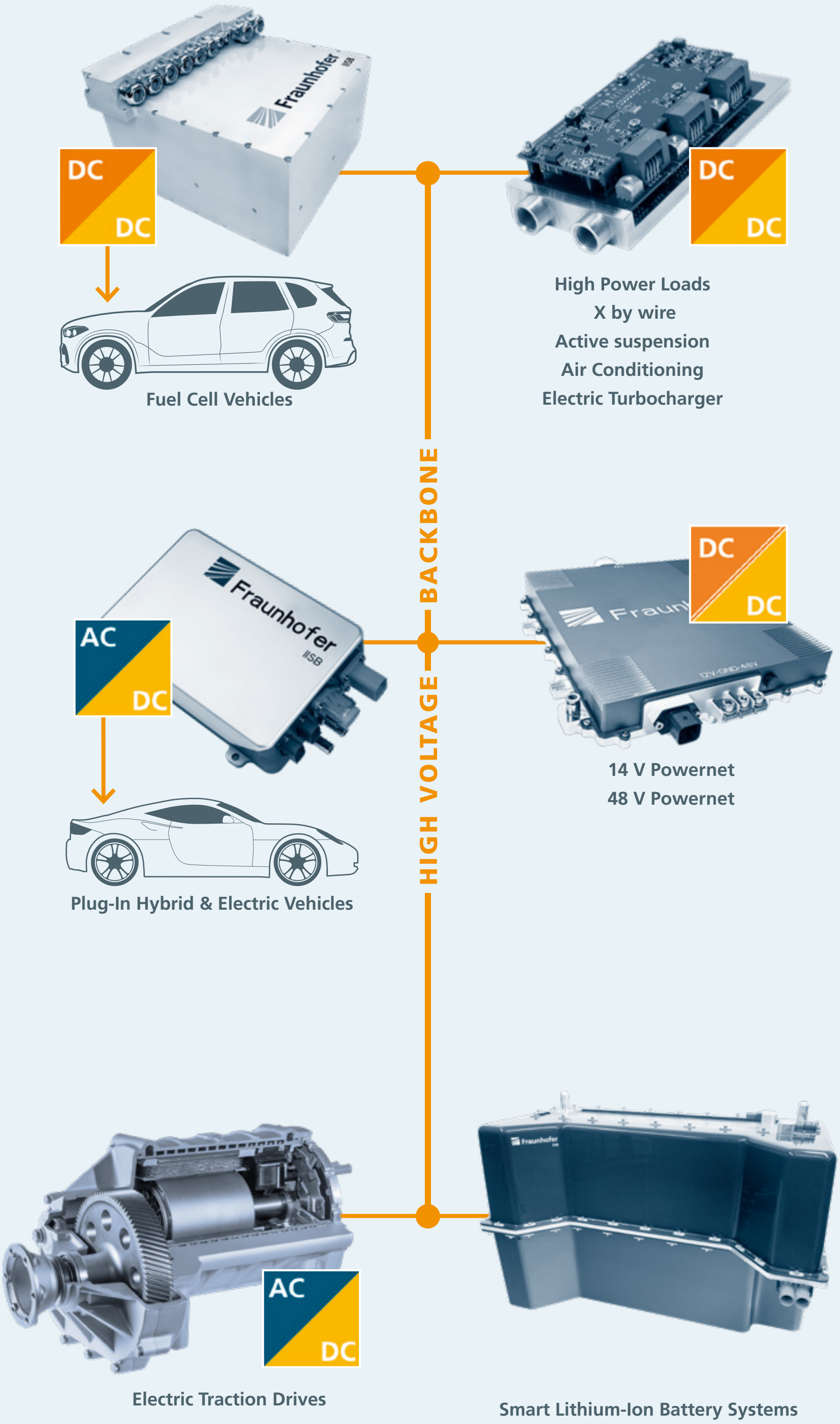
Fraunhofer IISB

Fraunhofer Institute for Integrated Systems and Device Technology IISB

Innovative Solutions for an Outstanding Performance

Vehicle Electronics

Our R&D Portfolio: The whole Spectrum of Power Electronic Systems necessary for Future Vehicles



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Advanced Vehicle Power Electronics with Innovative Solutions for an Outstanding Performance

As an application oriented research institute, our main interest is to advance into new ranges of system performance to open up new fields of applications for high performance, cost-efficient and sustainable power electronic solutions. This is both a challenge and an incentive for us. To find creative solutions, we are committed to leave the beaten track whenever necessary.

Research and development projects are carried out by highly qualified teams of engineers and technicians. All of these teams work in a number of well-equipped power electronics laboratories with access to a wide range of simulation and design tools, modern measuring, testing, and analysis equipment, as well as cutting-edge assembly and joining technologies. The fact that we make use of latest components, materials, and methods goes without saying.

Our partners come from small and medium-sized enterprises, science, and industry.

As an ECPE Competence Center (www.ecpe.org), partner in the Bavarian Cluster “Leistungselektronik” (Power Electronics), the ENERGIEregion Nürnberg e.V. and the »Leistungszentrum Elektroniksysteme« (LZE), we cooperate on international and regional levels.

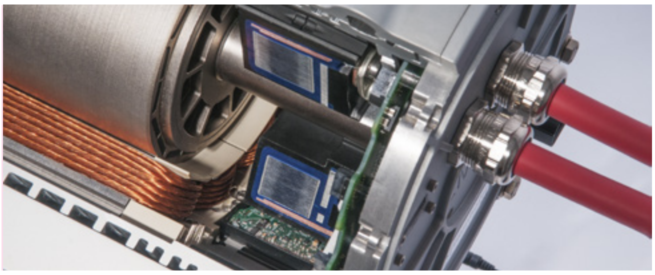
For an overview on all activities of our power electronics competence center please refer also to the brochures on energy electronics, devices, modules, and reliability available on our homepage:

www.iisb.fraunhofer.de

www.iisb.fraunhofer.de/vehicle-electronics

Electric Drives and Inverter Systems

The development of efficient, highly integrated and safe electric drive systems plays a key role for the electrification of individual mobility. A few basic e-motor configurations cover most of the electric drive applications in hybrid and all-electric vehicles: one or two electric motors in a single housing and wheel-hub motors. For all these configurations, innovative, cost-effective, and space-saving solutions for a system integration of the power electronics into or close to the electric drives are developed at Fraunhofer IISB.



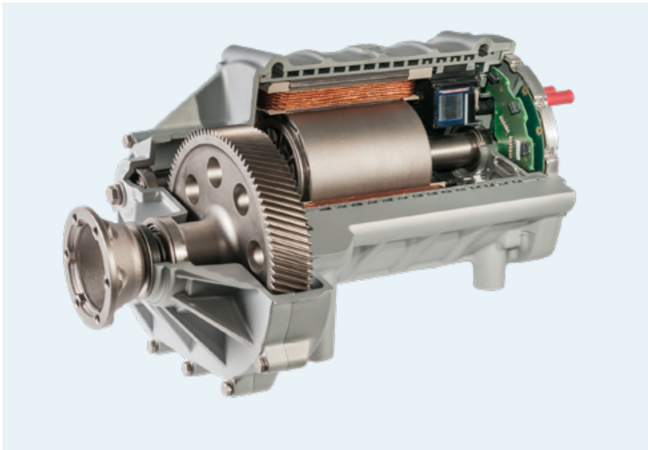
80 kW axle drive unit with integrated inverter close-up
© Thomas Richter / Fraunhofer IISB

For controlling the customer-specific inverters, an universal software platform is available with model-based implementation and a direct link between Matlab/Simulink™ and our powerful 32-bit target processor. Hardware and software development is carried out under consideration of ASIL requirements.

