameras replace the exterior mirrors. Wind noise is low on board the car, and there are no engine noises in an electric car in any case. The fascination of electric driving unfolds in the silence.

All primary lighting functions at the front of the car use Matrix laser technology. The bottom section houses a new, distinctive lighting signature comprising five lighting elements. Each of these combines an LED luminary with an extremely flat OLED element (organic light-emitting diode).

The rear lights also comprise two sections. Each of the top zones features nine red OLED units for the tail light function, with three more below. ■

Audi Audi e-tron quattro concept – Front right view ■

Spacious and comfortable: the interior

The package of the Audi e-tron quattro concept enables a spacious, comfortable interior for four persons and 615 liters (21.7 cu ft) of luggage. The interior has a light and open feel to it; its architecture melds harmoniously with the operating and display concept. All displays in the interior use OLED technology. The extremely thin films can be cut to any desired shape.

The concept study is equipped with all the technologies that Audi has developed for piloted driving: radar sensors, a video camera, ultrasonic sensors and a laser scanner. The data these supply come together in the central driver assistance controller (zFAS) in the luggage compartment. It computes a complete model of the car's surroundings in real time and makes this information available to all assistance systems and the systems for piloted driving. These technologies are also nearly ready for use in Audi production vehicles. ■

Audi Audi e-tron quattro concept – Interior ■

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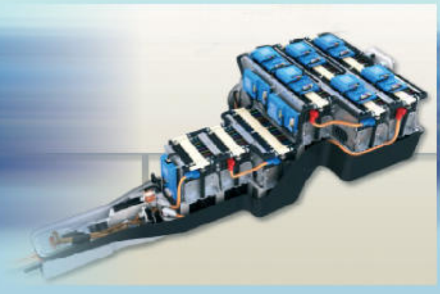
AVL Battery Management System



Electronic and software for innovative and precise battery operation

Electrical power, cell chemistry, number of cells, voltage level,

Such terms encounter an engineer while developing components for an electrical energy storage system. Due to the fact that electro-mobility is advancing, the battery has developed to a major component in an electric propelled vehicle.

In order to achieve higher vehicle power and electrical range it is necessary to connect various single cells in serial and parallel connection. In case of the American Tesla Model S a staggering amount of over 7000 battery cells are used. To ensure an optimum operation range and life time of the cells it is necessary to monitor their condition state. Important condition parameters for the battery management system are the cell voltages, -temperatures and the electrical current through the cells. All of them are processed in a central control unit, also called Battery Management Unit (BCU). They are input values of sophisticated algorithms e.g. charge and aging prediction (SoC & SoH). The acquisition of the cell relevant values, like cell voltage and -temperature, requires great electrical effort with further electronic control units, also called Module Controller (MC). All of the MCs are connected via the popular automotive bus system CAN to the main control unit, in order to transmit measurement values, diagnosis- and control information.

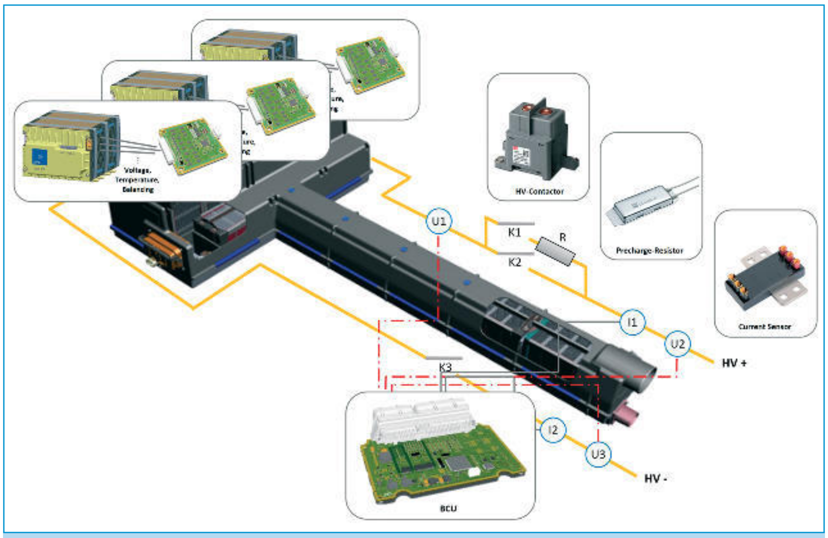


Figure 1: *Decentralized Battery Management Architecture* ■

This kind of architecture is called decentralized system because a great amount of electrical control units (ECU) are distributed among the battery. A major disadvantage of the system is the considerable complexity of the system, due to the fact that as many as 40 ECUs are connected within a communication bus. Furthermore CAN communication requires a voltage supply, galvanic isolation und a microcontroller for the control on each MC which raises complexity significantly. ■

