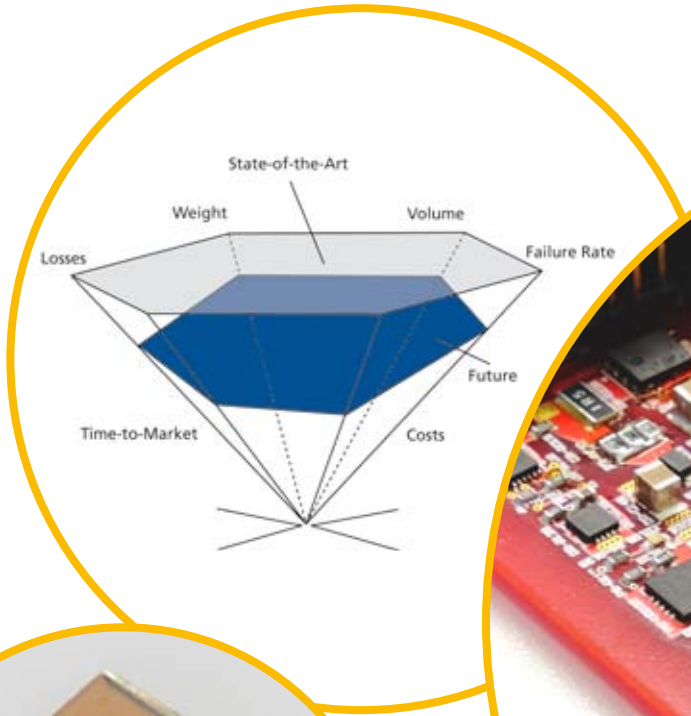
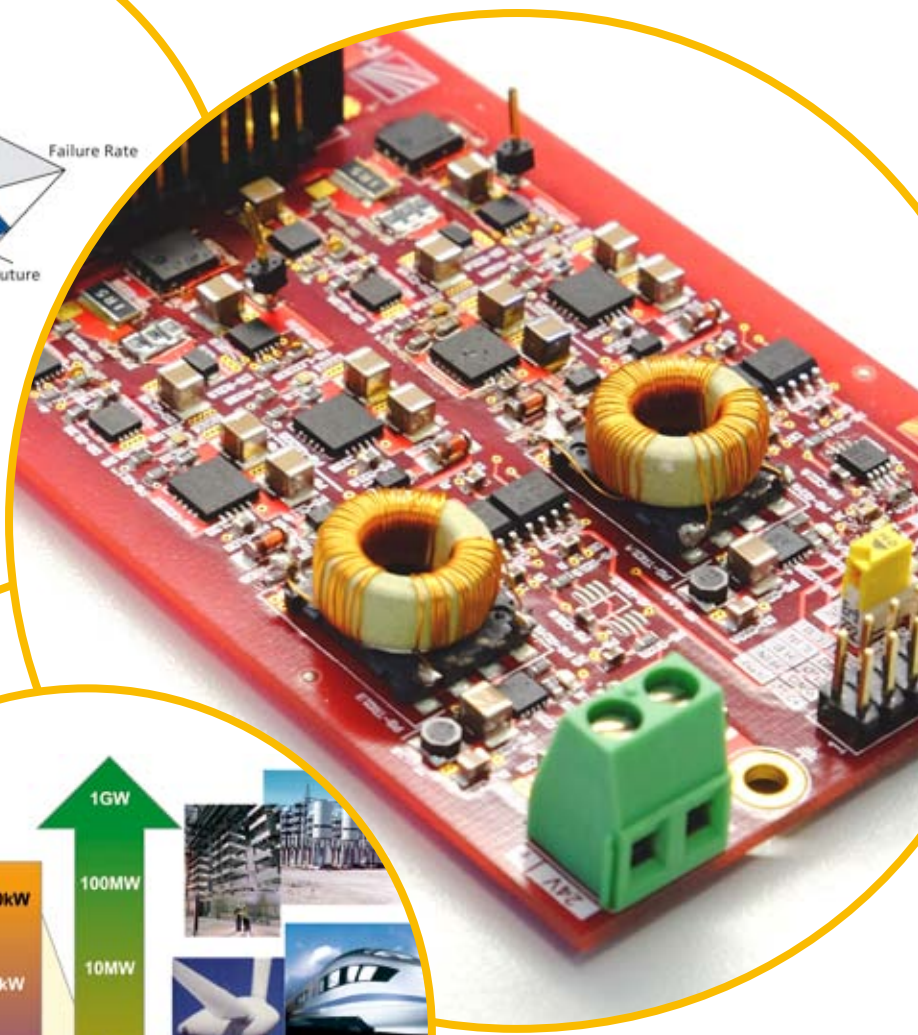
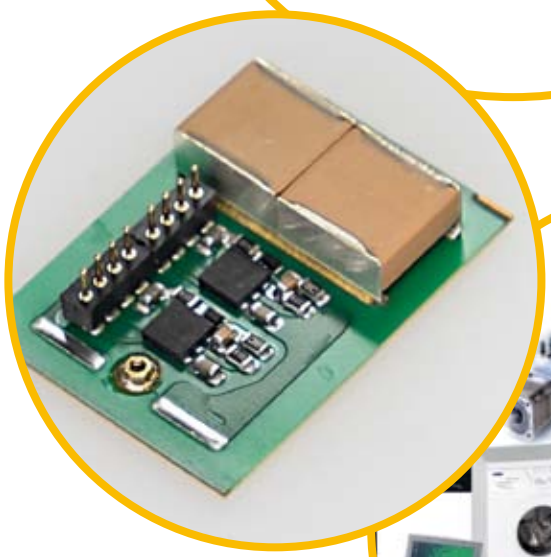
ECPE
European Center for
Power Electronics e.V.

The ECPE Network

Member Companies and Competence Centres







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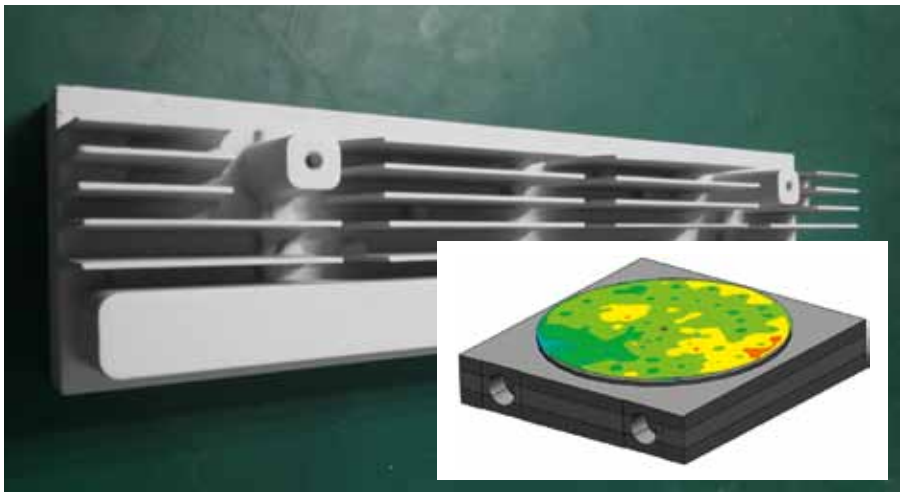
AAVID THERMALLOY

AAVID THERMALLOY S.R.L.



Thermal Management Solutions for Power Electronics around the World

Aavid, your trusted thermal management provider formed the Power Thermal Solutions Division to meet the specific issues facing design engineers in the Power Electronics Market. With the combined experience of its global sales, engineering and manufacturing presence, Aavid is able to provide optimal solutions to maximize thermal efficiency, minimize weight and system costs and reduce component and system size in every sector of power electronics; examples of this attitude are: High Density Die Casting, a new process to have high thermal conductivity aluminum alloys shaped as die casted products, or Vortex Liquid Cold Plate:
an innovative LCP design to have perfectly uniform and low temperatures at very low pressure drop. With its divisional headquarters based in Bologna, Italy, Power Thermal Solutions has manufacturing facilities in Europe, North America and Asia alongside local sales and design support in each of these regions.

Engineering & Design Services

Aavid's Engineering and Design Services business unit provides innovative, cost effective design, testing, analysis and prototyping services for companies throughout the world by utilizing their highly diversified thermal, mechanical, industrial and electronic design capabilities. Aavid is able to develop, test and verify its designs for customers by employing engineering teams around the world who are:

- highly specialized in their respective engineering disciplines and;
- convey significant and practical experience across a large breadth of industries and markets.

These capabilities coupled with its investment in the latest technological tools and

ABB is a global leader in power and automation technologies that enable utility and industry customers to improve their performance while minimizing environmental impact. The company seeks to improve performance, drive innovation, and attract talent, while always acting responsibly. With a presence in more than 100 countries, the ABB Group of companies employs over 140,000 people. The business is organized in four divisions: Power Grids, Electrification Products, Discrete Automation & Motion and Process Automation.

ABB Corporate Research is a global organization employing approx. 850 research engineers. At each of its seven research centers around the world, scientists are working hard toward novel technological achievements that will help strengthen the four ABB Group divisions. In line with ABB's mission to drive innovation, the mission of ABB Corporate Research is to maintain and strengthen the company's position as a technology innovation leader. ABB Corporate Research drives solution-oriented projects, facilitates recruitment of talent researchers, and serves as the primary interface for university collaborations and publicly funded projects. In Europe, ABB Corporate Research Centers are located in Baden-Dättwil (Switzerland), Västerås (Sweden), Ladenburg (Germany) and Krakow (Poland).

At the Corporate Research organization the power electronics research starts with the semiconductor: devices are designed and fabricated in a cleanroom facility, dies are packed and integrated into larger assemblies, where the devices are arranged in circuits with optimized topologies. From semiconductors to power electronics hardware and system aspects, the research covers the full spectrum. Application oriented power electronics research ranges from Power Supplies, Low Voltage and Medium Voltage Grids, UPS, PV Inverters and Energy Storage, Vehicle Charging, Drives and Wind converters, Traction Drives, Motion Control and Robotics, FACTS, Grid Interties, Energy Storage Systems and HVDC. The Corporate Research Center closely cooperates with the R&D centers of the ABB power electronics business units and the ABB Semiconductor factories.

Highlights Power Electronics Research at ABB:

- Semiconductor technologies, e.g. wide bandgap high power semiconductors.
- Power module technology development for industrial, traction and HVDC applications.
- Next Generation Power Electronics Building Block (PEBB) developments for multiple applications
- Power electronics multilevel topology developments, e.g. ANPC MV Drive or MMC HVDC technology, and its related control
- Integration of new technologies and development of new applications
- Research activities in magnetics, EMI and cooling of power electronics systems.

alpha
ASSEMBLY SOLUTIONS

ALPHA ASSEMBLY SOLUTIONS, INC.

Products. Partnership

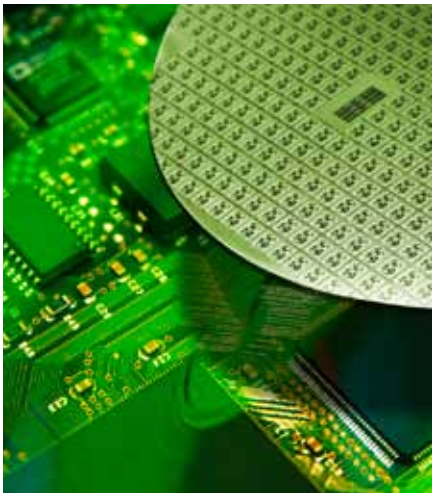
Alpha Assembly Solutions, a MacDermid Performance Solutions Business, is the global leader in the development, manufacturing and sales of innovative electronics assembly materials such as Solder Pastes, Exactalloy® Solder Preforms, Cored Solder Wire, Wave Soldering Fluxes, Bar Solder Alloys and Stencils.
With a global presence in over 30 locations throughout the Asia Pacific, Americas and Europe regions and the largest R&D manufacturing capacity in the industry, Alpha is able to bring customised and proactive solutions directly to electronics manufacturers in a wide range of industry segments, including power electronics, die attach, LED lighting, semiconductor packaging and automotive electronics.

Powering Solutions

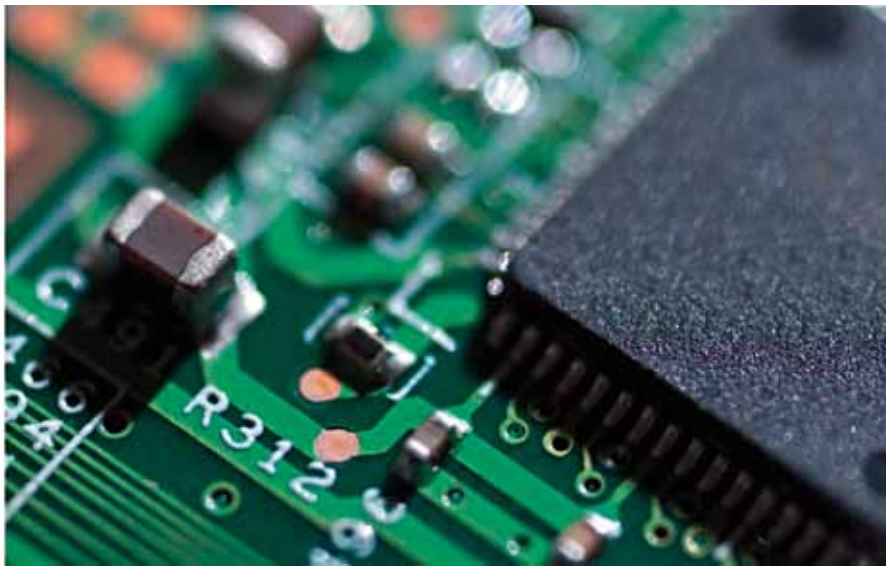
In response to the power semiconductor market's drive to improve reliability and device performance for automotive, alternative energy, transportation, consumer electronics, telecommunications, industrial and LED applications, Alpha Assembly Solutions has developed its Argomax® and Fortibond™ range of products.

ALPHA® Argomax® Sinter Technology products were developed in response to the industry's demand for increased die attach reliability and cost effective high volume manufacturing. The technology uses a low pressure sintering die attachment based on highly engineered particles, developed by Alpha's expert team of engineers. Argomax® creates extremely high thermal and electrical conductivity silver bonds with a high reliability and flexible bondline thickness for even the most challenging technologies.

The technology is available in paste, film and Argomax® 9000 preforms, a first for the Power Semiconductor Industry, and is suitable for a wide variety of applications, including power modules, power discretes, bipolar devices, cavity packages and wafer level processing.



Alpha's Fortibond™ technology was specially designed for LED manufacturers that require pressureless sintering in their die attach process. The technology is based on Alpha's proprietary pressureless silver sintering technology consisting of highly engineered silver particles and provides high thermal and electrical conductivity silver bonds, high reliability and flexible yet controlled bond line thickness.



Innovation for the future

alpitronic stands for a highly qualified team of young engineers, specialized in the development of complex electronic systems in hardware and software.
alpitronic's focus is centered upon power electronics and safety-critical systems.
alpitronic's commitment and flexibility in the development of innovative systems guarantee high quality solutions and short development times, which are achieved through a consistent, process-oriented approach. Model and simulation based development methods are fundamental to alpitronic's ability of innovation.

Common Goals

alpitronic is eager to face the complex challenge of developing innovative concepts together with their customers, from the first idea to the timely implementation – with competence and consistency.
alpitronic's design experts offer support for conceptual design and dimensioning of complex power electronic systems, design of microprocessor architectures of safety-related applications (ASIL / IEC 61508), circuit simulation, power loss and tolerance calculations, thermal and cooling system design, as well as optimization of costs and power losses on existing circuits.
In the field of system engineering, especially for automotive power electronics, alpitronic develops and tests inverters for traction and range extender applications, including special solutions like high switching frequency inverters with alpitronic's ARCP technology. alpitronic's motor test bench provides the facilities to do inverter and e-machine testing, including high precision power loss determination of components and the whole system.

alpitronic provides also development and manufacturing support: schematic and layout design, production and commissioning of prototypes, handling of the certification process, handling of small series production.

Pioneering Technology

alpitronic's new resonant switching ARCP technology for half-bridges allows high frequency switching of 50kHz and more at currents of several hundred amperes. The technology was first realized in a 100 kW inverter prototype (400V DC link voltage and phase current 250Aeff).
A 550Aeff device is currently in development. Switching frequencies of 50 kHz and more enable new applications like high-revving, or high pole count, compact motors. The technology provides weight and volume reduction of currently available inverters by 30% through reduced cooling demand and small EMC filter.

Alstom is a global player fully focused on transport

Alstom develops and markets systems, equipments and services for the railway sector. Alstom manages the widest range of solutions in the market – from high-speed trains to metros and tramways – and associated maintenance, modernisation, infrastructure and signalling solutions. Alstom is a world leader in integrated railway systems. It recorded sales of €6.2 billion and booked €10 billion of orders in the 2014/15 fiscal year. Headquartered in France, Alstom is present in over 60 countries and employs 32,000 people today.
Alstom's ambition is to be the preferred partner of its customers for their transport solutions in all geographic locations and all market segments.

Designing fluidity

Alstom continuously develops, supplies and maintains sustainable and integrated rail solutions for the urban and main line markets. These are technically, economically and environmentally efficient, designed to meet today's challenges of smarter mobility and tailored to each of the operators and public authorities which they serve.

Staying a step ahead

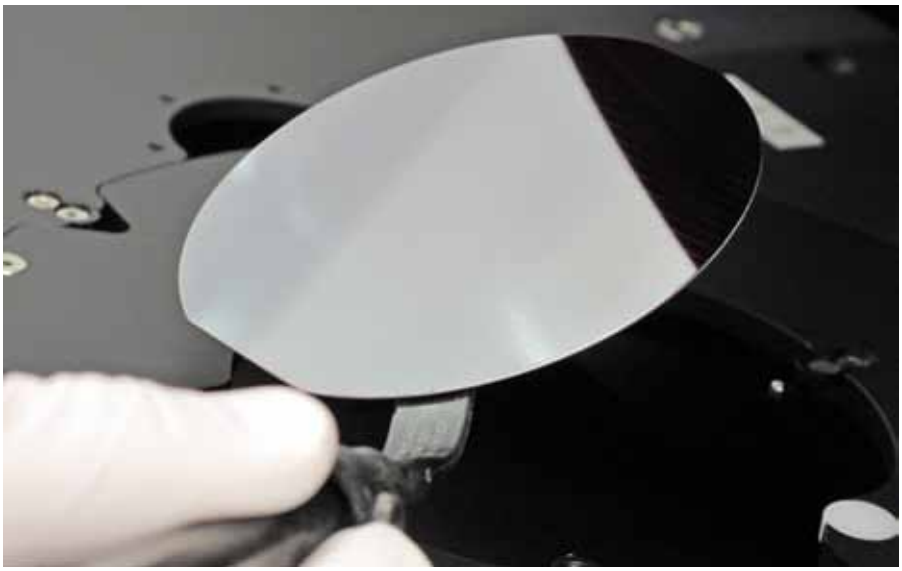
Alstom has built an international reputation on the performance and technological lead provided by its rail solutions.
The company is determined to maintain its focus on innovation to set itself apart from other market players while establishing its competitive edge and reducing the total cost of ownership of its products.This is why Alstom continues to invest in research and development.
Its roadmap has three major goals: meeting the expectations of customers and passengers, more effectively; staying competitive; and integrating leading technological developments into its products and services.In a world of evolving technology, Alstom's products and services incorporate the latest advances in connected solutions (including sensors, communication networks and data transmission protocols for signalling, smart maintenance, real-time passenger information and new 5G high-speed wireless standards) and automated systems (such as monitoring solutions, virtualisation tools and cybersecurity).

ANVIL SEMICONDUCTORS LIMITED

Anvil Semiconductors has developed a unique proprietary technology which, by growing thin layers of silicon carbide SiC on silicon wafers, rather than using expensive bulk SiC, enables wafer costs to be reduced by a factor of 20 and promises to deliver the advantages of SiC devices for the cost of conventional silicon ones. The proprietary process overcomes the critical problems of mismatches in lattice parameter and thermal coefficient of expansion between the two materials and can be readily migrated onto 150mm diameter wafers – and potentially beyond.

Another area of cost saving compared to conventional SiC technology comes from the processing of the active device. The cubic form of SiC (3C-SiC) grown on silicon is much easier to process than the hexagonal form of the material (4H-SiC) which is produced in bulk crystals. Indeed 3C-SiC can be processed in a conventional silicon CMOS line with the addition of one high temperature furnace.

Anvil is using third party facilities to produce production, device quality 3C-SiC on 100mm diameter silicon wafers with layer thicknesses that permit the fabrication of vertical 1200V power devices. These are being used to develop vertical 650V and 1200V Schottky Barrier Diodes (SBDs) and MOSFETs in 3C-SiC capable of current densities of at least 500A/cm^2. The SBDs produced to date show ideal characteristics, no silicon/SiC interface effects and excellent yields.



Anvil Semiconductors has offices in Coventry and Cambridge and has a small experienced team and an extensive network of Industrial and Academic partners to develop unique silicon carbide power device.

SiC offers many superior properties over silicon:

- SiC can sustain higher voltages reducing system complexity and cost whilst improving system reliability.
- SiC can carry higher currents with lower parasitic capacitances.
- SiC has a higher thermal conductivity and can operate at temperatures up to 400 °C (cf silicon 150 °C) reducing the cooling costs and complexity of applications such as hybrid vehicles.
- SiC is able to switch ten times faster allowing the use of smaller capacitors and inductors producing cheaper, smaller and more efficient systems.

Advantages of Silicon Carbide

APOJEE GMBH

Company

APOJEE GmbH is the German subsidiary of APOJEE SA, the French company created in 1999. With its 50 engineers and technicians, APOJEE develops and supplies high-technology in the fields of power electronics, test benches and ignition /combustion. Thanks to the skills of its recognized experts, the company both develops its own products but also customer specific ones. With its experienced engineers in the spheres of electronic and mechanical R&D, embedded software, multiplex systems, electromagnetism and modeling, production engineering and quality, APOJEE has skills covering the entire life cycle of a product. The company works with the major European automotive, aerospace and industrial players.

Power Electronics Know-how

Expertise in power electronics is one of APOJEE's key strengths. Performance, reliability and cost also depend on the mechanical, thermal management and the EMC: APOJEE possesses all these skills. The company defines specific products, conducts studies and then designs fitted architectures which leads to the creation of prototypes or pre-series. It finally supervises the whole industrialization process. Some significant products are: power supply for aerospace – Electronic hybrid automotive suppliers – inverters, DC / DC converters for electric/hybrid vehicles – embedded or external fast chargers (up to 43 kW). It also develops and produces a technology-based silicon carbide inverter. This motorsport inverter delivers 150 kW for 2.2 l. APOJEE experts have been using their thorough know-how in the automotive power electronics to contribute to the development of hybrid/electric vehicles for car manufacturers and suppliers, but also, to the definition and design of aeronautical power supply. Today, APOJEE is a team of over 30 people dedicated to the design and development of products incorporating power electronics.

Test Benches

To cope with the market demand, APOJEE developed and produced an innovative and modular testing system for the validation of power electronics components: Marvel. Highly standardized and widely deployable to reduce both investment and operational costs, Marvel is able to deal with the new functional requirements of future projects. A bay can take up to 22 modules reaching a maximum power of 440 kW (220 kWDC + 220 kWAC). Marvel's inverter has a high switching frequency (70 kHz) reducing current/voltage ripple, giving higher dynamic performance.

Ignition & Combustion Expertise

Complementing its power electronics and high voltage know-how, APOJEE is expert in combustion phenomena: the company contributes to the optimization and improvement of gasoline internal combustion engines. APOJEE supports its customers in their combustion analysis, designs and develops prototypes or systems that are specific to ignition (spark plugs, ignition coils). It also provides innovative test equipment intended for engine as well as ignition system designers. APOJEE works with European OEMs, Tier 1's and various Formula 1 teams.

Company profile

Ascatron is developing the next generation Silicon Carbide (SiC) power semiconductors using the company's proprietary 3DSiC® material technology with a quality and performance unattainable through current methods.

Ascatron is a Sweden based scale-up company with background in producing advanced SiC epi material for global customers since 2011. We have recently transformed from a service provider to a device product company with semi-fabless business model. Our target is to be a highly trusted and innovative supplier of SiC semiconductors for medium and high voltage power electronics in industry, automotive and renewable energy. Our vision is to provide the full power of SiC for maximum performance and sustainable use of electricity.

Technology

Ascatron's unique material technology (3DSiC®) makes it possible to entirely use the potential of SiC to handle very high power with minimal losses, while maintaining the reliability on the same level as for Silicon devices.

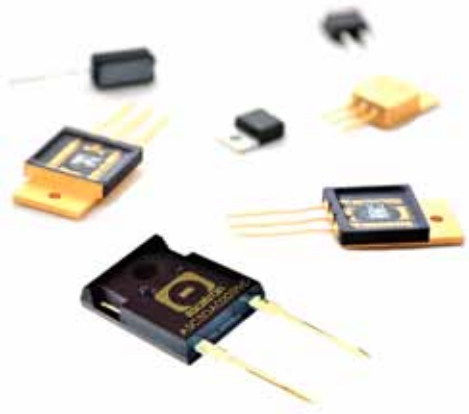
The main feature is a buried doped grid that sustains high voltage and reduces the electric field on the sensitive surface of the device. The implementation of the buried grid design is a result of the company's deep competence in SiC epitaxy.

The 3DSiC® technology makes it possible to lower the losses up to 30% compared to conventional SiC devices.

The 3DSiC® technology enables a modular design of the product line. Each device is divided in a high voltage module related to the desired voltage class, and a low voltage part for each type of component. Combination of different modules gives a wide range of products and selections for customers.

Products

Ascatron has a very ambitious launch plan the coming years to diversify the product portfolio with both power diodes and power MOSFET's from 1200 V up to 10 kV. Our 3DSiC® devices can be adapted to specific customer requirements including alternative packaging solution and current rating. The devices are supplied as packaged discrete or bare dies.



Services

Ascatron produces advanced Silicon Carbide (SiC) epitaxy material with best in class uniformity. We also offer custom specific device fabrication for prototyping and small volume production.

Our many years of knowledge within SiC epitaxy and power devices, as well as our flexibility makes us a dedicated and reliable supplier of products and services within Silicon Carbide.

AT&S

AUSTRIA TECHNOLOGIE & SYSTEMTECHNIK AKTIENGESELLSCHAFT

High end Production in Leoben

Unique market position

AT&S is the European market leader and one of the globally leading manufacturers of high-value printed circuit boards. AT&S industrialises leading-edge technologies for its core business segments Mobile Devices (Smartphones, Tablets, Ultrabooks, Consumer Electronics), Automotive (high-end applications like advanced driver assistance systems – lane change assistant, navigation – or safety features, gearbox, etc.), Industrial (machine to machine communication, power solutions,..), Medical (diagnosis like MRT or therapy applications like hearing aids, pacemakers, etc.) and Advanced Packaging (Chip embedding).

Global Presence / Customer and supply chain proximity

AT&S has a global presence, with production facilities in Austria (Leoben and Fehring) and plants in India (Nanjangud), China (Shanghai, Chongqing under construction) and Korea (Ansan, near Seoul). The company currently employs about 8,600 people.

Clear focus on high-end connecting solutions and applications

Depending on technological requirements, AT&S offers an extensive technological range of printed circuit boards specially tailored to customers' needs: from double-sided plated-through, multi-layer, HDI (high density interconnection, laser-drilled) or HDI Anylayer, IMS (insulated metallic substrate), flexible, rigid-flex and semi-flexible. Miniaturisation and modularisation are the key drivers in the electronic industry. Starting in 2016, AT&S will position itself in the high-end market at the new site in Chongqing (China) with two new leading-edge technologies: IC substrates for high-performing computing applications and substrate-like printed circuit boards – the basis for SiP (System-in-Package) technology.

Advanced packaging – important part of the future growth for AT&S

AT&S is the leading provider for Embedded Component Packaging Solutions. Its patented ECP® technology enables further miniaturisation while improving performance.

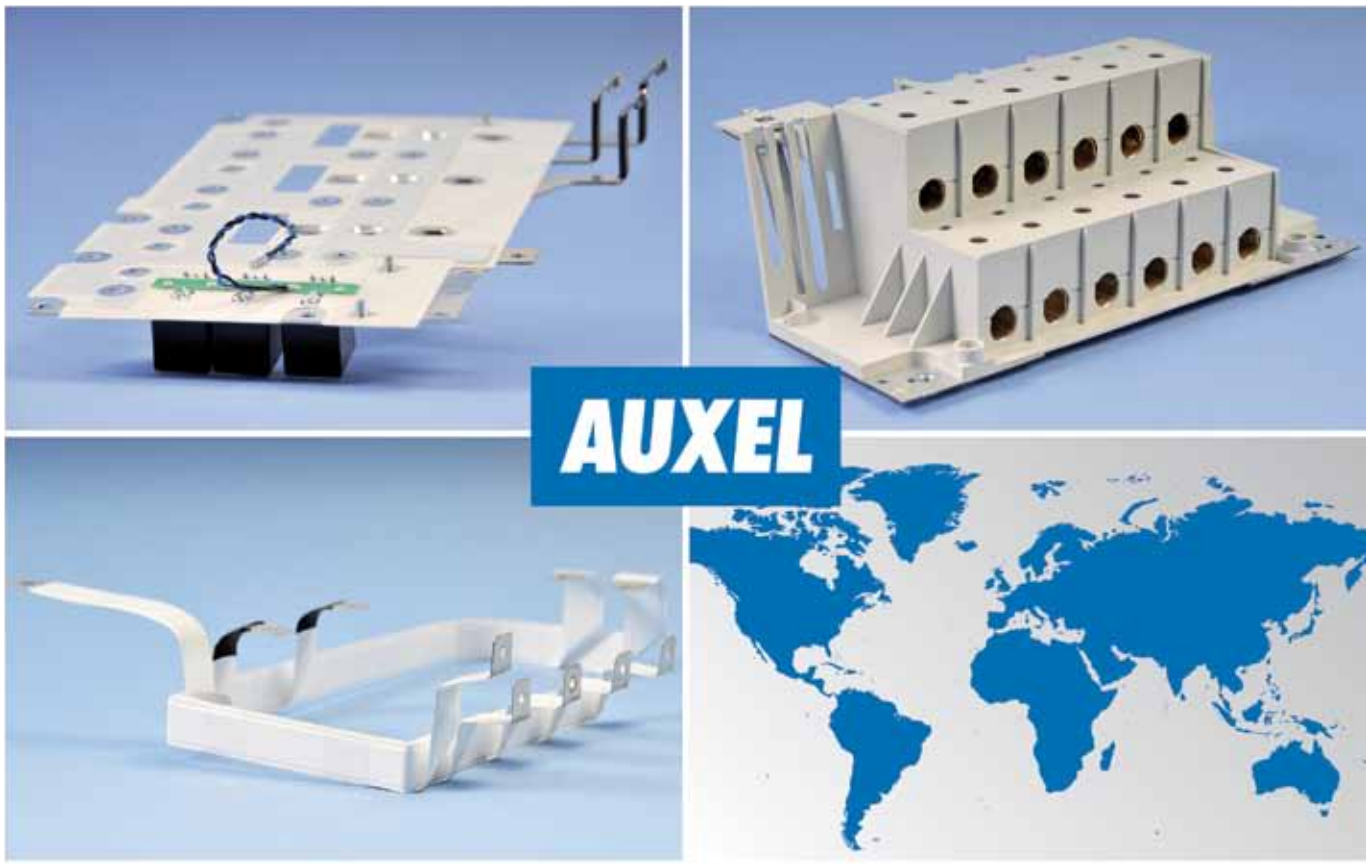
Power a further focus for embedding technology

Together with the EmPower consortium AT&S announced the stage of industrialisation for embedded power packages for Industrial and Automotive applications. This solution provides a significant increase in efficiency and performance and miniaturisation levels up to 50% for power modules compared to existing packaging solutions. New plating equipment for wafer level plating has been developed in order to realise double sided copper plated power dies. This enables a new supply chain for embedded power devices and new packaging solutions for applications in the power ranges from 50W to 50kW.

Further information for EmPower
http://catrene-empower.ats.net/

Embedding technology for volume production

2 KW Power converter with embedded GaN semiconductors



AUXEL, the Complete Range: Busbars – Interconnects – Power Distribution

AUXEL is the Power Electronics and Electronics Division of AUXEL FTG, a global company designing, manufacturing, selling and providing support for interconnection and power distribution products and applications, in the fields of Low Voltage Electricity, Power Electronics and Electronics.

Today, benefiting from an expertise of over 50 years, AUXEL FTG handles the most advanced technologies to address all challenges regarding Conducting Current, Insulating, Connecting and Assembling.

We offer you busbars, interconnects and power distribution solutions which answer your economic and technical requierements:

- Lower your production costs
- Increase your system reliability
- Increase electrical performance:
- Facilitate the development of new products:

Thanks to a global presence with sales offices, engineering departments and manufacturing units in a variety of key locations, AUXEL FTG is able to serve, co-design and follow its clients personally all over the world.

With a wide range of products recognized as innovative, reliable, safe and cost effective, AUXEL FTG provides solutions for various needs and markets: Industrial (Motor Drive,...), Transportation (Rail, Automotive, Avionics), UPS, Solar, Wind, Smart Grid, Electronics (Data centers, ...).

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A partner that speaks your language

CO_2 reduction, increasing complexity of vehicle and powertrain systems as well as the need to keep development costs under control – those are the challenges for the global automotive industry.

Your partner for the electrified powertrain

AVL is the world's largest independent company for development, simulation and testing technology of powertrains (hybrid, combustion engines, transmission, electric drive, batteries and software) for passenger cars, trucks and large engines.

AVL e-Storage System

Powertrain Engineering:
AVL develops all kinds of powertrain systems and is a competent partner to the engine and automotive industry since over 65 years.

Instrumentation and Test Systems:
The products of this business area comprise all the instruments, systems and software required for powertrain and vehicle development and test.

Advanced Simulation Technologies:
The simulation software portfolio is focusing on design and optimization of powertrain systems and covers all powertrain components up to vehicle level as well as all phases of the development process. Whether you are interested in a single measuring instrument or need an entire turnkey test facility – more than 6200 of our employees in over 40 countries are dedicated to exceeding your expectations.

Expertise in Electrification

AVL offers development services, simulation and testing tools for all components of the electrified powertrain like electric motors, high-voltage batteries, controllers and inverters. By choosing the AVL platform, customers can seamlessly develop, simulate and test components in a common environment from first steps "in-the-loop" to final assurance in a "real" environment/vehicle.

An Example: AVL Electric Motor Testbed

Electric motors play a central role in the development of new drive systems. They act as a primary drive unit and have to be optimized in power and efficiency, reliability and durability.
AVL Electric Motor Testbeds function as complete development, testing, verification and validation environments for different electric motor types (ISG, BSG and Axle Drives). They are used for determining and analyzing electrical, mechanical and thermal characteristics.

AVL e-Motor Test Bed

Highlights of the AVL Electric Motor Testbed

- Proven concept of the testsystem
- Modular system based on harmonized and approved components
- Flexible pallet system for most productive use of the test bed
- Continuous data recording, even for durability tests
- Full integration in testfield management systems or enterprise test data management systems
- Standardized or customized solutions in test rig or pallet system design

AVL Battery Test Bed

Bayerische Motoren Werke (BMW) emerged in 1916 from a company for Aircraft Engines in Munich. Today, BMW is a global provider of high-end automobiles and motorcycles. The headquarters of BMW AG is located in Munich. Besides domestic production sites in Munich, Dingolfing, Regensburg, Landshut, Leipzig and Berlin, manufacturing facilities are located in Austria, South Africa, USA, Mexico, Southeast Asia and Russia.

BMW AG currently employs approximately 105.000 people. In 2013 the sales quantity reached a volume of around 1.96 million cars and about 115 thousand motorcycles, which are sold in over 100 countries. In fiscal year 2012, the BMW Group achieved a turnover of around 76,8 billion Euros. In its research and innovation center in Munich, BMW employs about 6,000 engineers in innovative research and development topics.

Service Portfolio

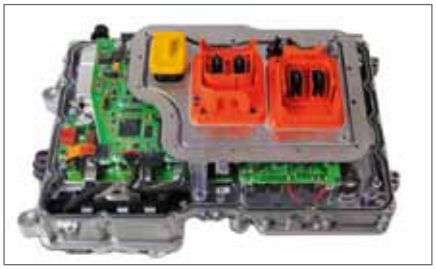
Electrification of the powertrain plays a central role on the path towards CO_2-free mobility. The BMW Group, with its further development of hybrid technology and eDrive powertrains, is consequently pushing these technologies in order to establish electric mobility as a sustainable solution for individual mobility.
The new BMW i3 is a pure electric vehicle using an all new light-weight designed LifeDrive concept. The correspondent

architecture of this vehicle posed considerable challenges regarding the electric drive components and their interaction.

In addition to the task of an optimal incorporation of the drivetrain into the vehicle also optimum light weight properties, modular design and high quality have been achieved and are combined with an efficient and dynamic electric drive system.

Corporate Objective

With the development and the in-house production of the key components for the BMW i3 and i8, Li-Ion battery system and electric motor, BMW has laid the foundations for the creation of further exciting powertrains in the future.
The BMW eDrive powertrains are characterized by their dynamic power performance, high efficiency, smooth running and optimized quality.
The power electronics responsible for the interaction between the battery and electric motor is also an in-house development of BMW.