Integrated Drive Systems

Following our smart drive approach, no complex HV harness is required for the electric power train – only a shielded DC-link cable connected to the energy storage. EMC problems are reduced significantly by avoiding any AC cabling in the vehicle.

This placement of electronics close to electric machines or even close to the internal combustion engine in hybrid cars leads to a higher level of thermal and mechanical stress.



80 kW axle drive unit with integrated inverter
© Thomas Richter / Fraunhofer IISB

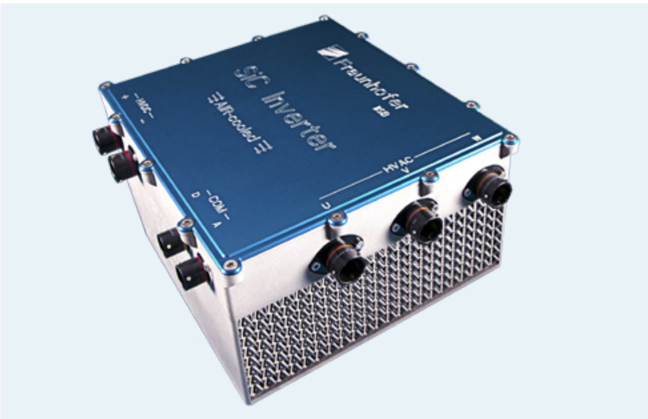
The use of common material concepts and innovative joining technologies, for example double-sided nano-silver-sintering of semiconductor devices, enables us to achieve the required robustness.

The integrated 80 kW drive-unit in the picture above was realized together with nine partners in the EMiLE project funded by the German Federal Ministry of Education and Research (BMBF). The drive is based on a novel Smart Stator Tooths (SST) topology with distributed and intelligent IGBT-based power-modules. This design combines high efficiency, improved manufacturability and new redundancy functionalities.

SiC and GaN Inverters for Highest Efficiencies and Motor Speeds

With state-of-the-art inverter systems (e.g. using Si-IGBTs and Si-diodes) the switching frequency in higher power-ranges is typically limited to values of 10 to 20 kHz due to high dynamic losses.

Novel Wide-Bandgap (WBG) semiconductors, like SiC and GaN switches, offer the potential for inverter systems with highest efficiencies, power-densities and especially switching frequencies far beyond the state-of-the-art. High-speed electric motors, like compressors and electric turbochargers, require higher inverter output frequencies and therefore higher switching frequencies to avoid additional losses and torque-ripple within the machine.



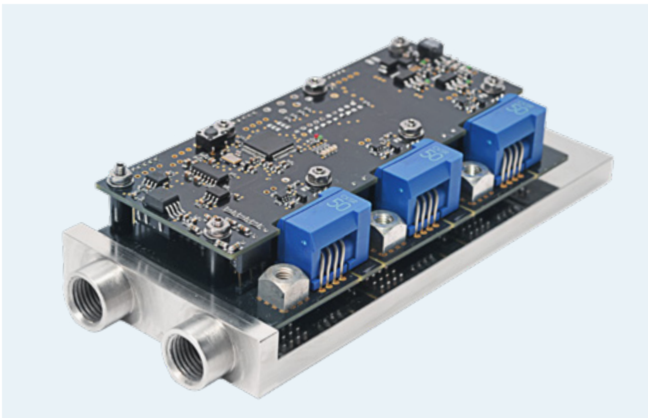
SiC-MOSFET based B6-inverter with forced air-cooling
© Anja Grabinger / Fraunhofer IISB

In order to meet these demands, investigations and product developments of inverters with wide-bandgap semiconductors are carried out. An example is a 60 kW inverter system. The use of silicon carbide 1200 V MOSFETs, ceramic-capacitors and a low inductive system design allow switching frequencies up to 100 kHz at reasonable efficiencies. The novel semiconductors with their reduced losses enable a power density of the overall power stage of >150 kW/l which is far beyond the state-of-the-art.

The increased efficiency of SiC inverters of up to >98% at nominal point also allows for air-cooling for applications that require it. An example is shown in the picture on the left. The inverter is designed for 800 V nominal voltage and a continuous output current of 70 Arms. The cooling structure is optimized for highest heat dissipation with high-speed fans and realized as a 3D-printed aluminum part.

We offer the following services for electric drive and inverter developments:

- Highly integrated drive solutions for hybrid or electric vehicles
- Complete in-house development and testing of inverter power electronics (incl. 3D integration)
- Development of WBG inverter systems for highest switching frequencies and efficiencies
- Vehicle integration of electrical drive and power management systems
- Motor control development for various machines (e.g. PMSM, IM, SSM, BLDC etc.)



60 kW SiC based drive Inverter: Powerstage for high-speed drives
© Thomas Richter / Fraunhofer IISB

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Mechatronic System Integration

The trend towards miniaturization and system integration in power electronics is mainly driven by applications with severe space restrictions such as automotive, robotics, or avionics. Major challenges arise from the fact that the installation space in these applications is usually predefined by mechanical requirements with less consideration for power electronics needs.

Wheel hub motor integrated 1200 V SiC inverter
© Thomas Richter / Fraunhofer IISB

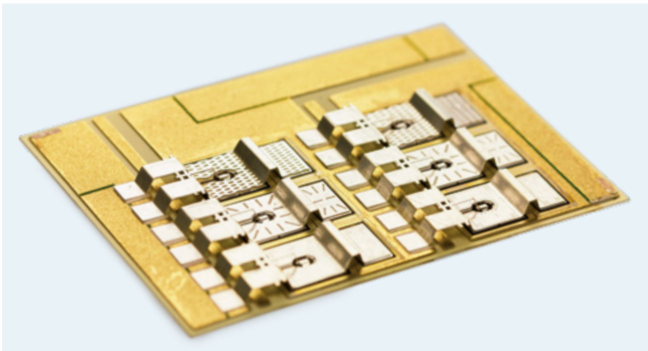
This often results in complex geometries and contamination in addition to high thermal and mechanical stress. However, the better use of space, the avoidance of expensive cables and failure prone connectors, and the reduction of EMI filter expense make it necessary to choose this path.

At Fraunhofer IISB, we have developed various concepts and solutions for the integration of electric motors and inverters into the drivetrain of passenger cars. Each design is adapted to the different locations of the e-drive within the drivetrain. Experience with air, water/glycol and oil cooling is available. Vehicle-specific requirements, such as coolant temperatures up to 115 °C and high vibrational loads are taken into consideration.

A mechatronic system integration requires more than just increasing power density. We are working on innovative integration concepts as well as on new device, interconnection, and cooling technologies that foster a 3D integration, increase ruggedness, and decrease costs of power electronics.