Innovative Research and Development

This issue was apprehended by AVL and successfully improved within a three-year funded project „Efficiency and cost optimized battery module controller for competitive electric vehicles." of Bayern Innovativ. Hereby following questions have been analyzed and implemented:

- Fundamental investigation about the different cell balancing tech-

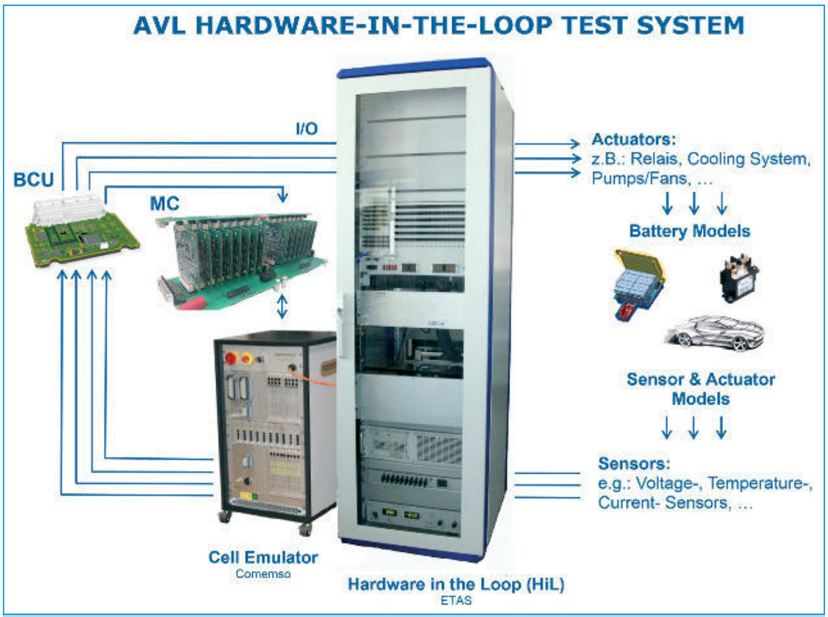


Figure 2: *AVL Hardware in the Loop Test Cycle* ▪

niques considering the cost-benefit.

- Analysis of the latest semiconductor integrated circuit generations and their system interface requirements.
- Development of a scalability concept for the module controller regarding the electrical design and functionality/software.
- Reflection and review of the developed concept considering functional safety according ISO26262.
- Hardware development including schematic and layout design.
- Analysis and implementation of the necessary software and control algorithms including the integration into AVL's battery management system.
- Manufacturing and test of the developed hardware and software in the HiL (Hardware in the Loop) test environment.
- Pre-verification of the module controller on a test bed battery.
- EMC qualification of the module controller in conjunction with the battery control unit with regard to the Daisy-Chain communication bus.
- Integration of the module controller in AVL´s self-developed traction battery with a voltage level of approximately 800V.
- Integration of the battery in AVL's full electric vehicle Coup-e 800.
- Vehicle calibration and proof of the development goals in real driving conditions.

In the course of the research project AVL's battery management system could be enhanced to a promising architecture ready for future applications. The novel BMS is supporting multiple ASICs now, which are particularly designed for battery cell monitoring applications. These ASICs feature high-precision measurement methods for cell voltage and temperature monitoring, diagnoses and most notably a proprietary cost efficient communication interface. Furthermore the new technology was tested through various validations in testing facilities e.g. EMC, environmental validation and by the currently ongoing vehicle trials in AVL's own technology platform Coup-e 800. ▪

Modularity

A requirement which is often stated during the discussion with customers and suppliers in the course of the development of a future battery system is "modularity". This is based on the fact that there are a variety of different cell geometries, chemistries and diverse applications, to range from automotive to home applications. Motivated by this situation, AVL set its goal to develop a modular BMS approaching this challenge. The new BCU generation is based on the requirements from the leading OEMs and can manage several battery platforms. However the usage of a BMS for a 48V application requires significantly different demands than one for a purely battery powered electric vehicle. Therefore AVL developed a modular E/E-architecture which merges the common features of both applications and extends it with special features, e.g. high-voltage measurement and in-terlock-line. But it is not only possible to build up a modular BMS on