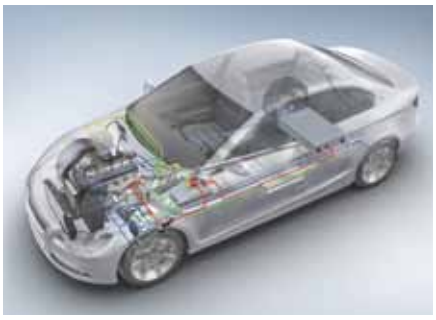


Robert Bosch GmbH

The Bosch Group is a leading global supplier of technology and services. It employs roughly 375,000 associates worldwide (as of December 31, 2015). The company generated sales of 70.6 billion euros in 2015. Its operations are divided into four business sectors: Mobility Solutions, Industrial Technology, Consumer Goods, and Energy and Building Technology. The Bosch Group comprises Robert Bosch GmbH and its roughly 440 subsidiaries and regional companies in some 60 countries. Including sales and service partners, Bosch's global manufacturing and sales network covers some 150 countries. The basis for the company's future growth is its innovative strength. At roughly 118 locations across the globe, Bosch employs 55,800 associates in research and development. The Bosch Group's strategic objective is to create solutions for a connected life. Bosch improves quality of life worldwide with products and services that are innovative and spark enthusiasm. In short, Bosch creates technology that is "Invented for life."

Power electronics: from technologies to product innovations

Power electronics is a key enabling technology in many areas in which Bosch does business, including e-mobility (fig. 1), industrial drives, power tools, and renewable energy (fig. 2).



1 Power electronics is a key enabling technology for the electric powertrain in hybrid and electrical vehicles, electric power steering, start-stop systems, and for body electronics

2 Photovoltaic inverters combined with intelligent energy management and storage solutions such as the VS5 Hybrid are innovative products of Bosch Power Tec

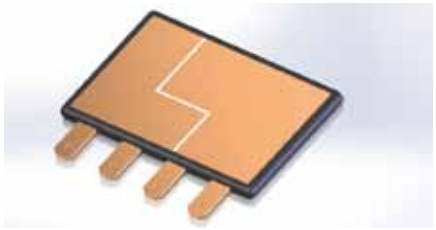
Cars in particular pose special challenges such as space and weight requirements, robustness under extreme mechanical and climatic conditions, and how to achieve volume production at low cost. Power electronic inverters, for instance, control the energy flow for electric driving in hybrid and electrical vehicles. More precisely, they convert direct current from the traction battery into the three-phase alternating current that powers the electric motor. Inverters also control energy recuperation, which saves on fuel, as well as the currents recharging the battery. The second generation of Bosch inverter systems has already entered series production (fig. 3 - 4).

3 Bosch power inverters are controlling the electric drives in hybrid and electrical cars (example: Inverter-Converter Gen. 2.3)

4 Modular design of automotive power inverters enables demanding design spaces in hybrid cars, resulting in individual solutions (example: Inverter_L7)

Miniaturization of power electronics plays a central role in product innovation: reducing space requirements, decreasing weight, improving efficiency, and ultimately lowering the cost of power electronics will make fuel-saving hybrid technology affordable to more and more drivers. In interdisciplinary teams of engineers, Bosch is developing miniaturization and next-generation power-electronics system integration on all technology levels, from semiconductor-components, power-modules and control units to overall electric drive systems.

Boschman Technologies is the world's leading supplier of automatic molding systems using Film Assisted Molding (FAM) technology and the experience built up with the molding technology Boschman Technologies also uses for the Ag Silver Sintering Presses for power packages to replace soldering.
Boschman Technologies develops new processes for the Ag-sinter technology under pressure and the encapsulation of power packages. Boschman Technologies delivers the encapsulation equipment and sintering presses to the worldwide semiconductor and electronic industry.
Boschman Technologies provides in a close cooperation with the semi-industry new processes and equipment for the Power packages.
The "basic" technology of molding with a protecting film started more than 15 years ago and the semiconductor industry looks with favour on the advanced processes of encapsulation. Boschman Technologies has the technology to (partly) encapsulate the Power packages in such a way that the "heatsink" area of the package can perform its function in a perfect encapsulated environment. .



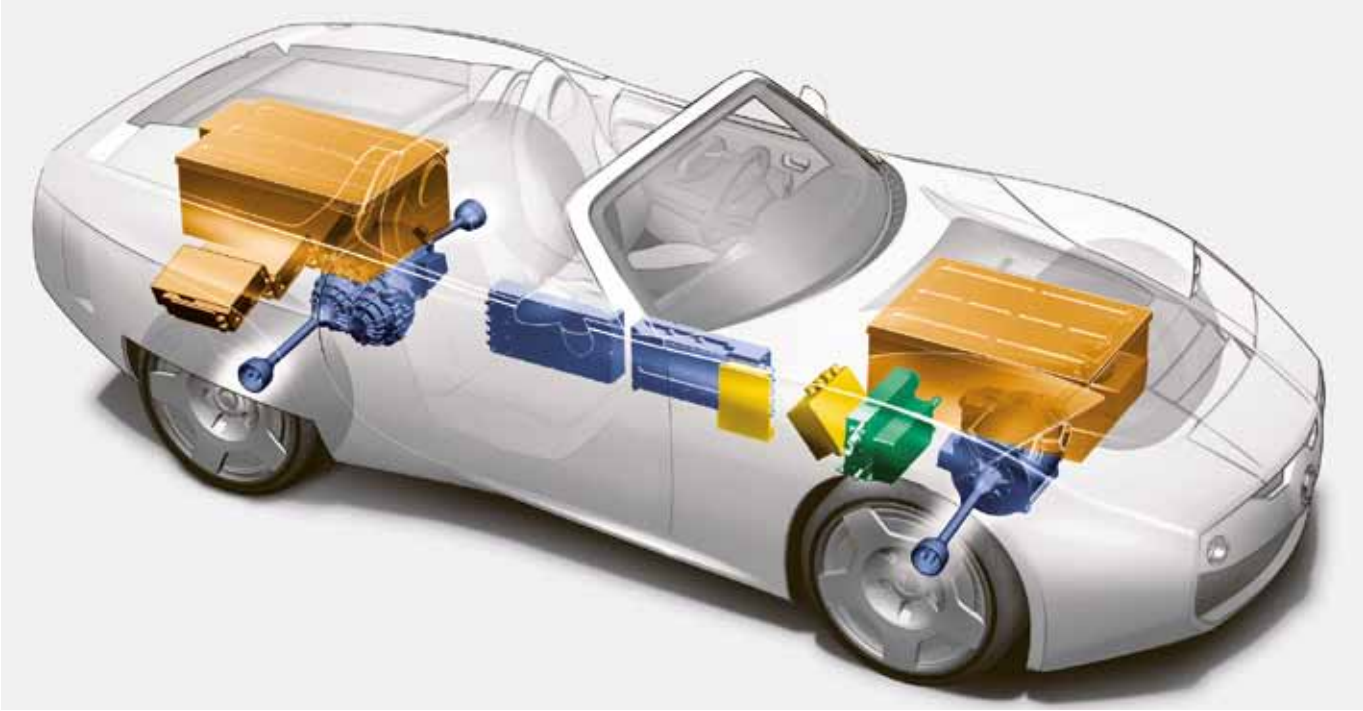
molded part

Transfer molding is the primary process method for the microelectronic encapsulation and with encapsulation material-epoxy molding compound (EMC), one of the first applications was the transistor package. Traditional transfer molding process has disadvantages including EMC bleed and resin flash, time consuming mold cleaning, mold wearing, package deformation during the ejection process and lead frame deformation or (ceramic) substrate cracking due to clamping. FAM deals with challenges of releasing components from the mold and keeping certain surfaces -heatsink- clean from molding compound.
Releasing from the mold and product surfaces is accomplished by a "seal film" and the seal film is refreshed after every molding cycle. The seal film is functioning as a gasket, reducing the clamping force, and allowing clamp and seal on dies and ceramic surfaces.
In close cooperation with the Ag sinter material suppliers Boschman developed a family of Ag sinter presses from Semi automatic up to complete automatic systems for high volume production.
The Dynamic Insert Technology, developed for the molding presses, Boschman Technologies is also using for the Sintering Systems.

Sintering in the Boschman presses is for lead frames, substrates or ceramic carriers and the film protects the die surfaces against damages. With the Dynamic Insert Technology the clamping on the dies and DBC's is done with a very precise force control compensating for built up tolerances.
The Boschman Systems are designed for low cost, fast and easy product conversion.

BRUSA

BRUSA ELEKTRONIK AG



Shaping the future of electric mobility

BRUSA Elektronik AG has shaped the global breakthrough of electric mobility from the very beginning and is now one of the major contributors in the field of highly efficient drives and power supplies for high performance.

Since its formation in 1985, BRUSA Elektronik AG, headquartered in Sennwald, Switzerland, has focused on developing highly efficient power electronics for electric vehicles. Electric drives, highly efficient DC/DC converters and battery chargers, high-speed motor controllers, and portable power electronics are just a few of the solutions BRUSA supplies to automobile manufacturers around the world.

The company is 100% employee owned and has enjoyed continued growth through diligent business development. BRUSA technology is world-leading. In 2013 the Inductive Charging System by BRUSA was awarded the renowned eCarTec award by the German state of Bavaria. Inductive charging offers a whole new level of convenience for owners of plug-in hybrids and electric vehicles; just park normally, and come back to a fully charged car. Creating this innovative user experience requires many levels of advanced expertise, and as a leading member of international inductive charging standardization activities, BRUSA's inductive charging FRAME® is the leading edge technology.

CADFEM – because 'CAE-Simulation' means more than just Software

Simulation opens up a huge range of possibilities. Companies and scientists develop groundbreaking innovations benefitting both people and the environment. Additionally, they save costs and development time by scouting potential new product concepts and implementing possible optimizations using CAE-Simulation tools.

Founded in 1985, CADFEM is currently regarded as one of the pioneers of numerical simulation based on the Finite Element Method (FEM). With 12 branch offices, over 170 employees and more than 100 design engineers, CADFEM is one of the largest European suppliers of Computer-Aided Engineering (CAE). CADFEM liaises closely with ANSYS, Inc. in Pittsburgh, Pennsylvania and is the ANSYS Competence Center FEM in Central Europe. Since CAE-simulation requires more than just software, CADFEM supplies all the tools which are decisive for success in simulation from one single source. Leading software and IT-solutions, consultancy, training and engineering. This means state-of-the-art expertise based on the latest developments in technology.

Products

CADFEM has at its disposal a complete program of CAE software and hardware from leading technology suppliers.

- ANSYS Software
- Complementary Tools
- eCADFEM – Software on Demand
- Hardware + Complete Systems

Service

CADFEM offers an extensive selection of services, enabling customers to fully exploit the potential of CAE.

- Information Days and Seminars
- User Support
- Process automization and Customization
- Simulation on demand

Know-how

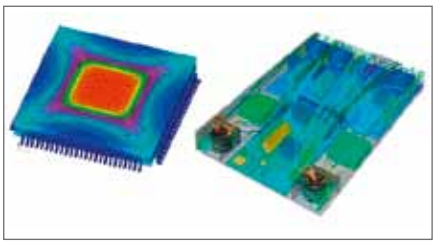
CADFEM liaises closely with businesses and research teams, fostering the exchange of the CAE-simulation experience among users.

- CADFEM esocaet
- CADFEM Users' Meeting
- TechNet Alliance
- CADFEM specialist media

Branch offices in Berlin, Chemnitz, Dortmund, Frankfurt, Hannover, Stuttgart.

Austria: CADFEM (Austria) GmbH,
Switzerland: CADFEM (Suisse) AG.

Worldwide: TechNet Alliance,
www.technet-alliance.com



Continental

Continental develops intelligent technologies for transporting people and their goods. As a reliable partner, the international automotive supplier, tire manufacturer, and industrial partner provides sustainable, safe, comfortable, individual, and affordable solutions. In 2014, the corporation generated sales of approximately €34.5 billion with its five divisions, Chassis & Safety, Interior, Powertrain, Tires, and ContiTech. Continental currently employs more than 208,000 people in 53 countries.

The Powertrain division develops and produces efficient system solutions for vehicle powertrains to optimize fuel consumption. The comprehensive range of products includes gasoline and diesel injection systems, engine management and transmission control, including sensors and actuators, exhaust aftertreatment technologies, fuel supply systems, and components and systems for hybrid and electric drives. Powertrain employs over 34,500 people worldwide. In 2014, it recorded sales of approximately €6.5 billion.

Power Electronics

When it comes to hybrid and electric vehicles, there appear to be many seemingly straightforward general assumptions. The range of the electric drive is determined by the battery; its acceleration characteristics by the electric motor. Yet in both cases, there is another decisive factor: the efficiency of the entire electric drive system – and this is determined primarily by the power electronics. This electronic system, which controls both the power as well as the energy recovery (recuperation), has a major influence here. It is also responsible for fully utilizing the potential of the electric drive, thereby making it fun to drive, which is caused in part by the high starting torque and the response behavior of electric motors. Continental, innovation driver in e-mobility for over ten years, is already in series production with the second generation of power electronics.

Third generation of Continental's Power Electronics – Inverter and DC/DC Converter in a single housing

Power Electronics integrated into axle drive system

In addition to the functionality and efficiency of the power electronics, the space requirements and weight are important criteria for automotive manufacturers. Therefore the power to size ratio of Continental's power electronics has been improved continuously. The third generation is six times more powerful than the first generation while the system weight has been reduced from around 12 kg originally to around 8 kg in the same time. This includes the inverter which supplies the motor with electricity and the DC/DC converter which supplies the 12 Volt boardnet.

We at Daimler AG as the inventor of the car and the truck assume responsibility for their future. Our Road to Emission-free Driving stands for our commitment to securing sustainable mobility. Our aim is to markedly reduce fuel consumption and emissions already today and to eliminate them entirely in the long term. To this end, we are developing a broad spectrum of state-of-the-art drive technologies that meet the specific requirements placed on today's and tomorrow's mobility in all modes of road transportation.

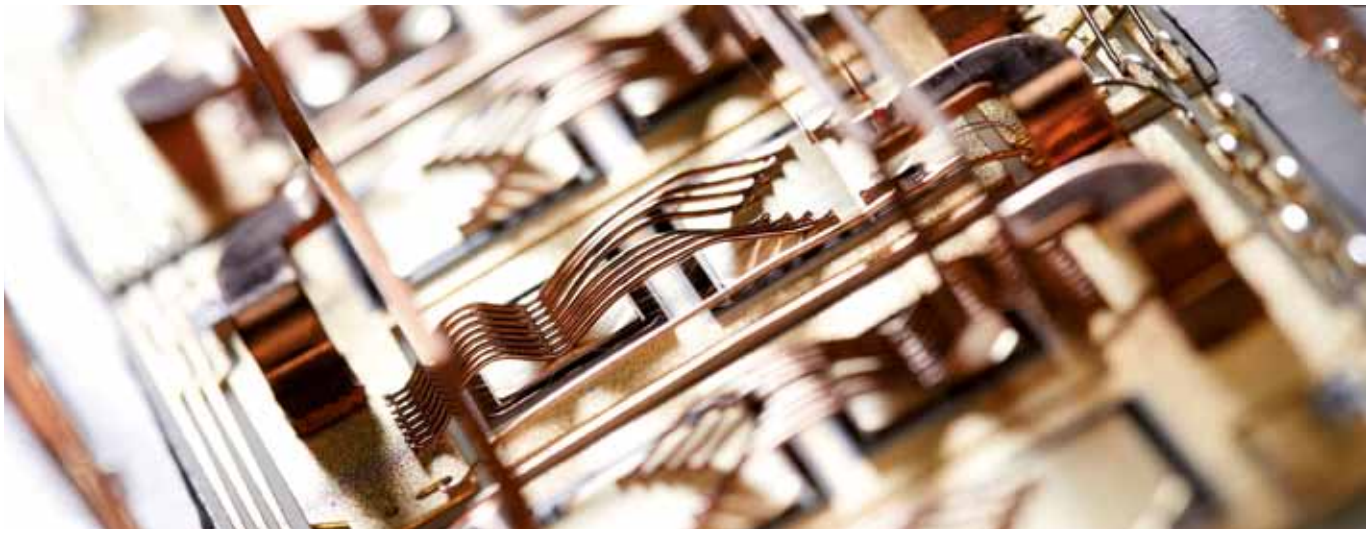
The key to greater efficiency and environmental compatibility lies in the electrification of the drivetrain. This offers great potential for improvement, which is being realized for example in auxiliary units, the automatic start / stop system, and hybridization. For this stage of Daimler's "road map", we have developed a modular hybrid system that offers various possibilities for extension in terms of performance and range of vehicle applications. All hybrid drive variants can be realized on this basis: from so-called mild hybrids, with electric recuperation and boost function, up to purely electric driving. The future of the modular hybrid system is shown by the Mercedes-Benz Vision 500 Plug-in HYBRID. With a certified consumption of only 3.2 liters of gasoline per 100 kilometers and a purely electric operating range of 30 kilometers due to a battery which can be recharged, it offers green technology in a fascinating luxury-category vehicle.

The future has begun: Daimler vehicles with battery and fuel cell have proven their technical feasibility and are ready for every day use: The smart fortwo electric drive, Mercedes-Benz A-Class E-CELL, Mercedes-Benz B-Class F-CELL, Mercedes-Benz Vito E-CELL, Fuso Canter E-CELL, and Mercedes-Benz Citaro FuelCELL Hybrid are already in operation today and offer electromobility in all areas.
But there are still a number of challenges that will prevent electric automobiles from being a familiar sight on the roads in the near future. Boosting operating range and performance, cutting systems costs, and establishing an infrastructure

are the requirements that yet remain to be fulfilled. Power electronics is a key to master these challenges.

In R&D we investigate and optimize all the key components for electromobility, including batteries, charging systems, electric motors, drive inverters, and auxiliary devices together with the HV power net architecture in the car.

DANFOSS A/S



Danfoss Drives A/S

Danfoss Drives is a division of Danfoss A/S with R&D centers in China, Denmark, Finland, Germany, India, Italy and the USA. We develop and market power electronics solutions that manage energy to the highest standards. Our technologies can be found in a wide range of industries such as Automobile, Chemical, Cranes/Hoists, Electronics, Food and Beverage, Heating, Ventilation/Air Conditioning, Lifts/Escalators, Marine/Offshore, Material Handling, Mining/Minerals, Oil/Gas, Packaging, Pulp/Paper, Refrigeration, Solar/Wind, Textile and Water/Wastewater.

Danfoss was first in the world to series produce variable speed AC drives. Since 1968 we have achieved a strong track record in reliable, versatile and easy to use drives. Exclusively focused on AC drives, we are constantly working with a wide range of customers where drives play an integral part of the business. We help to improve the customer's own product or process in order to bring the best possible performance. The secret behind our success lies in unique engineering craftsmanship and innovations. Our research focuses on making products smaller, smarter and more efficient, while upholding high standards of usability and quality. Our AC drives represent technology that not only helps save energy costs but also significantly improves the process control. With design centers on three continents we tap into competences worldwide and highly value our access to the European research community through ECPE.

Danfoss Silicon Power, DSP

DSP, a part of Danfoss Drives, is a leading developer and manufacturer of customized power modules and stacks. We specialize in application-specific designs in close cooperation with customers, using e.g. 3-D mechanical construction of power module components and coolers, thermal and reliability simulations and rapid prototyping. This customization approach helps customers; such as electric drive manufacturers, automotive players and renewable energy OEMs, provide highly differentiated offerings to the market. We also have emphasis on innovation and our association to the European research community through ECPE supports us in this. Danfoss Bond Buffer® (DBB®) and ShowerPower® are two such examples. DBB® is the next generation bonding and joining technology which can outperform the current industry standard by over 15 times. ShowerPower® is highly reliable, compact and a more cost effective solution than traditional indirect or direct cooling technologies can offer.

Delta – The power for a better future

The Delta group is one of the leading suppliers of power supply devices and DC brushless fans. Founded in 1971, with corporate headquarters located in Taiwan and with more than 80,000 employees the group realizes a turnover of US$ 6.6 billion today. The range of products covers power management products and electronic components, display and projection systems, industrial automation and LED solutions. Additional business areas include power supply solutions for renewable energies and the automotive industry.

Our mission is to provide innovative, clean and efficient energy solutions for a better tomorrow. With focus on this mission we continuously invest in our R & D design centers and production locations.

Delta Energy Systems (Germany) GmbH

With about 500 employees at the Soest and Teningen facilities we represent a rapidly expanding part of the Delta Group in Germany. On the basis of international interrelationships and our long-time experience in the development of standard and customer-specific power supply solutions we have become a well-established technology competence centre.

We deliver customized and innovate power supplies for computer (server and storage) and telecommunication industry,

network technology as well as medical, industrial and office automation applications. In the area of regenerative energies we offer inverters for photovoltaic systems, wind turbines and hydroelectric plants and are continuing to set the trends with products which are environmentally-friendly and future-oriented. In the electrical vehicle sector, we are increasingly becoming a supplier of charging devices for batteries, converters and inverters.

Our company culture which is characterized by openness and a climate of cooperation offers our employees the freedom to utilize their creativity to introduce their own ideas and innovation. The designs of the future will be determined by energy and environmental factors. We are investing in core competencies, knowledge, skills, creative thinking, research and innovative technology.

Our products are manufactured in generously-sized production facilities in Slovakia and Thailand. Both sites meet our high standards with respect of manufacturing competencies and quality control. In every individual case, the smooth transition from prototype manufacture to series production is ensured by means of early and active integration in the development process and by regular meetings on-site or via conference.

DODUCO GMBH

DODUCO is a global market leader in electrical contacts with locations in Europe and Asia. Through 90 years of experience the company has gained i.a. a broad know-how in precious metal processing, contact technology, current carrying electrical connections and coating technology.

With this product range and a one stop shopping possibility DODUCO is an important partner for many companies in a broad range of industries and in nearly all market regions.

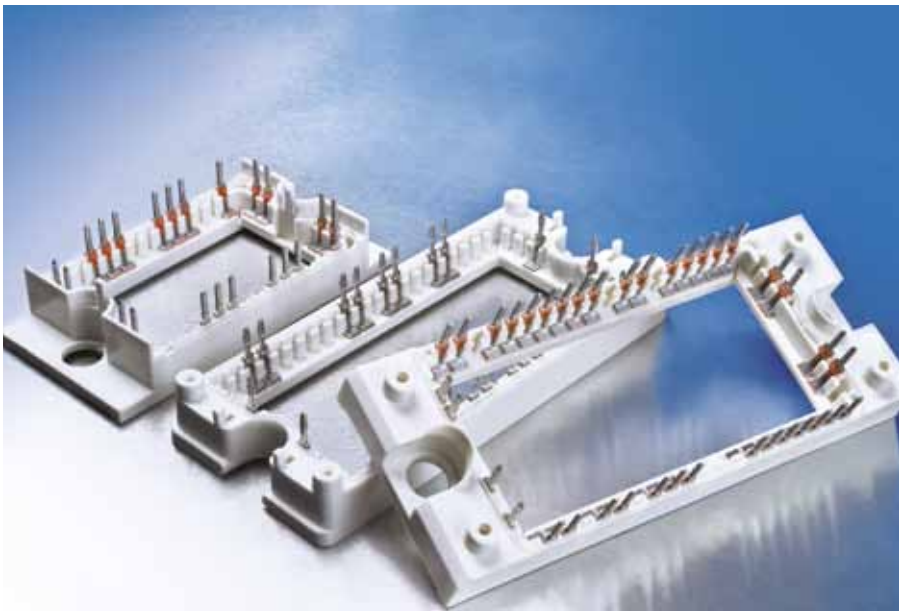
Our support for power electronics includes bondable materials, precision stamped parts, hybrid frames and housings, surface technology and a comprehensive R&D in design of hybrid packages.

Wire bondable base materials

DODUCO is one of the largest European source for AlSi-cladded copper alloy tapes, the most reliable surface for aluminum wire bonding. With an additional electroplated coating on the tapes all wiring applications can be achieved.

Precision stamped parts

DODUCO manufactures precision stamped parts for high power current as well as signal connection applications. We offer a flexible press fit connector system with high reliability for interconnection of PCBs.



Hybrid Frames and housings

Hybrid frames and housings

Based on decades of experience DODUCO is a market leader in hybrid frames engineering especially for power electronics and automotive applications. For the manufacturing we have the full range of production technology starting with material, tooling, stamping and plastic molding. Together with the design engineers of module suppliers we work in a close partnership to achieve cost benefits, fast design reviews, the best technical solution and a short time to market for our customers.

Coating technology

Coatings are required where wires are bonded and connections are made. DODUCO offers a wide variety of surface layers for low and high power applications as well as thermal management. Our R&D engineers work closely with material science specialists to develop the surface layers required in future.

As a true cooperation partner with a comprehensive know-how we actively incorporate our knowledge and experience into the improvement, new development and prototyping of customer products.

Dynex Semiconductor Ltd delivers advanced power electronic semiconductor and system solutions from its Lincoln, UK HQ. It is recognised worldwide as a specialist designer and manufacturer of IGBT, discrete bipolar devices and power assemblies. It now benefits from being part of CRRC Corporation of China with access to its volume manufacturing and applications expertise. Lincoln is the CRRC Centre of Excellence for power semiconductor R&D and electric vehicle power assemblies.

IGBT, FRD die and Module Technology

With advanced design and Si fabrication capabilities, Dynex offers high reliability standard and custom IGBT and diode modules with ratings up to 3600A and 6500V for automotive, aerospace, traction, HVDC, renewable energy & industrial applications. In 2017, Dynex introduced

the world's most capable Press-pack IGBT, with power ratings of up to 3000A at 4500V. Dynex modules are designed for operation under extreme conditions and are one of the main outputs from its advanced wafer foundry and assembly facilities. In addition, Dynex offers a Silicon die manufacturing foundry service to external customers.

Bipolar Products and Technology

Dynex's bipolar products consist of thyristors, power diodes, gate turn-off thyristors and fast recovery diodes. Dynex thyristors feature latest ion implant technology for marked improvements in switchable power density. Voltages extend to 8.5kV with current ratings to 7kA at silicon diameters up to 150mm. Dynex diode voltages extend to 9kV, currents to 11kA and are used on IGBT inverter front-end rectifiers, smelters and trackside rectification. Dynex is committed to the continued production of GTOs up to 4.5kV.

Power Assemblies

The long experience of utilising the Dynex semiconductor range, and an understanding of applications, enables the group to provide optimum power assemblies solutions. These include protection and control electronics, air and liquid cooled assemblies, semiconductor device test equipment, and pulse power systems. Heat sinks and clamping arrangements are available.

Silicon Carbide

Dynex has been involved in the development in wide band-gap power semiconductors, in particular silicon carbide (SiC), since 2011. Projects on SiC have included 1.2-3.3 kV SiC MOSFETs and SBDs, 3.3 kV Pin diodes, and hybrid/full SiC power modules for traction and other applications.

R&D Centre Assemblies – Electric Vehicles

The R&D Centre Assemblies group develop integrated power units for electric vehicles. Across the board knowledge enables the group to provide products with high power density. New technologies include intelligent gate drives, 3D thermal management, advanced packaging and EMC technologies, condition monitoring and health management.

TDK

EPCOS AG

A global leader in electronic components, modules and systems

TDK Corporation is one of the largest manufacturers of electronic components, modules, systems and devices in the world. The broad range of products and solutions includes passive components like ceramic, aluminum electrolytic and film capacitors, ferrites and inductors, high-frequency components and modules, piezo and protection devices, and sensors. These components are marketed under the product brands, TDK and EPCOS.

Focus on demanding markets

Relying on a strong worldwide R&D, manufacturing and sales network, the company focuses on demanding markets in the areas of information and communication technology and consumer, automotive and industrial electronics. The company has design and manufacturing locations and sales offices in Asia, Europe, and in North and South America.

Comprehensive technological competence

Ever smaller electronic components, modules, and systems now feature higher performance and improved electrical parameters. These products can be used for example in particularly demanding environmental conditions characterized by high temperatures or the presence of aggressive media. The design of such solutions is based on expertise in materials and processes, evaluation and simulation capabilities, as well as extensive knowledge in the areas of application, circuit, and packaging technologies.

Customer-oriented innovation

A wide range of components and manufacturing processes at the micron level result in components with functions and form factors that enable customers to design and produce their own advanced products. In this way, customers are offered technologically superior components and solutions that give them a competitive advantage.

Highest quality

Increasingly exacting quality requirements are being passed down through the entire production chain. Carmakers and manufacturers of automotive electronics systems in particular insist that their suppliers operate quality systems that cover every single function, and that are consistently focused on enabling these companies to master and constantly improve their processes. These demands have been condensed into the international quality system standard ISO 9001 and into the ISO TS 16949 standard which, based on the former, addresses the specific needs of the automotive industry.

About Fronius

For 70 years, the name Fronius has been synonymous with intensive research and the constant quest for innovative solutions to control energy. The perfect efficiency of every product has repeatedly been awarded both national and international prizes – one of the most recent being the Plus X Award 2013 as the "Most Innovative Brand of 2013" in the Energy category. Our 928 granted patents demonstrate just how important innovation is to us. Our headquarters and most of our production sites are in Austria, and we have subsidiaries in 21 countries on four continents. In addition, sales partners and representatives in more than 60 countries support our activities around the world. What fascinates us most is the perfect weld seam and a sustainable supply of energy. This motivation spurs us on to develop and market outstanding products and services for Perfect Welding, Solar Energy and Perfect Charging.

Perfect Welding

We develop welding technologies, such as complete systems for arc and resistance spot welding, and have set ourselves the task of making impossible weld joints possible. Our aim is to decode the "DNA of the arc". We are the technology leader worldwide and the market leader in Europe.

Solar Energy

Grid connected inverters, the unique Fronius Service Partner programme, products for the monitoring of photovoltaic systems make up our portfolio of products and services. All our activities are based on the motto "24 hours of sun", our vision for the energy revolution. This represents the future of energy supply over the coming decades from the perspective of Fronius. Our aim is to ensure a reliable, continuous and sustainable CO_2-free supply of energy.

Perfect Charging

Fronius battery charging systems have been specially developed for professional use with starter and traction batteries. With the Ri charging process, introduced in 2013, we have been able to set new standards in terms of energy efficiency and battery life. Our intelligent energy management systems ensure maximum cost-effectiveness and performance in intralogistics and the vehicle workshop. As know-how leader, we would be delighted to take on the planning of complete charging infrastructures for the intralogistics sector.

Fuji Electric
Innovating Energy Technology

FUJI ELECTRIC EUROPE GMBH

Corporate Profile

European Headquarters of
Fuji Electric Co., Ltd.

Foundation year

Fuji Electric Co., Ltd.: 1923
Fuji Electric Europe GmbH: 1987

Employee

Worldwide: Approx. 25,500
The Fuji Electric Group started out in 1923 as Fuji Manufacturing Co., Ltd.

Today Fuji Electric is a synonym and a brand for success and one of the largest corporate groups worldwide. Japanese and European Engineers combine together and are passionate about producing leading products of the highest reliability. Fuji Electric has been, still is, and, always will be, geared to technological innovation.

For decades, products of Fuji Electric have been successfully established in many industrial processes in Germany, Spain, Italy, France, UK and other European countries.

Power Electronics

Over a broad range of areas that encompasses industrial and social infrastructure – where there is growing demand for energy saving – we reduce CO_2 emissions and improve energy efficiency and stability by supplying products that combine power electronics technologies. These technologies include power semiconductor technologies and control technologies.

Semiconductor

For more than 30 year Fuji Electric has been delivering power semiconductors that save energy and improve efficiency across the wide range of areas including the industrial, new energy and vehicle electrical components areas. Our outstanding reputation in the market is based on a high quality & electrical performance combined with state of the art semiconductors.
In addition to its sales& logistic activities, we are providing a wide range of application support and customer specific module designs by our technical and module design center.

Fuji Electric offers a wide line-up of environmentally friendly semiconductor-based products ranging from IGBT power modules for industrial and automotive customers, which are an indispensable component in energy-saving power electronics, MOSFET, diodes, and control IC needed in high-efficiency power supplies. As manufactures and designer of its own Chip technologies, Fuji Electric offers an alternative source as a supplier and excels in researching new technologies as well as improving existing ones like packaging and SiC semiconductors.

Drive and Automation

Through its strong distribution network in Europe, Fuji Electric Europe delivers frequency inverters, PWM converters, servo systems and HMI into varieties of industrial markets. Fuji Electric has an extensive lineup of industrial-use inverters, which are key devices that help enhance the automation, labor-saving, and energy-saving attributes of machinery, equipment and devices. Excellent quality, superlative motor shaft performance and the highest efficiency, contributing to the "green" environmental effort, characterizes our product range.

Heavy Wire bonding – detailed view

F & K DELVOTEC Bondtechnik GmbH, the innovation leader in wire bonding, was founded in 1978 and has since then pioneered the development of new technologies that have subsequently progressed to become market standards. Until now F & K DELVOTEC won over 40 patents worldwide, and successfully delivered over 6.000 wire bonding machines to major accounts within the semiconductor, electronics and automotive industries.

As specialists for assembly and joining technologies we have been committed to continuing to develop reliable and efficient solutions for connecting electronic components.

In the field of wire bonding for customers in the semiconductor, E-Mobility, Photo-Voltaic and automotive industries, F & K DELVOTEC develops complete solutions for partial or full automation. The all-round service ranges from applications guidance in the selection and configuration of the wire bonding machines to attached buffer stations and magazine lifts all the way to the integration of handling systems for complex production lines. The standard portfolio covers bonding equipment in fine, ball/wedge and heavy bonding technology.

The boom in the market for power electronics continues unabated. Because of the physical limits to the current carrying capacity of wire bonded connections, F & K DELVOTEC developed a robust and extremely reliable technology for joining aluminum and copper ribbons on DCB and other substrates: laser bonding.

Already at the product development stage, F & K DELVOTEC is ready to help with pre-trials to evaluate the bondability of material surfaces, and with product design. This is of great value in Design for Manufacturability, shortens the development time and optimizes the process of adding value from the start.

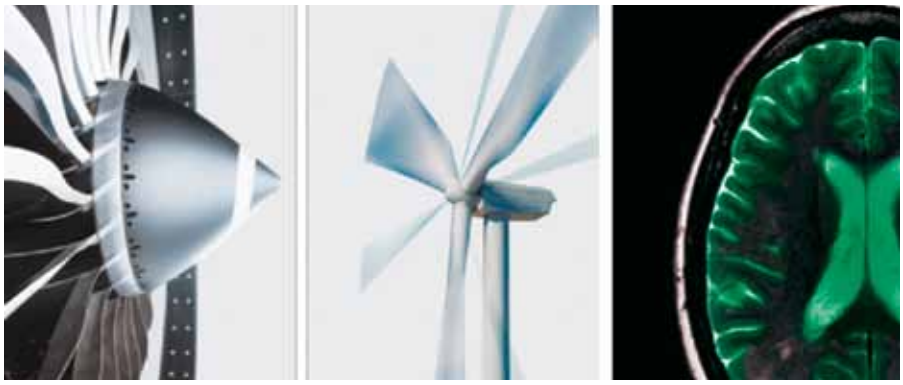
Only the best trained personnel can extract the best from bonding technology. That's why we support our customers during the complete lifetime of any F & K DELVOTEC wire bonder with a range of services in our Bond Academy. These run from applications advice through support during the product development to training classes regarding wire bonding in general and the machine operation. F & K DELVOTEC offers applications support, sample bonding, bond quality measurements and training throughout the lifetime of the wire bonders.

With our bonding experts the semiconductor industry, the automotive industry and other highly innovative electronic branches are in safe hands.

Ultrasonic Heavy Wire Bonder M17

GE imagination at work

GE GLOBAL RESEARCH EUROPE



GE technology hub in Europe

GE Global Research – Europe is GE's European technology hub specializing in power generation and propulsion systems, technologies for the oil & gas industry, systems for sensing and inspection, and advanced medical diagnostics.
With the new competence centers for high-power electronics and gas-engine technologies, GE continues to expand its R&D presence in Europe and underscores its commitment to technology leadership and innovation. The center is furnished with state-of- the-art experimental facilities and a high-performance computing infrastructure for numerical analysis and simulation.

Current research activities

Energy systems: Wind turbines and solar photovoltaics; thermal power plants and carbon-capture technologies; electrical machines and components; grid integration; system analysis and optimization; power conversion, transmission and distribution; heat-recovery solutions.

Oil & Gas: Centrifugal compressor technology, including turbo machinery aerodynamics and thermodynamics; electrical drives and controls.

Electrical Systems and Electronics: embedded systems and ASIC design; mechatronics and robotics; drive trains for renewable and hybrid applications; controls strategies; system integration and modeling.

Reciprocating Engines: Gas- and Diesel-engine technologies covering ignition, combustion, materials & thermal analysis, tribology, turbocharging & gas-exchange, and fuel & exhaust treatment processes.

Healthcare technologies: Diagnostic imaging involving high-field magnetic resonance methods (MRI); metabolic imaging biomarkers; critical-care systems.
Manufacturing technologies: Automated manufacturing of large-scale components for application in the aviation, oil & gas, as well as power-generation industries.