Our Focus is on:

- Customized power electronic systems for vehicle applications (automotive, railway, avionics, etc.)
- Vehicle integration of electrical drive and power management systems



Advanced double-side sintered power module
© Melanie Werner / Fraunhofer IISB

- Mechatronic integration of power electronics into vehicle components (incl. 3D integration)
- Advanced thermal management
- High voltage safety concepts
- EMC concepts and solutions
- Traction energy storage
- Simulation of power electronic systems within a vehicle environment
- Studies on hybrid and fuel cell vehicle powertrain topologies with special emphasis on topics like overall performance, efficiency, and system costs

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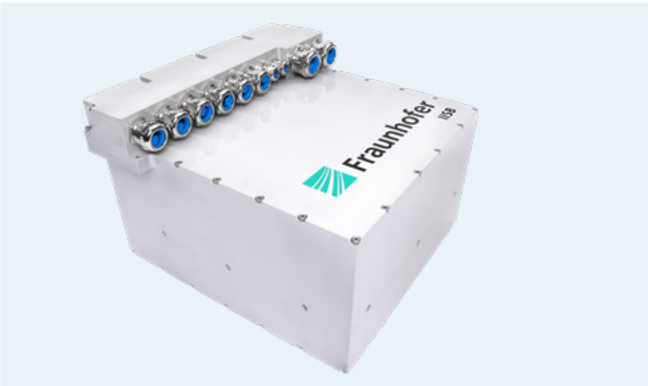
Non-Isolating High Power DC/DC Converters for Power Train Energy Management

Our high voltage, non-isolating, bidirectional converters are mainly used for traction energy management in case of recuperation, boost, the management of different power sources (e.g., fuel cell and battery), and fast charging. The DC/DC converters cover a power range up to about 600 kW with efficiencies up to 99%.



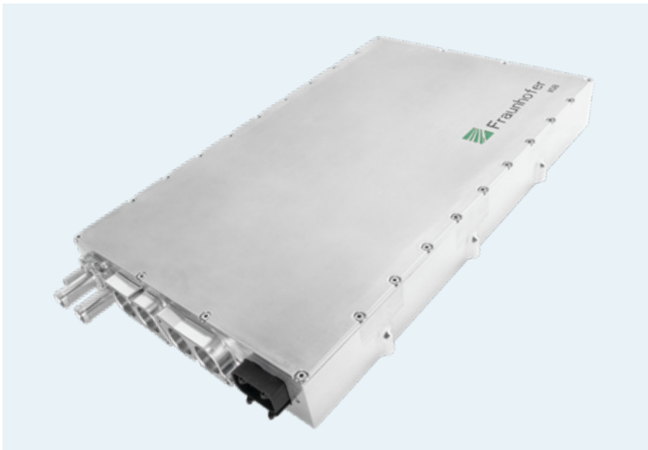
Hybrid Si and SiC multiport DC/DC converter with common DC-link topology © Anja Grabinger / Fraunhofer IISB

The type of cooling (air, water, or oil) is generally tailored to the specific application. A fully digital control and a CAN-bus interface for the communication with a vehicle control unit is standard. The secure and reliable operation is ensured with a passive and active discharge unit as well as isolation according to LV123 and auxiliary input protection similar to LV124.

We utilize the latest Si, SiC, and GaN devices. Our multi-phase concept makes it possible to shift the fundamental frequency of the DC link ripple voltage in the megahertz range, resulting in a considerable reduction of weight and volume of the passive components.

We build complete systems for our industrial partners, including high-power and bus connectors. Integrated in a sealed housing, these robust compact devices are used in R&D hybrid, electric and fuel cell cars for evaluating the electric power train. Efficiencies up to 99% over a wide range of load can be realized via a load-adaptive management of the number of active phases.

The high power density and low power to weight ratio of our DC/DC converters make them especially suitable for demanding motorsport (KERS) and aircraft applications.



Full SiC high performance 600 A, 850 V DC/DC converter for motorsport and automotive applications © Thomas Richter/ Fraunhofer IISB

Key Aspects:

- Ultra compact and efficient converter solutions
- User-specific housing, layout, communication, and electrical power specification
- High speed control loops for stable and save operation
- Easy current and voltage control by CAN

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Battery Chargers – Conductive & Inductive Solutions for Electric & Plug-In Hybrid Vehicles

In the field of conductive vehicle battery chargers, Fraunhofer IISB follows a modular design approach based on 3.7 kW galvanically isolated AC/DC converter units. With the modular circuit design approach, we are able to develop and realize a broad on-board charger product line for 3.7 kW, 7.4 kW, 11 kW and 22 kW demands.

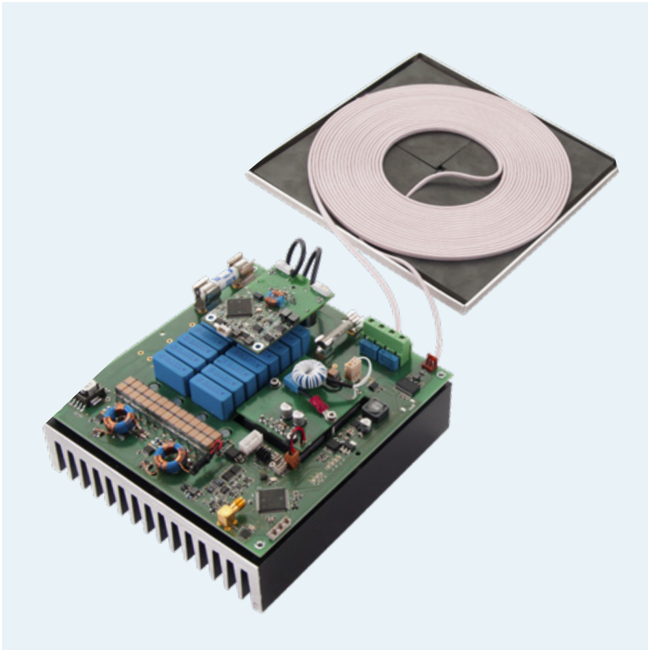
High power density battery charger
© Thomas Richter / Fraunhofer IISB

When it comes to inductive charging systems, we offer solutions with high transfer efficiency and small stray fields through minimal air gap, high positioning tolerance, lightweight pick-up, and a minimal package volume compared to underbody systems.

Besides pure battery chargers we also provide chargers with extended functionalities, such as bidirectional energy flow for applications in vehicle-to-grid scenarios, or an integrated mobile power socket (e.g. 230 VAC).

Key aspects:

- High power density and high efficiency
- User and application specific design
- Wide input voltage range
- Supporting charging mode 2 and mode 3 according DIN EN 61851-1



Positioning tolerant inductive charging solution
© Thomas Richter / Fraunhofer IISB

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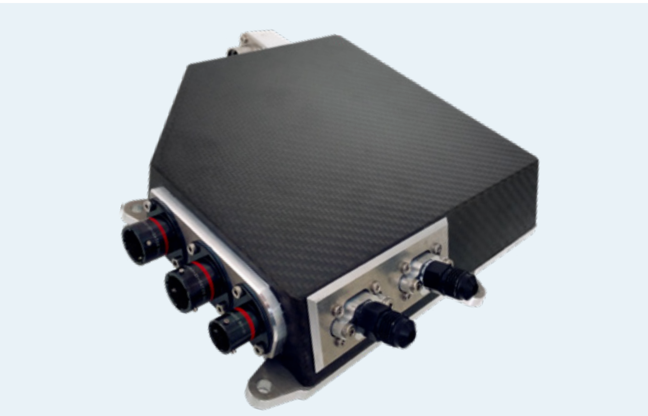
Isolating DC/DC Converters for the Connection of Board Grids and suppliying Auxiliary Devices

Fraunhofer IISB develops all kinds of galvanically isolated DC/DC converters for mobile applications. This includes, e.g., high voltage (up to 850 V) to low voltage (commonly 14 V, 24 V or 48 V) converters in the power range from 10 W up to approx. 5 kW. With efficiencies of up to 97 % and power densities up to 10 kW/dm³, they can be easily integrated into a small car, directly inside the high voltage battery system, or the drive inverter. The photo on the right shows how outstanding power densities and efficiencies are achieved through the use of modern power devices, fully digital control techniques and mechatronic approaches.