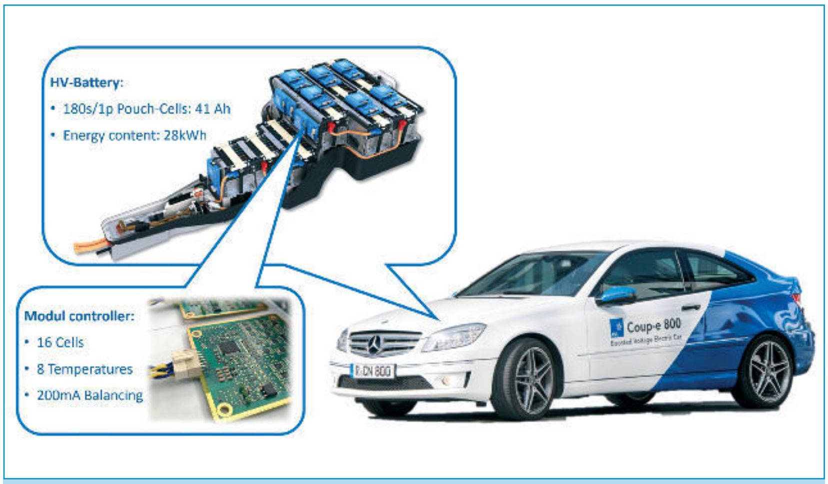


Fig. 3: *AVL Coup-e 800 with integrated Module Controller* ▪

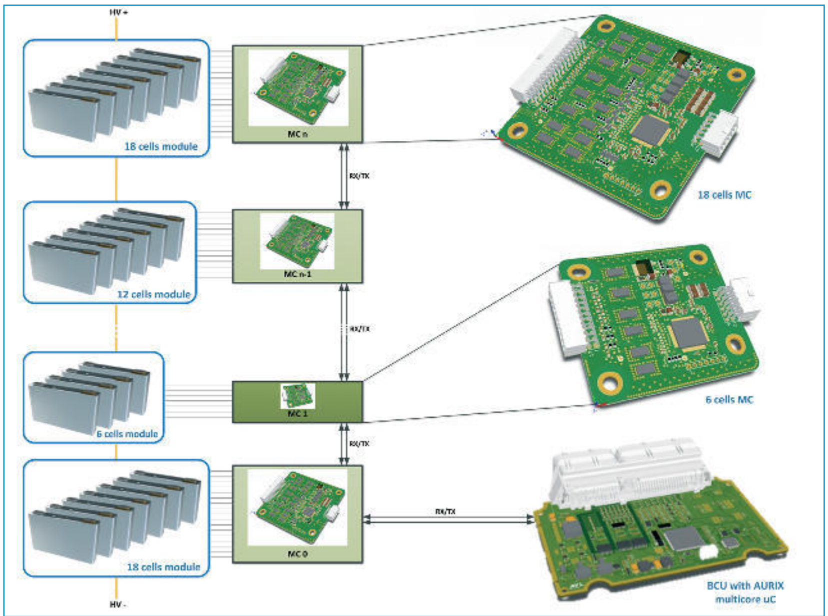


Figure. 4: *AVL Modular BMS Architecture* ■

system level but also on cell or module level. Depending on the vehicle type, e.g. electric vehicle (EV) or plug-in-hybrid electric vehicle (PHEV), the number of cells monitored by a MC are different.

Additionally it is reasonable to combine battery modules with varying size within one pack, in order to utilize the installation space and weight distribution among the vehicle as best as possible. Hereby a great challenge is to match small modules with 3s (3 in series connected cells) with large modules (18 in series connected cells) within one system. This configuration is especially challenging for the battery management regarding software and hardware capabilities. Prospective AVL wants to progress the development of a highly modular and cost optimized BMS which supports various customer requirements and applications. ■

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Hochschule Kempten
University of Applied Sciences

R & D at the University of Applied Sciences Kempten

Bavarian pilot region for electric mobility since 2009

Within several projects funded at Federal State, National and European level and conducted by the University of Applied Sciences Kempten (UAS Kempten), the regional energy provider Allgäuer Überlandwerk GmbH (AÜW) as well as the EV developer ABT Sportsline GmbH (ABT), the Allgäu region managed to establish itself as pilot region for electric mobility since 2009.