European network

GE Global Research – Europe advances GE's position as a leader in technology by leveraging European-based knowledge and resources. It maintains a strong and growing network of external partners, companies and academia, allowing GE to keep abreast of technologies and applications in which Europe is a global leader.

It also keeps close ties to European GE business units, primarily in the areas of energy, oil & gas, healthcare, and aviation. With its deep and broad expertise in research and technology, the center has become a critical resource for mid- and long-term product innovation pipelines at GE businesses.

Company

Hanon Systems is a one of only two global full-line automotive thermal solutions supplier in the world. Headquartered in Korea and with 39 manufacturing sites, four global technical centers in 19 countries across Asia, Europe, North America and South Asia, the company employs more than 15,500 people. In 2014, the company's global sales reached 5.4T KRW.

The European Technical Center (ETC) in Germany is one in a network of global development locations, each carrying a unique set of capabilities. ETC's on-site development capabilities are multi-faceted, from product development and R&D for components and systems, to vehicle integration, prototyping and vehicle, component and system testing. The R&D environment encourages out-of-the-box thinking and unites the engineers in bringing market relevant solutions to new challenges. Unique tools as well as a comprehensive and interconnected development toolset support our R&D endeavors and help see an idea through to a tangible end product.

Technology

Hanon Systems provides innovative solutions for eco-friendly and high-efficiency thermal management to bring value to customers and deliver occupant comfort. Products that address regulatory requirements and meet the needs of consumers in local markets include

- Heating, Ventilation and Air Conditioning
- Compressors
- Powertrain Cooling
- Fluid Transport
- Electric, Hybrid and Fuel Cell Vehicle Thermal Systems

Electric Compressor

For traditional internal combustion vehicles, the air conditioning compressor is driven by a belt connected to the engine; therefore, it can only operate when the engine is running. Electric and hybrid vehicles operate under different conditions that preclude conventional compressor designs. For both "green" vehicle applications, Hanon Systems has developed an innovative solution – the electric compressor.

Hanon Systems' state-of-the-art design includes an efficient scroll compressor controlled by an on-board electric motor and integrated power electronics. This modular approach allows the same basic packaging dimensions for the electric motor and power electronics to be designed for different DC bus voltage levels, ranging from 48V up to 500V applications.

The electric compressor operates independently, enabling the cabin to be cooled even when the engine is off. Its compact design fits within the traditional belt-driven compressor package space, minimizing vehicle complexity in platforms that offer hybrid-electric model variants.

To develop material systems more quickly and systematically, Heraeus opened a new application, research, and development center for electronics/power electronics at its Hanau site.

Heraeus Holding GmbH, headquartered in Hanau, Germany, is a leading international family-owned company founded in 1851. The technology group is constantly striving to improve its business performance through technical competence, a focus on innovation, operational excellence, and entrepreneurial leadership. Combining material and technological expertise, Heraeus's high-quality solutions ensure that users are, and remain, highly competitive. The company's portfolio of products, ranging from components to coordinated material systems, is used in the steel, electronics, chemical, automotive, and telecommunications industries, among others.
As a technology company, Heraeus is well-versed in the specialized requirements of electronics such as those used in automobiles, electric trains, industrial engines, and wind turbines.

From materials to system solutions

The technology group has made a name for itself in integrated circuit and mounting technologies with such high-performance products as soldering and sinter pastes, bonding wires and ribbons, terminals and lead frames, and copper thick film pastes. The Heraeus Material Systems portfolio program is now expanding to include metal-ceramic substrates (e.g. DCBs) and coordinated material systems. Customers use these primarily for power electronics, for example in sophisticated applications in the fields of automotive and industrial electronics. Heraeus is positioning itself in the market as a provider of system solutions that offers customers matched, prequalified and/or ready-made material systems. This makes Heraeus a reliable partner with regard to individual products and topics; the company's expertise on specific

In the application center employees are developing new materials and material systems. They are also building prototypes and modules, and testing them.

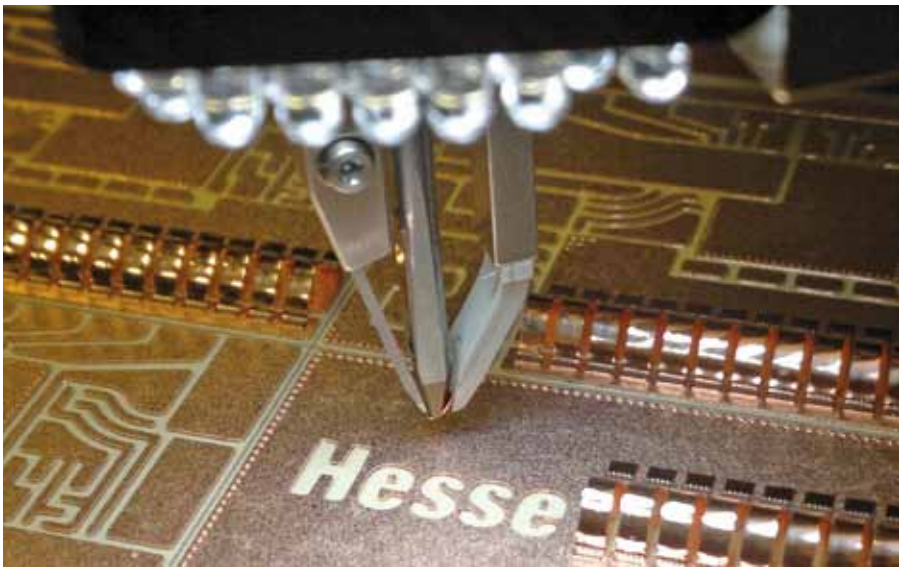
materials also enables it to create entire material systems. Providing these complete packages and solutions allows Heraeus to enter into an innovative, cooperative exchange with its customers and users. This makes it possible to better coordinate process and development capacities and reduce development time and costs.

Application center

To develop material systems more quickly and systematically, Heraeus opened a new application, research, and development center for electronics/power electronics at its Hanau site in 2015. There, employees are developing new materials and material systems like those mentioned above. They are also building prototypes and modules, and testing them to ensure that they meet customer specifications and application requirements. Heraeus takes into account the entire value chain and is already thinking about the demands of material technology several years from now.

Hesse GmbH – Your partner for ultrasonic and thermosonic wire bonders for all common wire dimensions as well as ultrasonic flipchip bonders in combination with standardized or customized automation solutions.

Hesse GmbH, founded in 1986 and based in Paderborn, Germany, develops and manufactures fully automatic ultrasonic and thermosonic wire bonders as well as ultrasonic flipchip bonders together with standard or customer-specific automation solutions for the semiconductor industry backend. Hesse GmbH is one of the world's leading producers of wire bonders using the ultrasonic wedge-wedge and the thermosonic ball-wedge technology and develops customer-specific production processes.
All relevant semiconductor manufacturers are among the worldwide clientele of Hesse GmbH. Distribution and service are performed from the headquarters or by subsidiaries in Hong Kong, the USA and Japan and together with partners in over 30 other countries.
The core competencies of the company are mechatronic systems, ultrasonic technology, control engineering and the detailed understanding and knowledge of the processes and physical effects relevant in ultrasonic joining technology.
In order to maintain and expand technological leadership, we conduct intensive research and development in all aforementioned areas.



Copper ribbon bonding in detail

Development goals include simple and wear-free constructions with highly integrated functionality and the integration of intelligent systems for achieving fault-free processes like the patented process integrated quality control (PiQC) which records and evaluates quality-relevant parameters in real time.

Process support, development and consulting:
We support our customers in developing and implementing individual process requirements. Our range of services includes:

- Sample-bonding
- Pre-production prototype
- Design validation builds
- Small series production
- Module production
- Process optimization


Bondjet BJ935 – Fully Automatic Heavy Wire Bonder

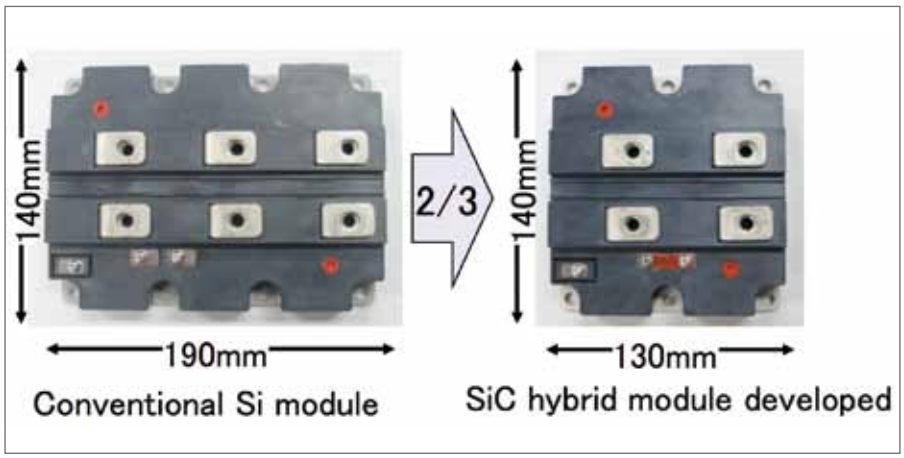
HITACHI
Inspire the Next

HITACHI EUROPE LTD.

Current rail inverters are mainly designed for a high voltage of 1500V from overhead wires and therefore downsizing of high voltage power modules is important. Hitachi has developed a compact 3.3kV/1200A hybrid module for rail car inverters having a high voltage resistance of 3.3kV using SiC. The hybrid module developed combines 3.3kV SiC-SBDs (Schottky barrier diode) and Si-IGBTs. To achieve a compact size module, Hitachi optimized both the SiC-SBD structure and the Si-IGBT device characteristics taking full advantage of device, circuit and loss simulations, and succeeded in reducing the module size to approximately two-thirds that of current Si modules.
In 2009, Hitachi developed 3kV-class SiC-SBDs which employ a JBS (Junction Barrier Schottky) structure that combines Schottky junctions with pn junctions, and mounted these in a power module, which led to the development of this compact SiC hybrid module for railcar inverters. Features of the technology developed are as below:

SiC-SBD

To achieve a compact power module, it is necessary to pass a large current across the SiC-SBD which has a limited surface area. By employing the JBS structure which combines Schottky junctions and p-n junctions, both conduction loss and leakage current can be reduced. This effect was further enhanced by applying device simulation to optimize the JBS structure successfully resulting in increased current per SiC-SBD surface unit area. Further, as the internal electric field of SiC is approximately 10 times that of Si, the optimal device edge structure was designed using device simulation to decrease the electric field around the device edge and assure the reliability required for rail cars.



Si-IGBT

Si-IGBT device with trench gate structure was developed, whose cell size was one third of previous generation device, leading to 20% loss reduction. The device characteristics were optimized by applying circuit and loss simulation in rail application circuits.
The compact 3.3kV/1200A hybrid module with the size two-thirds that of conventional Si module and maximum operating temperature of 150°C, was fabricated combining the Si-IGBT and the SiC-SBD technologies.

Hitachi also developed SiC hybrid inverter for rail cars that is compatible with 1,500V DC overhead power supply using the compact hybrid module and lightweight oil-free capacitors.
Size and weight of 40% smaller and lighter than current mainstream inverters, and 35% reduced power loss are successfully achieved.

Founded: 1999
Employees: about 35,000 worldwide*
Revenues: pro-forma revenue of ~EUR 5,150 million* in 2014 fiscal year (ending September)
Product portfolio: Semiconductors

About Infineon:

Infineon designs, develops, manufactures and markets a broad range of semiconductors and system solutions. The focus of its activities is on automotive electronics, industrial electronics, mobile devices and chip card-based security. Combining entrepreneurial success with responsible action, Infineon addresses some of the most critical challenges of society: Efficient use of energy, environmentally-friendly mobility and security in a connected world.

In January 2015, Infineon acquired US-based International Rectifier Corporation, a leading provider of power management technology, with revenues of 1.1 billion US-Dollar (2014 fiscal year ending June 29) and approximately 4,100 employees.

Target Markets and Products:

- Automotive: microcontrollers, discrete and integrated power semiconductors, power modules for hybrid and electric vehicles, voltage regulators, sensors, bus interface devices, radar ICs.
- Industrial electronics: power discretes, power modules, power ICs, driver ICs, microcontrollers, LED drivers, SiC and GaN components.
- Information and communication technology: small signal components, antenna tuning ICs, customized chips (ASICs), CMOS switches, MEMS, RF power transistors.
- Security: contact-based, contactless and dual-interface security controllers, customized chips with security functions.

Presence: 33 research and development locations, 20 manufacturing locations, and about 45 sales offices worldwide.

* non-audited figures

ISE MAGNETICS

ISE MAGNETICS (INDUCTIVE SYSTEMS EUROPE)

50 years of experience and knowhow

ISE MAGNETICS™ is a manufacturer and design house of inductive components; having several production and (sales) offices in western and eastern Europe, we also subcontract production in Asia which we strictly prescribe, controll and inspect. The ISE staff consists of 50 people. ISE's headquarters is located in the renowned Dutch High Tech area Brainport in the Netherlands.

ISE is member of the Magnetic Domains Group

which also consists the activities of PHYNICX Metallurgical Solutions. PHYNICX is highly specialized in controlled expansion & magnetic alloys and their applications and supplies magnetic shields and high precision soft magnetic parts.

Some of our applications and markets

• Electric drive • fast charging • SMPS • Aerospace and railway • automotive • defense semiconductor • medical • motion control • climate control • oil industry • lighting • Energy metering; NFMI

Design capability

ISE has experienced design & application engineers, to develop customer specific inductive components or assemblies for a wide variety of markets and technologies. In this process ISE makes use of simulation software and internally developed design tools; we create 2D and 3D drawings to enable our customers to assess the mechanical fit in their system.

Flexibility & rapid prototyping

Large stock of components, 3D printing, a mechanical workshop and internal grinding of cores enables ISE to provide fastlane solutions for both prototyping as initial series.

Up-to-date on magnetic materials

Profoundly experienced, up-to-date know-how-, know-where and knowledge of appropriateness of (new) magnetic materials or other components, but also through application of simple but smart variations, ISE often offers customer solutions at standard costing.

ADVANCED DESIGN & MANUFACTURING
INNOVATIVE CUSTOM INDUCTIVE SOLUTIONS

ISE and quality

Quality starts at design stage. Quality of design and product is inspected on prototypes and for series its being monitored during the production process and finally thoroughly tested; Applicable international norms are implemented and effective mounting, moulding and assembly technics, can even ensure shock and vibration requirements.

Applied procedures:

• FAI • DFM • DFMEA • PFMEA • PPAP and statistical analysis (Cpk/Cp). All our factories are certified ISO 9001 for manufacture of inductive components, our western Europe facility on designing as well.

Keysight Technologies Inc. (NYSE: KEYS) is the world's leading electronic measurement company, transforming today's measurement experience through innovations in wireless, modular, automotive, energy, industrial, and software solutions. With its HP and Agilent legacy, Keysight delivers solutions with world-class platforms, software and consistent measurement science. The company's nearly 10,500 employees serve customers in more than 100 countries. Keysight generated revenues of $2.9B in fiscal year 2016.

Keysight Technologies works with global automotive and energy leaders in the electronics industry – assisting them in driving their innovation, from simulation, to test, and out to the market – faster, and at a lower cost. A few of our key solutions for those market segments include, design and test solutions for smart grid and power management, power semiconductors, batteries, HEV/EV, powertrains, body and security, advanced driver-assistance systems (ADAS) and Connected Cars.

Power applications have become more complex with the convergence of technologies in various markets, from smart grid systems to automotive and consumer electronics. Keysight provides leading modeling and test solutions to simulate, characterize, verify and measure power efficiency as well as device performance for various applications. These include high-power functional tests for automotive mechatronics systems, advanced photovoltaic rechargeable batteries and solutions for high-power converters and inverters to tackle challenges posed by environmentally-friendly energy generation.

Keysight helps customers to bring breakthrough electronic products and systems to market faster – our solutions go where the electronic signal goes, from design simulation, to prototype validation, manufacturing test, and network optimization. More information is available at **www.keysight.com**.

LASSLOP
INDUKTIVE BAUTEILE

JOHANN LASSLOP GMBH

The Company

J-Lasslop is a medium-scale international company and has established itself for 50 years as a specialist in the development of inductive components. Our strength lies in customer-specific-solutions, according to requirements: quick, flexible and reliable – from individual items to series production. An efficient production of innovative inductive components is only possible with many years of experience, competence and creativity – always state-of-the-art. Hereby, the self-imposed requirements on the components "smaller-lighter-lower losses" are always the target of development work. These components have been widely implemented in the recent years, especially when very little space is available and the heat rice plays a critical role. With individually tailored advice we offer support from the early stage of development to find new solutions. As a result, the relationship between efficiency and design size is optimal.
Through continuous research and development and through the own construction of tools and mechanical engineering J-Lassop has found the market niche.

Resonant Converter 20kW-Trafo

3-Phases transformer with HF-Litz

Perfection is our scale:

- in our own tool-building facility
- special winding technology
- newest core materials

Inductive – Constructive – Innovative

- **Design Center**
  Our team designed and simulated the right components for your application. We integrate all aspects – from electronics over mechanics to the product's design.
- **Development of components**
  J-Lasslop has been working with its customers to develop optimized inductive components solutions. The results are customized components for a wide range of applications.
- **Sample and Prototype Building**
  We design and simulate the magnetic with all parasitic elements, just like the theoretical way, we can build in parasitic with the same elements.
- Innovative new winding technology, Lasslop Flat Wire Winding

Products and Core Competences

- Customer specific solutions for all electronics
- Development and optimization of innovative power electronics
- High Frequency Transformers from 1W to 5MW; From 1V to 400KV
- Power transformers and power chokes state-of-the-art "smaller-lighter-lower-losses"
- Specialist for highly efficient magnetic design and series-production of inductive components
- Expertise in magnetic design, Simulation of best magnetic design
- Practice tests of chokes, Supply of real current form up to 500 A, losses, heating treatment
- Contactless energy and data transmission
- Coils

PFC Choke

Customers Benefits

- Smaller
- Lighter
- Best Efficiency
- Lower Losses

Transducers are the hidden heart of power electronics

You use LEM transducers every day. They are present in trains, buses, lifts, cars and they help to protect vital equipment in hospitals, airports and data centres. They are in industrial motors, electric vehicles, solar panels and wind turbines as well as in battery-backed uninterruptible power supplies (UPS) that provide continuous power to computer servers.

LEM transducers help to make your world safer and more energy efficient. They provide the feedback signal which helps to control the motors which drive a vast number of machines, measuring complex currents and voltages from as little as 0.1 A in drills, to 20000 A in electrolysis equipment and up to 10000 V in the traction control for trains.

With higher accuracy and speed, the feedback signal from LEM transducers enables smoother control and operation. They also help to reduce energy consumption by 30% or more through the intelligent control of variable speed drives.

At the heart of … industry

LEM transducers help to make your world a smoother place. In lifts, for example, they help to prevent the doors closing on passengers. They keep the cabin stable when people enter and ensure that the lift rises and falls smoothly by adjusting the torque of the motor. Their signals are also used to stop the lift at exactly the right level.

At the heart of … transport

Trains propulsion is provided by electric motors driven by inverters. These inverters rely on LEM transducers to measure, optimise and adjust the power that is sent to the motors, improving both performance and reliability. In electric and hybrid cars, LEM transducers monitor energy levels to and from the battery as well as saving energy by controlling electric power steering.

At the heart of … renewable energy

LEM transducers, specifically designed for renewable power systems, control the energy flow and waveform of power sent to the grid from photovoltaic and other renewable energy systems. They measure the current to help optimally position the turbine to the wind and to

use the photovoltaic panels to their maximum efficiency in a safe manner.

At the heart of … uninterruptible power

Imagine a world where power can fail. A world in which data centres lose their data, hospital equipment stops working and systems come to standstill. Wherever continuous, uninterruptible power is critical, LEM's Sentinel Battery Monitoring System can monitor the condition of standby batteries to ensure that they are always ready to supply emergency back-up power.

LEM … at the heart of the future

Intelligent power management is critical for conserving energy. As the world's leading manufacturer of transducers, LEM is helping the world to move towards a greener, more energy-efficient future with products such as the Wi-LEM Wireless Local Energy Meter. By showing users exactly how much power is being used, Wi-LEM helps them to protect the future by reducing their power consumption.

LIEBHERR

LIEBHERR-ELEKTRONIK GMBH

Liebherr-Elektronik GmbH, based in Lindau (Germany), develops and manufactures high-grade electronic sub-assemblies and components for construction machinery, the aviation industry and railway applications. The company is part of the Components Division, one of ten product divisions within the worldwide active Liebherr Group. Founded in 2001, Liebherr-Elektronik GmbH today employs around 570 people, 135 thereof are working in the development department. In 2011 the company recorded a turnover of about 75 million Euros. The product range includes control and automation electronics for construction machinery and avionics, power electronics for highly dynamic flap control mechanisms, drive electronics for air conditioning systems for aviation and railway applications, converters, as well as display and operating panels for application in construction machinery and aircraft cockpits.

Its diverse portfolio represents the comprising know-how and expertise of the company. Liebherr's high-quality electronic systems distinguish themselves by their robustness and longevity in harsh environments. Products are designed to be safety critical, 'fit and forget', for long operating times and with long-term availability. Their development, production, and service are always oriented by project-specific and economic requirements. That is how Liebherr implements customised electronics solutions on the highest technological level and provides its customers a future-oriented partnership. Liebherr-Elektronik GmbH continually expands its technologies in order to achieve highest quality and reliability. The components must endure significant strain on specially developed test and simulation benches, for instance lightning strokes, moisture or strong vibrations. Only if the result is 100% satisfactory, a new development is qualified. Fully certified Liebherr-Elektronik GmbH has a series of certifications according to international industry, aviation and environmental standards. Regular internal and external audits ensure the sustainability of the quality-assurance measures in the individual departments.

For many years, Liebherr-Elektronik GmbH has been cooperating with several national and European research projects, such as MOET, JTI CleanSky, EfA, Energy-Cap or HyBa. In these projects, Liebherr's development team follows a technology roadmap dedicated to ensuring and enhancing the competitiveness of future products.

Electric Back-up Hydraulic Actuator for Airbus A380

Liebherr mobile crane LTM 11200-9.1

MACCON is a leading supplier for electric motors, motor controllers and Motion Control products. We are the partner for industry and research, when demanding drive and positioning problems are to be solved with the assistance of the electric motor.

We supply motors of all technologies as well as power and control electronics in the power range of 10W to 250kW.

Typical products and services:

- Electric motors of all types
- Electro-mechanical actuators (EMAs)
- Drive and control electronics
- Sensors (resolvers, encoders etc.)
- Electro-mechanics (steppers and small motors, clutches, slip-rings, solenoids etc.)
- Custom motor solutions
  - Motors made to measure!
- Custom drive solutions
  - Drive Electronics to match!
- Motion Control and engineering services (Motioneering®)
- Drive components for hard environments (Hi-Rel, military and aerospace)
- CAD Software for motors and electromagnetic systems
- Key Motion Control technologies

In addition we increasingly support applications in the fields of:

- Electric traction and propulsion
- Starters and power generation
- Dynamic and demanding servo-drive technology
- Energy-conversion for regenerative and green energy programs

High power Drive electronics for E-traction

The photograph above shows the open view of the MACCON MI/400-400 motor controller.
Some of the outstanding features of this modern motor controller and drive development platform are:

- compatible with DC, 3-phase AC-induction and DC-brushless motors
- wide voltage supply range (100-450V)
- continuous power output of up to >160kW
- 24V aux. supply (9-36Vdc)
- 400Arms continuous, phase current
- internal and external regeneration
- high power 3-phase IGBT output stage
- 3 current sensors
- mounted on base plate, water cooled

The heart of the MI/400-400 motor controller is the MACinverter®, which is possibly the most advanced state-of-the-art, embedded control card for the operation of electric motors available today:

Maschinenfabrik Reinhausen: Success in global niche markets of energy technology

Maschinenfabrik Reinhausen GmbH (MR), based in Regensburg, Germany, and its 27 subsidiaries enjoy success in the global niche markets of energy technology. In the 2012 financial year, 2,700 employees generated a turnover in excess of 630 million Euros. Over 50 % of the power consumed around the world is regulated by MR products.

The company's core business is the regulation of power transformer in power grids. This is done with the aid of on-load tap-changers and off-circuit tap-changers, which adapt the transmission ratio of the primary to secondary winding to changing load ratios and, together with additional, in-novative products and services, ensure an interruption-free power supply.

In 2011, a competence center for power electronics was established in Regensburg to create a pool of knowledge for power electronics inside our organization by bringing together highly skilled and highly motivated people into a single department. The engineering and testing of all power electronic devices for the REINHAUSEN group takes place here. For the development of power electronics, experts from several disciplines are needed.

Therefore, electrical engineers, mechanical engineers, software specialists and testing experts work together in our

competence center. These people are supported by an in-house test facility and the test center in REINHAUSEN in which high voltage and current levels can be applied.

The latest power electronic device that has been fully engineered by the REINHAUSEN group is the GRIDCON Active Filter. This device is able to compensate reactive power and harmonics (up to the 51st level) within the 400V and 690V net with a maximum power of 600kVAr per cabinet. The inverter uses a three-level topology with a voltage link.

The REINHAUSEN group is able to supply power electronics for grid applications in all power ranges up to the highest voltage ranges.

Mentor Graphics offers many products but all with the same aim:

to enable companies to develop better electronic products faster and more cost-effectively. This extends to the MicReD product range, specialising in Thermal Characterization and Testing of electronic components from LEDs to IGBTs.
Mentor Graphics offers the T3Ster®: enabling thermal characterization of semiconductor device packages including digital ICs, stacked dies, and MCMs, and power electronics devices, including MOSFETs and IGBTs which can be tested at high power. Together with T3Ster, TeraLED® enables the full thermal, photometric and radiometric characterization of power and HBLEDs. The DynTIM®, provides a cutting-edge solution for measuring thermal performance of thermal interface materials (TIMs). With DynTIM® the thermal conductivity of greases, pastes, phase-change materials, adhesives and solid samples can be measured with high accuracy.

REAL-TIME FAILURE DIAGNOSIS:

MicReD Power Tester 1800A and 3600A are the only machines built for manufacturing as well as laboratory environments that do automated power cycling while producing analytical data for real-time failure-in-progress diagnosis. They are designed to perform lifetime testing to test the reliability of applications that use power electronic modules. The Power Tester series is unique in that it provides fully automated transient thermal resistance and cycling at the same time, on the same machine, without having to remove the device under test during the process. The Power Tester 1800A and 3600A sense current, voltage, and die temperature while using structure function analysis to record changes or failures in the package structure. While running power cycles, the real-time structure function analysis shows the failure in progress, the number of cycles, and the cause of the failure, eliminating the need for a lab post-mortem. The testing and characterization data produced by the Power Tester series can be used to calibrate and validate detailed models in FloTHERM and FloEFD thermal simulation software.

Test a Wide Range of Power Electronics: Includes metal-oxide semiconductor field-effect transistors (MOSFETs), insulated-gate bipolar transistors (IGBTs), and power diodes.
Conduct Continuous Power Cycling until Failure: Component can be left on the tester.
User-Friendly Touch-Screen Interface: Records a broad range of information during test including detailed structure function analysis to record changes in the package's thermal structure.
Apply Different Powering Strategies during Operation: Constant power on/off time, with constant case temperature swing, constant junction temperature rise, or constant applied power.

MITSUBISHI ELECTRIC
Changes for the Better

MITSUBISHI ELECTRIC R&D EUROPE (MERCE)

Overview of Mitsubishi Electric R&D Centre Europe

Mitsubishi Electric R&D Centre Europe (MERCE) is a Research & Development laboratory affiliated to the Mitsubishi Electric group with its head office in Japan. Its main role is to support the various group activities through applied research.

The laboratory invents new generations of communication systems and future technologies in the field of energy and the environment. The R&D projects enable the development of a highly-connected and environmentally-conscious global society.

To enhance its research activities, MERCE is fully committed to an open innovation approach through various bilateral and multilateral cooperation activities with European partners.

Power Electronics Systems

The expertise of the laboratory lies in the design of systems requiring new topologies for innovative power electronics. The main goal is to meet the top demand of the third millennium – sustainable energy.

The laboratory designs new power converters based on innovative and strongly integrated architectures, as well as intelligent systems. These converters achieve greater energy efficiency while considerably reducing costs. This is a major advantage when developing complex systems such as solar farms, air-conditioning systems, and new transport and production networks for heterogeneous electrical power.

MERCE is also at the cutting edge of R&D for the design and test of reliable components, both on Power Module and on converter level. Asset management technologies are being investigated to produce dependable systems and increase customer satisfaction. Other technological domains of interest to the laboratory are power distribution (Railway, HVDC) and highly efficient motor drives.

Communication Systems

MERCE is a major player in the field of ICT but also a centre of expertise in formal methods for software development. The laboratory's expertise in network and digital communication enables the development of new technologies and architectures required to build future generations of communication and broadcasting systems that cater for concepts such as Internet of Things.

The People

The laboratory has established itself as part of an international group where scientific excellence, curiosity, team spirit and a multi-cultural mindset are the key qualities of its employees. MERCE also plays an active role in training young postgraduate students by providing an extremely dynamic working environment that includes leading researchers in their respective fields.

Nidec Control Techniques – Global leaders in motion control technology

Nidec Control Techniques has been at the front of customer-focused drive technology for over 40 years. We're dedicated to the advancement of automation. From product development at our headquarters to our 45 Automation Centers around the world, we provide solutions relevant to the industries in your region. We ensure high performance, reliability and energy efficiency across every application.

Our History

We've always been a company who dreams big.

Founded in 1972 as KTK in Newtown, Wales, we took our name from our three founders. Their vision was to provide a new drive that met the needs of the market. The following year they did just that. The KTK 415V DC thyristor drive improved **performance, reliability** and **energy efficiency for motor control**.

As we grew, so did our network. We developed close relationships with our customers. This led to a wave of product innovations including the Commander AC and the Mentor, **the world's first digital DC drive**. In that same year, we became Control Techniques.

We were closer to industry than ever before. This helped us solve one of the biggest problems in automation. One single programmable drive that could run open-loop, closed-loop, and servo.

The first intelligent drive: the Unidrive. Not only did the Unidrive control any motor, it could communicate with a broad range of fieldbus. This gave our customers the freedom to improve their systems. Onboard intelligence made it possible to program our drives, giving greater control and enabling new possibilities.

The year was 1995. The same year Control Techniques joined Emerson.

Our high performance systems found their niche; where failure wasn't an option, you'd find our drives. Crane systems, elevators, stage, high performance automation OEMs and factories all specified Control Techniques. Unidrive M, Digitax ST, and Mentor MP took the risk out of i ndustrial breakdown.

Fast-forward to 2016, in Kyoto, Japan.

The Nidec Corporation, the world's largest motor producer saw the possibilities of our customer-focused technology. Eager to build high performance drive control into their business, they began talks. For us, this was the perfect fit.

In February 2017 Control Techniques joined the Nidec Corporation.

We're now part of operations in over 40 countries, connected to approximately 300 companies who employ over 110,000 people. **Nidec's vision is to be the world's number 1 for everything that spins and moves**. From small precision to supersized motors; we create next-generation drive technology for an interconnected world.


AAVID THERMALLOY
ABB
Power and productivity for a better world™
alpha ASSEMBLY SOLUTIONS
Alpitronic
ALSTOM
Designing fluidity
ANVIL SEMICONDUCTORS
APOJEE
ascatron
AT&S
AUXELFTG
AVL
BMW
MINI
BOSCH
Invented for life
boschman
BRUSA
CADFEM
Continental
DAIMLER
DELTA
DODUCO
DYNEX
TDK
Fronius
SHIFTING THE LIMITS
Danfoss
FEK
DELVOTEC
GE imagination at work
Hanon SYSTEMS
Heraeus
HESSE
MECHATRONICS
Fuji Electric
Innovating Energy Technology
HITACHI
Inspire the Next
infineon
ISE
MAGNETICS
KEYSIGHT
TECHNOLOGIES
LASSLOP
INDUKTIVE BAUTEILE
LEM
LIEBHERR
MACON
MOTION UNDER CONTROL
MR
Mentor Graphics
MITSUBISHI ELECTRIC
Changes for the Better
Nidec
-All for dreams
CONTROL TECHNIQUES
PHILIPS
plexim
electrical engineering software
power integrations
ROGERS
CORPORATION
Power Electronics Solutions
ROHM
SEMICONDUCTOR
SCHAFFNER
shaping electrical power
Schneider Electric
SCHWEIZER
SEMIKRON
innovation + service
SENSITEC
KÖRBER SOLUTIONS
SPS
SMART POWER SYSTEMS
SET
SEW EURODRIVE
SIEMENS
SILVER ATENA
AN ASSYSTEM COMPANY
SMA
sumida
SuperGrid Institute
Powering the electrical grid of the future
thyssenkrupp
TOSHIBA
Leading Innovation
TRIDONIC
enlightening your ideas
TT Electronics
Power and Hybrid
VAC
VACUUMSCHMELZE
Vincotech
VISHAY
WE
WÜRTH ELEKTRONIK
YASA
ZF
AIRBUS GROUP
amx
AUTOMATRIX
BOMBARDIER
BOYD
CORPORATION
CAF
Power & Automation
DENSO
GaN Systems
HE
SYSTEM ELECTRONIC
LGF
KOSTAL
MAGNETI MARELLI
dau
EBG
ON
ON Semiconductor
Panasonic
ideas for life
PiNK
REFU
Elektronik
ROHRER
Valeo
ZES ZIMMER
Electronic Systems
ENERGIE
region
Wir gestalten Energie. Gemeinsam.

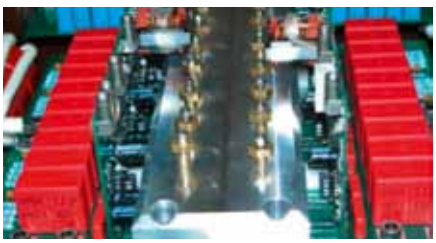
The foundation of Philips was laid in 1891 when Gerard Philips and his father established Philips & Co. in Eindhoven, Netherlands. Within a few years Philips became the largest producers of light bulbs in the world. Motivated by the Industrial Revolution in Europe, Philips' first research laboratory was established in 1914 resulting in innovations in the field of both X-ray and radio technology. Over the years, the list of inventions has been growing to include many breakthroughs.

Royal Philips of the Netherlands is a technology company, focused on improving people's lives through innovation in the areas of Healthcare and Consumer Lifestyle. Philips is a leader in cardiac, acute and home healthcare, as well as male shaving, grooming and oral healthcare.

At the Hamburg site X-ray tubes, generators and complete systems have been designed and produced for more than 100 years. Hamburg became the footprint for all Philips Medical Systems activities in Germany. Today the site hosts two Business Units:

Generators, Tubes and Components

GTC has five sites worldwide, with the headquarters located in Hamburg. Besides Hamburg we have factories in Netherlands, USA, and China. In the past, GTC limited their sales only to other Philips' businesses. Nowadays we also supply components to other manufacturers.
With one of the first X-ray tube factories in the world, GTC developed from a producer of standard glass tubes to a global high-tech company. This was achieved by creative and innovative designs along with modern manufacturing methods.
Today we have 3 product areas, including systems components as well as modern X-ray systems.
GTC state of the art spiral groove liquid bearing for our X-ray tubes product line has been the cornerstone component for our Cardiac Imaging Systems. Innovations like this have contributed to Philips worldwide leadership position in the Cardiac Market.



Experimental high-power high-frequency converter

Solutions in:

- High Voltage Generation
- X-ray Tubes
- X-ray Detection

Diagnostic X-Ray

DXR, part of Imaging Systems, develops, manufactures and markets Healthcare systems for the global market. Hamburg is the worldwide Headquarter for development, production, service and marketing. The global footprint includes locations in China, Brazil, India and Sweden.

Solutions in:

- Direct/Computed Radiography
- Analog/Mobile Radiography
- Universal Radiography/Fluoroscopy
- Mammography

Our Mission and Vision

With our products, services and people we improve the quality of healthcare through meaningful innovation. As a global organization we deliver differentiating X-ray generation and detection solutions allowing our internal and external customers to lead their market segments. We work together with the Markets to be a profitable organization, delivering unmatched customer experience in Diagnostic X-ray Solutions. We expand access to more than half a million people every day across the globe. We attract the best people who share our passion.

plexim
electrical engineering software

PLEXIM GMBH

Plexim – Innovative design tools for power electronics

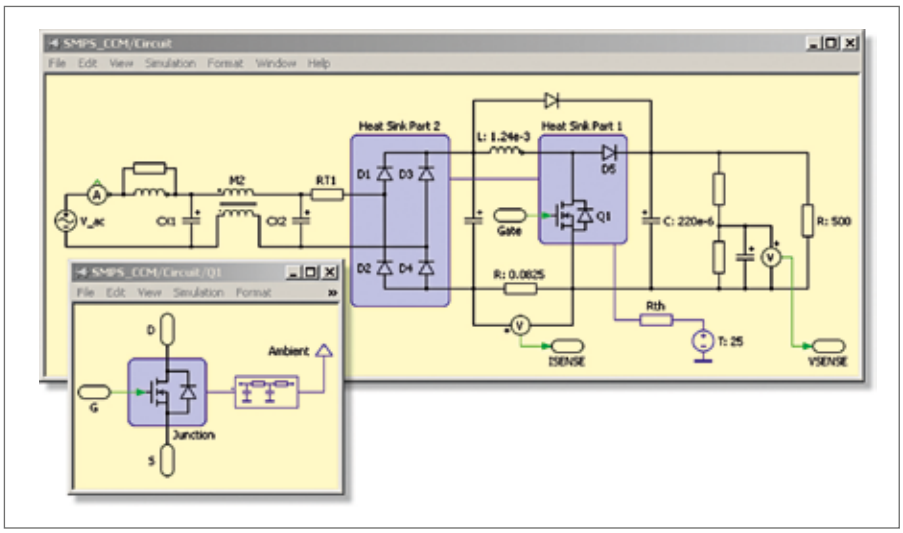
Plexim is a global leader in simulation software for power electronic systems. Our software enables industry customers to innovate their products at a faster pace by reducing development cost and time.