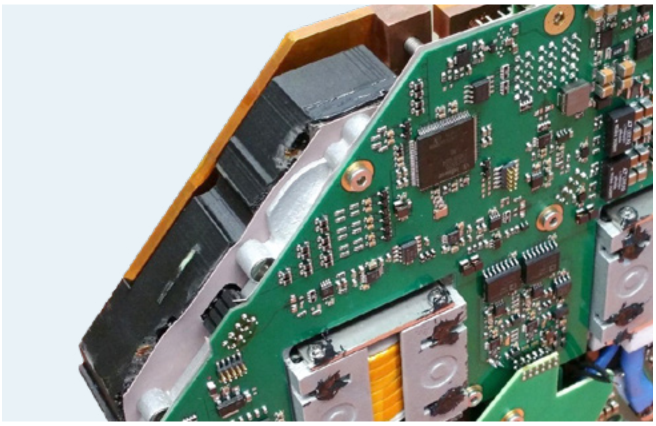


Galvanically isolated 3 kW DC/DC from 800 V to 12 V for sports cars © Anja Grabinger / Fraunhofer IISB

As with other Fraunhofer IISB vehicle electronics prototypes, galvanically isolated DC/DC converters can be developed for plug-and-play installation, with automotive qualified connectors. Such a converter could be used within two different voltage ranges for applications in light or heavy trucks and can be controlled via CAN interface. The serial connectable phases on the primary side enable the use of automotive qualified Si power semiconductors with 600/650 V blocking voltage to achieve a DC-Link voltage up to 800 V.

Key Aspects:

- Galvanic isolation
- Supply of auxiliary devices with high power demand in vehicles
- Very high power density up to 5 kW/dm³
- High efficiency up to 95 %
- Very high input voltages (up to 850 V)
- Modular multi level design
- Automotive qualified (Si) power semiconductors



Galvanically isolated 3 kW DC/DC from 800 V to 12 V for sports cars © Anja Grabinger / Fraunhofer IISB

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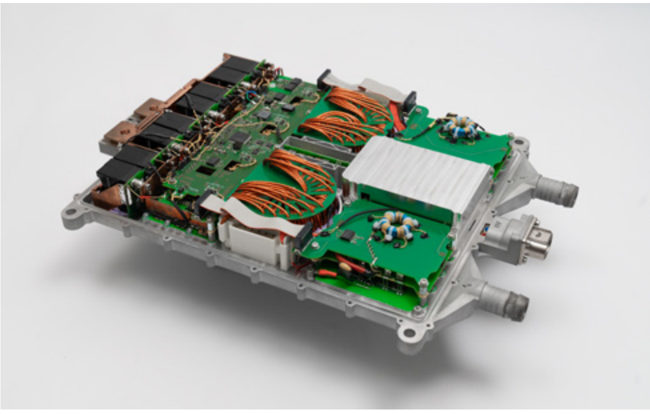
Aircraft Power Electronics

Making use of more than 20 years of experience in delivering complete prototype systems for automotive applications, the IISB is able to provide technologies for the complete high voltage "backbone" of a more/all electric aircraft, ranging from non-/isolating DC/DC converters and AC/DC motor/grid inverters to complete battery systems and DC grid control technologies. The novel WBG semiconductors with their reduced losses together with advanced low-inductive system designs and innovative cooling solutions enable power-densities far beyond state-of-the-art, paving the way towards more and all electric aircrafts.



11.2 kW insulating HV/LV DC/DC converter for aircraft applications with 3D printed liquid cooling plate - weight less than 6 kg © Elisabeth Iglhaut / Fraunhofer IISB

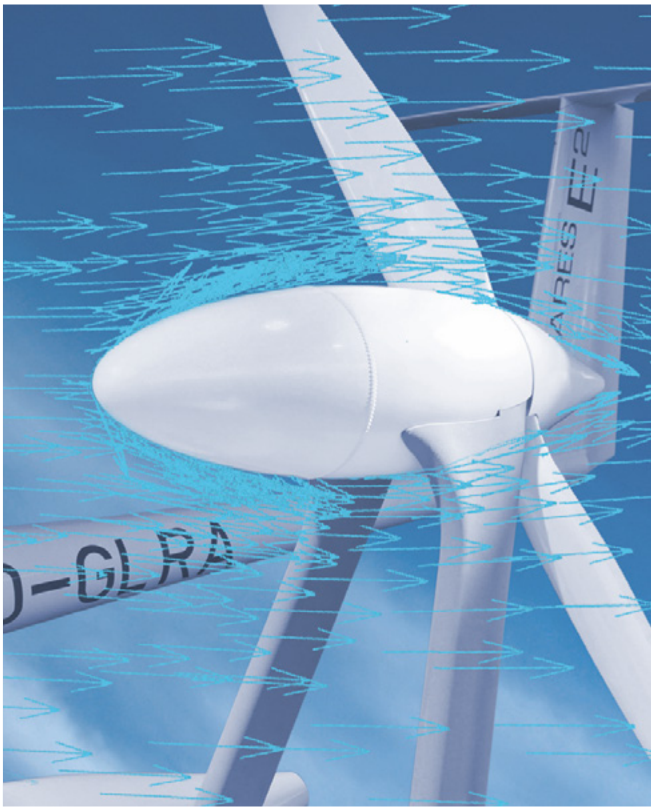
Full-custom System Development

We offer the fully custom development and realization of extremely lightweight and integrated power electronic systems - from the first concept to the testing and delivery of the complete prototype system.