As early as in 2009, in the context of the project "eE-Tour Allgäu" which was promoted by the programme "ICT for electric mobility" of the Federal Ministry for Economic Affairs and Energy (BMWi), tourists and locals could rent 50 different electric vehicles to discover the Allgäu in an ecofriendly manner. In the project "IRENE" starting in 2011, the UAS Kempten, the AÜW, the Siemens AG and the RWTH Aachen could analyse the integration of renewable energies and electric mobility on behalf of the BMWi. Therefore, the distribution grid of a municipality was equipped with measurement equipment and stabilized with a stationary battery with a peak performance of 300 kVA and a capacity of 170kWh. The successful implementation and the good visibility were continued in the lighthouse project "econnect-Germany" of the BMWi in 2012. A network of seven German municipal utilities developed and tested sustainable and intelligent electric mobility with focus on municipalities and companies. Diverse issues in the research field electric mobility are additionally sponsored by the Free State of Bavaria since 2011 via the technology network Allgäu TNA for electric mobility. ■

Fig. 1: *eBox (on the basis of a VW T6) for delivery traffics of the ABT Sportsline GmbH* ■

Allgäu EVs of the ABT Sportsline GmbH

Based on extensive methodical analyses and the acquired knowledge, the setup of a small-series production of 40 battery-powered vehicles for the delivery traffic by ABT was initiated in the showcase project "E-Lieferungen im Allgäu". The vehicles were designed for the delivery traffic of the Deutsche Post DHL Group and employed and tested in their distribution fleets as well as in regional companies. The UAS Kempten essentially contributed to the advancement and the qualification of the batteries and provided crucial inputs regarding the acquisition and analysis of the usage and load conditions of the vehicles. Moreover, it acquired knowledge concerning the user acceptance. ABT gained expertise and developed plants for the small-series production of purely electric light commercial vehicles in 3 segments: the ABT eCaddy, the ABT eT5 and the ABT eBox on the basis of a VW T6 with long

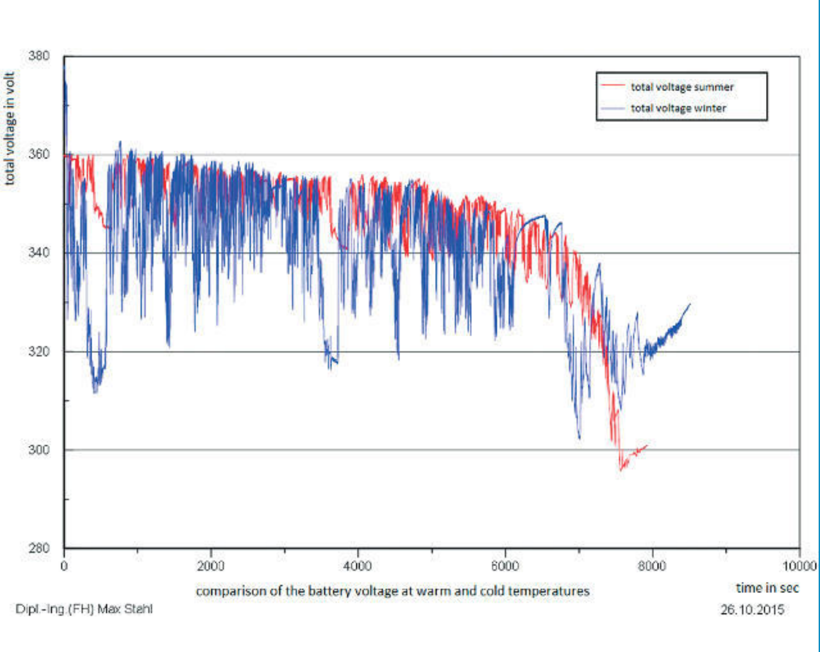

Fig. 2: *Battery voltage at driving until discharge in summer/winter* ■

wheelbase, 4,25 t admissible total weight and a loading space of 20 m³ (fig. 1). ■