Our leadership is based on latest software technologies and simulation algorithms combined with innovative modeling concepts. By carefully listening to engineering experts, we offer our customers pioneering solutions for their needs of today and tomorrow.

Since 2002 our software has become the industry standard for power electronics simulation across various industries. Typical application areas are renewable energy, automotive, aerospace, industrial and traction drives, and power supplies. Our customers include market leaders such as ABB, Bombardier, Bosch, Danfoss, GE, Philips, Siemens, SMA and Vestas.
With own offices in Zurich and Boston, and with the support of our local representatives worldwide, we are always close to our customers.

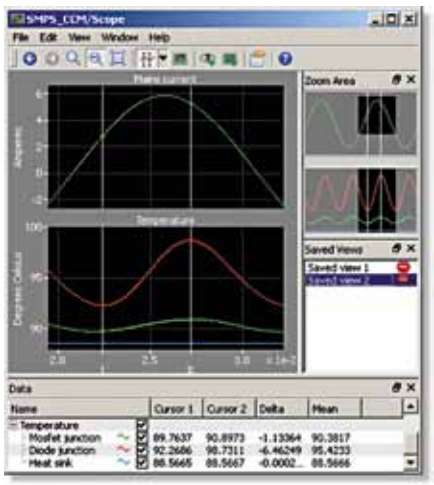
Simulation software PLECS

Our circuit simulator PLECS makes it simple to model and simulate complex electrical systems along with analog and digital control. Supporting a top-down approach, it lets the designer start with ideal component models in order to focus on the system behavior. Low-level device details can be added later to account for parasitic effects.



With the intuitive, easy-to-use schematic editor, new models are set up quickly. Thanks to a proprietary handling of switching events, simulations of power electronic circuits are fast and robust. From simple power electronic converters to a complex electrical drives, PLECS will help design engineers to quickly obtain the simulation results they need.

PLECS is available in two different editions: A blockset for MATLAB®/Simulink® and an independent standalone solution. The PLECS Blockset is seamlessly integrated with Simulink. This allows to access the functionality of Simulink and extend the scope of system-oriented simulations. The PLECS Standalone edition is a simulation platform on its own. It provides optimized solvers to speed up the simulation of electrical circuits and control systems. PLECS Standalone is a cost-effective yet powerful alternative for dynamic system simulation in general.



Compact and reliable IGBT driver

Power Integrations, Inc., is a Silicon Valley-based supplier of high-performance electronic components used in high-voltage power-conversion systems. Power Integrations' integrated circuits and diodes enable compact, energy-efficient AC-DC power supplies for a vast range of electronic products including mobile devices, TVs, PCs, appliances, smart utility meters and LED lights. Our SCALE™ IGBT drivers enhance the efficiency, reliability and cost of high-power applications such as industrial motor drives, solar and wind energy systems, electric vehicles and high-voltage DC transmission.

All drivers are distinguished by leading-edge technology, outstanding functionality, unrivalled quality and a first-class price/performance ratio. These SCALE™ IGBT drivers are based on the unique SCALE ASIC chipset (ASIC = Application-Specific Integrated Circuit).

The highly integrated SCALE-2 chipset allows about 85% of components to be dispensed with compared with conventional drivers. This advantage is impressively reflected in their increased reliability with simultaneously minimized cost.

SCALE Driver Cores

SCALE Driver Cores are PCB-based modules equipped with all the basic functions of a driver. They are mounted on a circuit board containing all the additional components required to match the driver to specific IGBTs or applications, such as an input interface, gate resistors, active clamping and more.

SCALE Plug-and-Play Drivers

SCALE Plug-and-Play Drivers are complete ready-to-use IGBT drivers that have been perfectly matched to a wide range of IGBTs. Users only need to mount them onto the corresponding IGBT module. The system can then be put into immediate operation with no further development or matching effort.
Power Integrations is willing to defend its leading position in the sector of power electronics with high investments in R&D. Its success is not based on perfect products alone: high flexibility, many years of experience in working together with customers and daily efforts to offer optimal solutions are key success factors for Power Integrations.

ROGERS CORPORATION

Power Electronics Solutions

Power Electronics Solutions at Rogers Corporation

Rogers' advanced, customized components enable the performance and reliability of today's growing array of Power Electronics devices. Rogers' material technologies are significantly increasing efficiency, managing heat, and ensuring the reliability of critical devices used in converting energy into controlled and regulated power that can be used and managed. Rogers' Power Electronics Solutions division covers three major product lines:

ROLINX® busbars

Rogers designs and manufactures laminated and powder coated busbars which meet the most stringent requirements for rail traction converters, grid, wind and solar converters and drives for industrial applications. ROLINX® busbars feature low inductance, controlled partial discharge, high current capabilities and compactness. As the global leader in the world of laminated busbars, ROLINX®'s main differentiators are superb quality and reliability, electrical and mechanical expertise, co-engineering and flexible lead times.

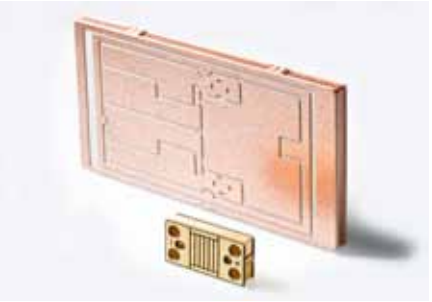
curamik® ceramic substrates

curamik® ceramic substrates consist of pure copper bonded to a ceramic substrate such as Al_2O_3, Zr doted Al_2O_3, AlN or silicon based Si_3N_4. Rogers provides two technologies to attach the substrate with the copper. DBC (direct bond copper) – a high temperature melting and diffusion process where the pure copper is bonded

onto the ceramic and AMB (active metal brazing) – a high temperature process where the pure copper is brazed onto the ceramic substrate. The high heat conductivity of the ceramic as well as the high heat capacity and thermal spreading of the thick copper cladding makes curamik® substrates indispensable to power electronics.

curamik® micro-channel coolers

curamik® micro-channel coolers consist of several layers of pure copper with very fine structures. These layers create three-dimensional structures for cooling high performance electronics. The design of the different layers can be adjusted to customer-specific requirements. curamik® coolers are used for Laser Diode cooling, but also for the cooling of high-performance components, high brightness LED or solar-cell arrays.



ROHM Semiconductor – Quality at all times

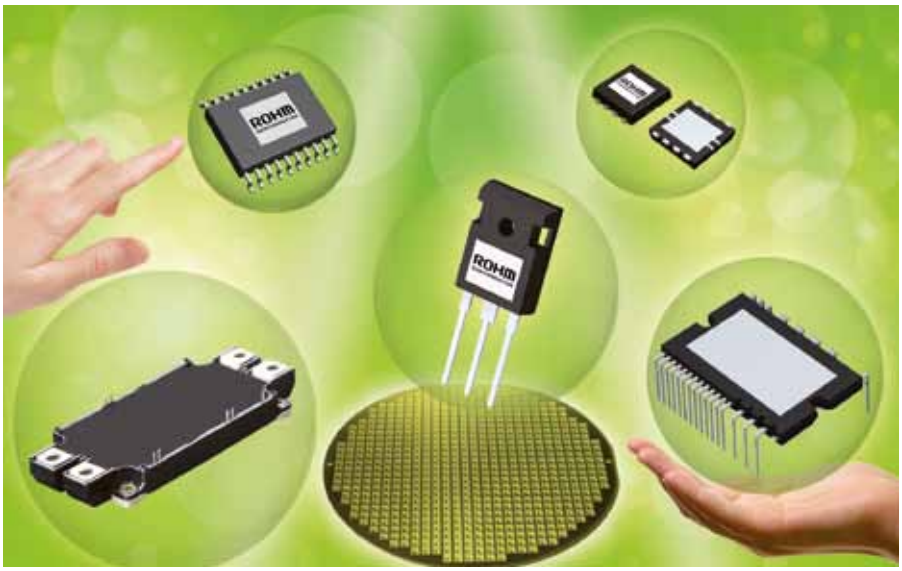
ROHM is a leading global semiconductor and electronic component manufacturer having its headquarters in Kyoto/Japan. The Company's portfolio includes numerous products ranging from innovative power management solutions to eco devices. Its SiC diodes, SiC MOSFETs and modules are widely deployed in automotive, industrial, and energy harvesting applications. SiCrystal AG, a German-based company and part of ROHM group, has adopted a 6 inch integrated SiC wafer production system, which is the successor to the current 4 inch wafers. ROHM is able to offer full-scale mass production of SiC components providing high reliability and advanced characteristics.

Acquires Powervation

The strategic combination of Powervation's Intelligent Digital Power™ platform with ROHM will enable addressing a broad range of fast-growing market opportunities, as customers increasingly seek digital power solutions to power next generation high density systems and ICs such as Processors, Memory, FPGAs and ASICs.

New Technology Highlight of SiC MOSFET (MOS)

In 2015 ROHM started mass production of Gen.3 SiC MOS (Trench Gate Structure) enhancing the MOSFETs family of products; which in turn contributes in general to the evolution of Power Electronics.



Industry's First Mass-Produced "Full SiC" Power Modules

ROHM has pioneered power modules equipped with SiC-MOS and SiC-SBD, which allow substantial reduction in switching losses.
Currently ROHM is co-operating with various power module manufacturers all over the world, in order to maximize the SiC appeal in the global market.

Isolated SiC/IGBT Gate Drivers

The new family of isolated gate drivers facilitates compact designs. Therefore, they are considered to be optimal for inverters and DC/DC converters; they are capable of driving SiC MOS and IGBT as well. With the market's highest CMR of 100 kV/µS, along with multiple protection functions, they guarantee a stable and high frequency operation.

World's lowest VF – SiC Schottky Barrier Diode (SBD)

Compared to Si-FRD, SiC-SBD has ultra-small reverse recovery time. This reduces switching losses dramatically and allows operation with High-speed switching, which contributes to end-product miniaturization.

Power Shunt Resistors

Based on an innovative metal alloy, ROHM started mass production of ultra-low OHM power shunt resistors up to 5W and low TCR, which are suitable for high current detection circuits, such as automotive applications and motor control units.

ECOsine harmonic filter for improving power quality and efficiency in electrical grids.

dU/dt output filter for reduction of voltage stress at motor windings, protecting AC motors from destructive effects of peak voltages.

Shaping electrical power

The Schaffner Group is a global leader in providing solutions that ensure the efficient and reliable operation of power electronic systems by shaping electrical power. The Company's portfolio includes EMI filters, power magnetic components and power quality filters with related services. Schaffner components are deployed in electronic motor controls, in wind power and photovoltaic systems, rail technology applications, machine tools and robotics, electrical infrastructure, as well as in power supplies for a wide range of electronic devices in sectors such as medical technology. For the automobile industry, Schaffner develops and manufactures components for convenience and safety features in cars and filter solutions for electric vehicles as well as their charging infrastructure. Headquartered in Switzerland, Schaffner serves its global customers through its engineering and manufacturing centers in Europe, Asia and in North America. Through significant investments into research and development, the Company strives to expand its leading position in growing markets.

Innovation success factors

We are convinced, that efficient and focussed networking is one of the most important innovation success factors. This is why Schaffner is very open for R&D contacts with industry as well as with universities and research institutes. Schaffner's research is focussed on the mitigation of distortions, generated by modern power electronic systems. This requires a deep understanding of the distortion sources and of adequate suppression concepts for the different types of distortions, supported by sophisticated computational engineering knowledge. Novel magnetic materials as well as construction principles, production processes and design tools for magnetic components get our best attention, in order to permanently improve our capabilities to serve the very different requirements of our customers.

In a world of ever increasing competitiveness, only the best quality, the best manufacturing processes, the best supply chain, the best sales processes, will guarantee success.

Between energy generation and its usage, Schneider Electric provides technology and integrated solutions to optimise energy usage in markets like energy and infrastructure, industry, data centres, buildings and residential.
With a unique portfolio in electrical distribution, industrial automation, critical power and cooling, building management and security, Schneider Electric is the only global specialist in energy management and a world leader in energy efficiency. With more than 110,000 employees in over 100 countries, Schneider Electric leverages its people diversity as a strength to understand its customers and the world we are living in. In 2010, 37% of Schneider Electric's sales were in new economies such as Brazil, Russia, India and China.

Schneider Electric evolves in an industry tackling the most exciting challenge of our time: the energy and climate change challenge. Since 2004, the Group has created a unique business portfolio and doubled its size in terms of revenue and people, both by a strong organic growth and a selective acquisition strategy. Schneider Electric has also built a balanced footprint in terms of end-markets and geographies to be more resilient and agile in capturing growth opportunities.

Schneider Electric devotes 5% of its sales every year to Research and development with over 7,500 R&D engineers in centres worldwide.

Products and services

- Electrical distribution
- Processes automation, control and supervision
- Power supplies
- Energy control and monitoring
- Utility management: lighting, ventilation, elevators, intruder alert, etc.
- Smart electrical networks management
- Single site, multi-site production data management
- Machine control and monitoring
- Uninterruptible power supplies
- Cooling systems with rack-based cooling technique to avoid overheating
- Online supervision and analysis
- Data exchange: voice-data-image and radio technologies
- Home automation: supervision, energy, lighting, heating control
- Training and maintenance
- Security

Solutions

Power management

- Power Management Systems
- High Density Metering
- Energy Tariff Optimization
- Power Quality Mitigation
- Local LV/MV Protection & Control
- Intelligent Power & Motor Control
- Renewable Energy Conversion
- Charging solutions for electric vehicles

Process and machines management

- Process & Machines Management Systems

- General Machines Control
- Packaging Control
- Material Handling Control
- Hoisting Control

IT / sever room management

- IT / Server room Management Systems
- Uninterruptible power supply
- Cooling Control
- Surveillance

Buildings management

- Indoor/outdoor lighting control
- HVAC Control
- Room Control

Security management

- Security Management Systems
- Access Control
- Video Security
- Fire & Life Safety
- Intrusion Detection

SCHWEIZER ELECTRONIC AG

Schweizer Electronic AG stands for state-of-the-art technology and consultancy competence. SCHWEIZER's premium printed circuit boards and innovative solutions and services for automotive, solar, industry and aviation electronics address key challenges in the areas of Power Electronics, Embedding and System Cost Reduction. Its products are distinguished for their superior quality and their energy-saving and environmentally-friendly features. Together with its partners Elekonta Marek GmbH & Co. KG, Meiko Electronics Co. Ltd. and WUS Printed Circuit Co., Ltd., the company offers in its division electronics cost- and production-optimised solutions for small, medium and large series. In future, SCHWEIZER plans to jointly tap the chip embedding market together with its partner Infineon Technologies AG.

With about 760 employees SCHWEIZER achieved sales of 115.5 million Euro in Fiscal Year 2015 (ending December). The company was founded in 1849, is managed by family members and listed at the Stuttgart and Frankfurt Stock Exchanges (ticker symbol „SCE", „ISIN DE 000515623").

Excerpt of product portfolio

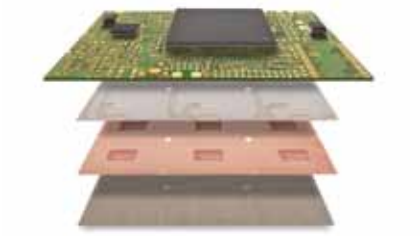
SCHWEIZER's innovative solutions address key challenges in the power electronics sector. Already today, the automotive industry applies SCHWEIZER PCBs which can operate up to 1,200 Ampere.

The **Heavy Copper Board** technology e.g. is used today in high volume production facilitating an ampacity of several hundred Ampere. The **Inlay Board** applies copper inlays with a thickness of up to 2 mm, creating areas on the PCB which allow for current peaks of significantly more than 1,000 Ampere.

Combining logic and power electronics within one single PCB and ensuring extremely good heat dissipation characteristics the **Combi Board** is for applications such as high power 3 / 6-phase drives, controlled power distributors and all solutions requiring a combination of logic and power.

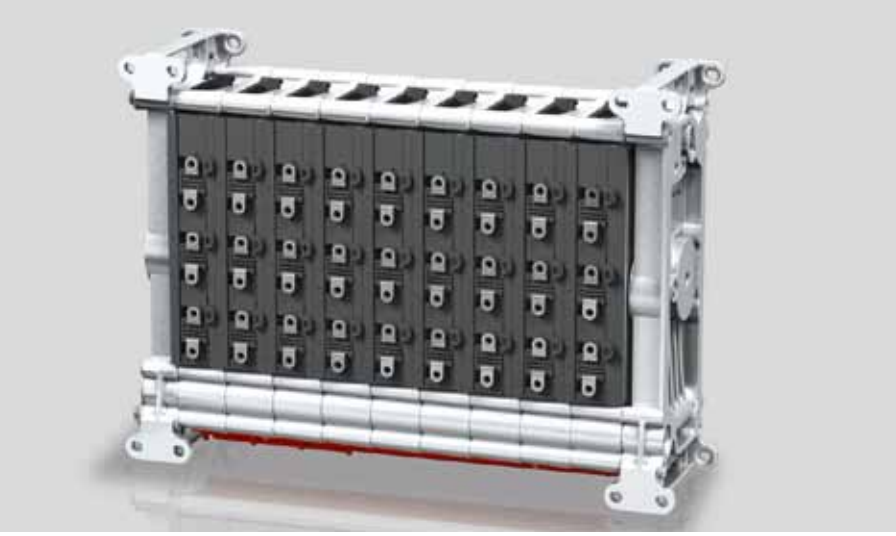
Facilitating high thermal conductivity and good electrical isolation at the same time, the **IMS Board** can be applied in all solutions, which require high power electronics such as DC/DC converter, motor control units or as DCB/DBC substitute.

The **p² Pack technology** is based on standard PCB processes, combined with semiconductor solutions as MOSFETs, IGBTs and SiC. It can be applied in power electronic solutions with 3 or more phase drives for e.g.: power steering, climate compressors, high end fans as AC/DC and DC/DC converters.



Smart p² Pack layup

SEMIKRON is one of the world's leading manufacturers of power modules, stacks and systems primarily in the medium power range (approx. 1 kW up to 10 MW). Our products are at the heart of modern energy efficient motor drives and industrial automation systems. Further application areas include power supplies, renewable energies (wind and solar power) and utility vehicles. SEMIKRON's innovative power electronic products enable our customers to develop smaller, more energy efficient power electronic systems. These systems in turn reduce the global energy demand.



3-phase inverter SkiiPX, SKiN inside

SEMIKRON is a family owned business founded in 1951, headquartered in Nuremberg, Germany.
Today the company has a staff of more than 2,900 people in 25 subsidiaries world-wide. This international network with production sites in Germany, Brazil, China, France, India, Italy, Korea, Slovakia and the US ensures fast and comprehensive service for customers. By establishing the ONLINE SHOP in 2009, SEMIKRON increased its presence for customers. The SEMIKRON ONLINE SHOP offers 24-hour availability and world-wide access with multi-language sales and technical support.

In 2011 SEMIKRON introduced a revolutionary packaging technology for power semiconductors which does away with bond wires, solders and thermal paste. The new SKiN Technology is based on the use of a flexible foil and sintered connections rather than bond wires, solders and thermal paste. This results in a higher current carrying capacity and 10 times the load cycle capability – unthinkable with the restrictive wire bonding used in power electronics in the past. Therefore inverter volume can be reduced by 50%. This reliable and space saving technology is the optimum solution for vehicle and wind power applications.

Wire bond-free packaging technology for power semiconductors

SENSITEC
KÖRBER SOLUTIONS

SENSITEC GMBH

CMS3000 current sensor family for highly dynamic current measurement with up to 2 MHz bandwidth.

Our Company

Sensitec GmbH was founded in 1999 in Lahnau, near to Frankfurt, in Germany. The demand for MagnetoResistive (MR) sensors for industrial and automotive applications was great and continues to increase. Sensitec was able to establish itself in this rapidly expanding market and grew continuously. Already in 2000 Sensitec was able to take over the Institute for Micro Structure Technology and Opto Electronics (IMO) in Wetzlar. This institute already had more than 10 years research and development experience in the field of magnetoresistive sensors. In 2003 Sensitec took over control of the Naomi technologies AG in Mainz and from this point on has owned Europe's most efficient and modern factory for the production of sensors based on the AMR- and GMR-technology. The range of products could be significantly widened since then.

Our Philosophy

Sensitec is a leading supplier of magnetoresistive sensor technology and magnetic microsystems. Our core capabilities lie in the design, development, production and marketing of sensor solutions for the measurement of magnetic, electrical and mechanical variables according to the requirements of customers in a wide range of different application fields. Numerous patents and licences for the production and application of MR sensors, backed by a broad spectrum of experience and knowledge in this field, provide the foundation for these capabilities.

Our Products

Sensors from Sensitec are based on the magnetoresistive (MR-) effect and are used for

- angle measurement
- length and position measurement
- current measurement
- magnetic field measurement

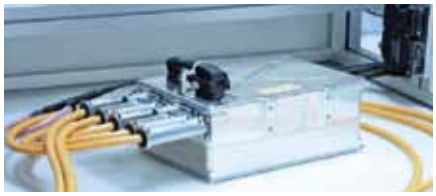
MR sensors offer high accuracy, high resolution, robustness, high sensitivity and high reliability. They are wear-free and easy to integrate. In close co-operation with our customers we develop and manufacture reliable and performant MR sensors in series production. The advanced and innovative solutions from Sensitec can be found in many areas such as

- industrial automation
- measurement and control equipment
- medical equipment
- automotive applications
- aerospace
- laser technology etc.

From chip design and production, to the design of customized measurement scales and the development of integrated signal processing electronics for specific applications, Sensitec is a reliable and competent system partner.

Compact and cost-effective SMD current sensor with external primary current path

SET Power Systems
is a member of the AVL Group and a leading global supplier of inverter testing systems. Our main focus is on smart power electronics that operate at very high switching speeds and thereby provide close-to-analog amplifier characteristics. We have established a new testing method that was used in 2003 for the first time: a virtual electric motor replaces the conventionally required mechanical loading system, thus providing a complete testing environment in a lab. Since then, the testing tool "virtual e-machine" has been perfected and is now available to our customers as a closed power-hardware-in- the-loop-solution (P-HiL). The testing scope ranges from auxiliary units to high-performance drive inverters.



Drive Inverter Testing
is one application for high speed switching amplifiers. Today, drive inverters for electrical motors have demanding requirements on functionality and safety – which must be tested in a close-to-reality environment. The core of our inverter test system is the e-machine emulator that reproduces the function and dynamic behaviour of a real electric motor in realtime using mathematical models.

These test systems have been designed to be extremely flexible in order to cover a large variety of tests for a wide range of inverters and converters. The power spectrum ranges from approximately 10 to more than 400 kW with voltages of more than 900 V and currents of up to 1.200 ARMS.

Our Virtual E-Machine
is a "game changing technology" for drive inverter testing. E-machine emulation (EME) technology is an elegant way to bypass the "mechanical world" used to test inverters. Wherever an electric motor is used to test drive inverters, EME technology demonstrates convincing advantages. This solid-state e-motor has no rotating parts and no mechanical limitation. Inverter testing with a virtual e-motor replaces heavyweight mechanical setups with real motors and dynamometers.

Improved Test Methodology
for inverters is one outcome of the virtual e-motor technology. The e-motor emulator is a Power-Hardware-in-the-Loop system that permits test methodology to be run according to the new functional safety regulation ISO 26262.

Close-to-Reality
is the design target for an e-motor emulator. SET Power Systems specializes in high dynamic amplifiers, high-speed instrumentation and high fidelity motor models to provide realistic e-motor characteristics over the complete operational range.

No Mechanical Limitation
is the obvious advantage of the emulator technology, which allows:
- Extremely high dynamics
- Excellent fault stimulation
- Motor change via software

A Wide Range of Test Applications
has already been addressed:
- Auxiliary ECUs
- Powertrain inverters
- Industrial inverters
- Aerospace inverters
- High speed inverters
- Formula 1 KERS

SET GMBH – SMART EMBEDDED TECHNOLOGIES

Innovative – For the success of our customers

SET GmbH is an innovative technology company that specializes in developing power semiconductor reliability test systems, HiL and function test systems, as well as electronic development and manufacturing for the automotive, aerospace, and semiconductors industries. We offer qualified project coordination, starting from defining system requirements, developing and manufacturing hardware, mechanical systems and software, up to implementing the finished system. With the aid of our trainings and consulting we reduce the total cost of test (TCoT) and support the economic success of our project partners and customers.

Power Semiconductor Reliability Test Systems – For complete monitoring of the devices under test

Power electronics is deployed everywhere around us – from cars to wind power plants, from solar parks to e-bikes – therefore it is more important than ever to qualify power semiconductor devices and explicitly test their reliability. Our test systems (IOL, Power Cycling, HTRB, H3TRB, HTOL) do not only offer a high number of DUTs per system, they also have a single device temperature control in order to precisely keep the device at the desired junction temperature. Furthermore our systems provide high-resolution data for the process of analysis and therefore reduce TCoT while simultaneously reducing test time.

Reliability Test Systems for Power Semiconductors

HiL & Functional Test Systems – Tailored to our customers' specific needs

Our large kit of modular components enables us to provide customized test solutions tailored to our customers' specific needs. Using this wide range of finished and tested modules, we are able to quickly and efficiently respond to our customers' needs and configure customized HiL & functional test systems for a diverse range of applications, e.g. for power electronics like power inverters or electric motor emulators (EME).

HiL & Functional Test Systems

Electronic Development & Manufacturing – All in one stop

Our employees offer proven expert knowledge and application know-how in the development of finished products, embedded electronic systems, embedded software applications and SOM solutions on the most varied complexity levels. Constant further training and close research partnerships with universities and institutions keep our skills up-to-date and put us in the position to turn new technical concepts into economically viable solutions. One example in the area of power electronics is the development and manufacturing of several DC brushless inverter solutions.

HTRB Test System

We provide movement.

SEW-EURODRIVE is movement, tradition, innovation, quality, and service all in one – we prove this to our customers every day and have done so for almost 85 years. We do not just move countless conveyer belts, bottling plants, sports stadium roofs, gravel plants, assembly lines, processes in the chemical industry, your luggage at the airport, or even you on escalators; no, we also are moving ourselves. In our company, there is no such thing as standstill. Every day, nearly 550 researchers and developers are working on creating the future of drive automation and making it a little better. Collectively, about 16,000 employees around the world are moving to solve our customers' tasks and optimize their processes. This is how SEW-EURODRIVE has evolved throughout its history to become the market leader in the industry of drive automation with a turnover of about EUR 2.6 billion.

The movement you need is created with various product solutions and drive systems. Depending on the requirement or the industry, SEW-EURODRIVE offers individual solutions from the comprehensive modular concept with gearmotors and frequency inverters, servo drive systems, decentralized drive systems, and industrial gear units.

The individual drive system, custom to your tasks

If you want to be successful you have to know the tasks and processes of your customers and industries. This is why SEW-EURODRIVE looks beyond the borders of drive engineering to find the solution that is ideal for you. With an oftentimes unconventional way to view and approach things, we have been setting the trends and standards in drive engineering for years. In this way, "engineered and made by SEW" has become a seal of quality in the world of drive engineering. The solution for your task of tomorrow exists today at SEW-EURODRIVE – in our universal modular concept of gearmotors, control systems, software, service, and extensive accessories, the foundation is already in place to fulfill your requirements comprehensively and as quickly as possible. The uncompromising quality of our market-oriented products, all developed and constructed at our own plants, are the pillars of our commercial success.

"People do not need products, they need solutions." True to this motto, SEW-EURODRIVE has decided to not only develop and produce gearmotors in-house but also supply the customized electronic solutions for these components. Only control systems that are perfectly matched to the drives ensure an optimum flow. This setup gives developers, designers and planners of systems and projects drive solutions from one source that let them put in motion and efficiently control individual motion sequences or entire processes.

SIEMENS

SIEMENS AG

Power electronics drive many of todays and future products and systems

Siemens is positioned at the leading edge of technology and is with 80 billion revenues and around 400.000 employees one of the largest electric and electronic companies worldwide. Power electronics play an important role in all four sectors – many products include such devices in all

Magnetic resonance imaging scanner Magnetom Verio

voltage and power levels. Siemens has intensive research programs in the field of power electronic components itself but especially in the field of their application in products and systems. Internal research as well as close research cooperation with universities is the base for new technologies as part of new products and systems for demanding markets and applications.

Improving public healthcare

Power electronics are an essential part of many medical equipment and systems of the sector Healthcare. For example by high speed dynamic controlling of the currents for generating high strength magnetic fields inside magnetic resonance imaging scanners (MRI).

More, more efficient and more sustainable energy

For many years power electronics are used in high power and high voltage energy equipment – for instance thyristors and IGBTs for high voltage DC transmission (HVDC). The transformation of todays grid to handle an ever increasing amount of fluctuating renewable decentral energy generation requires an efficient transmission of electrical energy locally as well as over wide distances. All options and techniques to solve this have as a common base the need for power electronics to provide the necessary control of electrical energy transmission.


Thyristor blocks for HVDC transmission


Cyclo converter Sinamics SL150

Modern cities and infrastructure

Reliability, safety, security and flexibility play an important role in medium and low voltage power distribution, in urban railway infrastructure as well as with innovative smart grid technologies. Urbanisation stands for a rapid growth of cities to mega cities and this drives the need for power electronic equipment to distribute and control electrical energy flows in a highly densified urban environment.

Automation and drives technology

Automation and drive products were the main application of power electronics for many decades. More or less every factory and plant use such equipment. New applications with very dynamic growth emerge with small and big scale regenerative power generation such as photo voltaic and wind turbines and the electrical passenger car.

SILVER ATENA
ELECTRONIC SYSTEMS ENGINEERING GMBH

Experts in power electronics

As an independent system supplier SILVER ATENA develops safety-relevant electronic systems for applications in the aerospace & defence, aero engines and automotive industry. Services include system development, hard- and software development, implementation, testing and qualification. We apply established methods and processes to guarantee high-voltage and functional safety. Based on years of experience in the development of complex control units, the company is also a vendor of customised, modular hardware-in-the-loop test systems (HIL), which solve client's product validation tasks. These services are completed by system, process and technology consulting services.

1.5 kW from 12 V: Control unit for an active roll stabiliser.

As a system supplier we develop solutions that meet the challenges of e-mobility from smart charging via power management to drive systems and auxiliary units. We take over single work packages or the overall responsibility for products such as inverters, converters or motor control units. Prototypes during development phases as well as series products can be supplied by SILVER ATENA.

300 V converter for the precise control of a brushless DC motor

SILVER ATENA has been working in power electronics intensively for many years. Results among others are a power control unit for the Formula 1, a 60 kW recuperation and boost system (KERS – Kinetic Energy Recovery System) with an efficiency of more than 95%. In addition a control unit family suitable for voltages ranging from 12 V up to 600 V has been developed for high-speed-rotating electrical motors, which are used in active roll stabilisers, pumps, fans or compressors, for example. SILVER ATENA's most recent development in this domain is a high voltage DC/DC converter with 450 V/ 550 A and more than 100 kW power.

As part of a test house concept, the company also offers in-house testing capacity, which is already used by well-known customers.

SMA SOLAR TECHNOLOGY AG

SMA Solar Technology AG is the worldwide market leader for solar inverters, and a provider of innovative energy supply solutions for mass transit and mainline rail transportation.

The inverter is technologically the most important component in any solar power system: it converts the direct current generated in photovoltaic cells into alternating current suitable for the grid. In addition, it is an intelligent system manager, responsible for yield monitoring

and grid management. SMA Solar inverters are characterized by a particularly high efficiency of up to 99 %, which allows for increased electricity production. The multi award-winning product range covers solar inverters for roof systems, major solar projects and off-grid systems, enabling SMA to provide a technically optimized inverter solution for all size categories and system types. Its range of services is complemented by a worldwide service network.

Highly flexible production

SMA's business model is driven by technological progress. The highly flexible manufacturing plants for solar inverters in Germany, North America and China have a capacity of approximately 15 GW a year. The SMA Group also operates a manufacturing plant for electromagnetic core components in Poland. Due to its flexible and scalable production, SMA is in a position to quickly respond to customer demands and promptly implement product innovations. This allows the

Company to easily keep pace with the dynamic market trends of the photovoltaic industry and at the same time absorb short-term fluctuations in demand for solar inverters.

Represented in all major solar markets

SMA Solar Technology AG is headquartered in Niestetal, near Kassel, and is represented in 20 countries worldwide. The Group employs a staff of over 3,500.

Since June 27, 2008, the Company has been listed in the Prime Standard of the Frankfurt Stock Exchange (S92), and since September 22, 2008, the Company's shares have been listed in the TecDAX. In 2014, SMA generated sales of more than about 1 billion Euros.

ST is a global semiconductor company with net revenues of US$ 6.90 billion in 2015, offering one of the industry's broadest product portfolios. ST serves customers across the spectrum of electronics applications with innovative semiconductor solutions for Smart Driving and the Internet of Things.

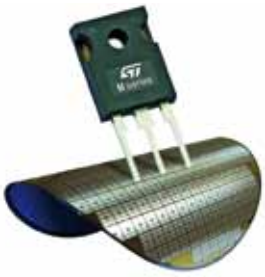
ST's Smart Driving products and solutions are making driving safer, greener and more connected through the fusion of several of our technologies. Driving is greener with our energy-management processors, Power Electronics at the heart of all automotive subsystems, Wide Band-Gap technologies (SiC and GaN) for electric cars, Sensors, and more.

Internet of Things solutions from ST are for smarter personal devices, homes, cities, and manufacturing. ST is a leading supplier of all the key technologies going into the next generations of personal consumer devices: Sensors, Microcontrollers for low and ultra-low power processing, Power and Analog components, and RF & Connectivity products. ST addresses the rise of the smart home and smart city systems through their core: energy consumption and management systems, or the future smart grids and their applications.

ST provides a range of technologies enabling manufacturing and other industrial sectors to achieve better efficiency, flexibility, and safety through automation and robotics – this is what we call *smart industry*. The current shift, often labelled the "fourth industrial revolution" is making industrial systems smarter with the combined application of a broad range of products, including Microcontrollers, Sensors and Actuators, Motor Control, Signal Conditioning, Industrial Communication Solutions, Power Supplies, Protection Devices, Wireless Modules, and Display and LED Controllers. By getting more from technology to get more from life, ST stands for life.augmented.

ST has maintained an unwavering commitment to R&D. Almost one fifth of its employees work in R&D and product design and in 2015 the Company spent about 21% of its revenue in R&D. Among the industry's most innovative companies, ST owns almost 15,000 patents and pending applications corresponding to over 9,000 patent families, including more than 500 original new patent applications filed in 2015. The Company draws on a rich pool of chip fabrication technologies, including advanced FD-SOI (Fully Depleted Silicon-on-Insulator), mixed-signal, analog and power processes.

STMicroelectronics was one of the first global industrial companies to recognize the importance of environmental responsibility and, over the past 15 years, the Company's sites have received more than 100 awards for excellence in all areas of Sustainability, from quality and product responsibility to corporate governance, social issues, employee health and safety, and environmental protection.



SUMIDA AG

About SUMIDA

SUMIDA Group is a global manufacturer of high quality inductive components and modules. Our products are used in a number of applications within the Consumer Electronics, Automotive and Industrial markets. With our solid business foundations in Asia, Europe and the US we pride ourselves on our ability to cultivate strong relationships with our customers. This is our key strength allowing us to offer customized solutions to fit their needs on top of supplying standard components for the broader spectrum market.

Vision & values

Our vision is to continue to be a leading innovator in inductive technologies which support the development of electronic products that serve to improve peoples' quality of life, raise energy efficiency and source alternative power for a brighter tomorrow.

Innovation based on experience

Beside its wide range of standard components, SMT power inductors and chip inductors, SUMIDA offers high competence and long standing experience in the development of customized inductive components and modules.

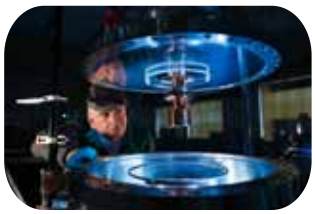
Focus on power conversion

Our in-house R&D and manufacturing of leading-edge ferrites and powdered metal cores enable our development teams to design tailored solutions of highly efficient inductors and transformers for challenging automotive and industrial applications in a power range up to 30kW. The usage of special rapid prototyping machinery enables us to fulfill customer requests in very short time. Thus time-to-market of engineering prototypes and small series production can be greatly reduced.