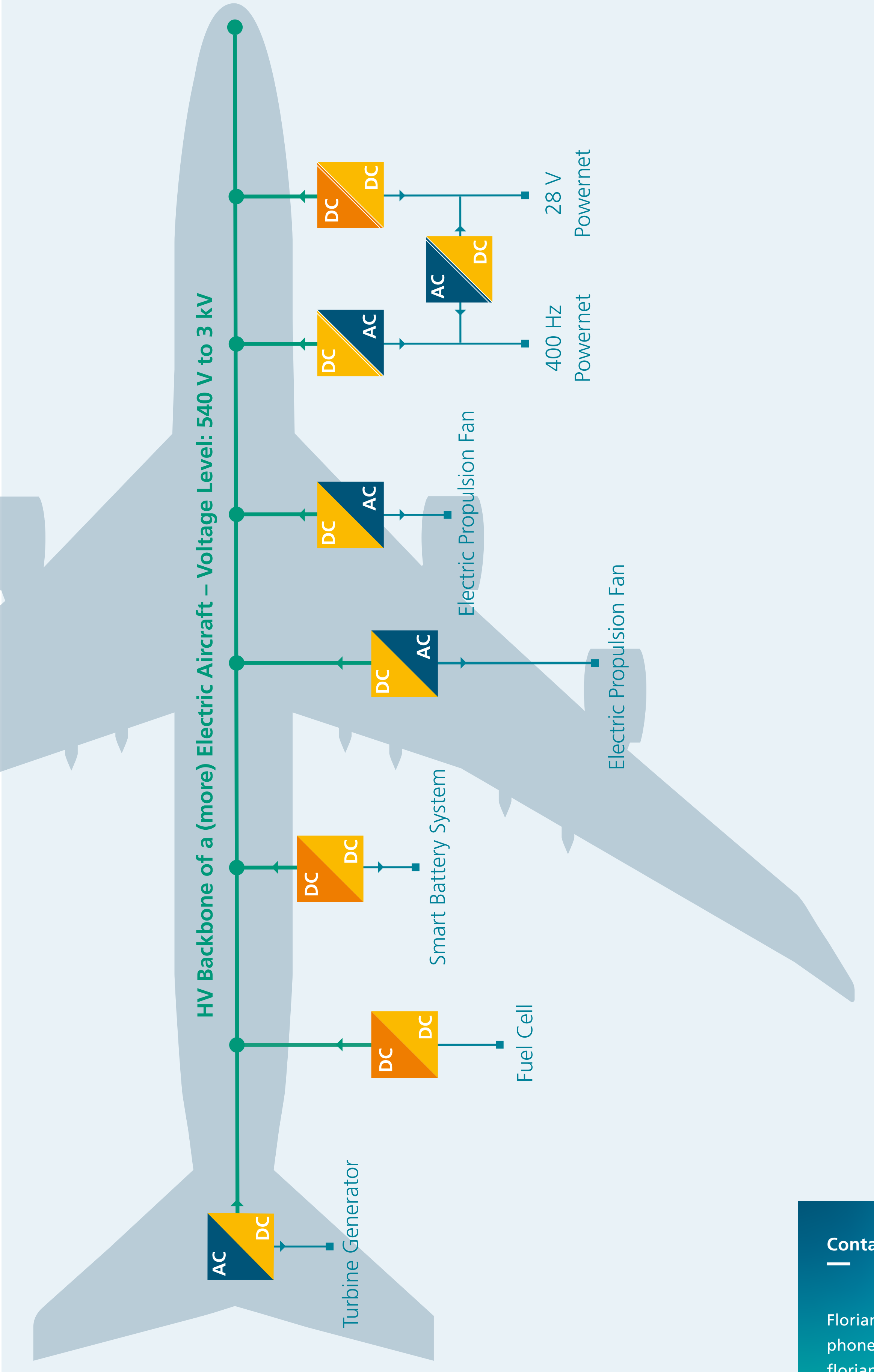
Based on our experiences with DC grid management, we are able to deliver solutions for complete drivetrain system architectures for aviation applications, with voltage range from 60 V to 3 kV and power range from 1 kW to several MW:

- Multiphase traction drive inverters
- Isolating and non-isolating DC/DC converters
- Bidirectional AC inverters for multigrid coupling
- Custom battery systems & battery management
- Medium voltage multilevel designs
- Thermal CFD simulation chain for customer-specific air and liquid cooling solutions
- DC grid management & control functionalities
- High gravimetric power density
- Customized power electronics for special applications and requirements

We will gladly provide you with further and detailed information upon request. You are more than welcome to contact us for a technical discussion about your specific application. The IISB is your research partner in power electronics for next generation avionic applications, either in collaboration within publicly funded research projects, or in bilateral developments under complete NDA.



15 kW aviation 6-phase motor drive inverter with passive laminar flow air cooling and fail operation capabilities - weight 1.5 kg © Florian Hilpert / Fraunhofer IISB



HV Backbone © Fraunhofer IISB

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Electric Drive Technology Platforms

Artega on the road © Kurt Fuchs / Fraunhofer IISB

Fraunhofer IISB is developing various research platforms for the evaluation and optimization of hybrid and electric vehicle powertrain components.

The hybrid vehicle platform is based on a conventional AUDI TT, the electric vehicle platform is an ARTEGA GT.

In the case of our hybrid vehicle platform, the original front-wheel drive remains untouched but is supplemented by an »active rear axle«. This modular, easy to implement, through-the-road parallel hybrid concept allows a lot of attractive features to be realized:

- Recuperation of braking energy
- Boosting with additional torque
- Temporary electric four wheel drive (T-4WD)

All converters necessary for electrical energy management, power supply, and charging are integrated into the energy storage, which therefore transforms into a smart battery unit. This kind of system partitioning follows the basic idea of a "site-of-action integration" and minimizes high voltage cable harness and system costs.

An innovative multiport DC/DC converter is used in the electric vehicle platform for managing the high-voltage electrical system. This allows a flexible combination of different energy storages with different voltage levels (e.g., a traction-battery with additional supercap storage).

An integrated drive unit with two independent electric machines and a maximum power output of 2 x 80 kW allows an independent torque allocation for each wheel of the rear axle.

Further research topics within the vehicle project:

- Operational strategy with variable DC-link voltage for increase of part-load efficiency
- Position-tolerant inductive charging
- Model-based vehicle control system using Matlab/ Simulink™ and Space
- Street legality

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Electric Vehicle Test Center

Vehicles with an electrical power train put completely new demands on test systems. The vehicle test center at the IISB is dedicated to electric vehicles and allows for the testing and characterization of all components of an electrical power train, as well as complete electric vehicles.

Electric Test Bed for single and dual Motor Traction Drives up to 1 MW

Single motor drivetrains as well as two motor axle drives can be characterized with a test bed which is especially designed for electric vehicle drives.

Two e-motors can load the SUT with arbitrary load profiles within a performance range up to:

- Torque: 7500 Nm / 1150 Nm / 590 Nm
- Rotation Speed: 2700 rpm / 17500 rpm / 35 000 rpm
- Power: 1 MW
- DC Supply: 1000 V / 2000A

A professional automation system combined with high-precision recording equipment for DC and AC currents, voltage, torque, and speed allows the measurement of:

- Inverter and motor efficiency characteristics
- Speed-torque characteristics, and provides
- Vehicle and road simulations.

A Matlab/Simulink™ interface sets a direct link to our vehicle simulation platform.

Air conditioned 4-Wheel Dynamometer

The achievable cruising range of an electric vehicle is not only a function of vehicle data, battery size, and driving cycle. Auxiliary systems, e.g., for air-conditioning or lighting, affect the cruising range, as well as the highly temperature-dependent properties of the traction battery.

Electric vehicles can be characterized using our 4x4 dynamometer without expensive test bed adaptions of the vehicle. The entire dynamometer is housed in a chamber that can be temperature-controlled from -25 °C to +45 °C.

Preferred applications of the dynamometer are:

- Overall power train efficiency, energy consumption and cruising range characterizations
- Road and driving cycle simulations
- Evaluation and parameterization of simulation models
- Development of drivetrain control algorithm

Roller test bench © Anja Grabinger / Fraunhofer IISB

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Electro Magnetic Compliance – EMC Tests for Automotive and Industrial Applications

The EMC lab at Fraunhofer IISB offers pre-compliance measurements during the development process of our prototype systems and the components of our industrial partners. We offer a broad range of services from consulting in case of EMC problems via different measurements according to harmonized standards to very detailed circuit and layout optimizations.