Battery research

By measurements and trials on new and aged batteries, in the laboratory as well as during operation (fig. 2), appropriate simulation models for the entire electric powertrain were developed and verified in the Institute for Electrical Energy Systems (IEES) of the UAS Kempten. Thereby, a reliable electric dimensioning of powertrains with lithium ion batteries for various application profiles was permitted. ■

Usage and load analysis

Over the course of several projects, the UAS Kempten developed and refined an ICT infrastructure to test the usage and load conditions of electric vehicles in different use cases (fig. 3). Specific data loggers in the vehicles are directly connected to the CAN bus and gather relevant data such as the electric current and voltage of the battery, the state of charge (SOC), different temperatures and position data via GPS. The data are transferred once per minute telemetrically via UMTS to the server of the UAS Kempten where they are checked on plausibility, corrected and written into a database by an automatic importer.

The web portal Fleetalyzer is a tool for the administration, visualization and the analysis of data acquired of the vehicles registered in the database. Every partner obtains access to their data and hence the possibility to supervise their vehicles online.

The questions pursued in the context of different projects as well as the required data analyses for the evaluation were automated. Frequently, information are based on one tour (e.g. the course of the road, the route length, meters in altitude, energy consumption, number of stops, course of the performance, the start and end times, loaded, consumed and recovered energy, SOC, percentage of motorways, urban and rural roads, evaluation of the driving style considering the road type, outdoor temperature).

Examples of successful applications of electric vehicles: For the delivery of letters and parcels, but also for the usage in various use cases involving craft businesses, the application of electric vehicles is recommendable as they frequently drive along similar route profiles. However, due to the many starts and stops the energy demand is considerably higher (fig. 4).

Fig. 5 displays the analysis of the SOC over the course of a day that illustrates the potential of the development of an intelligent charge management for fleets

Another example of the analyses refers to the specific energy consumption per kilometer (here: for a selected car within a year, fig. 6). In the case of this car, the average specific energy consumption was:

winter: 424 Wh/km

summer: 259 Wh/km

The energy demand of the vehicles highly depends on the individual driving style and has major effects on the potential range of the elec-

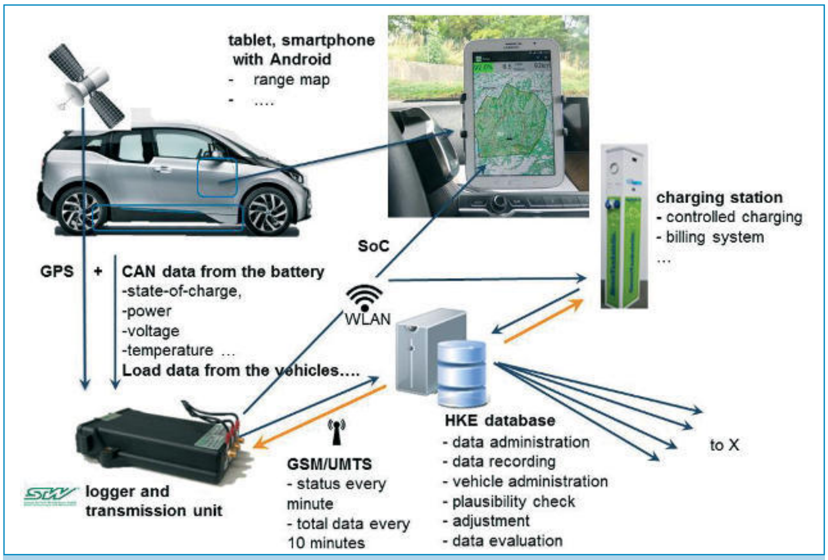

Fig. 3: *ICT infrastructure and data acquisition in the Allgäu e-mobility projects* ■

	Delivery traffic	Test drive
Standing time	~ 76%	4%
Stops	125	9
Energy consumption	7,75 kW/h	5,25 kW/h

Fig. 4: *Example of delivery tour of 25 kilometers* ■

tric vehicle. In comparing test drives on mixed routes the energy consumption doubled in case of a sportive driving style towards a very reserved driving style. To support the driver, a gamified range app including the evaluation of the current driving style was developed. Resultant, recommendations for the alteration of the driving style and thereby an increase of the range can be derived. ■

E-mobility coaching

One of the main obstacles in the context of the implementation of electric vehicles is the insecurity concerning the compliance of the range demands. Based on its expertise, the UAS Kempten offers an "e-mobility coaching" that provides interested fleet operators and private users with sound data and thereby supports an appropriate decision making regarding the switch to electric mobility.