Furthermore our experience in the integration of busbars, EMI filters, sensors and electronics enables us to offer innovative, value-added module solutions.

Production & technology

With its distinctive vertical integration, a wide range of technologies, production sites in Europe, Asia and North America and a powerful project organization, SUMIDA offers a complete package of high quality solutions for customers with demanding technical and economical requirements.

An institute for energy transition

SuperGrid Institute is a collaborative research platform in the field of low-carbon energy, bringing together the expertise of industry and public research in the logic of public-private co-investment and close cooperation between all stakeholders of the sector.

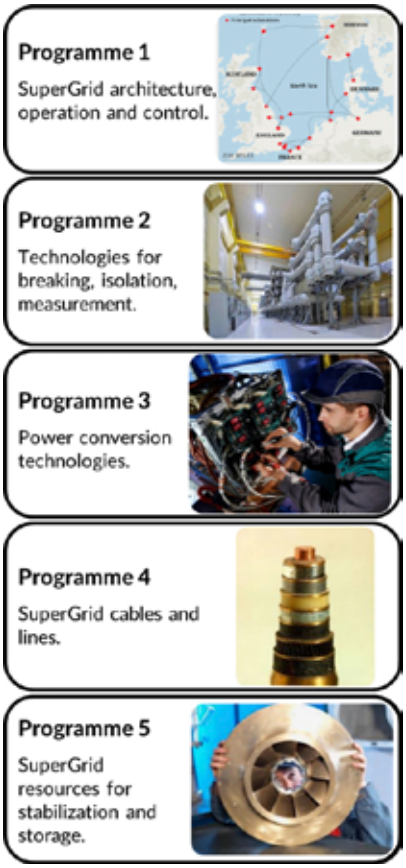
The institute aims to develop technologies for the future electricity transmission network, using direct current and alternating current at very high voltages to transport energy from renewable sources to distant load centres. With flexible storage solutions the intermittent nature of renewable energy can be managed while ensuring the stability and security of the network.

Research programmes

The activity of the institute is organized in several research axes.

Programme 1: Study and deliver hypothesis on how to design and control a HVDC grid. Grid architectures and protections, normal and degraded operation.

Programme 2: Development of breaking technologies for HVDC grids, HVDC substation technologies including insulation and SF6 free technologies for HVAC switchgear.



Programme 3: Power converter topologies and controls to address the needs of future DC grids. Enabling technologies for power electronic converters (medium frequency transformer, SiC semiconductors, etc).

Programme 4: HVDC cables, ageing monitoring, new technologies for off-shore cable nodes and new advanced materials.

Programme 5: Hydro pump storage. Variable speed technology contribution to power system stability.

Competences at a glance

- New grid architecture principles, off-shore HVDC grids.
- HVDC grids protection.
- Hybrid AC-DC grid control.
- Off-line and real-time grid simulation.
- Breaking and protection technologies for HVDC grids.
- SF6 free breaking technology for HVAC grids.
- Ultra-high voltage technologies.
- Power conversion technologies for high voltage and medium voltage.
- High power semi-conductor technologies.
- Power cables for HVDC on-shore and off-shore.
- High performance insulating materials.
- Variable speed water pump-storage.

THYSSENKRUPP PRESTA AG

At thyssenkrupp around 155,000 employees work to develop innovative products and solutions for sustainable progress.
With an engineering expertise in the three areas of Material, Mechanical and Plant, the group enables its customers to gain an edge in the global market.

The thyssenkrupp group consists basically on six business areas

- Components Technology (CT)
- Elevator Technology (ET)
- Industrial Solutions (IS)
- Materials Services (MX)
- Steel Europe (SE)
- Steel Americas (AM)

Within the Components Technology sector, automotive products such as steering systems and camshafts can be found. Steering systems which formerly had been purely mechanical products, have become much more comfortable with hydraulic servo assistance which is now being more and more replaced by electromechanical steering systems (EPS). During this evolution, thyssenkrupp Presta has acquired the necessary knowhow in electronics and power electronics.

Of course, also steer-by-wire projects are already in the focus of the company, knowing that autonomous driving will surely get reality within the next years.

Based on the different and funded knowledge within the whole group (hard- and software for EPS, assembled rotor shaft, materials, industrialization,…) a new activity has been created in 2017 which is connected to the Components Technology branch and geographically located in Eschen, Liechtenstein: the Competence Center for e-mobility which will focus on integrated electric drivetrain solutions.

This Competence Center will focus on electromagnetic motor design, inverter technologies and topologies, other functions like steering and braking, as well as manufacturing of the whole drivetrain. They are strongly supported by the R&D team in Budapest which will develop the control hardware and software.

PMI: Hybrid SiC device

PPI: 125 mm IEGT

Power MOSFET

TOSHIBA is developing power MOSFET for the consumer, automotive and industrial market.

For Low-Voltage MOSFET (VDSS≧30V to 250V) TOSHIBA has released the "U-MOS VIII-H" and "U-MOS IX-H" series featuring improved ON-resistance and switching performance compared to conventional series. U-MOS stands for Trench MOS.

For mid- to high-voltage MOSFET (VDSS≧600V to 800V), TOSHIBA has started series production of the super junction structure using the "Single-Epitaxial (SE) process" for 600V as technology leader from 2012.
That technology is now being expanded to higher voltages like 650V, 800V and in conjunction with fast recovery body-diodes.

TOSHIBA will further improve the MOSFET performance (package and silicon) and so to contribute to high-efficiency and downsizing of various power electronics systems.

High Power Devices

Key markets for TOSHIBA's high power devices (VCES≧1700V to 4500V) are industry, railway transportation, power quality, transmission and distribution. Required features are "Energy Saving" and "High Efficiency". To respond to such challenges, TOSHIBA had released the IEGT (Injection Enhanced Gate Transistor) technology tailored to cope with high breakdown voltages and low power losses. Higher junction temperature and higher current rating products will support such customer requirements. Two main packages are currently available:
PPI (Press Pack IEGT) and
PMI (Plastic Module IEGT).

PPI (VCES=3300V, 4500V) are TOSHIBA original packages using pressure contact structures. Basic features are specifically downsizing, much higher power density, high efficiency and high reliability in the field of electricity conversion such as industrial drive systems, power quality and HVDC (High Voltage Direct Current).

TOSHIBA is also adopting new compound material like SiC (Silicon Carbide). So, new discrete devices like SiC SBD (650V, 1200V) and hybrid SiC (Silicon IEGT + SiC SBD) in 1700V and 3300V are already available in the market. SiC MOSFET (1200V) will be released soon as well. Those products are realizing much lower power losses, much higher efficiency compared to conventional silicon-based power devices.

Discrete packages for low and high voltage MOSFETs

TRIDONIC
enlightening your ideas

TRIDONIC GMBH & CO KG

About Tridonic

For more than 60 years Tridonic has been a successful innovation driver on the lighting market. This pioneer of digital lighting control is now focusing its attention increasingly on LEDs as the technology of the future, with more than 80% of current R&D projects devoted to it. The broad offering for creating semiconductor-based and conventional lighting solutions ranges from individual components to complete systems. The focus is

on LED systems comprising light sources and converters. An extensive portfolio of conventional control gear for different lamp types and light management systems rounds off the programme.

This global company is shaping the technological changes on the lighting market together with its strategic partners and places great emphasis on intensive and personal contact with its customers. The innovative product portfolio, in-depth application know-how and excellent service are aspects that luminaire manufacturers, architects, electrical and lighting planners, electrical installers and wholesalers all find impressive. Solutions based on components and systems from Tridonic meet the highest quality requirements for indoor and outdoor lighting in reference installations throughout the world – as either standard products or customised solutions.

The Yonghui Supermarket in Putian, China has switched lighting installation to Tridonic's LED system

In their search for intelligent lighting solutions for a wide range of applications, customers benefit from the specialist knowledge of Tridonic's experts. This package helps users make the best possible use of the opportunities of semiconductor-based light, namely a reduction in energy consumption thanks to the high efficiency of LEDs, compliance with specific requirements such as colour selection, colour consistency and, if necessary, colour changing. As a system supplier, Tridonic enables individual lighting moods to be configured using high-quality LED light sources together with controllers in a perfectly matched system.

Tridonic GmbH & Co. KG has its headquarters in Dornbirn in Austria. It is a subsidiary of the publicly quoted Zumtobel Group and has offices or partners in 73 countries. In the 2012/13 fiscal year more than 1,900 employees generated sales totalling 378 million euros.

9% of sales were invested in research and development. Around half of Tridonic's 2500 patents already relate to LED and OLED technologies. More than 300 employees work in research and development to boost the innovative strength of Tridonic.

The company is also a pioneer in sustainability. Tridonic was the first manufacturer in the lighting industry to introduce environmental product declarations (EPDs) in accordance with ISO 14025 and EN 15804.

TT Electronics
Power and Hybrid

Our Company

TT electronics Semelab manufacture ultra reliable high performance semiconductor solutions designed to operate in any environment.

We research, design, manufacture and distribute an innovative range of semiconductor products throughout the world.

We are experts in custom packaging and screening, servicing aerospace, space, defence, industrial and HEV markets.

Our R&D teams have an excellent track record for developing imaginative electronic solutions and our design engineers have created a wealth of high performance products.

Our manufacturing divisions have ensured supreme quality and reliability. And our sales teams and distribution partners have opened international markets to some of the best electronics solutions available.

Our Mission Statement

We are manufacturers of ultra reliable, high performance discrete semiconductors, power modules & hybrid microelectronic solutions designed to operate in any environment. Our mission, through our flexibility and innovation, is to be recognised as trusted technology leaders in the Defence, Aerospace, Industrial and HEV markets.

Our Products

MOSFETS

- MOSFETs, JFETs
- MOSFET Modules
- Standard and Custom packages
- Second Source Modern Hermetics
- ALFET Audio Lateral MOSFETs
- BUZ Lateral MOSFETs

DIODES

- Diode Modules
- Hi Rel Discretes
- Diode Arrays
- Gallium Arsenide
- Silicon Carbide Diodes

RF

- RF Power MOSFETs
- Diamond Performance FETs

MODULES

- Custom Power Modules
- Multi Chip Arrays

IGBTs

- IGBTs
- IGBT Modules

BIPOLAR

- Discrete Bipolar Transistors
- Single Dual, Quad & Custom
- Hi Rel Arrays
- Traditional Metal Packages

VACUUMSCHMELZE

VACUUMSCHMELZE GMBH & CO. KG

ADVANCED MATERIALS – THE KEY TO PROGRESS

VACUUMSCHMELZE is a global company with more than 4000 employees and production locations as well as sales offices in more than 40 countries. As one of the leading companies VACUUMSCHMELZE develops, produces and markets magnetic materials and products derived of them.

HIGH PERFORMANCE MATERIALS

All our materials are manufactured in our own vacuum furnaces or rapid solidification casting equipments.

- Soft magnetic NiFe or CoFe materials
- Amorphous and nano-crystalline rapidly solidified alloys
- Magnetic, semi-hard formable materials
- Alloys with special physical characteristics
- Brazing alloy foils of rapidly solidified materials

These materials are the basis for a wide variety of products. We supply alloys in the form of tapes, strips, round rods or wires. Many are also available as lamination packages, stamped and bent parts as well as magnetic shieldings.

TAPE WOUND CORES AND CUT CORES

Highest permeabilities and flux densities as well as minimal losses of our materials allow the design of advanced magnetic cores. Many of these are based on the latest generation of soft magnetic materials, the nanocrystalline alloy VITROPERM®

INDUCTIVE COMPONENTS

Our knowledge of cost effective design and quality manufacturing, our own material base and our experience with international markets lead to innovative components of extreme reliability.

- Current sensors with a minimal offset and the lowest possible temperature drift, e.g. for variable frequency drives or for photovoltaic inverters
- Compact power transformers with high efficiency in the several 10th of kilowatt range based on our nanocrystalline cores, e.g. for welding, traction or renewable energy applications
- Reliable and safe trigger transformers for power semiconductors
- EMC components with nano-crystalline cores are smaller and more efficient
- Precision current transformers with amorphous and nano-crystalline cores for long-term stable electronic energy metering
- Differential current transformers for highly sensitive residual current circuit breakers.

RARE-EARTH PERMANENT MAGNETS

As a leading supplier of permanent magnets we use our experience in application and development to offer the best in product quality.

- Specific process engineering combined with alloy competence
- Reliable performance at the highest standards also in mass production quantities
- Processes for optimised corrosion resistance developed by VAC
- VACODYM® Nd-Fe-B rare earth magnets rank among the most powerful magnets in the world. Nowadays electrical heavy-duty machines are operated with VAC magnets far into the MW power range; for instance as propulsion systems in ships or as generators in wind turbines.
  Besides permanent magnets we also manufacture complete magnet systems of every required size and complexity for a wide variety of applications.

Vincotech

VINCOTECH GMBH

Vincotech, an independent operating unit within Mitsubishi Electric Corporation, develops and manufactures high-quality electronic power components for **Motion Control, Renewable and Power Supply** applications. With some 500 employees worldwide, backed by vast experience and a long history in electronics integration, Vincotech leverages these assets to help customers attain maximum market success. Vincotech has consistently achieved strong growth, clearly outperforming the market.

In 1996, the company first planted a footprint in a market that holds great promise for the future, power modules. Ever since, a dedicated team has developed state-of-the-art technologies engineered to create compelling new components, both standard and customized, for motor drives, solar inverters, welding equipment, and power supplies. Today Vincotech is a market leader in **power modules.**

Headquartered in Unterhaching near Munich, Germany, Vincotech also owns and operates a site in Bicske, Hungary. The ISO9001- and TS16949-certified factory in Hungary develops and manufactures all power modules. Engineered to comply with the RoHS standard, these modules are subjected to a battery of electrical and functional tests prior to packaging to ensure they fully satisfy Vincotech's rigorous standards for quality.

The name Vincotech stands for highest product reliability, excellent customer service, and flexible, competitive solutions, all of which culminate in outstanding customer satisfaction. A Highly motivated and experienced engineering team at the R&D center, supported by skilled technical service crews in all major regions, provide the underpinning for the company's strong technology portfolio.
Vincotech offers a wide range of power module topologies, standard solder-pin connectors, **Press-fit technology,** innovative **thermal interface material (TIM),** and a broad power spectrum

ranging from 4 A to 1800 A and from 600 V to 2400 V. The offering encompasses Intelligent Power Modules (IPM), Integrated Power Modules (**PIM,** a combination of input rectifier, inverter and brake chopper), **sixpack inverters,** and **rectifier, PFC-, H-bridge, half-bridge, booster, NPC** and **MNPC converter modules.**
Our new **Integrated Simulation Environment (ISE)** helps to select the right power module for your application.
As a leader in power modules, Vincotech delivers off-the-shelf products and customized solutions to satisfy every demand. Our customers are welcome to participate in the innovation stream.

Vincotech, your reliable partner

Drive for Customer Satisfaction and New Advanced Technologies

Vishay Intertechnology, Inc. is one of the world's largest manufacturers of discrete semiconductors and passive electronic components. They are used in virtually all types of electronic devices and power electronics. Vishay's innovations in technology, successful acquisition strategy, product customization, and "one-stop-shop" service have made the Company a global industry leader. Modern electronic components need to incorporate high power densities in more and more compact designs – which Vishay focuses on both in semiconductors and passive components.

Selected Vishay components for INDUSTRY 4.0 power conversion applications.

Semiconductors

Vishay's breadth of semiconductor technologies, paired with its own foundry and packaging operations including high-power semiconductor packaging, provide an ongoing source of innovative components for the power electronics industry. The portfolio includes MOSFETs (low-voltage and high-voltage), ICs (power and analog), a wide range of diodes and

Selected Vishay components for assisted and autonomous driving, EV, HEV, and charging infrastructure.

rectifiers (fast and super-fast, single, tandem, and bridge), power semiconductor modules (MOSFETs, IGBTs, diodes, SCRs), and many different types of optoelectronic products such as sensors, couplers, and solid-state relays – many of which are automotive AEC-Q qualified. Vishay is a market and technology leader in power rectifiers, low-voltage power MOSFETs, and infrared sensors and components.

Passive Components

Robustness and reliability mark the passive components of Vishay. The Company offers a wide range of power and very high-power electronic components and customized parts, including high-power HVAC capacitors; film-RFI, DC-link, and electrolytic capacitors; and ceramic single-layer, multilayer, high-Q, RF, tantalum, and polymer capacitors for power converters, small and large drives, and power transmission. Resistive products manufactured by Vishay include a wide range of power ratings up to 4 MW for dynamic braking and high-power safety applications including forced air and liquid-cooled assemblies. The Vishay resistor portfolio includes an almost complete range of technologies, including thin and thick film, metal oxide, carbon, polymer film, MELF, and wirewound and Power Metal Strip® technologies, as well as non-linear resistors, resistor networks, and arrays. High-power inductors, chokes, planar transformers, and customized magnetics complete the product offering. The portfolio is completed by a wide range of sensors and transducers for industrial and off-road applications.

Going Forward to New Horizons

Many innovations come from Vishay, including Power Metal Strip® resistors, thick film power resistors, IHLP® inductors; TrenchFET® MOSFETs, TMBS® rectifiers, wet tantalum capacitors, and capacitors for power electronics. Our breadth of component and packaging technologies, paired with our ability to customize, enable us to participate in technology trends such as Industry 4.0 and support alternative energy generation and transmission projects, drives and inverters for wind and photovoltaic systems, smart grids, meters, and power distribution infrastructure such as on- and off-board chargers, hybrid and fully electric vehicles, and autonomous driving. IoT is the ongoing challenge for more efficient and small form factor products including energy storage devices such as ENYCAP® hybrid supercapacitors.

About us

Würth Elektronik eiSos GmbH & Co. KG is a manufacturer of electronic and electromechanical components for the electronics industry. Würth Elektronik eiSos is part of the Würth Group, the global market leader for fastener technology. The company employs currently 6,500 people and generated sales of 555 million Euro in 2016.

The Würth Elektronik eiSos product range covers EMC Components, Capacitors, Inductors, RF Inductors and LTCC Components, Transformers, Components for Circuit Protection, Power Modules, LEDs, Connectors, Switches, Power Elements in Press-fit Technology and Assembly Technique.

As one of Europe's largest manufacturer of passive components, Würth Elektronik eiSos sets itself apart from other component manufacturers in the following ways:

- All catalogue products are available from stock
- Free sample service
- Delivery of samples within 24-48 hrs
- No MOQ
- Design support from technical sales force and Field Application Engineers
- Reference designs with all leading IC manufacturers
- Design kits with free refills
- Free EMC and Power seminars
- Software tools for selection of components

In addition to components, Würth Elektronik eiSos also supplies engineers with expertise. The "Trilogy of Magnetics", "Abc of Capacitors", "Trilogy of Connectors" and "Simulation in LTspice IV" application manuals provide professionals and other interested parties with a compendium of practice-oriented expertise, which is unique of its kind.

Würth Elektronik eiSos is active with direct sales in 40 countries worldwide. 16 manufacturing facilities located in all important markets worldwide guarantee the rapid delivery of components.

Würth Elektronik: more than you expect!

YASA

YASA LIMITED

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YASA designs and manufactures compact, lightweight and powerful electric motors, motor controllers and dc-dc converters for use in advanced hybrid and electric vehicle powertrains.
The company's revolutionary electric motors and controllers enable cost-effective vehicle hybridization and electrification – especially when there is a desire for minimum powertrain size and weight. This is because the high-power density of the e-motors and controllers provide vehicle engineers with additional flexibility to increase electric vehicle range, load carrying capacity or performance without compromising cost.

About YASA.

The company was formed in 2009 to exploit electric motor technology developed by the company's founder and current CTO, Dr. Tim Woolmer during his DPhil studies at the University of Oxford.

The YASA motor (YASA stands for yokeless and segmented armature) was quickly adopted in motorsport and high-performance vehicles including the Jaguar CX-75 and Koenigsegg Regara.
Today, YASA supplies custom and off-the-shelf e-motors and controllers primarily to automotive customers from its headquarters and 100,000 unit pa series production facility near Oxford in the UK.

YASA Power Electronics Technology

YASA's focus on high-power density powertrain solutions is reflected in the development of revolutionary power electronics technology that leverages learning from YASA e-motor development, particularly for very efficient liquid cooling. Proprietary cooling architecture and YASA manufacturing technology enable the company to manufacture e-motor controllers with apparent power density in excess of 40 kVA / Litre.

YASA Product Example (Pictured)

The YASA 400V, 600A controller is an automotive grade controller / inverter designed for use with YASA and other motor types including permanent magnet and induction types. Control is via CAN bus with ISO 26262 functional safety support up to ASIL C. Multiple monitoring and control interfaces are provided.

- Input voltage range: 50 to 400 V dc
- Continuous Output current: 300 A RMS (3-phase)
- Mass: 4.9 kg
- Volume: 5.1 litres (excluding terminal area)

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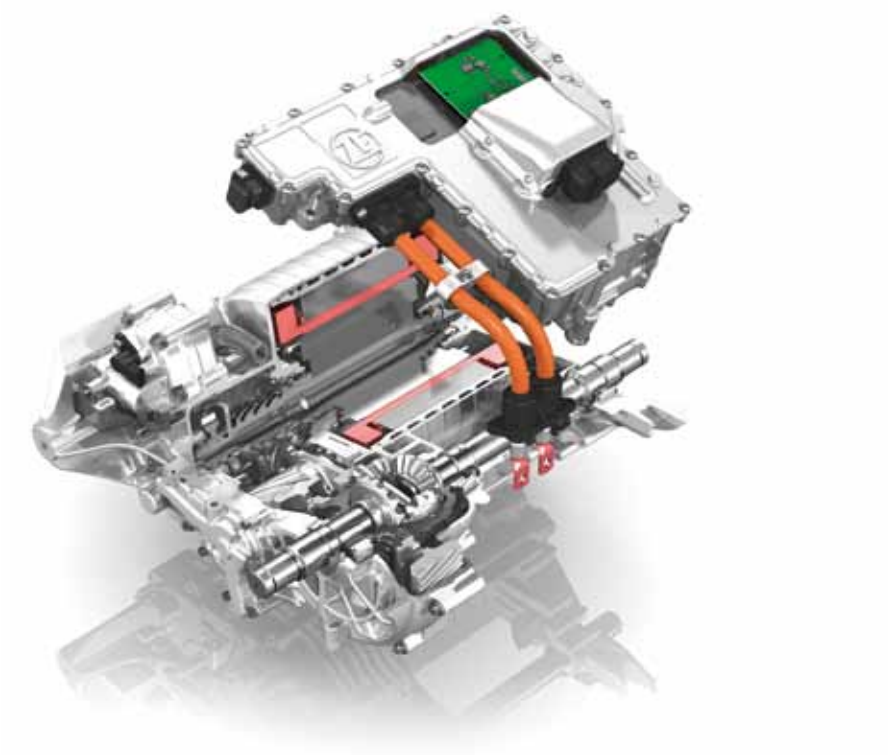


ZF is a global leader in driveline and chassis technology as well as active and passive safety technology. The company, which acquired TRW Automotive in 2015, is now represented at about 230 locations in some 40 countries.
The two companies, which were still independent in 2014, achieved a sales figure exceeding €30 billion with 134 000 employees. As in previous years, both companies have invested approximately 5 percent of their sales in Research and Development (recently €1.6 billion) in order to be successful with innovative products.
ZF is one of the top three automotive suppliers worldwide.

The company was founded in 1915 for the development and production of transmissions for airships and vehicles. The "Motion and Mobility" slogan clearly states the company's core mission: Right from its foundation, ZF has developed and manufactured innovative products for all people around the globe who want to move things reliably, comfortably, and safely, and experience the ultimate in efficient mobility. Quality, technological leadership, and innovative power have always defined the Group's identity – today as much as ever.

In the field of e-mobility, ZF offers system components including power electronics for a wide variety of applications from a single source. In this context, the technology company follows a modular approach, which satisfies all functionality requirements as well as the commercial demands of vehicle manufacturers. The ZF portfolio includes all components for the cost-effective electrified driveline including control units and power electronics, starting with individual hybrid modules, plug-in hybrid systems, through to all-electric concepts.

The electrification of the driveline will enable us to achieve future emission targets. Here, downsizing of power electronics to integrate an electric motor and PE into a transmission is a possible key in reducing the costs of hybrid systems. Reducing installation space, weight, and the number of interfaces and components, as well as increasing efficiency are the drivers of innovation for new developments. ZF focuses on a broad technology spectrum in terms of power electronics: from power modules and passive components to signal electronics and system integration.

AIRBUS Group Innovations, Germany
www.eads.com

AMX Automatrix, Italy
www.amx-automatrix.it

Bombardier Transportation, Switzerland
www.bombardier.com

Boyd Corporation GmbH, Germany
www.boydcorp.com

CAF Power & Automation SL, Spain
www.cafpower.com

DENSO AUTOMOTIVE Deutschland GmbH, Germany
www.denso-europe.com

GaN Systems Inc.
www.gansystems.com

HE system Electronic GmbH & Co. KG, Germany
www.he-system.com

LGF Elektrotechnik GmbH & Co. KG, Germany
www.lgf-filter.de

Leopold Kostal GmbH & Co. KG, Germany
www.kostal.com

Magneti Marelli Powertrain, Italy
www.magnetimarelli.com

Miba Energy Holding, Austria
www.miba.com

ON Semiconductor GmbH, Germany
www.onsemi.com

Panasonic R&D Center, Germany
www.panasonic.de

PINK GmbH, Germany
www.pink.de

Refu Elektronik GmbH, Germany
www.refu-elektronik.de

Rohrer Mess & Systemtechnik GmbH, Germany

www.rohrer-muenchen.de

Valeo Systèmes Electriques, France

www.valeo.com

Volkswagen AG, Germany

www.volkswagen.com

ZES Zimmer Electronic Systems, Germany

www.ces.com

ENERGIEregion Nürnberg e.V., Germany

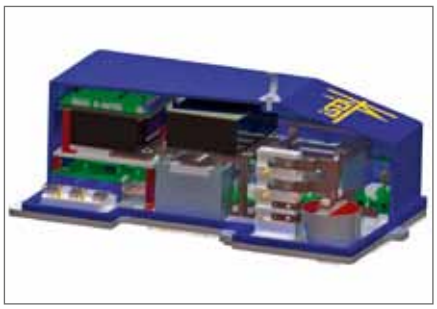
www.energieregion.de

RWTH AACHEN UNIVERSITY

AACHEN UNIVERSITY OF TECHNOLOGY (RWTH)

The Institute for Power Electronics and Electrical Drives (ISEA) of RWTH Aachen University has been working on Power Electronics, Power Semiconductor Devices, Electrical Drives and Electrochemical Energy Storage Systems for more than 45 years. Under the supervision of institute director Prof. Dr. ir. Dr. h. c. Rik W. De Doncker and the head of the Electrochemical Energy Storage Systems Group Prof. Dirk Uwe Sauer, the focus of ISEA is on research and development activities in close co-operation with national and international companies, as well as on public funded research projects. In addition, ISEA offers engineering services.

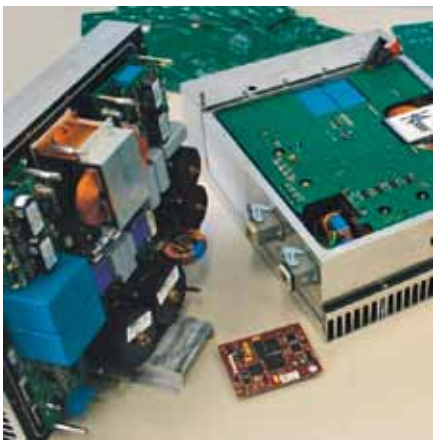
One of the main research areas of the institute are power electronics, drives and batteries for electric, hybrid and conventional vehicles. Researchers work on electrical architectures and drive trains on the system level and investigate, for example, the effect of different voltage levels and the utilization of DC/DC converters on the overall efficiency or the integration of the energy storage into the grid, as well as on the component level, for example designing highly efficient converters or investigating the aging behavior, diagnostics, and energy management of battery packs. Drive inverters including sensorless and highly dynamic torque control are also a major topic. A special focus lies on the design and realization of switched reluctance drives, which feature a low-



Integrated Power Unit (DC-DC converter and drive inverter) for hybrid electric vehicle, Europa-PlugIn project

cost robust design and are very suitable for compact high-speed drives. Also the acoustic behavior of drives is investigated and optimized. Device level research is conducted, too, such as specific package design for semiconductors for automotive applications.

Another main research area is sustainable energy. Also here, power electronics and storage systems are key technologies to



Bi-directional charger for electric vehicle, SmartWheels project

enable a largely renewable energy generation while maintaining a stable grid. As an example, ISEA works on highly efficient converters for solar applications and has developed a test bench for the characterization of commercially available photovoltaic inverters.

Macro battery cell, ePerformance project

Furthermore, the institute is also active in the research fields of traction applications, home appliances and industrial applications.

Currently, more than 70 scientists and engineers jointly research and study at ISEA together with more than 50 students. The close cooperation of experts for power electronics, drives and battery systems enables highly optimized systems for all the applications described above.

Overview

The Institute for Power Generation and Storage Systems is part of the E.ON Energy Research Center (E.ON ERC) of RWTH Aachen University. The center is a public private partnership that was founded in 2006. Research in the center focuses on energy savings, energy efficiency and sustainable energy supplies. Five institutes out of four different faculties strongly cooperate in projects related to grids and storage systems, buildings and city quarters, as well as heat and power plants. At the energy markets plane, questions related to consumer behavior, policies, social aspects, and technology choices and diffusion are being addressed.

Prototype of 5 MW DC-DC-Converter

The Institute for Power Generation and Storage Systems works in the area of medium-voltage power electronics and drives and also on stationary energy storage systems. The current research topics involve the installation of a test bench for power electronics and electrical drives with a power rating of up to 5 MW and rotational speeds of up to 15,000 1/min, the design and construction of a 5 MW dc-dc converter, the analysis of medium-voltage direct current grids and power electronic components for wind energy converters in the MW-range. PGS is headed by Professor Rik De Doncker, who is supported by Professor Dirk Uwe Sauer, head of the research group "Electrochemical Energy Conversion and Storage Systems".

Mission Statement

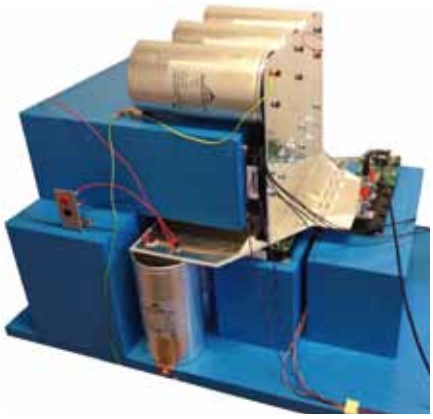
PGS aims at researching, developing, and applying power electronic conversion and storage technologies (medium-voltage building blocks) to significantly improve the performance in terms of efficiency and life cycle cost of generation, storage, medium-voltage distribution and DC transmission systems.

This requires

- Design, fabrication and testing of high-power semiconductor switches (clean room)
- Development, design and testing of medium-voltage power converters (AC-DC and DC-DC converters)
- Development of controls and real-time emulators
- Development, design and testing of fast hybrid switches for protection of DC distribution and transmission systems (cables)
- Analysis, design and development of electrochemical storage systems

AALBORG UNIVERSITY
DENMARK

AALBORG UNIVERSITY



A non-destructive-tester for high power

Highlights in Power Electronics at Aalborg University

- Power electronics is one of the strategic research and education areas at Aalborg University
- Multi-disciplinary research programs on efficient and reliable power electronics
- 7 full professors, 6 associate professors, 1 part-time professor, and 2 adjunct professors.
- 60+ PhD students; 20+ postdocs and research assistants; 20+ visiting scholars; 3 in-house company divisions

Key Research Areas

- Reliability of power electronic components, converters, and systems
- Renewable energy applications (e.g., wind turbine systems, photovoltaic systems)
- Power electronics based power systems
- Power module packaging
- Automotive and industrial drives
- Microgrids and smart grids

University-Industry Collaborations

The power electronics research at Aalborg University places great emphasis on national and international collaborations with peer universities and companies. A recent example is the establishment of two strategic research centers, the Center of Reliable Power Electronics (CORPE, www.corpe.et.aau.dk) and Intelligent and Efficient Power Electronics (IEPE, www.iepe.et.aau.dk), in collaboration with Danfoss, Grundfos, KK Wind Solutions, and Vestas, with a research budget of 25 million Euros.

1 MVA power stack. IGBT modules.

A Unique Education Model and PhD/ Industrial Course Portfolio

The power electronics program strives for the highest excellence in education to produce exceptional candidates who are highly educated in power electronics. The education of undergraduate and master students is based on a unique Problem-Based Learning (PBL) model implemented at Aalborg University since 1970s. For PhD education and also for the benefit of industrial companies seeking state-of-the-art research results, a number of PhD/industrial courses are given every year, which is open to the public worldwide.

Lab Facilities

Power electronics laboratories with world-class facilities have been built up in the last 20 years at Aalborg University. A list of the laboratories in power electronics and its applications is given below:

- Advanced Electric Machine and Drive Laboratory
- DC Microgrids Laboratory
- Flexible Drive Systems Laboratory (FDSL)
- Fuel Cell and Battery Systems Laboratory
- Grid Integration Laboratory (GIL)
- Medium Voltage Laboratory (up to 20 kV /2 MVA testing capability)
- Intelligent Microgrids Laboratory (iMGL)
- Photovoltaic Systems Laboratory (PVLAB)
- RTDS Laboratory
- Smart Energy Systems Laboratory
- Vehicle and HeavyLab
- Reliability Testing Laboratory

Multiple power electronics converters based energy processing system.

Overview and education:

The University of Applied Sciences Augsburg is located in the South of Germany and has a history of more than 300 years. In the last century intermittent it was called "Rudolf Diesel Polytechnikum" with respect to Augsburg's most popular engineer Rudolf Diesel, the inventor of the world wide well known diesel engine. Today, the University of Applied Sciences Augsburg has approx. 4500 students and is well established. The educational arm consists of seven faculties. One of them is the department of Electrical Engineering with approx. 600 students and 18 professors. It contains the power electronics institute with actual 35 students per year, too.

In the power electronics course of the Bachelor- degree following items will be discussed:

- Passive components, the influence of the EMI behaviour and filter topologies
- Today's most important semiconductors
- DC/DC converter
- DC/AC and AC/DC converter
- Principles of SMPS

IIn cooperation with the University of Ulster (Belfast), a Master course will be offered. In the "power electronics and drives"- lecture the students learn details of space vectors and different types of three phase inverters. Mini projects complete the course.
The new degree "Master of Applied Research", university experiences come together with the industry. For details, please contact us.

In the lab:

The power electronics laboratory is well equipped for education as well as research and development investigations. The focus is on the small and medium power rage. The AC-power supply is designed for voltages up to 1000V and the maximum (line)-power is up to 40kW. In the lab a 500V/ 10kW- DC- network is available, too. A wide spectrum of measuring systems allows analysing the EMI-behaviour as well as a high precision power determination. Combining these with our infrared camera for thermal investigations complex system tests can be done. But it has to point out, that outsourcing or a very rapid prototyping can not be offered.

Research and development:

The focus of the institute is on high efficient PFC- stages. In Today's topologies, a bridge rectifier rectify the mains voltage. The output of the bridge rectifier is connected to a boost converter. Input

rectifier and the PFC diode build up two rectification stages. This reduces the efficiency more then necessary. Bridgeless PFC's have less conduction losses. Due to the missing rectifier bridge bridgeless PFC-converter causes a higher common mode noise than with Today's standard boost converters. A simple and low cost new L-C-EMI- filter was found out and published. After that, a digitally control circuit was designed. Also the input voltage respectively input current measuring was optimized.

Some other investigations with industrial partners are:

- Thermal and electrical failure analysis of solar inverters
- Analysing of the influence of modern diodes (SiC, GaAs) on the total PFC-stage efficiency.
- Influence of IGBT or MOSFET on the efficiency in electronic ballast
- Energy recovery inverter for agricultural application
- Analysing of thyristor- controlled arc welding systems

POWER ELECTRICAL AND ELECTRONIC SYSTEMS
UNIVERSITY OF EXTREMADURA

PE&ES staff and buildings where PE&ES facilities are hosted

General Information

The University of Extremadura (UEx) is a public Spanish university, located in Extremadura. It was established in 1973, and today more than 200 research groups and more than one thousand competitive scientific lines give a superb research background to the University. The Power Electrical and Electronic Systems Research and Development Group (PE&ES), is located in Badajoz (Spain). It is composed by different professional profiles covering Doctors, Engineers and Physicists and has more than 15 years of experience in the fields of power electronics applied to power grids, renewable energy sources, smart grids, energy storage, electric vehicles, and monitoring and control systems.

Facilities

PE&ES has several labs hosted in two different buildings, covering both basic research (where PhD Students do their Thesis under the guidance of Senior Researchers) and applied research (for products and prototype manufacturing and testing). PE&ES has advanced equipment to design, build and validate converters and their control algorithms, and various types of rapid prototyping platforms, as dSpace, National Instrument or Speedgoat. Specifically, it has the infrastructure requirements for testing converters up to 15kW, as Grid or PV plants emulators. A new lab rated up to 100kW will be available in 2017.