EMC- aerial © Anja Grabinger / Fraunhofer IISB

The immunity to electromagnetic interferences can be tested in our Fully Anechoic Room (FAR) according to industrial and automotive standards. These tests include all relevant pre-compliance measurements in the context of a homologation testing according to 2004/104/EG directive or ECE R10 Rev. 3 of the United Nations.

Our engineers are working in several national standardization committees. We can thus guarantee competent expert advice and up to date information on EMC topics to our partners.

EMC Test Chamber

The electric energy converted in hybrid and all-electric vehicles is about two orders of magnitude above the one processed in conventional cars, while EMC limits are nearly the same. The structure of the electric power net is also completely different due to safety requirements. EMC is therefore a central issue in the development of electric powertrain systems.

For pre-compliance measurements and immunity tests of electric powertrain components and entire vehicles, our test center includes an EMC test chamber, fully equipped with test and measurement systems up to 1 GHz. The EMC chamber can be passed with a mid-size passenger car. Walls, floor, and ceiling of the chamber are lined completely with ferrite absorbers, which qualifies the chamber for measurements in a wide frequency range.

The systems under EMC test can be supplied with coolant and with electrical energy via high power feed-through filters (690 VAC , 250 A and 1000 VDC, 500 A).

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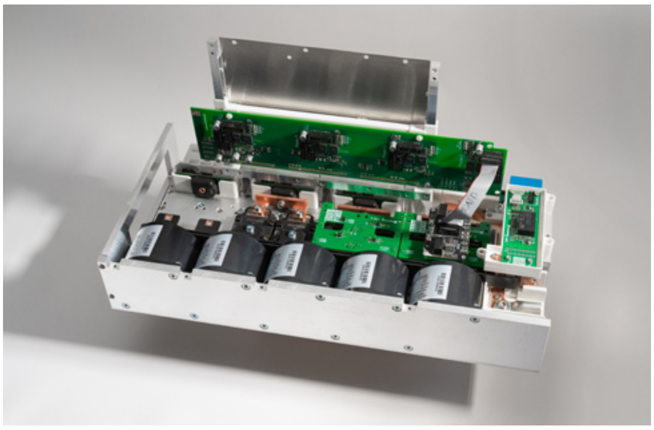
Medium Voltage and Megawatt Power Test Lab

The number of applications with voltages above 1 kV has been increasing in the last years – automotive, railway, ships, aircraft and energy just to name a few. Our mission is to perform research, develop and test technology demonstrators for DC and AC medium voltage applications. In order to test power converters in the medium voltage range of 1 kV up to 30 kV, a specialized testing room with isolated measuring equipment and safety precautions is required.

The 220 m² medium voltage test bench at Fraunhofer IISB allows for the testing of medium voltage components and systems by offering power supplies and sinks up to 15 kV DC and 30 kV AC for converter systems up to 30 MW. A 900 kW water cooling supply can be used to cool the device under test or evaluate the device performance at elevated temperatures deliberately. Furthermore, a grid simulator made of two Modular Multilevel Converters (MMC) with power hardware-in-the-loop concept allows for testing under realistic conditions with arbitrary disturbances like frequency variations or voltage dips. Customized double pulse setups for Si/SiC/GaN devices and a 1 MW 1 kV electric drive test bench complete the test capabilities. The accessibility of hydrogen allows for future extension of research in hydrogen powered systems linked to electrical energy grids for stationary and mobile applications.

Our research topics also include the development of converter systems from scratch to extensive benchmarking at our partners test facilities, if suitable supported by artificial intelligence powered workflows and digital twins. Topology studies are carried out for 2-level, 3-level and multilevel inverters including FPGA control and SoC development. Examples developed 100 % by our team include Modular Multilevel Converters up to 10 MW for energy (20 kV) and ship applications (6 kV) as well as railway traction inverters operating at 450 kW and 1 kV (see images).



Railway traction inverter operating at 450 kW and 1 kV with 60 % weight reduction and driving cycle loss reduction by 30 % compared to state of the art © Elisabeth Iglhaut / Fraunhofer IISB

Medium voltage test lab with Modular Multilevel Converter (MMC) and high power supplies up to 30 kV and 3.2 MW © Anja Grabinger / Fraunhofer IISB

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Corrosion in Power Electronic Systems and Environmental Testing

Due to the steadily increasing packaging density in power electronic modules and the application in harsh environments, voltage driven corrosion is a crucial topic in this field. Especially important corrosion mechanisms in electronic devices are electrochemical migration (mostly on ceramic circuit carriers) and cathodic-anodic filament formation (on PCBAs). Both mechanisms are induced by humidity and electrical voltage and lead to the formation of dendrites which cause short circuits and are responsible for device failure.

Environmental testing is an important tool for corrosion analysis. Influences like temperature, humidity, and corrosive gases or aggressive ions on degradation and corrosion of electronic devices and materials can be investigated. Thus, different application conditions can be simulated in our lab.

Dendrite formation on a ceramic circuit carrier caused by ECM © Anja Grabinger / Fraunhofer IISB

Tests performed in the environmental lab at IISB

- Damp heat testing (e.g. H3TRB)
- Temperature cycling
- Corrosive gas testing (e.g., single or mixed gas)
- Salt spray testing
- Highly accelerated stress test (HAST)

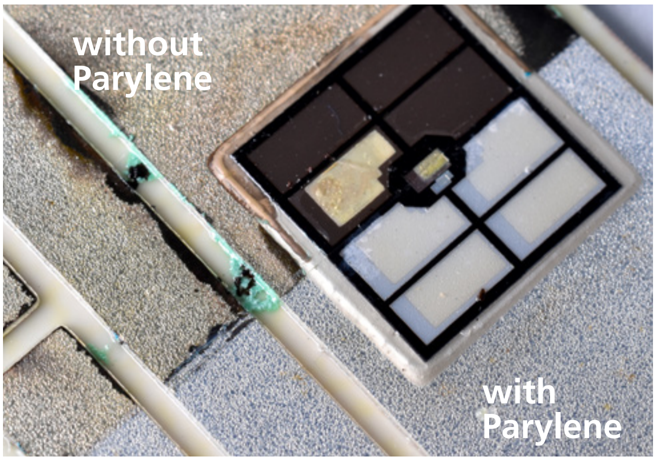
Analyzing methods at the IISB

Samples or modules are analyzed optically and/or electrically after testing.

- SEM (+EDX and FIB)
- Scanning acoustic microcopy
- Partial discharge measurement
- Leakage current measurement
- Lock-in thermography

If necessary, decapsulation and cross-sections can be done prior to analysis.

Besides environmental testing, protection of power electronics against corrosion is an important topic at the IISB.