Mobility check

Over a period of 6 weeks, the tours of existing conventional vehicles are recorded to describe the current mobility demands. These tours are then simulated with virtual models of electric vehicles and evaluated respectively the required range, the suitable charging infrastructure, costs and potential CO_2 savings. The capacity of the fleet vehicles and the integration of electric vehicles with due regard to the charging times are also analysed.

Experience electric mobility

The UAS Kempten offers potential purchasers of EVs the possibility to experience the favored electric mobility beforehand by testing electric vehicles of its own fleet.

Fleetalyzer app

The electric mobility app with the web portal Fleetalyzer supports users of EVs with a reliable indication of the existing range, an

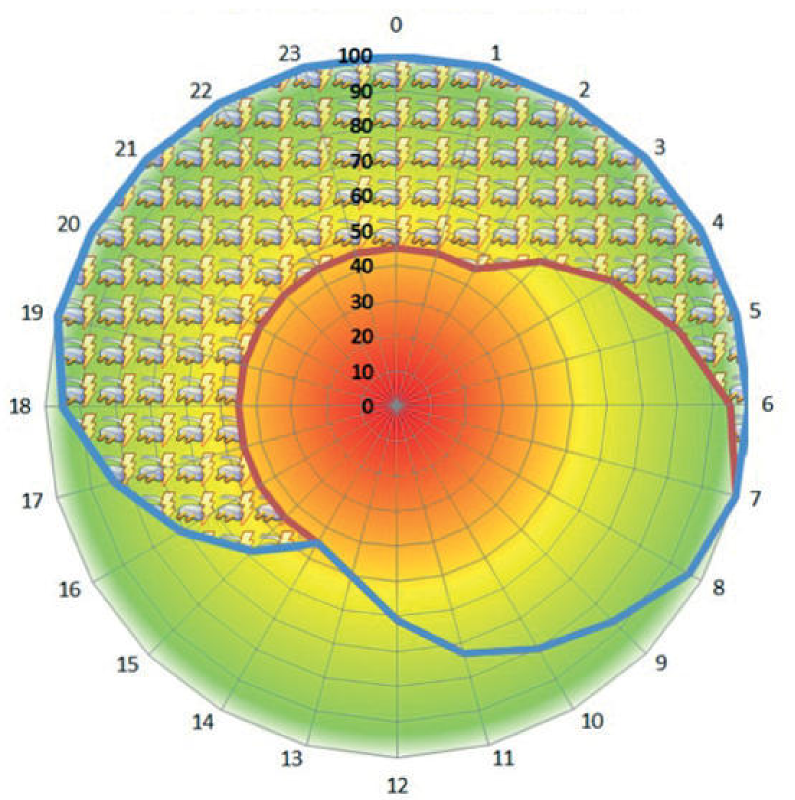

Fig. 5: *SOC history over the course of a day; blue: recorded data, red: possibility of later charging* ■

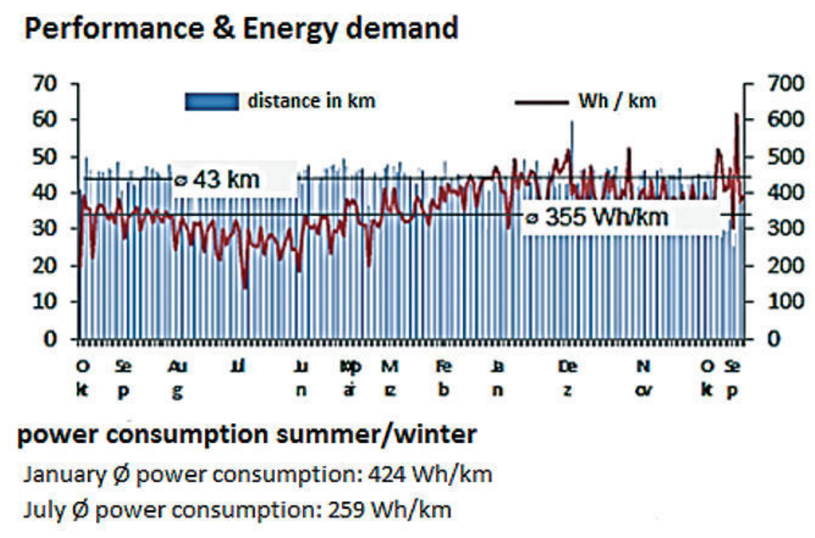

Fig. 6: *Driving performance and energy demand (DPDHL)* ■

evaluation of the current driving style, an anticipatory indication of the necessary charging demand and a cost analysis (fig. 7).