Competences

PE&ES can design and develop new converters using the most promising topologies and technologies and their corresponding controllers. Auxiliary electronic circuits, as improved drivers or advanced measurements boards using advance sensors or remote monitoring, can also be designed and developed.
PE&ES has developed several converters using SiC or GaN semiconductors and new IPM products to validate their use in high power renewable energy, smart grids and electric vehicle applications.

CITCEA – UPC, CENTER OF TECHNOLOGICAL INNOVATION IN STATIC CONVERTERS AND DRIVES

CITCEA-UPC is a technology transfer centre of Universitat Politècnica de Catalunya (UPC BarcelonaTech), specialized in responding to the needs of enterprises to build functional prototypes that can be industrialized and commercialized. In order to carry this out, it is built a client-supplier relationship with the enterprises we collaborate with.

The center is expert in all types of applications requiring the control of energy, also known as Enertronics, and the control of the movement, also called Mechatronics.

Enertonics

Enertonics is the synergistic combination of electronic signal and power, computing and control systems. In this area CITCEA-UPC has expertise in wind energy, photovoltaics, Smarts Grids and Microgrids, railway, grid integration of electric vehicles and IEC68150 standard. The engineers of the center have become specialized in double-fed induction generator, back-to-back converters, PMSG, HVDC, off-shore wind energy, grid stability, energy market, FACTS, energy pricing, PSS, DigSilent and EMTP-RV.

Mecatronics

Mecatronics combines the fundamentals of mechanical, electrical, and computer engineering. CITCEA-UPC develops this field working on power electronics, drives, motion control, electrical machines, automation and industrial communications. Researchers operate with digital control of power converters, DSP, frequency converters, energy storage, battery chargers, CHAdeMO, PLC, high precision synchrotron power supplies, automation, CAN, industrial communications, ASi, web servers and microprocessors.

Training

CITCEA-UPC offers training for enterprises and professionals in its fields of expertise, since in an economic context where knowledge is increasingly important the human capital of an enterprise becomes a valuable asset. For this reason, ongoing training is a basic element for competitiveness. The masters, professional courses and tailor-made courses offered by CITCEA-UPC provide specific and cutting-edge knowledge which mean improved productivity in the workplace and advances in the area of professional career.

More activities

Several patents and utility models have been developed in the recent years in the field of mechatronics, energy systems and motion control. Moreover, CITCEA-UPC is involved in several cooperation project supported by the European Commission.

In addition, the center has organizes seminars and workshops with the participation of internationally renowned experts. In October 2007 the center organized 9th edition of Electrical Power Quality and Utilization (EPQU'07) and in 2009 the "European Conference on Power Electronics and Applications (EPE'09)" in Barcelona.

Since 2001 CITCEA-UPC has been part of the TECNIO network, which provides support for technological innovation, driven by ACC1Ó, an organism of the Government of Catalonia.

UNIVERSITÄT BAYREUTH

UNIVERSITY OF BAYREUTH, DEPARTMENT OF MECHATRONICS

Overview

The Department of Mechatronics at the University of Bayreuth has been founded in 2011 under the leadership of Prof. Dr.-Ing. Mark-M. Bakran. Approximately 1.150 of the more than 12.500 students in Bayreuth are enrolled in an engineering science field of study. The department teaches courses from electrical basics and mechatronics to power electronics and electrical machines in vehicles. From 2013 on, the Department of Mechatronics is located in a new building equipped with modern electrical laboratories for students as well as researchers.

Research Topics

Mechatronics is a made-up word for the linkage of mechanical, electrical engineering and information technology. It has a bridging function over these three disciplines and deals with the functional and constructional integration of these different aspects in applications. The research focuses on up to date topics from fields of propulsion technology and energy management with power electronics as the linking and also central element. Core areas are:

- New power electronic devices
- Energy conversion with high power density
- Development of new circuit techniques
- Integration of energy storages
- Safe power electronics
- High-Voltage Direct Current Transmission Equipment

Equipment

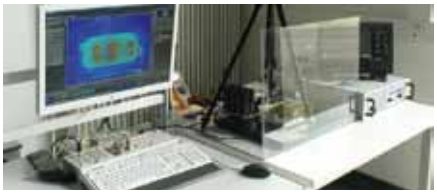
The new laboratories offer a wide range of specialized measurement, supply and control tools for power electronics evaluations. Highlights of the technical equipment are:

- High-voltage IGBT test bench for benchmarking new power electronic devices
- Power sources for high-voltage and high-current experiments:
  - 6 kV / 20 A
  - 80 V / 1,5 kA
  - 10 kV / 1 A
  - 400 VDC/100 A/32 kW (bidirectional)
- Temperature and climate test chamber as well as thermal camera for device testing at thermal limits and reliability investigations
- High resolution 12-Bit oscilloscopes
- dSPACE and FPGA systems for rapid prototyping
- Partial Discharge Measuring System (20 kV)
- Zimmer LMG500 1 to 8 Channel Precision Power Analyzer

Industry Cooperations

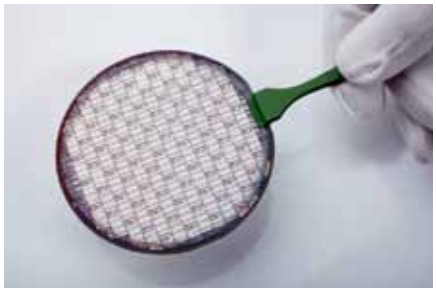
To link the scientific world with commercial products the Department of Mechatronics cooperates in several research projects with industry partners:

- Weight and lifetime optimized energy storage system with bidirectional charging unit
- Inverters with high power density
- Fast switching IGBTs in low-inductive systems
- Converter topologies for meshed DC-grids



FBH's Portfolio

The FBH is an internationally recognized competence center for optoelectronic and electronic research based on III-V compound semiconductors. It operates industry-compatible and flexible clean room laboratories with vapor phase epitaxy units for the growth of GaAs- and GaN-based epitaxial structures and a III-V semiconductor process line for wafer diameters up to 4 inches. The work relies

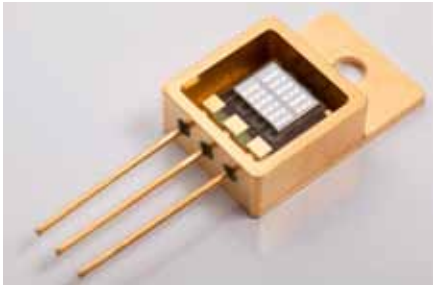


Processed GaN-on-SiC wafer containing power transistor chips

on comprehensive materials and process analysis equipment, a state-of-the-art device measurement environment, and excellent tools for simulation and CAD. In close cooperation with industry, its research results lead to cutting-edge products.

GaN Power Electronics at FBH

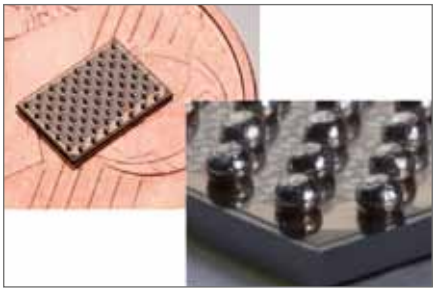
Gallium nitride (GaN) is characterized by its excellent dielectric breakdown strength. Thus, GaN-based High Electron Mobility Transistors (HEMTs) offer excellent power densities and combine high electron mobility with high saturation velocity. They are therefore well-suited for high frequencies, high voltages and very fast and low loss (efficient) switching applications.



Flip-chip mounted 50 A/ 250 V normally-off GaN power transistor

Innovative devices for power electronic applications aim at achieving fast and efficient high-voltage switching capabilities combined with normally-off behavior. Our developments towards GaN power HEMTs focus on increasing the breakdown voltage up to 1000 V. Further objectives are to develop and realize device concepts for low on-state resistances down to 10 m cm² as well as for normally-off devices. Accordingly, we optimize epitaxial designs and growth procedures as well as technological parameters and specific features such as field plates, passivation layers, and layout designs compatible to high-voltage applications.

By concentrating electrons in the transistor channel, high breakdown voltages are achieved. Thus, corresponding epitaxial layer designs are used providing a repelling electrostatic force to the electrons (back barrier designs). For normally-off GaN power transistors, we are focusing on p-GaN gate technology. This technology renders the intrinsic potential distribution close to the gate such that the devices can only be switched on at positive voltage. A threshold voltage of +1.5 V and a gate dynamic range of +5 V are characteristic values. Our high-current transistors up to 150 A rely on a two-dimensional scaling of the transistor width



250 V / 75 A GaN power transistor optimized for flip-chip mounting GaN power transistor

considering thermal issues and combining it with flip-chip mounting capability.

The combination of these properties qualifies FBH transistors for power applications in automotive electronics, terrestrial and space-borne solar converter technology and others.

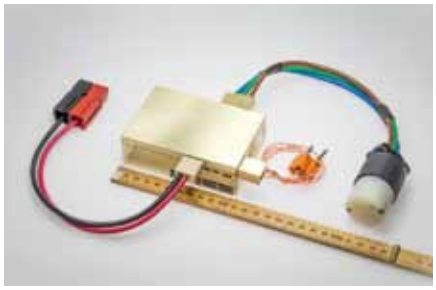
We are actively involved in various projects funded by industrial as well as public national and European sources.

Fraunhofer IZM

FRAUNHOFER INSTITUTE FOR RELIABILITY AND MICROINTEGRATION IZM

Power Electronics at Fraunhofer IZM

IZM has all necessary expertise in the entire development chain, from system design, packaging, thermal management, electromagnetic compatibility, through to reliability and damage analysis.



Solar converter with embedded module, Little Box Challenge

Electrical System & Circuit Design

Applications for power electronic components are endless – in industrial drives, to generate renewable energy, in transport and more. The IZM is developing groundbreaking solutions for demands such as:

- High switching currents
- High voltages
- Very fast switching for SiC/GaN and highspeed Si-devices
- Mechanical stability

Embedded SiC-power module

- Strict EMC specifications
- An extremely long lifetime
- High reliability

Electromagnetic Compatibility

IZM is specialized in EMC and provides consulting and research for all phases of product development. Starting with basic research into interference phenomena in specific applications, we cover the entire spectrum, including troubleshooting after product delivery. We use in-house simulation processes developed specifically for frequent problems, as well as sophisticated measurement series.

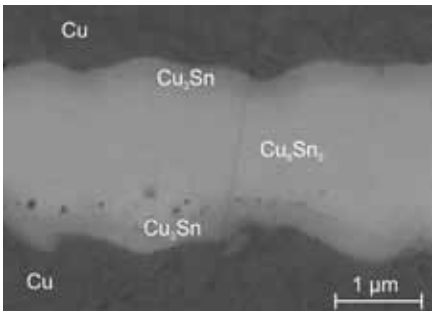
Thermal Management

The heat is dissipated from the chips through various interfaces, thermal interface materials, spreaders and substrates before being released into the environment by a heat exchanger (cooler). All of the specified points have to be optimized to guarantee that the heat is removed reliably and to meet the application's requirements.

Packaging

IZM has a wide area of packaging techniques at its disposal:

- Large-area solder joining; Ag sintering; diffusion soldering/bonding
- Heavy wire and ribbon bonding
- Embedding technologies as well as housing/encapsulation
- X-ray and US microscopy, visual inspection and mechanic testing



Diffusion bonded layer

Reliability

The damage behavior of materials and components are carefully analyzed and characterized in experiments; selected material and geometry parameters can be simulated (FEM). Technology-specific material properties are a particular focus of measurement technology at IZM. Among other things, such properties are the key extending the lifetime of a solder joint or a wire bond, and for measures that improve reliability.

Laboratories for power module and packaging qualification

- EMC-Lab
- Thermal measurement and thermal/mechanical simulation
- Active and passive power cycling
- Quality and reliability testing incl. combined and accelerated lifetime tests
- Material characterization: EBSD, FIB, SEM, EDX, Nano-Indentation

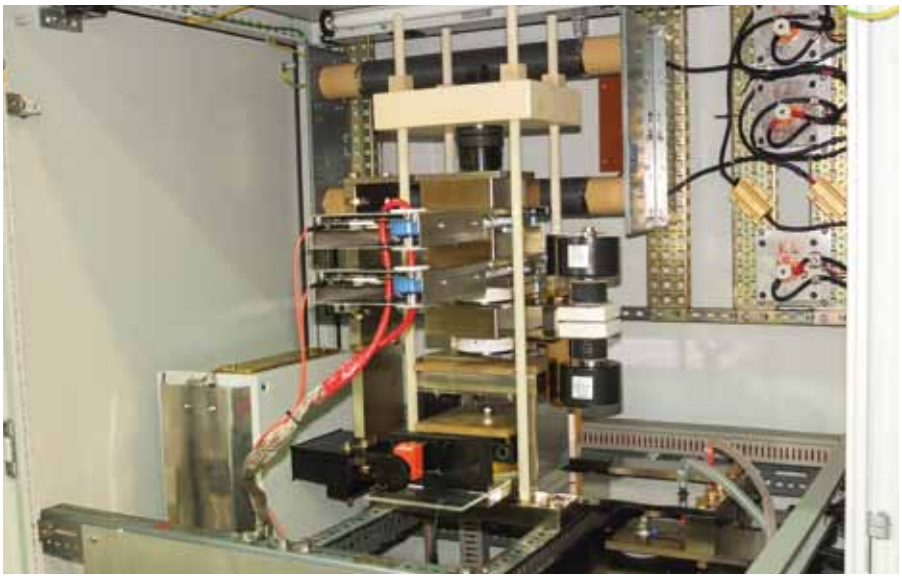
Research Interests / Projects

1. Energy Efficient Electric Drives

We are developing various methods to increase efficency of drive systems e.g. by improvement of low load efficiency by motor design (e.g. Ld > Lq), software based multi dimensional optimum geometry parameter search, and online minimum loss search depend on both load and speed.

2. EV Control

We design motor controllers for electric vehicles with minimum loss control strategies based on analytical or numerical algorithms.



IGCT Magnetizer with Integrated Quality Control of Magnets

3. Drive Production Technology

We are working on various technologies for large scale production, e.g. winding techniques combining high slots fill factors with low production cost, permanent magnet magnetizers including quality check during the magnetization process, and folded power electronics for motor integration.

Modular wind power generator

4. Wind Power

We realize small wind turbines for urban applications based on a modular system with permanent magnet generators, and we develop fast control systems for doubly fed induction generators according to latest grid connection requirements.

5. High speed drives

We have built several high speed drives with induction and switched reluctance machine in the 30,000 - 50,000 rpm range. Currently we set up a permanent magnet system.

Our lab provides power supply of up to 400 V, 50 Hz, and 630 kVA. There are several variable frequency supplies, liquid cooling units up to 100 °C and power measurement equiment for various variable speed test benches. Our software includes analytical tools for classical induction, DC, synchronous and switched reluctance motor design (own and commercial tools), finite element software for electromagnetics and multiphysics, and mechanical construction software.

Foldable Power Electronics for Motor Integration

IMS LABORATORY

The IMS Laboratory of Bordeaux develops original and coherent research actions in the domains of:

- Modelling and elaboration of materials, sensors and microsystems for the electronic devices; modelling, design, integration and reliability analysis of components, circuits and assemblies;
- Identification, command, signal processing and images, supervision and conduct of the complex and heterogeneous processes.

The fields of application of the laboratory concern in particular transports and are investigated through numerous European, national or regional projects.

Key Research Fields and Competence Areas:

Reliability:

- Behavioral modelling based on physical phenomena
- Multi-physics approach: electrical, thermal, physico-chemical, mechanical, EMC
- Interaction on the three domains: material, device and system
- Identification and modelling of degradation and failure mechanisms
- Life time distribution modelling

Power semi-conductor devices:

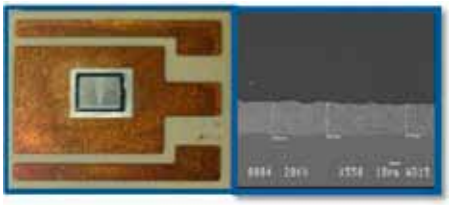
- Influence of thermal and mechanical stresses on active devices
- Electrical, thermal and mechanical characterization of Si, SiC, AsGa
- Finite elements electrothermal modelling for gate power devices (IGBT, MOSFET) under extreme operating conditions
- Electrothermal behavior in harsh environment

System topologies and assembly:

- Development of characterisation tools for complex assemblies
- Determination of parametric degradation laws
- New 3D-oriented mounting technologies of assemblies (low pressure sintering contact paste)

Energy storage systems and hybrid sources management:

- Characterization of storage devices close to the use (SCap, batteries…)



- Behavioral modelling closely related to physics
- Ageing monitoring, failure mechanisms identification
- Ageing modelling and specification of State Of Health criteria
- Taking into account the module integration constraints (real system)
- Simulation of the interaction storage / power and management electronics
- Hybridization strategy adaptation to the storage device

Highlights:

Virtual prototype design platform

- FEM simulations tools
- High performance computing platform

Assemblies characterization

- Failure analysis equipment
- Electrical, thermal and mechanical characterization

Ageing tests platform

Characterization and cycling of energy storage systems platform

- Electrochemical workstations
- Accelerated ageing from power cycling, endurance
- Environment (climatic chambers, ovens…)

Vehicles with inductive charging systems (up to 200 kW) in Braunschweig

Institute

The Institute for Electrical Machines, Traction and Drives (german: IMAB) was founded in 1920 and has a great tradition in academic teaching and research in the fields of electrical machines and power electronics.

Today, two professorships cooperate closely at the institute: Prof. Regine Mallwitz is professor of Power Electronics, the chair of Electrical Machines and Drives is held by Prof. Markus Henke. This combination gives excellent preconditions for the comprehensive research and development of complete electric drive systems and power electronic equipment.

High speed motor test bench (up to 200 kW, 30.000 min-1)

Research

Currently, research topics focus on electromechanical drive solutions for hybrid and full electric vehicles including also auxiliary power supplies und battery charging topologies and decentralized energy systems powered by batteries or photovoltaic modules. Central aspects are small weight and size of all components and the whole system.

Increasing the engine's speed is one basic approach to increase its power density of drive systems. Intelligent system design, innovative circuit topologies and new component technologies are the key factors in power electronics.

Some of the latest general research topics in power electronics at IMAB are:

- Investigation of the potential of new, fast switching power semiconductors based on silicon (Si), silicon carbide (SiC) and gallium nitride (GaN).
- Approaches to overcome negative impacts of fast switching devices on gate drivers, EMI and passive components.

Full SiC boost converter (100 kW, 100 kHz)

- Improvements of the heat transfer in high density power electronic systems.
- Development and test of various prototypes in a power range from 1 kW up to about 250 kW.
- Development of reliability tests especially of semiconductor devices.

Staff and equipment

Traditionally, highly motivated and dedicated students and young scientists are attracted by IMAB. High competence in engineering and scientific work is passed down from generation to generation.

On more than 660 m² of laboratory area the IMAB is equipped with several test benches for rotating and linear electric machines as well as for power electronic devices and systems. Several DC and AC sources are available to emulate batteries or photovoltaic sources, electric machines or AC grids. A wide range of applications and power levels can be covered.

The institute's workshop is experienced in building all kinds of prototypes, making the path from scratch to the running system in the test field a short one.

Universität Bremen
IALB BCM Bremer Centrum für Mechatronik

UNIVERSITY OF BREMEN
INSTITUTE FOR ELECTRICAL DRIVES, POWER ELECTRONICS, AND DEVICES (IALB)

The Institute

The 1994 founded IALB focuses on electrical drives, mechatronics, andrenewable energy (Prof. Bernd Orlik) and on power semiconductor components, their environment, and applications (Prof. Nando Kaminski, details see below). Both fields are members of the Bremen Center of Mechatronics (BCM, see www.mechatronik-bcm.de).

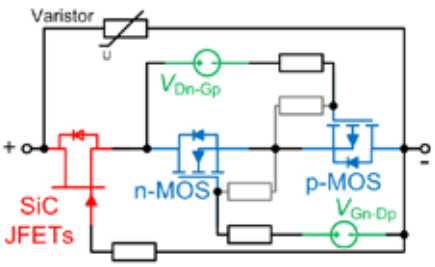


Fig.1 – Over current breaker based on the dual thyristor principle but realised with MOSFETs and a SiC JFET in cascode configuration

Semiconductor Basics

Basic semiconductor physics and properties are investigated and modelled. A special focus is on alternative semiconductor materials like silicon carbide (SiC) and gallium nitride (GaN), which play an increasingly important role in power semiconductor devices. The IALB operates a deep level transient spectroscopy (DLTS) and admittance spectroscopy equipment.

Device Concepts

The optimisation of existing components, the investigation of new concepts, and the modelling of devices are carried out by means of simulation and in cooperation with leading semiconductor manufacturers e.g. Infineon and ABB. Examples for current activities are the investigation of the RC-IGBT with respect to turn-off, snap-back, and diode behaviour as well as the investigation of a novel device concept for DC-switches. For semiconductor simulation Sentaurus of Synopsis Inc. is used, if necessary in mixed mode with circuit and thermal simulation.

Packaging and Reliability

Housing technology and cooling affect the reliability of semiconductor devices significantly. A current core activity of the IALB is the investigation of IGBT modules under humidity, temperature and high bias. Test facilities for climate and load cycling are available. Another very important aspect of the packaging is parasitics.

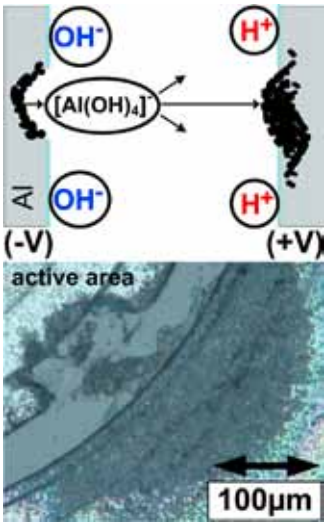
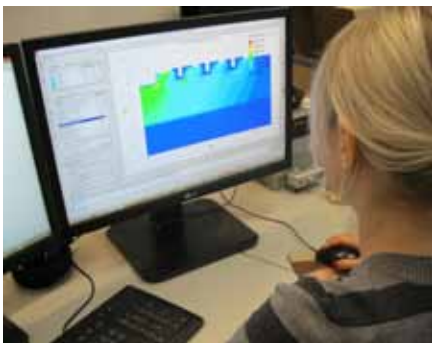


Fig.2 – Aluminium corrosion mechanism and degradation found in the failure analysis after humidity testing

The determination of such components is done by means of measurement and simulation (ANSYS-Q3D by Ansoft Corp.), respectively.

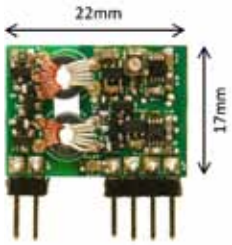
Application

The focus with respect to applications is on the interaction between circuitry and devices. One activity is IGBTs used for resonant switching. With rising switching speed and frequencies especially with SiC and GaN devices parasitics play an increasingly important role and affect the EMC-performance considerably. This is investigated by simulation and measurements e.g. double pulse testing.



The Bristol Power Electronics Innovation Centre is an interdisciplinary forum for power electronics activities at the University of Bristol. It combines two main entities, the Electrical Energy Management Group and the Centre for Device Thermography and Reliability to form an interdisciplinary team of 8 Academics and 40 Researchers dedicated to power electronic systems. This research is funded from international government agencies and industry with a portfolio that includes EC JTI Clean Sky projects and the UK EPSRC Centre for Underpinning Power Electronics.

Bristol has strong expertise in exploring new developments in power semiconductors, including wide band-gap devices, and, working alongside our industrial partners, in exploiting advancements in power electronics in providing new capabilities and products.



Energy efficiency resonant gate driver module, with recovery of stored gate energy

Electrical Energy Management Group undertakes research into low carbon electrical systems that are enabled by advanced, compact and highly efficient electrical machines, and power electronic conversion. The management of electrical power is the core challenge, with a focus on the systems employed in aircraft, automotive drive systems, renewable energy plant and micro-grids. Applications range from μW miniature energy scavenging to 200kW hybrid-electric vehicle powertrains.

- Supporting technologies for GaN and SiC power devices: novel gate drivers, switching-aid circuits, new circuit topologies, control methods, sensors…
- High-performance passive component design: multi-physics design optimisation, thermal and loss analyses, new mixed-material structures, novel integrated magnetic components
- Power electronic systems for the managing of energy at sub Watt levels for use in energy harvesting and HV supplies; novel circuit topologies, exploitation of non-linear behaviour
- Coupled electromagnetic/thermal/electrical system modelling, multi-objective optimisation, accurate reduced order/functional modelling of power electronic system elements
- Robust minimal sensor control methods, design for fault tolerance

Centre for Device Thermography and Reliability performs international leading research in power device thermal management and reliability including the development of new testing methodologies. The group's expertise is used to support development of new device concepts, in collaboration with key industrial partners in the UK, Europe, USA and Asia

99% efficient three-phase inverter using super-junction devices.

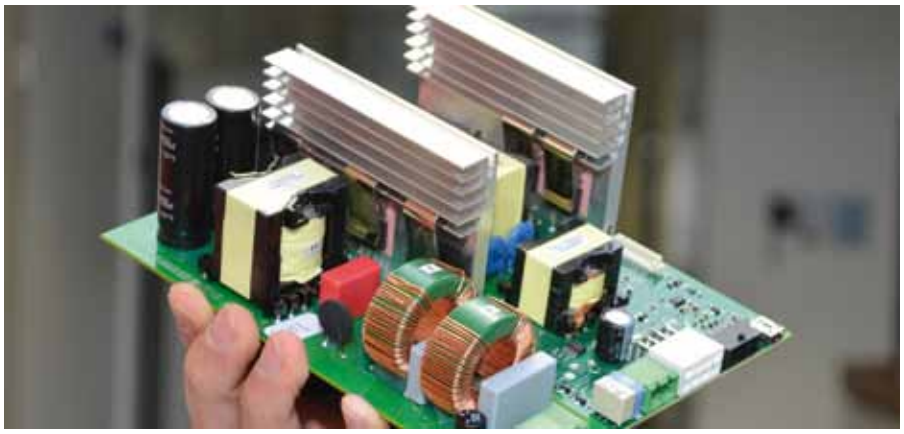
- Novel materials, such as GaN, SiC, diamond, GaN-on-Si, GaN-on-diamond for electronics, including integration such as GaN-diamond (power and RF electronics) on device/chip level
- Development of new thermal, optical and electrical reliability testing methodologies (Raman thermography, transient trap analysis, electroluminescence, and various others)
- High power electronics packaging solutions (silver-diamond composites, metal multi-composite laminates)
- Device simulation (electronic, thermal and stress)

Advanced electrical, thermal and optical testing of GaN, SiC, Diamond power devices

NTB
Interstaatliche Hochschule
für Technik Buchs

FHO Fachhochschule Ostschweiz

NTB UNIVERSITY OF APPLIED SCIENCES BUCHS, SWITZERLAND



The Power Electronics Laboratory

The Power Electronics Laboratory at the NTB University of Applied Sciences Buchs focuses on modern Power Electronics research with a team of about ten specialists and graduate students. The vast majority of the projects are carried out in close collaboration with local or international partners in industry. The primary focus is on applications in the lower power range where typically switched mode techniques are employed.

Research Fields and Competence Areas

The R&D activities in the area of circuits range from classical PWM converters to resonant topologies for a large variety of applications. These include adapters, battery chargers, power factor corrector frontends, inverters, motor drives, high voltage sources to name but a few. Typical fields of application are industrial and consumer electronics, renewable energy systems, drives and chargers ranging from IT equipment to electric vehicles. The scope of projects varies from feasibility studies and comparative investigations to simulations and analyses, the realization of prototypes all the way to industrialization and certification of complete designs.

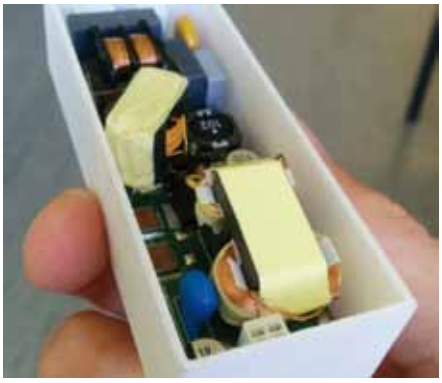
Emphasis is also placed on advanced magnetic components. For example, optimized coupled inductors in multi-phase PWM converters or integrated magnetics placed in LLC-resonant converters are utilized to achieve high power density designs. The tools used include FEA simulations as well as lumped reluctance models.

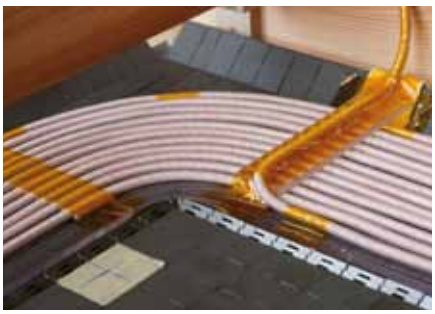
A further research field is wireless charging for electric vehicles. Recent and current work includes prototypes for 3.5 kW, 7 kW and 22 kW charger systems. The key to success is to optimize the coupler geometry and the electronic circuit simultaneously and not as separate systems. DC-to-DC efficiencies of well above 95% have been reached over an air gap of 16 cm.

Finally, small signal analysis and modelling are integral parts of Power Electronics circuit design. Analytical derivation of the transfer functions of new topologies as well as loop gain measurements on existing circuits are tools to optimize analog or digital control circuits.

Equipment

The laboratory is equipped with state-of-the-art hardware and software tools. These include a climate chamber, an EMC test setup, a spectrum analyzer, a network analyzer, frequency response analyzers, power analyzers, a range of DC and AC power sources and sinks, as well as high-end oscilloscopes.





Presentation

The research group on Power Semiconductor Devices operating in the Industrial Electronics Laboratory of the Department of Electrical and Information Engineering (DIEI - LEI) – University of Cassino and Southern Lazio, is very active in research dealing with modeling, simulation and experimental characterization of power semiconductor devices with a particular attention to the physical mechanisms which may cause the device failure and can affect reliability and robustness of the modern power semiconductor devices. The research interests include the operations of power devices and modules at high temperature and at the edges of their safe operating area (short circuit, overcurrent, inductive unclamped tests, etc...). The research group has also matured a broad experience in the theoretical and experimental study of Total Dose (TID) and Single Event Effects (SEE) on power semiconductor devices due to gamma, proton, neutron and heavy ion irradiations.

Facilities

DIEI-LEI laboratory houses a high-voltage test room (Fig. 1) where several equipments are hosted. Among them it is worth mentioning several versions of non destructive power semiconductor testers (ranging up to 5kA and 6.5kV) where devices or modules are tested with a protection circuit able to prevent the device failure at the occurrence of instabilities.

Fig. 1 – The high voltage test room.

Fig. 2 – Non destructive tester for power semiconductor devices at temperature ranging from -50 °C up to 200 °C.

The tests can be performed at case temperature ranging from -50°C up to 200°C thanks to a machine which is able to convey directly on the samples under test a pre-cooled/heated special fluid (Fig. 2). In such a way the components under test are brought to the desired temperature without the need of cooling/heating the whole apparatus.
The group is able to perform irradiation tests according to the international standards and has also developed new irradiation test methodologies which, together with 3D FEM simulations, permit a better understanding of device failures during irradiation experiments. The research group has access to several irradiation facilities: Tandem and Cyclotron at the INFN – LNS, Catania, SIRAD at the INFN – LNL, Legnaro, CALLIOPE (gamma rays), TAPIRO neutrons irradiation facilities at ENEA-Casaccia and Frascati Neutron Generator" – FNG at ENEA-Frascati.

Main collaborations

The research group has recently collaborated with HITACHI Rail (formerly ANSALDOBREDA) in the non destructive characterization of high power modules and the development of high efficiency power converters (rated at 30kW), with Fairchild in the study of IGBT Short Circuit and with ST-Microelectronics for the development of radiation hardened power MOSFET.

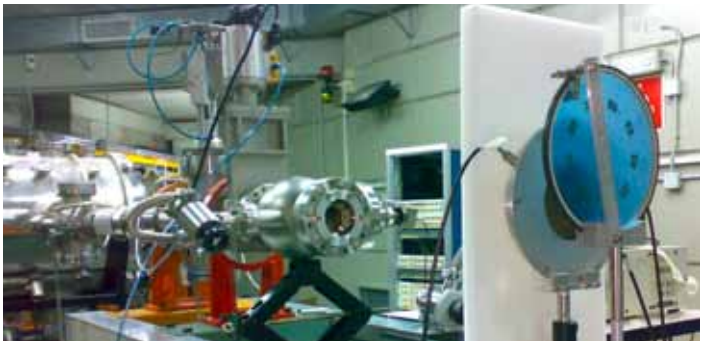


Fig. 3 – Beam line for heavy ion irradiation at the cyclotron of the Laboratori Nazionali del Sud – INFN, Catania, Italy.

National Research Council of Italy

NATIONAL RESEARCH COUNCIL OF ITALY (CNR)

The Institute

The Institute for Microelectronics and Microsystems (IMM) belongs to the Physics and Matter Technologies Department (DSFTM) of the National Research Council of Italy (CNR), the largest Italian public research organization. IMM has the headquarters in Catania and research units located in Agrate, Bologna, Rome, Naples, Lecce and Catania. The Institute has a permanent staff of about 200 people, with expertise in physics, chemistry and electronics engineering. The temporary staff counts also several Post-Docs and Ph.D. students.

The research activity is focused on innovative solutions for micro and nanoelectronics, advanced materials and processing for smart components, optoelectronics and photonics, sensors and multifunctional micro/nanosystems. In particular, IMM has a recognized experience on wide band gap semiconductors (SiC and GaN) device processing and physics, carrying out fundamental research with important implications in power electronics.

Key research fields and competence areas

The main research interests and competences are focused on the physics of SiC and GaN power devices (Schottky diodes, JBS, MOSFETs. HEMTs, MISHFETs, MOSHEMTs,…), including materials, processing and devices behavior. The key research topics include:

- Physics of metal/semiconductor interfaces (Ohmic and Schottky contacts)
- Transport phenomena at dielectrics/semiconductors interfaces
- Carrier profiling after doping and activation
- Post-oxidation annealing of gate oxides and mobility in WBG transistors.
- Atomic Layer Deposition (ALD) of novel dielectrics materials
- Integration of 2D materials (like graphene, MoS2, …) on WBG devices technology

Facilities and highlights

The research activity takes advantage of the facilities of the Institute, in particular, of a clean room equipped for lithography (direct laser writing, e-beam and nano-imprinting lithography), etching (plasma etchers with F and Cl chemistry, dedicated wet benches), thermal processes (conventional and rapid annealing furnaces), metal layer deposition (multi-target sputters and evaporation systems), atomic layer deposition. Moreover, the Institute holds competencies and equipments to carry out a wide range of advanced morphological, structural and electrical characterizations (TEM, XRD, AFM, SPM, Hall, I-V, C-V,...), required in power electronics devices technologies.

The Electrical Machines and Power Electronics Group (EMPEG) of the Department of Electrical, Electronics and Computer Engineering includes 5 full time scientists with 4 Professors and 1 Post-Graduate, 5 technicians and administrators, and several Ph.D. and graduate students. Since 1975 the research activities are devoted to Power Electronics, Power Devices, and Energy conversion systems, dealing with power electronic converters, electrical machines and drives, and their application in industrial processes, energy conversion from renewables, automotive and traction applications, home appliances. All members are actively involved in several international projects and maintain active collaborations with several scientific entities and industrial companies and research laboratories all around the world.EMPEG is headed by Prof. Ing. Angelo Raciti.

Key Research Fields & Competence Areas:

- Power Electronic Devices and Drivers: modelling and characterization
- DC/DC, DC/AC Converters, PFC, Renewable Energy and Fuel Cells Applications, Converters for Home Appliances
- Induction and Synchronous Motor Drives, PM Motor Drives, Sensorless Control, Fault Tolerant AC Drives, Wind Power Systems Control
- Modelling and Simulation of standard and special machines, Finite Element Analysis
- Analysis and testing of CFL and SSL lamps

EMPEG Laboratory Highlights:

The laboratories are equipped with various state of the art equipments. The main facilities are:

- EMC Test Laboratory with an anechoic chamber
- Test Benches for Electrical Drives (up to 50kW) with measurement and analysis tools
- Fuel Cells Test Bench
- Circuit Simulators and FEM Packages for Machines, Drives, Converters, and Devices

There are test benches for testing electrical and electronic components, and also for photovoltaic systems, in particular to provide static and dynamic curves of the inverter and the characteristic curves of photovoltaic panels.

TECHNISCHE UNIVERSITÄT
CHEMNITZ

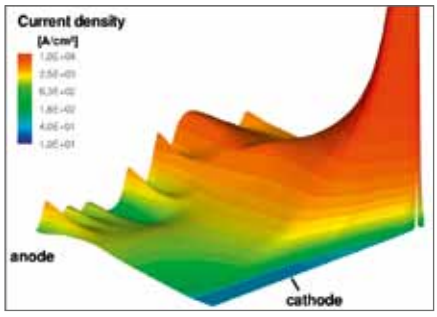
CHEMNITZ UNIVERSITY OF TECHNOLOGY

Chair for Power Electronics and Electromagnetic Compatibility

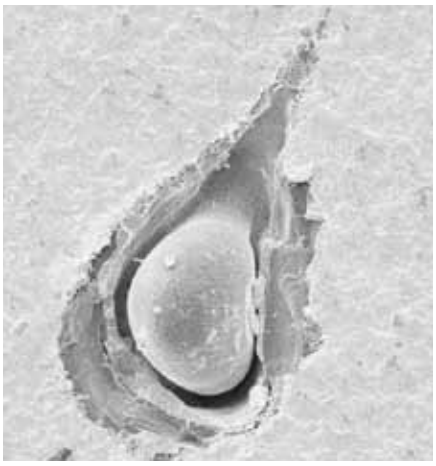
At Chemnitz University of Technology, the Chair of Power Electronics and Electromagnetic Compatibility is responsible for the education and research regarding power devices, thermal-mechanical problems of power electronic systems, power circuits and electromagnetic compatibility.