Protection against corrosion by Parylene coating: AMB circuit carrier after exposure to hydrochloric acid © Antonia Diepgen Fraunhofer IISB

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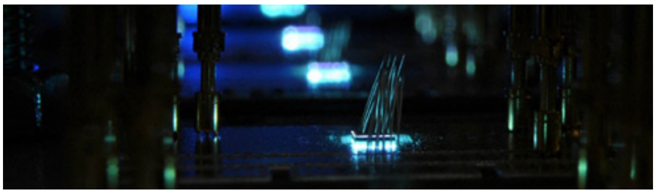
Test & Reliability

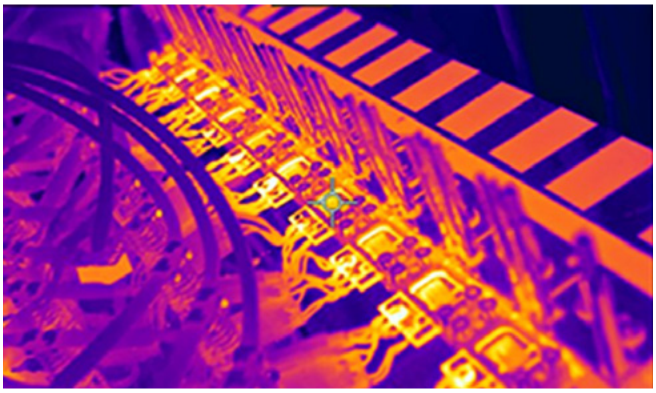


Power Cycling of SiC Diodes © Thomas Richter, Fraunhofer IISB

Lifetime aspects of power electronics are under investigation in this research field. We perform a large variety of tests like power cycling, temperature cycling or humidity storage and many others – with special focus on AQG324 and beyond:

Characterization

- Thermal resistance (Rth value)
- Avalanche and short-circuit capability
- Insulation test and partial discharge



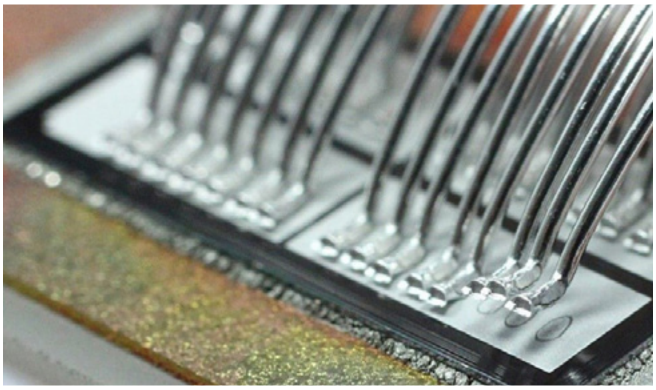
Infrared Image of SiC Diodes in power cycling test © Jürgen Leib, Fraunhofer IISB

Environmental Tests

- Thermal shock test (TST, pTST)
- Vibration (V) & Mechanical shock (MS)
- Temperature Humidity Storage (THS, HAST)

Lifetime Testing

- Power cycling (PCsec / PCmin)
- High/Low temperature storage (HTS/LTS)
- High-temperature reverse bias (HTRB)
- High-temperature gate bias (HTGB, DGS)
- High-humidity, high-temperature reverse bias (H3TRB)
- High temperature forward bias (HTFB)



A huge variety of characterization and analyses tools are available e.g., for measurement of the thermal impedance of power devices, lock-in thermography, scanning acoustic microscopy, static and lock-in thermography, scanning electron microscopy, focused ion beam sectioning and others. The results are used to further improve the technologies

In addition, they are utilized to parameterize existing or to create new lifetime models. The physics of failure method is addressed whenever possible.

All activities are not limited to active devices only. Passive components like inductors and capacitors are covered as well as different as well as different potting materials.

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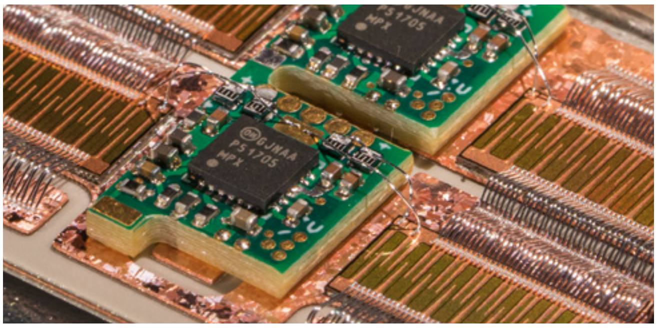
Power Modules for WBG applications



Multilayer GaN-Power-Module with integrated boost stage
© Thomas Richter / Fraunhofer IISB

Power modules are the key factor to systems with high efficiency and power density. Especially new generations of wide-bandgap semiconductors like SiC and GaN enable power modules for high currents as well as for a high switching performance far beyond state-of-the-art.

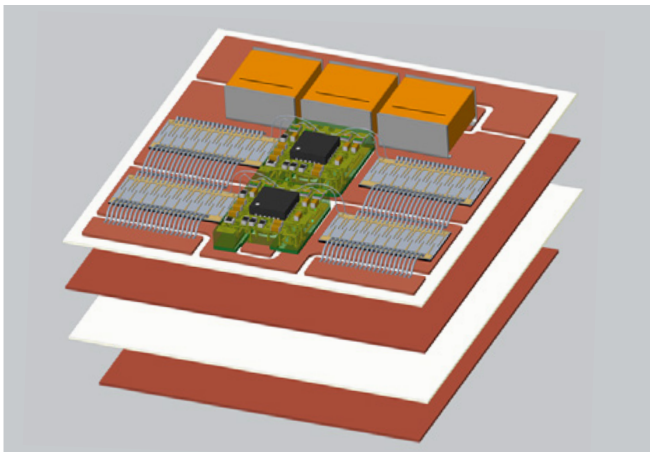
Modules for high power and current are achieved either by innovative cooling concepts like double sided cooling, by high reliable die attach technologies (e.g. top and bot side sintering) as well as by a high parallelization of dies.

Investigations on new approaches for highest switching speeds like multilayer substrates, integration of driver components within the module as well as additional components like RC-snubber elements into the power module show how to fully exploit the performance of WBG-semiconductors.

All technologies from concept to prototyping are available at the IISB to achieve the best possible customer-specific power module approach: Beginning with power module technology and concept development, electrical as well as thermal simulations followed by the realization of power module proto¬types and small series on current production facilities our activities are completed by module characterization and realization of complete data sheets for power modules. Exemplary this research activities are shown on a GaN-power-Module approach with integrated driver boost stage for high switching performance and current capability. A multilayer ceramic substrate in combination with module integrated boost stage and capacitors enable high switching speeds with simultaneously high current load due to the ceramic substrate. The full development line of prototyping, electrical modeling as well as characterization lead to a deep understanding of the success factors for new power module approaches.