Acceptance studies

The implementation of electric vehicles accompanied continuous in-depth interviews with all users to identify their specific requirements and motives as well as their behaviour and decision-making processes. It became apparent that a multilevel survey on experiences promoted the contemplation of the drivers regarding their work and likewise the acceptance of the new technological requirements. Moreover, an increased identification with and enthusiasm for the new technology could be noted. ■

Conclusion

- Electric mobility works for commercial and delivery traffic, particularly due to predictable operating times and deployment routes.
- Reliable information concerning the favored mobility are important to enable fleet operators to take an appropriate decision regarding a switch to electric vehicles – e-mobility coaching.
- There is market demand for delivery vehicles of different sizes, but no series offered from manufacturers.
- The operation of electric vehicles, particularly in fleets, requires instruments for the planning of the range and the charging – Fleetalyzer.
- The gamification of the workflow and the operating procedures in the car can enhance the attraction of electric vehicles and facilitate the usage – Drivalyzer.
- The acceptance of the new technology increases with the inclusion and education of the target group. ■

Fig. 7: *Reliable range indication with driving style evaluation* ■

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Fast charging and Audi wireless charging

Progress in charging technology is crucial to the success of electromobility. Whether charging with direct or alternating current, the new solutions from Audi for all-electric cars and plug-in hybrids will be extremely convenient for customers. There will also be wireless options. Market launch is scheduled to begin in 2017.

Up to 150 kW of power – fast charging with direct current

Direct current charging with 150 kW of power is the next step. With this technology, a sporty SUV such as the Audi e-tron quattro concept would be able to charge its large 95 kWh battery to 80% capacity in less than half an hour, enough for a cruising range of around 400 kilometers (248.5 mi). A full charge – enough for more than 500 kilometers (310.7 mi) – would take around 50 minutes.

Audi and other German manufacturers use the Combined Charging System (CCS). It enables electric cars to be charged with direct current (DC) and alternating current (AC) using the standard Combo 2 connector. The official charging solution of the European Union, which is based on the CCS standard, has already been ratified. To further promote these standards worldwide, Audi co-founded the Charging Interface Initiative (Char IN) with BMW, Daimler, Opel, Porsche and Volkswagen, connector manufacturers Mennekes and PhoenixContact, and the TÜV SÜD inspection authority in May 2015. In China and Japan, where other standards already exist (GB/T and CHAdeMO, respectively), country-specific requirements will be accommodated. Installation of CCS charging stations has already begun in Europe and the United States. The majority of stations currently available on the market support DC charging with 50 kW.

Audi Q7 e-tron 3.0 TDI quattro, Wallbox with control panel, electric charging ▪

With a high-performance fast-charging infrastructure along transport axes, all-electric cars would be suitable for universal use. Current efforts are geared toward ensuring the establishment and operation of a fast-charging infrastructure with at least 150 kW by the market launch of the first all-electric sport SUV from Audi. The Audi e-tron quattro concept introduced at the IAA in Frankfurt was equipped with the CCS charging interface. The new standard allows for charging with up to 350 kW.

Audi considers it very important to offer the customers of its all-electric models a very convenient and capable charging system. This also requires cooling of the charging connector while connected to the charging station. This is the only way to continuously transfer the full power without thermally overloading the pins. In real-world driving, DC fast charging represents significant value-added for customers, particularly for long trips. ▪