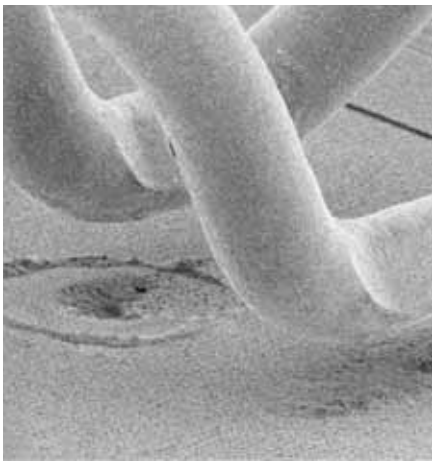
Reliability and Ruggedness of Power Devices

Ruggedness: Power devices must withstand overload conditions, they have to be rugged. Short circuit capability of high voltage IGBTs (SC I, SC II) is measured. A further point is the surge current capability of Si and SiC diodes. The reverse recovery behavior is of special interest. Switching behavior and ruggedness of high power diodes are investigated. Experimental analysis goes along with numerical device simulations. Detailed analysis of the electro-thermal processes in devices leads to design suggestions for improved ruggedness. Additionally, the group offers failure analysis, including opening of the power module for a profound analysis and the preparation of failure reports including evaluation. The group cooperates with Fraunhofer ENAS and can use optimal analysis tools, if necessary.



Simulation of current filaments in a high-voltage diode


Destruction of a power diode by a current filament


Bond wire lift-off created by power cycling

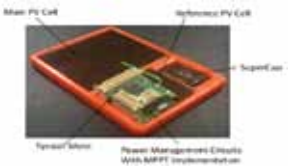
Reliability: Power devices are tested for their reliability and durability on eight self-built power cycling stations, between 100A and 400A, up to 2000A are in construction. Power cycling is the most important for life expectation of the devices. Research work is focused on detailed models for the failure mechanisms. Thermal-mechanical simulations are applied to illustrate local mechanical stresses and strains in the device resulting from the mismatch in the thermal expansion of the material layers.

Additional reliability test stations are hot reverse test (up to 2500V DC and 200°C) and high-humidity high temperature reverse bias test.

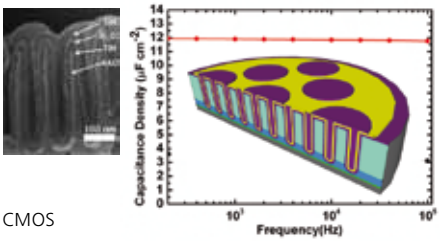
The group is involved in various national and international projects with global players from semiconductor industry, with automotive industry regarding electric and hybrid electric vehicles, in large offshore wind power, in inverters for solar plants. The research in different projects is supported by industry partners, SINTEF Norway, the EU, BMWi and BMBF, DFG and ESF/SAB.

Overview

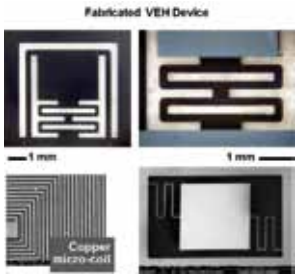
Tyndall is Ireland's largest research institute and a focal point for ICT research. Its strengths lie in photonics, electronics, materials and nanotechnologies and their applications for energy, healthcare, environmental and communications. Research covers a very broad range 'from atoms to systems'. This includes theoretical modelling and design, novel material, nanotechnology, device processing and fabrication, packaging and integration; and novel systems integration.

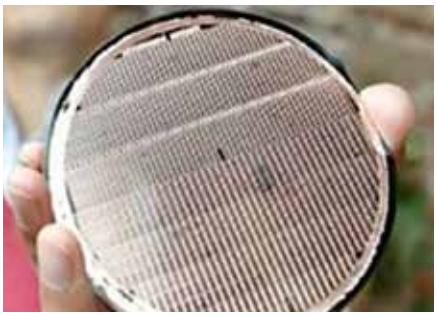


Self-powered Indoor Solar Tyndall WSN mote Compatible SuperCap



CMOS





Fabricated micro-inductors/transformers

Miniaturised magnetics

Energy and Environmental applications

Tyndall activities address global energy/environmental issues, particularly the EU 2020 Energy strategy (20% reduction in energy & CO_2, 20% integration of renewables).

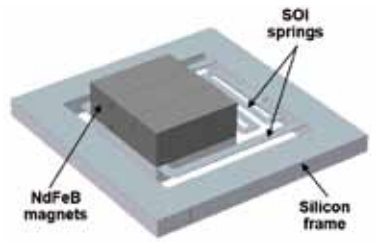
Relevant technologies include:

- Wireless Sensors and Embedded Systems, based on the Tyndall WSN (Wireless Sensor Network) mote, for energy efficiency monitoring and control and conditional monitoring
- Thermal modelling of devices and assemblies
- Energy Harvesting hardware (transducers, storage devices, power management circuits & ICs) & models for self-powering of IoT (internet of things) devices
- Fundamental technologies to improve device efficiency through research in Magnetics on Silicon, Packaging and Miniaturization, Current and Magnetic Sensors, Batteries and Fuel Cells

Energy Efficiency Integration Activities

Tyndall is actively involved in several EU projects and international consortia including

- Hosting IERC – the International Energy Research Centre, primarily focused on industry led integrated ICT solutions for demand side management.
- PwrSoC (power supply on chip) research, including chairing/hosting several international PwrSoC conferences.
- Co-ordinating PowerSwipe, EU's 1st power supply on chip project, miniaturising and integrating high density trench capacitor substrate technology with novel thin film magnetics and a microcontroller chip. www.powerswipe.eu



Fabricated vibrational energy harvester

TECHNISCHE UNIVERSITÄT DARMSTADT

Description of research activities

The research activities of the Institute can be grouped into two main areas:

1. Interaction between Power Electronic Systems and Power Grid

Due to the success of Power Electronics – enabled by the availability of powerful and efficient semiconductors and expedited by the extensive installation of renewable energies sources such as photovoltaics and wind power – electrical energy has to undergo a multitude of transformations by means of power electronic systems during the way from generation to consumer. Therefore, the characteristic of the grid and the power quality (stability of voltage level and frequency, harmonic content) will be essentially influenced by Power Electronic systems and components. Therefore, emphasis has to be given to the following aspects:

- Active power filter and selective harmonic cancellation
- Optimizing of (passive) filter for active infeed converter
- Handling of unsymmetrical load (occurrence of zero and negative sequence)
- Avoidance of unintended interaction between power electronic systems through the grid
- Island operation and black-start capability

Teststand for an inverter with active neutral for unbalanced power infeed

2. Energy efficient drives

The efficiency of a drive system is determined by the electric machine and the control methods implemented in the frequency converter. Requirements for efficiency of drives are described in the European standard EN 50598 "Ecodesign of Drives".

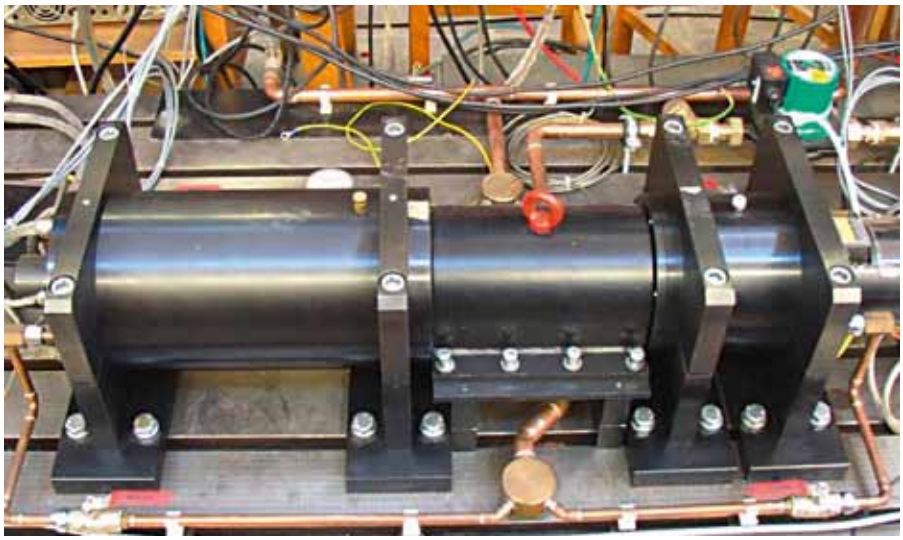
2L-VSC SiC inverter with low common mode voltage

Nowadays, predominately synchronous or induction machine are being used for drives. Alternatively, reluctance machines are under consideration in order to achieve a better tradeoff between efficiency and costs. However, control of reluctance machines including precise control of torque and position over the whole speed range is hard to implement, especially if there is no room for the application of position sensors for cost and reliability reasons.
Our research is focused on the precise torque and position control of reluctance machine taking into consideration the characteristics of the machine and the frequency converter.

Lab Facilities

The lab AC power is supplied by 5 transformers including voltage levels of 230V, 400V and 525V with a total power of more than 1MVA. Additionally a DC grid with up to 1.5kV and 192kW is available.

Institute staff in the lab facilities



Test bench for a magnetic levitated PM synchronous motor 40 kW, 4000 rpm

The Institute "Electrical Energy Conversion" belongs to the Faculty (Department) of "Electrical Engineering and Information Technology" at Darmstadt University of Technology. It has a long lasting tradition, because it arose already in 1919 from the former Institute „Electrical machines", that was founded by Erasmus Kittler, the worldwide first university professor for Electrical Engineering (1882). Under the direction of Prof. Dr.-Ing. habil. Dr. h.c. Andreas Binder lectures, tutorials, laboratories und excursions with the focus on electrical machines, transformers and actuators, drive systems and electrical trains and E-drive systems for cars are offered.

Bearingless high speed PM Motor

Research at the institute

Currently there are 15 research assistants (PhD) and 1 post doctor doing researches with the main focus in the following fields: high-speed drives, magnetic levitation, bearing currents at inverter supply, drive components for the electrical traction (train, car), linear motors and direct drives, generators for wind and hydraulic energy, numerical design of electric machines and mechatronic drive systems.

Equipment

The institute is equipped with two lab halls with total 1200 kVA-Transformer-supply. The labs have load facilities for electrical machines up to approx. 250 kW. Rotary converters can supply machines up to 40kVA @ 400/800 Hz or 200 kVA @ 200 Hz. A high-voltage-transformer offers a power up to 250 kVA with 3/5/6 kV. The mechanical workshop can manufacture prototype of E-motors up to 100 kW while the electrical workshop develops control modules, measuring adapters and makes modification of inverters etc.

Test bench of slot less PM synchronous linear motor (drive for stratosphere-infra-red-telescope SOFIA)

TU Delft

DELFT UNIVERSITY OF TECHNOLOGY

Delft University of Technology is the oldest and largest university of technology of the Netherlands with 17,000 bachelor and master students and 4,700 employees. With its unique technological infrastructure, broad knowledge base, worldwide reputation and successful alumni, TU Delft makes a significant contribution to finding responsible solutions to urgent societal problems, at both national and international level.

Fault-tolerant, high power density integrated machine and drive for aerospace applications (75 kW, 4 kW/dm^3)

Research field and highlights

The research programme of the Electrical Power Processing (EPP) group addresses issues that drive the advancement of electrical power processors and at the same time brings into the picture broader systems design issues. Our research is driven by:

- New and improved materials and technologies;
- Power density, force density, conversion efficiency and system integration.

Power electronics and electromechanics are the central enabling technologies for advanced energy applications.

Power Electronics is a vital part of renewable energy conversion, mobility, transport and Smart Grids. The four main research themes in the group and some examples of projects in these areas are:

High power density (4kW/dm^3) inverter for 2.2 kW drive (95% efficiency) – ECPE project

Renewable Energy Conversion

- PV panel integrated dc/dc converters for distributed power tracking
- High power transformerless PV inverter
- Wave energy generators

Transport and Mobility

- Converters and system integration for marine applications
- Fault-tolerant high-speed integrated machine and drive for aerospace applications
- Contactless energy transfer for charging of electric vehicles

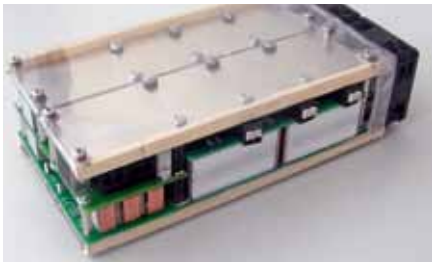
Smart Grids

- Active power flow control
- Virtual synchronous generator
- Fault current limiter

Technology Innovation

- Novel standardised passive components and technology for automated multi-layer SMT assembly of PCB power converters
- Packaging of wide band-gap (SiC, GaN) power converters
- High power dc/dc converters
- Systematic design approaches for EMI in drives

The EPP group carried out one of the ECPE flagship programmes "Industrial Drive – System Integration" focused on integration technologies and thermal management of inverters for low power industrial drives. The 2.2 kW project demonstrator had a power density of 4 kWdm^3, 4 times higher than state-of-the-art industry products at the time.



High power density (4kW/dm^3), high efficiency (>99%) fully SiC, SMT compatible inverter for 2.2 kW drive (4.5 kW peak power) – ECPE project

Facilities

The group has a well equipped laboratory with various machines sets and a distribution panel making it possible to interconnect machines and power electronic converters at different locations inside the laboratory. Ac and dc voltage levels up to 5 kV and power levels up to 50 kW is possible. Other equiment include EMI and thermal measurement equipment, pulsed power sources and energy storage devices.

Fig. 1: Test stands of the Chair of Electrical Machines and Drives for research and education

The Chair of Electrical Machines and Drives is a part of the Institute of Electrical Power Engineering which was founded in 1894. The students taught in the institute belong to the study branches "Electrical Power Engineering" and "Mechatronics". The research work of the chair is to make substantial contributions to the fundamental and applied research for efficient energy transducer systems, generators and electrical drives. In addition count both linear and rotating machines and line-side and motors-side inverters and their control (Fig. 1).

Fig. 2: Focuses of research

Key Research Fields & Competence Areas (Fig. 2)

- Modeling, design and optimization of transducer systems
- Magnet bearing technology, direct drives and mechatronic drive solutions
- Renewable electromechanical transducers, especially for wind energy plants
- Motor and drive systems in hybrid and electric cars
- Cooling systems for electrical machines
- Converters, industrial electronics for variable speed drive systems and generators

Fig. 3: Power converter interferences lab

Laboratories / Equipment (Fig. 3)

- Laboratory of machines and drives with separate power supply up to 100 kW, voltage 3 x 400V, 3 x 600 V, sinusoidal ac-three-phase mains up to 500 Hz
- Universal test stands for converter-fed machines, measuring and testing equipment for machines, transformers and measuring transformers
- 7 Research labs (400m²)
- 3 Labs for teaching and practical training (112m²)
- 1 PC-Pool

Teaching

- Courses lead to the Dipl.-Ing. certificate or to the Master-degree
- PhD students

Member of Staff

Scientific staff:	5
Non-scientific staff:	2 + (2)
Scientific tutorial assistant:	1
Scientific staff (third party funds):	17
PhD students:	2
External PhD students:	10
Tutorial assistants:	5
Diplomates:	12
Students in seminar projects:	10
Trainees:	20

Technische Universiteit Eindhoven University of Technology

electromechanics power electronics epe

EINDHOVEN UNIVERSITY OF TECHNOLOGY (TU/e)

The Electromechanics and Power Electronics (EPE) group conducts research in the area of electromechanical and power electronic systems, and aims at driving innovation and opening new application fields in close collaboration with both Dutch and international industry.

Main research areas in power electronics:

- Ultra-compact/low-weight/efficient power converters
- Application of new semiconductor devices (e.g. GaN and SiC)
- Intelligent battery management solutions
- Advanced methods and tools to enhance the analysis and design of multi-level, multi-port converters
- Multi-objective optimization of converter systems, linking multiple performance indices such as efficiency, weight, costs, reliability and EMC
- Hardware-in-the-loop technology for algorithm and component testing
- Dedicated high-precision low-noise power amplifiers
- Wireless energy transfer

High-precision, high-bandwidth amplifier based on ultra-level topology

Disruptive conceptual innovations are combined with a detailed, system-oriented, and multi-objective design/optimization approach. Comprehensive experimental verification of the theoretical concepts is provided through the development of near-industrial hardware demonstrators, which provide the basis for the initiation of future, cutting edge products.

20 kW, 3-phase, bidirectional, isolated AC-DC converter based on SiC MOSFETs

Typical application areas:

- Automotive industries
- Renewable energy industries
- Rail transportation
- Aerospace and more-electric aircraft
- Medical systems
- High precision and lithography applications, robotics, industrial systems, etc.

Besides power electronic systems, other key expertise areas of the EPE group are electromechanical and mechatronic systems, in which the EPE group obtained a strong, world-leading reputation in multi-physics modelling, analysis, design methodologies, and multi-objective optimization.

Electromagnetic vibration isolator

The group is collaborating in many national and international projects and research activities. It is actively involved in various Horizon 2020 and FP7 projects and has a broad international network that includes a large number of leading companies, research institutes, and universities.
Currently, the EPE group consists of 4 Assistant Professors, 9 Fellows from industry, 26 PhD students, 2 post-docs, 5 PDEng students, and is continuously expanding.
State-of-the-art, highly equipped laboratories (> 600 m^2) for production, testing and characterization are available, as well as a large variety of simulation software, DSpace hardware and software, measurement equipment, thermal chambers, and high and low power loads.

EPE laboratory

Power Electronics for Energy Efficiency

The Fraunhofer Institute for Integrated Systems and Device Technology IISB performs applied R&D on power electronic systems for all fields of application, like industry, household, and consumer appliances, electric mobility, energy supply, and power grid technology. The ambition of the institute is to make power electronics more energy and cost efficient, reliable, robust, and compact. The strength of IISB is based on its competencies in power electronics and mechatronic system integration in conjunction with its wide experience in materials research and semiconductor technology for microelectronics. This includes smart power ASIC design, innovative circuit topologies and control algorithms, embedded software, system simulation, thermal management, energy management, new materials, and interconnect technologies, active and passive devices, EMC, reliability, and failure analysis.

With its power converters, IISB regularly sets international benchmarks, e.g., in terms of efficiency or power density. The institute closely collaborates with its industrial partners, e.g., from automotive, energy system, or semiconductor industry.

Power electronic systems for hybrid and electric vehicles

For already ten years, IISB has been working on power electronics for electric mobility. In its laboratories in Erlangen and Nuremberg, innovative components and systems for the electric powertrain, for elctrical energy storages and charging infrastructure are developed. This also comprises complete electric powertrain modeling and concept engineering. IISB has an extensive test center for electric cars. It is Competence Center Automotive in the ECPE and active member in the Forum Elektromobilität e.V., the Bavarian Power Electronics Cluster, and the National Electric Mobility Platform. Together with the Federal Ministry of Education and Research, IISB is the initiator and organizer of the DRIVE-E student promotion program in electric mobility.

Power electronics for smart grids

Power electronics is getting increasingly important for future electric energy supply. IISB develops essential components of smart and high-performance power grids, e.g., high power switches for HVDC. The institute works on new micro grid concepts based on local DC networks and operates an application platform for energy efficient power supply in a home, office, and lab environment.

FRIEDRICH-ALEXANDER-UNIVERSITÄT ERLANGEN-NÜRNBERG, EAM

Overview

The chair of Eletrical Drives was founded in 1973 as 6th Chair of the Department of Electrical, Electronic and Communications Engineering.

Because of the variety of production machines, different motor types have been developed over the years, which have essentially been operated directly connected to an electrical grid.

Due to the progress in microelectronics and power semiconductor elements it is increasingly possible to control the speed of the motors digitally with the aid of power-electronical converters. The significant advantages of modern electrical drive technology are improved energy efficiency and improvement of the technical processes

The electrical drive technology entails the following topics

- electrical drives
- power electronics
- electrical machines
- digital control
- field buses

and their combination to the optimal drive system for the respective application.

Research

Power electronics

Controlled electric drives often have to decelerate electrically the motor with the coupled mechanical load to a complete stop. The kinetic energy stored in the drive system shall be economically fed back into the grid. For that purpose a new converter topology is being analysed, whose feedback inverter unit operates without pulse-width modulation and works with a smaller dc-link capacitor. Up to now, Silicon elements (Si) have been used in power electronics exclusively. But new elements from silicon carbide (SiC) and gallium nitride (GaN) feature substantial advantages for power electronic applications. Therefore these new elements are being tested for the application in converters for electrical drives.

Digital control of three-phase drives

In many applications three-phase induction motors are used almost exclusively today. Permanent-magnet synchronous motors weigh less and are smaller in volume and are more efficient at a comparable performance which make innovative solutions in chassis suspension possible. The renouncement of a sensor offers additional clearance. Therefore the operation of a permanent-magnet synchronous motor with sensorless controls is being investigated.

Laboratory equipment/ apparatus equipment

- 17 workplaces up to 30 kVA with 400 V three-phase supply system, machine bed,
- 200 kW-test location with direct current and three-phase current drives, 400V – 690V, crane

Test bench for sensorless operation of permanent-magnet synchronous motors including realtime development system, motors and converters.

- Real-time development systems for open-loop and closed-loop control with graphical user interface
- Power measurement with up to 6 phases in one device
- Torque measurement from 2 to 2000Nm
- Measuring technology for power semiconductors
- Miscellaneous electrical devices and converters

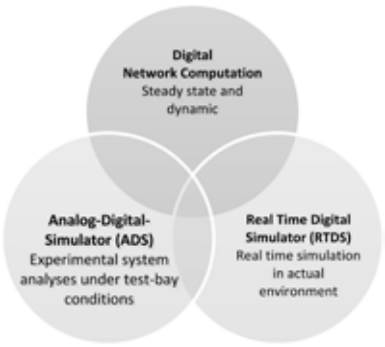
Offers of the chair for co-operation relations and for the transfer of technology and research

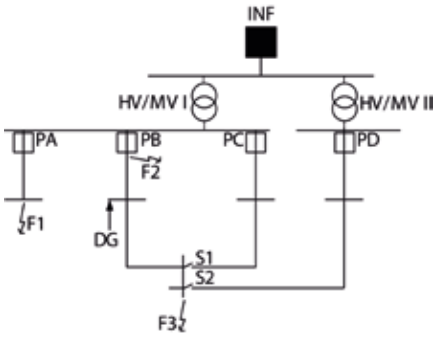
- research and development from the exploratory focuses
- testing and measuring of drive systems
- development and investigation of power electronic circuits
- Calculation and design of electrical machines
- simulation of drive systems

About us

The Chair of Electrical Energy Systems at the Friedrich-Alexander University of Erlangen-Nuremberg was established on 1st April 2011.

In both training and research, we are predominantly engaged in the development and operation of future innovative electrical energy power supplies, as well as the design of such systems. We wish to achieve with the training we offer and our work in research, a scientific contribution to the future advancements of sustainable energy systems. In doing so, we count on practical relevant interdisciplinary collaboration and cooperation in a national and international environment.





Courses

We offer a broad range of training from basic academic instruction up to specialized subjects for Bachelor and Master degree studies in Electrical Engineering and Energy Technology:

- Fundamentals of Electrical Engineering
- Components of electrical energy systems
- Operational behaviour of electrical energy systems
- Network control and power system management
- Power electronics in three-phase AC networks: HVDC transmission and FACTS
- Power generation and trading in deregulated markets
- Laboratory: Analog-Digital-Simulation
- Practical Workshop: Network operation and control
- Study Seminar: Sustainable energy systems

We provide and mentor Bachelor and Master Science degree studies on the aforementioned subjects and research.

Research Focus

Our field of research is orientated to the current challenges and innovation of electrical energy systems :

- The development and design of large scale transmission systems (e.g. Electricity Highways, Offshore-Grids, etc.)
- Design and integration of High Voltage Direct Current (HVDC) transmission systems and Flexible AC Transmission Systems (FACTS)
- System integration of centralised and decentralised renewables, in particular, wind, photovoltaic and solar thermal power plants
- Innovative storage concepts for volatile energy sources and their integration into the network
- Intelligent and future-orientated operation and management of transmission grids in a deregulated environment
- "Smart Energy Systems": interaction and repercussions of decentralised systems on the transmission.

Research Concept

Our research work involves the simulation of components and the system behaviour of electrical networks. Network models are able to be developed by means of coupling digital network computations and the experimental simulation of energy systems. This is carried out by bench scale testing, verifying the models against each other and analysing them in terms of their operational behaviour. The results provide important findings for the design and performance of real systems, the development of new technologies, as well as determining the necessary investment costs .

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
TECHNISCHE FAKULTÄT

FAPS

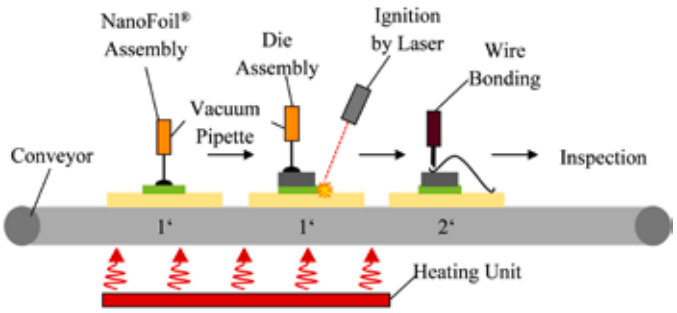
FRIEDRICH-ALEXANDER-UNIVERSITÄT ERLANGEN-NÜRNBERG, LEHRSTUHL FÜR FERTIGUNGSAUTOMATISIERUNG UND PRODUKTIONSSYSTEMATIK (FAPS)

Research from miniaturized electronic devices to complex mechatronic systems

FAPS concentrates its research activities on innovative manufacturing technologies at all levels of mechatronics, from a miniaturized device to a complex system. For that purpose FAPS employs more than 90 dedicated researchers and technicians. The Institute operates two laboratories on an area of 2500 sqm with most modern facility equipment to ensure highly innovative developments in mechatronics manufacturing.

A key research field of the institute FAPS is packaging of electronic components and the assembly of electronic devices:

- simulation-based manufacturing and analytical processes,
- structuring and metallization of 2D and 3D circuitry by laser direct structuring, selective laser sintering, aerosol jetting, and plasma-based coating systems,
- stencil printing and dispensing of solder and sinter paste as well as conductive adhesives,
- highly accurate component placement,
- high pressure convection and vacuum vapor phase soldering,
- thin wire and thick wire bonding,
- Innovative production line concepts with reactive multilayer materials
- SPI and AOI,
- optical, mechanical, thermal and electrical quality insurance
- reliability tests and lifetime modeling.



Innovative production line concepts based on new packaging technologies such as reactive multilayer materials

These core competences in electronics production are used for the development of miniaturized PCBs, multi-functional mechatronic integrated 3D-devices and high performance connectivity and integration technologies for power electronics. The qualification of mechatronic devices is performed by test systems for climatic, temperature, corrosive, vibrational and electric loads. A well-equipped metallography and inspection equipment like X-Ray including CT or confocal laser scanning microscopy can be used for failure detection. Capable software systems enable computer based development and simulation of products, processes and production facilities.

Additional to the field of electronic production FAPS researches in the area of bio-mechatronics, systems engineering and electric drives technologies. A key project is the E|Drive-Center where manufacturing technologies for electric drives like winding, magnet assembly and metal sheet packaging and the enhancement of interconnection technologies between electric drives and power electronics are developed.

FAPS creates and realizes innovation through the integration of knowledge from different fields, in particular

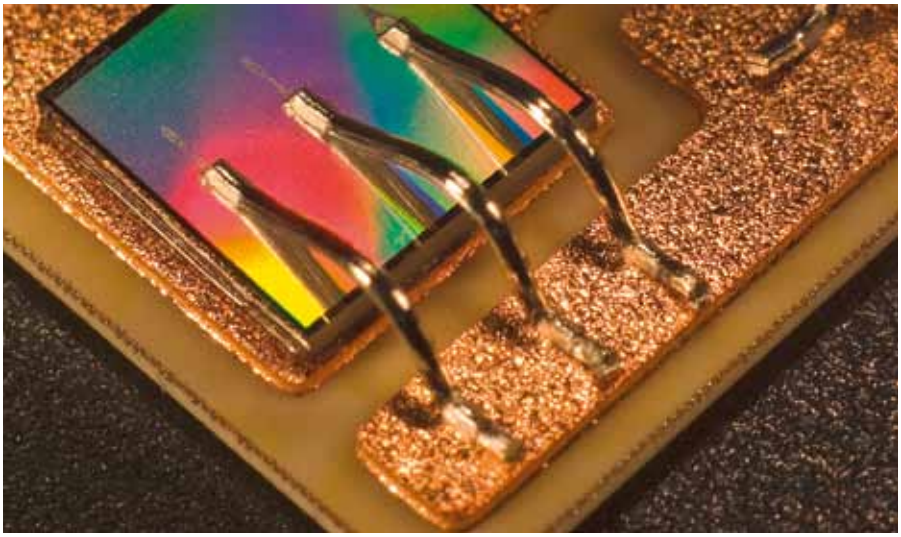
- disciplines of mechanics, electronics, information technology, bionics and optics,
- integration levels from the component to the system,
- the entire product life cycle, from concept, via development, production, use, through to recycling,
- by university research and teaching, industrial cooperation and spin-offs,
- through sustainable and efficient methods for the production, distribution, use, storage and reuse of resources.

Conductive adhesives and copper wire bonding enable new interconnection technologies for power electronic applications

DEVICES FOR MICRO, NANO, AND POWER ELECTRONICS

The Chair of Electron Devices (LEB) of the Friedrich-Alexander-University Erlangen-Nuremberg focuses on research and development on semiconductor device technology and fabrication. Key interests include development and simulation of innovative production processes and novel semiconductor devices as well as optimizing equipment and materials for micro, nano, and power electronics. Electrical characterization of power electronic devices and development of power electronic components are also part of research activities of the chair.

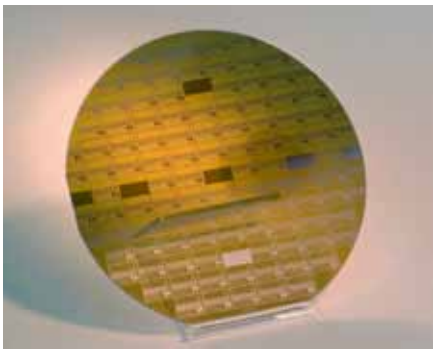
The Chair of Electron Devices closely cooperates with the Fraunhofer Institute for Integrated Systems and Device Technology IISB. Together, they run the University's clean room that provides more than 1000 m^2 of lab space for research on processes and devices.



Monolithically integrated devices for power electronic applications

Novel Power Electronic Devices

Researchers at LEB investigate concepts for manufacturing and optimizing innovative devices and corresponding technology steps. Silicon-based semiconductor devices and passive components such as monolithically integrated RC snubbers are an important field of study. Research focus also lies on devices based on silicon carbide (SiC). Besides processing equipment for standard silicon technology, facilities specially adapted to requirements of SiC-device manufacturing are available.



Power electronic devices on silicon carbide substrate

Energy Efficiency in Automobiles

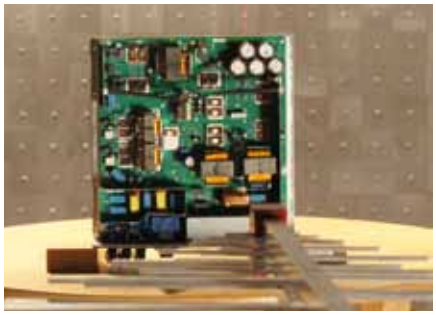
The interdisciplinary group project "TechFak EcoCar" is a student research program to investigate efficient energy usage in electrical automobiles. Students of various fields of study, e.g., electrical engineering, electronics and information technology, mechatronics, power engineering, mechanical engineering, material sciences, and computer sciences, participate in this project. An electric vehicle as a testing platform allows students to apply their theoretical knowledge and gain practical experience.

Energy efficient car concepts – „TechFak EcoCar"-project

FRIEDRICH-ALEXANDER-UNIVERSITÄT ERLANGEN-NÜRNBERG

Research at LEMF

The chair of Electromagnetic Fields is lead by Prof. Dr.-Ing. Manfred Albach. In addition to fundamental problems of technical electrodynamics, the core research areas include electromagnetic compatibility, power electronics and the design of magnetic components.



Shielded chamber for EMC testing

Power Electronics

This research area focuses on conversion circuits for small and medium power levels. Such converters can be found in consumer electronics, communication and information technology, lighting, telecommunications, automotive and medical technologies.

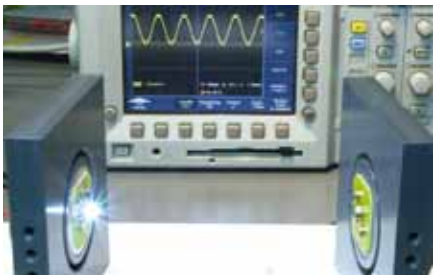
- Resonant as well as soft-switching pulse width modulated topologies for the optimization (efficiency, volume and weight) of power supplies
- Electronic ballasts for lighting applications
- Optimization of power supply systems under industrial constraints
- Digital control techniques of switched mode power supplies for the improvement of their stationary and transient behaviour, e. g. for medical applications
- Examination of critical components, such as switching behaviour of MOSFETs and diodes, large signal properties of magnetics, driver circuits
- Software aided design of switched mode power supplies with respect to specification requirements – multi-level simulation

Electromagnetic Compatibility

… is the ability of an electrical device or system to operate satisfactorily in its electromagnetic environment without causing interferences for surrounding equipment and without being influenced by external interferences.

- EMC of electronic modules and components
- Mains current distortion (power factor correction circuits)
- Conducted and radiated interferences
- Susceptibility of electronic modules and components

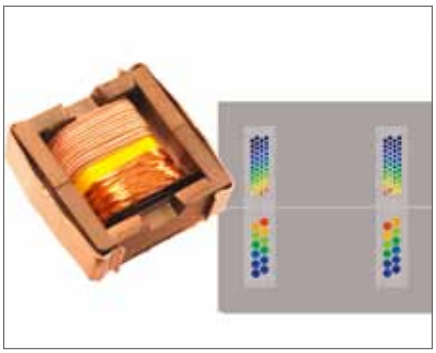
In addition to theoretical examinations, also EMC measurements are performed within the laboratories of the chair.



Characterisation set-up for LED drivers

Design of Inductive Components

Main emphasis is placed on analytical methods for the calculation of loss mechanisms within the core and the winding as well as on the derivation of equivalent circuit models for high frequency and large signal operation.



Simulated loss distribution in magnetic components

Maxwell's Theory

The whole spectrum of electromagnetic field theory is covered, beginning from stationary field problems up to high frequencies:

- Fundamental problems of technical electrodynamics
- Calculation of electromagnetic fields

Industrial Cooperation, Research and Technology Transfer

- Optimization of switched mode power supplies
- EMC analyses and measurements
- Dimensioning of magnetics for power electronics
- Calculation of electromagnetic fields

UNIVERSITY OF APPLIED SCIENCES ESSLINGEN

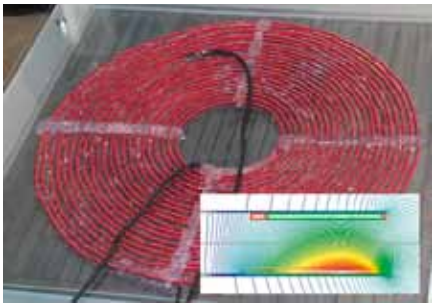
The Faculty of Mechatronics and Electrical Engineering at Esslingen University of Applied Sciences currently comprises 24 full-time professors and about 800 students who are mainly working in the field of mechatronic systems. The mechatronic approach of the faculty is focused on combining and integrating several scientific and technical disciplines in the design process of a complex system, containing mechanical and electronic components as well as computer technology and software. To realize such an overall approach, expertise on system level is required as well as detailed knowledge in several fields of engineering sciences. Hence, besides of control techniques, communications, and manufacturing technology, power electronics plays an important role in the design of modern mechatronic systems.

The laboratory Machines and Drives, led by Prof. M. Neuburger, is basically responsible for drive trains. Main tasks are designing and validating electrical energy converters and electrical machines, including different types of electrical drives.

To achieve the required key performance indicators, a multidisciplinary approach is used, not only taking into account the basic functional aspects, but also covering additional requirements and quality parameters such as electromagnetic compatibility (EMC), acoustics, or construction dependent component placement during all phases of the developing process. This approach aims to tear down the barriers historically grown between several subjects of engineering sciences. In this way, the overall performance of a system can be optimized, rather than having optimal partial solutions.