Our power module competences

- Concept studies on power modules with new approaches on materials, coolers, applications
- Realization of electrical digital twins for the power modules
- Realization of prototype power modules up to small series
- Characterization of power modules



Multilayer GaN Power module with integrated boost stage
© Holger Gerstner / Fraunhofer IISB

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Cleanroom Laboratory for Power Module Manufacturing

AVT Clean room labratory © Anja Grabinger / Fraunhofer IISB

A variety of equipment and deep understanding of die interconnection processes is required for the realization of innovative power module approaches. Our power module concept studies, prototypes as well as small series are manufactured in our well-equipped class 7 cleanroom laboratory at the IISB

Our Competences

- Printing and jetting of solder and sinter pastes
- Silver sintering (pressure-assisted as well as pressureless)
- Soldering of dies and modules (in vacuum as well as overpressure)
- Direct bond as direct connection between semiconductors as well as semiconductors and substrate
- Wire bonding for top side connection
- Potting
- High performance coating with parylene
- Prototypic structuring of substrate materials by laser-structurization

Highlights from our equipment park

- Die handling and positioning with an accuracy down to 0.5µm (Finetec-Fineplacer, Datacon Evo 2200)
- Jet Printer MY700
- Sinter presses (Schmidt Servopress, Boschmann Sinterstar up to 900kN)
- Systems for soldering & pressureless sintering (e.g. Budatac VS320, Asscon VP6000,…)
- Wire bonder (100 to 500µm Al/Cu, Ribbon-Bonding) & Shear tester
- SAM, microscopy, grinding technology,…

AVT Clean room labratory © Anja Grabinger / Fraunhofer IISB

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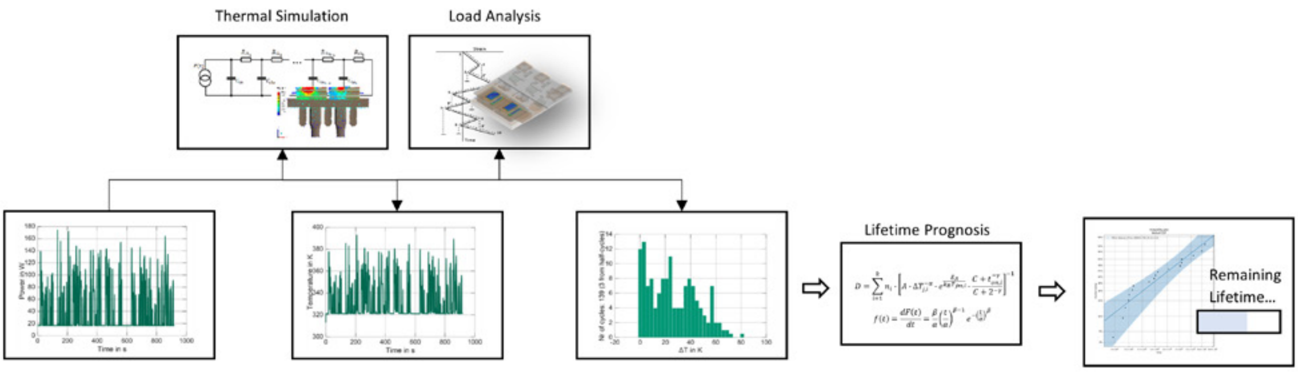
Lifetime Prediction for Power Electronics



Lifetime Digital Twin - Steps in the lifetime and reliability estimation procedure of power electronics. © Fraunhofer IISB

A robust and reliable design that meets the demands from field operation is a key feature for modern power electronics. We support our customers during each step in the lifetime and reliability estimation procedure to avoid over-engineering, increase power density and enhance the competitiveness of your products:

- Development of lifetime estimation strategies (experimental and theoretical).
- Statistical methods according to industrial standards and guidelines.
- Numerical and analytical modeling of physical degradation mechanisms.
- Relative lifetime improvements by numerical design optimization studies.
- Objectives: Electronic systems, subsystems and components.

Temperature Profile

- 3D-transient thermal finite-element-analysis and coupled computational-fluid-dynamics
- 1D-modeling by electro-thermal analogue circuits

Load Analysis

- Extraction of closed mechanical hysteresis loops from temperature load signal by use of counting algorithms
- Field simulations via coupled finite-element-analyses

Lifetime Model

- Determination of system response and damage variables
- Accelerated ageing tests (e.g. power cycling, thermal cycling, shock and storage tests, etc.)
- Non-linear transient finite-element-analyses
- Modeling of damage evolution
- Empirical, by observable variables, e.g. temperature swing, heating voltage, thermal resistance
- Physical, by internal variables, e.g. inelastic strain, plastic strain energy density, damage variables (CDM)

Prediction of Lifetime & Reliability

- Accumulation of damage per load increment
- Calculation of lifetime and reliability

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Evolonic Team © Isabella Hufnagel / Fraunhofer IISB

Promotion of young Scientists in Cooperation with the University of Erlangen-Nürnberg (FAU)

Well-educated and commited engineers are indispensable for the development of innovative concepts and to continuously drive research forward. This is why we are strongly dedicated to fostering interest in the engineering profession and supporting pupils, students and young engineers wherever possible.

The Vehicle Power Electronics department of the Fraunhofer IISB offers a lot of opportunities for young scientists and engineers, such as:

- Jobs for engineers, scientists, and research assistants
- Topics for master and PhD theses (in cooperation with the University of Erlangen-Nürnberg)
- Taster traineeships and internships

An exciting example for a successful cooperation with students from the Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) is 'EVOLONIC'. The EVOLONIC student team was founded at the FAU Faculty of Engineering in 2008. In this team, students work on challenging projects for the mobility of the future in their spare time or as part of their final theses. An electric car and an electric motorcycle were already developed and built, but the group's current focus is on electric flying.

The Fraunhofer IISB supports EVOLONIC with technical knowledge, components for the electrification, as well as laboratory equipment and testing facilities for the vehicle modifications. For some students, this project was the starting point for a future career at the Fraunhofer IISB.

Team EVOLONIC is currently developing the third generation of its electrical long-range aircraft. Here, the students deal with the construction of a flying robot, which combines innovative concepts of aviation to an efficient, autonomous flying, and overall scalable concept.

Research focuses on the development and construction of all custom components, such as wing design, battery systems, flight control, and much more.

In order to achieve these goals, the students work on questions as a team as well as individually in final theses and internships.

www.evolonic.de

Our Vehicle Power Electronics Experts Teams

9 Research Groups with over 100 Engineers and Technicians

Vehicle Electronics Department

Head of Department: Dr.-Ing. Bernd Eckardt
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Drives and Mechatronics

Group Manager: Dr.-Ing. Maximilian Hofmann
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- Electric Drivetrains
- Inverter Development
- 3D Integration, Mechatronics
- E-Vehicle Test Center

AC/DC Converters

Group Manager: Dr.-Ing. Stefan Zeltner
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- Vehicle to Grid
- Insulating Converters
- Modular Power Electronics
- Circuit Simulation

DC/DC Converters

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- DC/DC Converter Systems
- Digital Control
- System Simulation
- System Integration

Innovative Power Modules

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- Power Module Design & Simulation
- Power Modules Prototyping
- Characterization

RF-Electronics and EMC

Group Manager: Stefan Ditze
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- Inductive Power Transmission
- High Frequency SiC/GaN Converters
- EMC Test Site
- Semiconductor Characterization

Grid Interface

Group Manager: Dipl.-Ing. Stefan Endres
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- Charging Systems
- Resonant Converters
- Rectifier Topologies
- EMC Optimization

Aircraft Power Electronics

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- Aviation Power Electronics
- Advanced System Design
- Thermal CFD Simulation
- Environmental Testing

Medium Voltage and Megawatt Power Test Lab

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- Megawatt power electronics
- Mulitlevel system modeling and design
- Power device and system characterization

Test and Reliability

Group Manager: Dr. rer.nat. Jürgen Leib
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- Digital-Twin and Lifetime Prediction
- Characterization and Failure Analytics
- Device and Module Test e.g. AQG324
- Corrosion - Test and Protection

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