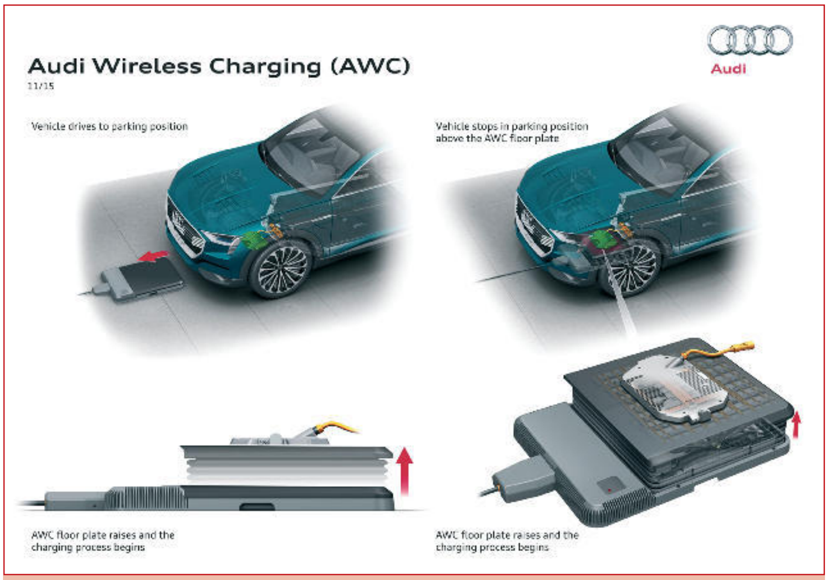
Audi wireless charging – wireless charging with alternating current

DC fast charging is virtually impossible in the private infrastructure due to the limited grid power. AWC (Audi wireless charging) is an inductive AC charging technology Audi is developing as an alternative that also makes home charging extremely convenient. The company hopes to launch AWC in 2017.

With AWC, the energy is transferred via a floor charging plate connected to the electric grid. The plate has an integrated primary coil and an inverter (AC/AC converter).

Connected to a 16 ampere, single-phase outlet, the first-generation system offers a charging power of 3.6 kW, with higher powers of up to 11 kW possible in the next version.

When the customer approaches to within a few meters of the charging plate with his Audi e-tron, the plate establishes radio contact with the car. The driver then sees the precise position of the floor plate on the display. Charging can begin immediately after proper positioning or according to a timer. With the piloted parking systems Audi is currently developing for production use, the car handles positioning itself.



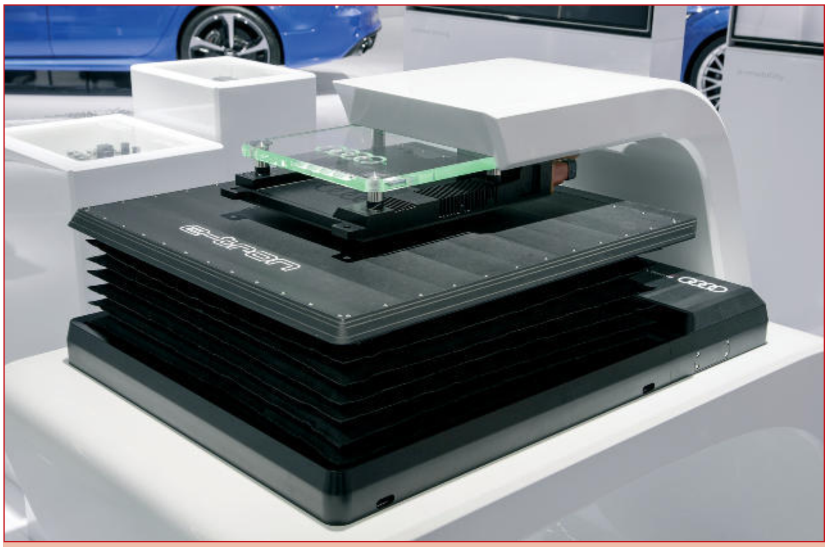
Audi wireless Charging (AWC) - Principle ■

The driver can get out of the car and then initiate the parking procedure remotely via her smartphone.

Prior to charging, an integrated electric motor in the floor plate raises the primary coil. This minimizes the distance between it and the secondary coil, which is integrated into the front section of the Audi e-tron floor pan, regardless of the specific vehicle. The floor plate‘s alternating electromagnetic field induces an alternating current in the car‘s secondary coil across the air gap. An AC/DC converter inverts the current, which is then fed into the high-voltage electrical system. There it charges the battery and powers additional consumers such as the heating or air conditioning as needed. The driver can interrupt the charging process at any time, and charging stops automatically when the battery is full.

Because the alternating field is only generated when a car is over the plate and the coil is active, there is no risk to people or animals. The small air gap prevents the magnetic field from interfering with electronic devices.

The first generation of the AWC technology is ideal for use in home garages or office building parking garages. A later version can be integrated in a modified form into the public infrastructure, such as into the asphalt of roads and parking lots. ■



Audi Wireless Charging (AWC) - Charging station ■

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