Examples of successfully realized projects are a wireless power transmission for EV-charging stations, or the setup of a completely self-designed wind energy plant for small scale and home applications.

To achieve its research assignment, the lab Machines and Drives has numerous resources available. Besides of the professors and the technical staff members located in the lab and its several sub-labs (e.g. high voltage lab, EMC lab, or electrical drives lab) a photovoltaic test field is available on the campus in Göppingen. Unlike other photovoltaic power plants, this test field is not operated in a commercial environment, and hence allows performing research projects without limitations due to financial interests.



Besides of applied research, the main task of the Faculty is education and training of highly qualified junior employees for industry. To achieve this goal, different study programs are offered. Besides of the classical full time study program, cooperative study programs and also part time study programs are offered for both, undergraduate and graduate students. Moreover, doctoral programs are also possible in cooperation with other Universities. The excellent ranking of the Faculty of Mechatronics and Electrical Engineering indicates the high level of education which is offered by the Esslingen University of Applied Sciences in general and at the site in Göppingen in particular.

Fraunhofer IAF

FRAUNHOFER INSTITUTE FOR APPLIED SOLID STATE PHYSICS IAF

About

The Fraunhofer Institute for Applied Solid State Physics IAF in Freiburg is one of the world's leading research institutes in III/V semiconductor technology and modules. Within its five business units Power Electronics takes a leading role. Fraunhofer IAF develops energy-efficient solutions for energy conversion, broadband communication systems, high data rate transmission, imaging, detectors as well as semiconductor lasers. In cooperation with a broad range of international project partners, Fraunhofer IAF performs its expertise material and process technology, in chip design, and in the manufacturing of devices and modules. In 2015, the institute had 280 employees including more than 30 PhD students.

Power Electronics at IAF

Power electronics at IAF is based on the development of Gallium Nitride (GaN) on up to eight inch silicon and diamond electronics, both with GaN on diamond substrates, and on the longer term, real diamond electronics. Overall, GaN-based devices on Silicon already have a direct impact on future efficient power conversion systems and will thus help save energy and miniaturize systems. GaN technology is promising for automotive, photovoltaic, IT- and consumer applications as well as motor control and appliances. Based on the longstanding experience and the successful industrialization of GaN RF-processes in Europe Fraunhofer IAF in power

Multiwafer MOCVD growth machine for up to 8-inch growth of GaN on Silicon.

electronics concentrates on the critical aspects of:

- Defect-reduced material growth up to 8-inches in diameter,
- Process development with a focus on integration for fast switching,
- In-depth characterization, chip-related packaging, EMC, and reliability.

The needs for ever-higher transistor performances and reliability drive a continuous search for improved epitaxy, process technology, and advanced characterization. GaN on diamond in wafer transfer approaches and, generically as a semiconductor material with ultimate performances are being developed for improved thermal performances. For pure diamond electronics, baseline growth of diamond and processes are under development.

Epitaxy

GaN-based devices with generically a wider bandgap than silicon have a much higher critical electrical field and, together with high carrier concentration and high mobility, they offer superior trade-off of specific on-state resistance $R_{DS(ON)}$ versus breakdown voltage rating and show low switching losses. For GaN to be cost effective silicon reenters GaN devices as a substrate material with large diameters, which is a challenge regarding defect reduction, overall material quality, and overall process yield. Fraunhofer IAF optimizes material growth with a strong focus on material characterization on improved growth schemes and machines.

Process Development and Reliability

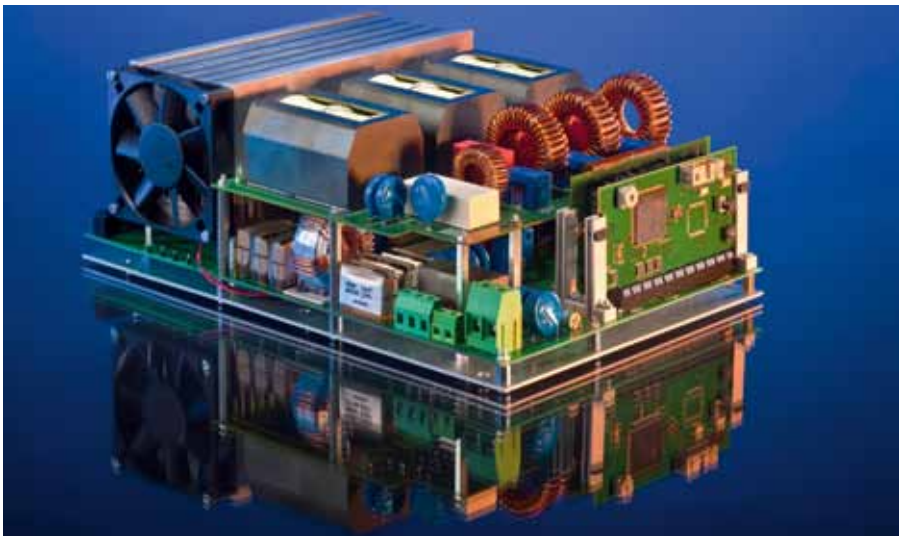
IAF's baseline AlGaN/GaN high-voltage process technology is based on devices with standard 0.5 µm gate lengths. We pursue performance and reliability improvements of AlGaN/GaN-based devices for various voltage classes up to at least 1200 V and currents currently as high as 200 A per chip.

Characterization

IAF concentrates on the characterization of the static and losses on devices level, on critical defects, on EMC for the proposed increase of the switching speed of the GaN-based converters to the 10 MHz range, e.g. using multilevel converters. Starting from the material growth reliability is the central aspects for high-power-density devices, currently for large-area devices. We expect GaN to evolve in power electronics driving performances to unprecedented levels in converters and to open new applications and cost performance trade-offs.

Power Electronics and Control Technology for Renewable Energies

The Power Electronics Department at Fraunhofer ISE is specialized on the development of highly efficient DC/DC converters and inverters up to the megawatt range. Our fields of work extend from analog and digital circuit design through layout up to digital control technology. The department is organized in four groups, which are focused on the following topics:



Highly compact three-phase PV-inverter with SiC-transistors

Module-Integrated Electronics and Future Devices

We develop reliable and longlived module-integrated electronics for harsh environments. The potential for developing conventional transistors of silicon is now largely exhausted. To progress our developments further, we use the latest power electronic components of silicon carbide (SiC) and gallium nitride (GaN). These components enable significantly higher switching frequencies as well as higher inverter efficiency.

String Inverters, Off-Grid Inverters and Power Electronics for Energy Storage

We develop power electronics, control software and MPP-Trackers for string inverters which meet the continually growing market demands and standards. The rapid expansion of renewable energy requires the integration of large-scale energy storage units into the grid. We are developing innovative power electronics for this purpose. We also offer our expertise for off-grid power supply ranging from the development of high-performance charge controllers through highly efficient standalone inverters to complex control technology for photovoltaic hybrid systems.

Central Inverters and Solar Power Plants

With the equipment in our megawatt laboratory and our 5 MW outdoor test field, we are able to develop, operate and test central inverters up to a power of 1 MW. Extremely accurate measurement technology and special test equipment (e.g. a »low voltage ride through« test facility) enable us to test inverters according to the currently valid specifications. Improving efficiency and reliability, reducing costs and weight, and the demands of new feed-in regulations for photovoltaic power plants are the major topics for our research and development activities.

Grid Integration and E-Mobility

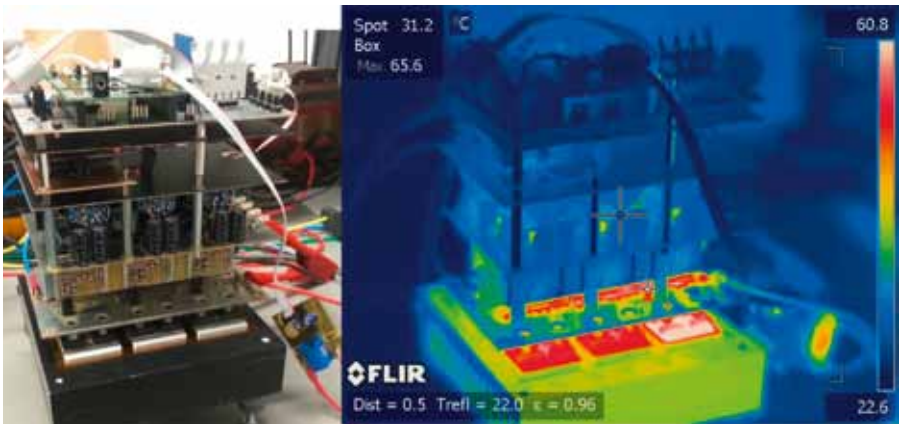
We develop solutions and control algorithms to integrate large proportions of fluctuating power generated from renewable energy sources, and implement grid-supporting and grid-forming functions in inverters.

For plug-in hybrid vehicles and electric vehicles we develop cable-based bidirectional stationary rapid chargers and on-board chargers as well as inductive chargers. With the integration of additional functions like compensation of harmonics, provision of reactive power, grid support and low voltage ride through (LVRT) capability, the chargers are even able to improve the grid quality.

GRAZ UNIVERSITY OF TECHNOLOGY

The Electric Drives and Machines Institute at Graz University of Technology has a long-standing tradition of research into electric and electromechanical energy converters, power electronics, and the integration of these components into systems. Located in the second largest city in Austria, it is part of a university with a focus on the engineering and technical sciences. The university includes some 12000 students and close to 2500 members of staff, the institute is embedded in a network with other universities within the city, the country, Europe, and beyond, thereby benefitting from a strong research and increasingly international climate.

The competence of the institute was complemented and extended in April 2010 when Prof. Muetze, who had worked previously in Germany, the US, and the UK, became head of the institute, further directing the institute into an international network of research and development activities. The new leadership also brought forth the construction of a new, modern laboratory building for research and teaching activities. This facility provides around 300 m^2 of floor space, up to 500 kVA power capabilities, including 690 V systems and variable AC and DC voltages up to 600 V, as well as the appropriate modeling and measurement equipment. A power electronics test laboratory is also situated on the first floor to complement the research in this area.

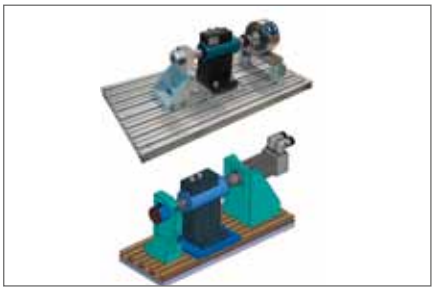


DC current link PWM inverter and its true color thermo graphic image.

A significant part of the research activities is carried out in cooperation with national and international industrial partners, covering the areas of electromechanical as well as solid-state power converters, design of power-electronics based systems including control and interactions between system components, and the development of prototypes and experimental verification in the institute's own laboratories. With activities both in the area of power electronics and in the field of electric machines, the institute is ideally placed to work on questions that arise from power electronics to electric drive systems applications.


New laboratory building.

Examples for current research projects cover the wide range of topics from starting of a line-operated synchronous machine with damper winding to the electric and thermal design of drives for electric traction applications, and small low-cost drives of a few hundred Watts rated power for mass production. Further activities include motor-inverter interactions, such as inverter-induced bearing currents, and the development of new power converter topologies, such as a power supply reaching titanium level efficiency for a wide range of input voltages.


Test rig for fractional horsepower drives (Mechatronic Systems GmbH, Wies).

Cutting Edge Research Facilities

CEA Tech, the technology research division of France's atomic and alternative energy commission CEA, is made up of three institutes (Leti, Liten and List), which together develop a comprehensive portfolio of technologies for ICTs, energy and healthcare.

Power Electronics at CEA Tech

Power electronics is a key strategic activity at CEA Tech. In conjunction with multiple industrial partners, CEA Tech's scientists develop new integrated systems based on GaN and SiC technology. Research is primarily driven by electrical mobility and static photovoltaic/storage applications, in which GaN/Si and SiC devices are ideally suited to DC-DC and AC-DC converters. These devices effectively enhance final system efficiency through their higher power density and greater compactness. CEA Tech's value proposition embraces the entire technology chain from power converter design to system integration, characterization and optimization.

Power GaN/Si Technology and Devices

CEA Tech develops 200 mm epitaxial GaN-on-Silicon wafers. In 2015, these devices achieved state-of-the art electrical performance for the 600V GaN normally-off transistor and, in 2016, demonstrated GaN capability at 1200V. GaN MIS N.OFF technology is ideally positioned to increase system efficiency in the 600V - 1200V and 30 - 100A ranges at lower cost than competing technologies. CEA Tech also develops schottky GAN/Si diodes. Lateral GaN/Si capability opens the door to new monolithic functionality. Using the same technology platform, we have developed a bidirectional current/voltage switch, which offer new opportunities for enhancing system architecture (AC-AC matrix converter, etc…), to give higher efficiency, more compact systems at lower cost.

GaN IC, 3D Integration and Packaging

GaN IC represents a method of extending the limits of at least MV applications by working on converter miniaturization at higher system frequency. CEA Tech is currently developing different strategies to achieve this goal, including a hybrid approach based on a PSOC flip chip and a dedicated self-biased ASIC insulated silicon driver powered in stages. Further developments include an interposer with TSV and bump, and implementation of an integrated monolithic approach based on the integration of the driver, control and protection on the same die.

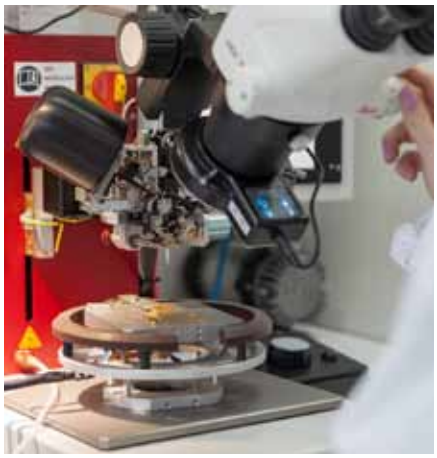
CEA Tech is working on compact low inductance modules (half bridge with drivers) for higher voltage and kW applications combined with 3D wafer level packaging. We are also developing an innovative ultra-compact 2-sided cooled, 3D module to maximize efficiency and CEM based on an interleaved converter design.

New Ferromagnetic Devices for HF Applications

Increasing converter frequency dictates the need for low loss passive devices, especially inductors. CEA Tech has a unique platform for building new ferromagnetic inductors featuring extremely low losses. We are developing a 200W DC-DC converter operating at 5MHz and subject to low magnetic leakage and power losses (<50°C).

System Integration

CEA Tech is developing 600V - 3.3kV HV SiC device-based converters PV, focusing on current source inverters, UPS and storage applications and electrical mobility. Moreover, 600V and lower MV converters are being developed based on GaN/SiC devices for W and kW applications. Another research area covers HV (several kV) DC devices to raise overall system efficiency and power density.



LABORATOIRE G2ELAB

The G2ELab is a university Lab, covering a wide spectrum of expertise in the field of Electrical Engineering, from material characterization to system studies. The research ranges from long term research up to collaborative research supported by a strong involvement in partnerships with large compagnies and SMEs. With more than 100 permanent staff, 110 PhD and 50 Masters, G2Elab appears as a major actor both nationally and internationally in these areas.

Power Electronics Group

While unconventional energy sources and storage solutions have recently emerged, power electronics increasingly rises to an efficient interface between wide-ranging sources and applications. The diffusion of the power converters nowadays affects the majority of industrial and mass consumption domains over a large scale of power levels.

Our team (17 faculty members, roughly 30 PhD students) has chosen for the last ten years to focus on ground breaking researches. Those are aiming to improve the design of the next electrical energy management systems, both on the technological and conceptual level. Therefore, power integration has become a unifying topic in our team. We are working towards conceiving and laying the technological foundations required for our domain's improvement. The team is also pursuing research on modeling tools development to better answer our design needs for packaging and electromagnetic compatibility. To reach those goals, three interdependent topics are investigated:

Research Topics

Integration technologies, both monolithic and hybrid, from the chip to the converter and its cooling system

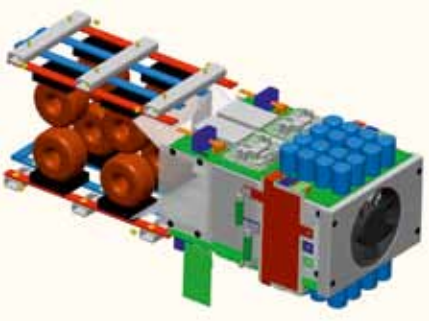
The guiding principle of our investigations is the system integration, while considering the power converter's environment. Four projects are currently under study:

- Passive components integration: integrated L-C-T structures or multi functional substrates,
- Active components integration: multiple floating potential devices and associated electronic circuitries,
- Heat transfer and spreading techniques and their integration within power converters,
- Assembling and packaging of power components: interconnects optimization and coupled approach between the power component and its electro-thermal-mechanical environment.

Modeling and design tools for passive components and electromagnetic systems

Power devices electromagnetic modeling is mandatory as soon as the structure design is started. This approach guarantees the control over a maximal number of physical parameters. This modeling is done with a fine knowledge of components within the structures and through the complete system simulation. Two projects are developed:

- Magnetic components modeling (coils and transformers),
- Modeling of any electric wiring (printed circuit boards, thin wires, sheets, busbar).



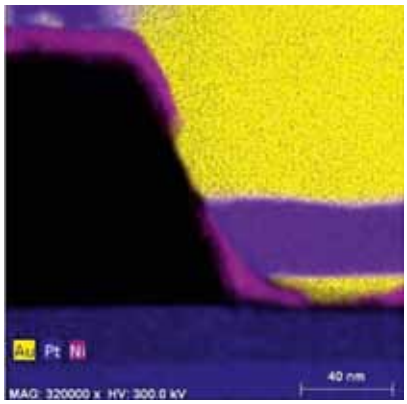
200 kVA soft switching rectifier/inverter (Collaboration G2Elab - Schneider-Electric - L2EP)

Power converters design and promotion for unconventional energies and power grids

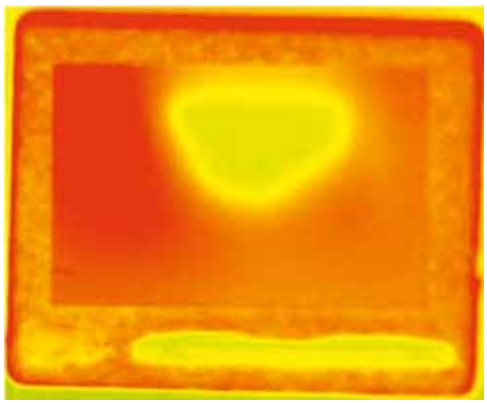
The general objective is the design of switched-mode power supplies. This research is focusing on the increasing numbers of criteria imposed on the environment, in relation with the applications. Those criteria are divided into two categories: compatibility with the converter's environment, both electrical and/or thermal, and the volume power density rise as a consequence of the integration. These researches are mainly applied to unconventional energies (fuel cells, solar cells, uninterruptible power supply) such as power converters for power grids (embedded power grids for trains and airplanes, electricity distribution networks).

Fraunhofer IMWS

FRAUNHOFER INSTITUTE FOR MICROSTRUCTURE OF MATERIALS AND SYSTEMS IMWS/ CENTER FOR APPLIED MICROSTRUCTURE DIAGNOSTICS CAM



TEM EDS mapping of a GaN HEMT gate structure



Pulsed thermography of a defective Power MOSFET device with interface delamination

About Fraunhofer IMWS/CAM

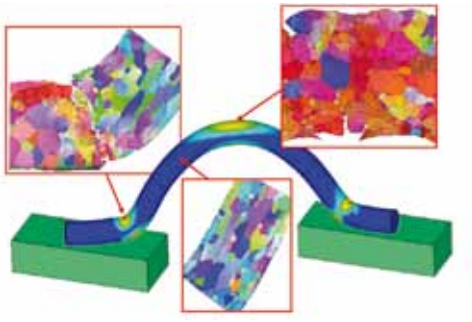
Fraunhofer IMWS/CAM is a leading service provider for failure diagnostics and materials assessment. Contract R & D for industry in the area of semiconductor technologies, microelectronic components, microsystems and nanostructured materials is our day-to-day business. Fraunhofer CAM covers the entire work flow from non-destructive defect localization over high precision target preparation to cutting edge nanoanalytics, supplemented by micro-mechanical testing and numerical simulation. In preparation for future challenges, we do undertake intense forefront research in cooperation with international partners from academia and industry. See www.cam.fraunhofer.de for further information.

Failure Diagnostics in Power Electronics

Fraunhofer IMWS/CAM provides failure analysis for power semiconductors, including power ICs, MOS transistors, IGBTs, diodes and sensors developed for operation under standard and harsh environment. In addition to Si-based systems, we investigate and analyze the behavior and performance characteristics of novel SiC and GaN based devices including related dielectrics, metallization layers and contact systems.
Particular attention is paid to a fundamental understanding of interface material properties and mechanisms relevant for new interconnection and packaging approaches. Current activities cover the characterization of heavy wire bonding materials, Ag-sintering, diffusion soldering, new substrates and housing materials. Fraunhofer CAM closely collaborates with leading manufacturers of analysis and testing equipment with explicit focus on the development of innovative tools and test methods for quality assessment and failure analysis valuable for the electronics industry.

Portfolio

- Microstructure/failure analysis of power semiconductors on wafer and chip level (ICs, MOS transistors, IGBTs, diodes based on Si, SiC and GaN) and of packaged components and modules (including high temperature operation > 250°C)
- Material characterization of high temperature-stable metallization and conducting systems
- Characterization of interconnection materials like heavy wire bonding contacts/materials (e.g. Al, Cu, Al/Cu clad wires/ribbons)
- Characterization of encapsulation and housing materials
- Modeling and numerical simulation of mechanical, thermal and thermo-mechanical device and material properties
- Development of tools and methods for failure diagnostics and quality assessment specifically adapted to power electronics



Finite Element model and grain structure characterization by Electron Backscattered Diffraction (EBSD) for a low cycle fatigue analysis of heavy wire bonding interconnects

POWER ELECTRONICS
HELMUT SCHMIDT UNIVERSITY
UNIVERSITY OF THE FEDERAL ARMED FORCES HAMBURG

Introduction:

The Helmut Schmidt University is a campus university with four faculties where 2500 bachelor and master students are taught. Within the faculty of electrical and information engineering the chairs of electrical machines and drives, electrical power systems and power electronics are responsible for the education in electrical engineering. These institutes are characterized by their effective cooperation and an excellent technological infrastructure. Since 2007 Prof. Hoffmann has been the chair of power electronics. His team currently consists of seven PhD students, one principal engineer and three engineers in the laboratory.

Gate driver circuit with internal protection

Research Scope and Competence Fields:

Power Topologies and Converter Technology:

- Analysis and experimental verification of high frequency switching converter topologies
- Design of load resonant high power inverters with switching frequency above 200kHz
- Efficiency improvement of Uninterruptible Power Supplies (UPS)
- Modular and interleaved controlled DC-DC-converters
- Multilevel converter topologies

Semiconductors and Gate Driver Circuits:

- Parallel operation of uni- and bipolar power devices
- Measurement and characterization of power semiconductors
- Modular high-voltage switches featuring reduced gate driver power consumption
- Gate driver circuits for IGBTs, MOSFETs and JFETs for switching frequencies up to 500kHz
- Analysis and experimental verification of wide bandgap semiconductors (active and passive silicon carbide and gallium nitride devices)

Modeling and Simulation:

- Real-time simulation (hardware-in-the-loop) of power converters
- Simulation of power converter topologies (e.g. resonant converters for lighting applications)

Miscellaneous:

- FPGA based active harmonic compensation
- Calorimetric tests of passive components

High frequency multilevel inverter

Liquid-cooled DC-DC-converter with very high power density

Laboratory Equipment:

Hardware:

- AC power supplies up to 500V with a maximum power of 200kVA in a frequency range from 15Hz up to 400Hz
- DC power supplies with a voltage range of ±440V and a maximum power of 100kW
- Programmable DC power supplies up to 1000V and 150kW
- Precision multi-channel digital oscilloscopes with bandwidths up to 1.5GHz and sampling rates of 20GS/s
- Miniature Rogowsky-current-transducers with a bandwidth of 200MHz
- Digital frequency analyzers and precision power function meters
- Precision high power curve tracer (up to 3kV and 400A) for power semiconductors
- Optical and fibre optical temperature measurement systems
- Precision Climate chamber
- High voltage sources up to 60kV

Software tools:

- MATLAB/Simulink, SIMPLORER, PLECS, Mathcad, LTSpice, LabView, RT-Lab

IAL laboratory

The Institute's Profile

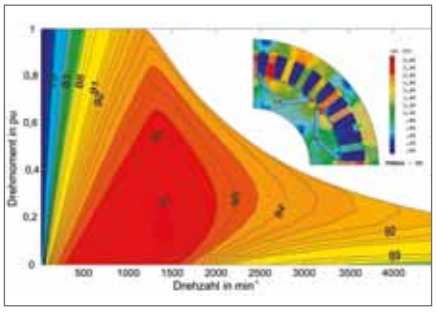
At the Institute for Drive Systems and Power Electronics, experts for electrical machines, power electronics and drive control are working on research projects covering the entire field of drive technology, reaching from the microwatt to the multi-megawatt range. A unique feature of the IAL in the German-speaking part of the world is the close co-operation of two full professorships in drive technology united in one institute, each of the professors having approximately 10 years of practical experience in industry.
The joining of the two formerly independent institutes Electrical Machines and Drives and Power Electronics to one institute in 2001 reflects the technological development towards integral overall systems. On the one hand, this structure is the ideal basis for a close co-operation, and on the other hand, it offers distinct expertise in both chairs.

The IAL presently consists of 2 full professors, 3 retired professors, 2 senior researchers (post docs), more than 40 research associates, 11 administrative and technical staff members and approximately 50 students.

Chair of Electrical Machines and Drive Systems

The main research work in the field of electrical machines focuses on the development of calculation methods and software as well as on the research, precalculation and elimination of technically important parasitic effects like magnetically excited noise, torque pulsations or bearing currents.

The chair is actually held by Prof. Dr.-Ing. Bernd Ponick, whose fields of activity especially comprise harmonic field effects in induction and synchronous machines, small electrical machines and micro actuators, combined analytical and numerical



Efficiency map of a PMSM with buried magnets in V shape

Converter for electrified scooter Piaggio MP3

calculation methods, transient phenomena in drive systems, special effects concerning converterfed machines and fault analysis in electrical drive systems.

Chair of Power Electronics and Drive Control

The competences in the field of power electronics are reaching from the characterisation of power semiconductors and the development of innovative gate drives, the design and optimisation of power electronic circuits including filters, to converter control and modulation methods, and the control of electric drives with or without mechanical sensors.

The chair is held by Prof. Dr.-Ing. Axel Mertens, whose fields of activity comprise applications of power electronics and drives in hybrid and electric vehicles, in wind energy and distributed power generation, and in industrial applications.

Aalto University

HELSINKI UNIVERSITY OF TECHNOLOGY

Scope

The Institute of Intelligent Power Electronics (IPE) covers the whole interdisciplinary area of power electronics by interconnecting several research groups of Aalto University. The basic knowledge includes the converters used in switching power conversion. In real applications, expertise in motor drives, instrumentation, signal processing, automation, and control is needed.

IPE brings together expertise in this area within Aalto University and acts as a flexible link between them and industry. The main goal of the institute is to promote research co-operation between industry and the participating units of the Aalto University. Research projects are typically funded by Academy of Finland, Tekes – the Finnish Funding Agency for Technology and Innovation, and Finnish industry.

Expertise

The expertise within the institute concentrates on the following research groups headed by a professor:

- Automation Technology: automation technology and robotics with a wide variety of robotic test-bed equipment, special instruments and pilot processes.
- Control Engineering: control theory, estimation and identification, neuro-fuzzy technologies
- Electric Drives: control, design and analysis of electric drives

- Electromechanics: design and analysis of electric machines and inductive components
- Industrial Electronics: signal processing and intelligent instrumentation, soft computing
- Power Electronics: switching power conversion, converter topologies, power supplies

Power Electronics and Control Group

The research team works in different R&D groups. Power electronics, electrical drives as well as control engineering are the main research areas of the department.

Scopes:

Drive Engineering

- digital control of asynchronous and synchronous machines as well as brushless d.c. machines
- digital control of linear drives
- analysis and development of control algorithms for sensorless and adaptive control

Converter Technology

- control methods for power electronic switches
- analysis of converter topologies for technological applications
- SMPS
- EMI optimization
- converter design

Microcomputer Applications

- 8bit, 16bit, 32bit
- digital signal processors (DSP)
- FPGA design

Modelling/Simulation

- model levels for power electronic switches
- simulation of converter topologies
- simulation of control loop structures

Power Quality

- active filters
- dynamic reactive power compensation
- harmonics compensation

Power Electronics and Electrical Drive Engineering Lab

Industrial Electronics Group

The term "Industrial Electronics" refers to systems engineering as a whole, consisting of electrical hardware and software components in connection with specific process parameters which provide the basis for the realisation of industrial manufacturing technologies, handling and processing technologies.

Scopes:

Power semiconductor applications

- characterisation, test and application of power electronic components and power semiconductor devices
- drive and protection of power semiconductor devices

Technological switched mode power supplies

- design of high power supplies for electro-process technologies
- high current applications (induction heating, electroplating, et al.)
- high voltage applications (X-ray, corona, ozone, plasma, laser, et al.)
- high frequency applications (induction heating, X-ray, et al.)

Overall system approach

- application technology – physical process – energy conversion process – optimised power supply – system integration – digitalisation

The Industrial Electronics Group is a member of "Thuringian Center of Innovation in Mobility – ThIMo".

Highly equipped special labs

The following equipment is available for teaching and research:

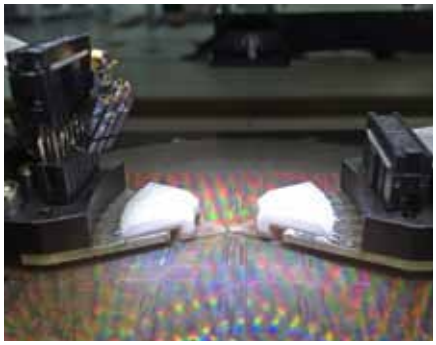
- Power Electronics Labs
- Electrical Drive Engineering Labs
- Electrical Machines Labs
- Power Semiconductor Device Test Labs
- Computer Simulation Labs

universität innsbruck

UNIVERSITY OF INNSBRUCK

Overview

The University of Innsbruck is a public university. It was founded in 1669 and is the biggest and most important research and education institution in western Austria and comprises today more than 28.000 students and more than 4.500 staff and faculty members. Located in the heart of the Alps, the University of Innsbruck offers the best conditions for successful research and teaching, and international rankings confirm the University's leading role in basic research.



The group of Microelectronics and Implantable Systems (MEIS) enjoys a strong national and international reputation for its competences in analog and application specific integrated circuit design.
Project partners benefit not only from the group's extensive expertise in semiconductor engineering, circuit topologies and architectures but also from its comprehensive laboratory and measurement equipment.

ASIC-Design

When it comes down to the design and development of circuit components, capacitive and inductive DC/DC converters, gate drives and temperature sensors are listed among the key competences in MEIS's portfolio. Furthermore, semiconductor development is possible in either Si CMOS / LDMOS, SiGe or GaAs technology applying node sizes ranging from 350 to 55 nm. Circuit design capabilities include simulation over process, voltage and temperature corners as well as yield estimation based on monte carlo evaluations.

Anechoic Chamber

Further, radiated emissions are investigated in an anechoic chamber enabling non-reflective, high precision measurements. Hereby, self-interference due to internal backscatter of electromagnetic waves is excluded by an absorptive chamber interior. Likewise, external noise sources are shielded away from the devices under test.

On-Wafer measurements

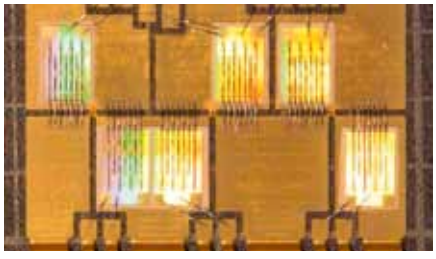
Additionally, a semiautomatic wafer-prober executes on-wafer tests on scales from single dice up to 300 mm wafer sizes. At the same time, the temperature behavior up to 200 °C can be determined if so desired.
In general, the scope of engineering and measurement possibilities allows for high-precision design, verification and validation of appliances and thus also for yield optimization of integrated circuits. Everything combined makes MEIS a high achiever and an excellent choice for research and development.

Service Offers

Apart from the research work done in semiconductor and micro systems technology, ISIT offers many processing, qualification, and test steps as a service for our industrial customers. Many years of experience with electronic assemblies enables the engineers to elaborate solutions in packaging processes, in manufacturing quality evaluation, in reliability and lifetime testing, as well as in failure and damage analysis. Within research projects, the design and production of application specific power devices (MOSFETs, IGBTs) has been accomplished.

Further Institute Highlights are:

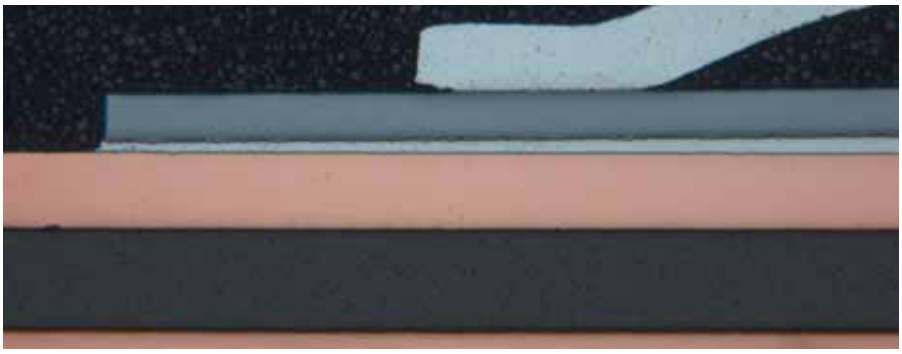
- Semiconductor production line in cooperation with Vishay Siliconix Itzehoe GmbH
- IC Technology
- Micro systems - MEMS
- EN ISO 9001:2008 certified quality management system



Lead frame power module with ISIT MOSFETs (NELE), ready to be epoxy moulded

Packaging Technology

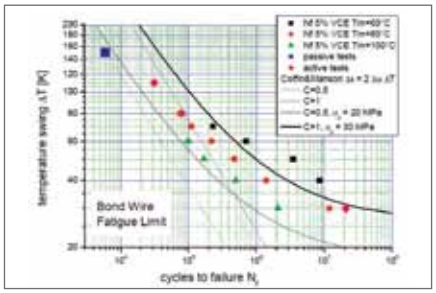
Conventional and advanced packaging technologies are available, e.g. paste printing, component or die placement, and reflow soldering (vapour phase, vacuum). Soldering process development can be done by in-situ x-ray observation of the melting process even with vacuum applied. Semiconductor chip top connections are made by large wire bonding, but new assembly concepts are evaluated with wafer level chip size packages (WLCSP) or with modified metallisations, e.g. by wafer level NiAu plating on the standard Al metallisation.



Metallographic cross section of a power module assembly

Quality and Reliability

Static and dynamic electrical measurements confirm data sheet values, e.g. break through voltage, on resistance, stationary and transient thermal resistances. Several power cycling test benches (current up to 2 kA) are available for reliability testing.



Power module reliability, experiment and model prediction

A dedicated power supply allows testing of photo voltaic inverters (solar panel and field simulation) and IR thermography (Lock-In) is used to reveal hot spots.

Analysis is done by x-ray inspection, scanning acoustic microscopy, scanning electron microscopy, as well as by metallographic cross sections.

Modelling

Modelling of thermal performance (thermal resistance, stationary and transient) has been applied to assemblies and cooling units (air, water). Modelling of the thermo-mechanical behaviour of assemblies and the damage mechanisms evaluates critical loads and allows the prediction of lifetime due to creep and fatigue.

Elektrotechnisches Institut (ETI) – Institute of Electrical Engineering

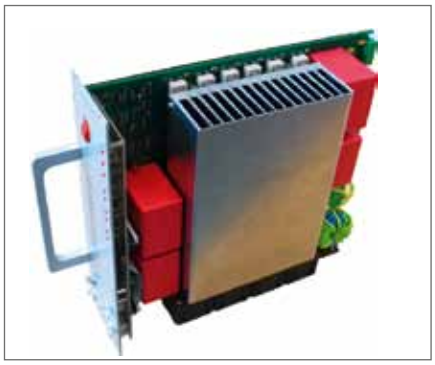
The Institute of Electrical Engineering (ETI) was established and built in 1895 by Engelbert Arnold. It is currently led by Prof. Dr.-Ing. Michael Braun, chair for Electrical Drives and Power Electronics. In 2011 and 2015 two additional chairs have been established, one focusing on hybrid and electric vehicles, headed by Prof. Dr.-Ing. Martin Doppelbauer, and one for power electronic systems, headed by Prof. Dr.-Ing. Marc Hiller.
A colloquium with presentations and discussions about current research projects and innovative product developments is held regularly at the institute.

Electrical Drives and Power Electronics

Fields of activity and current research projects:

- Modular Multilevel Converters
- Short time storage systems with Double Layer Capacitors
- E-Mobility and Smart Grids (joint research projects IZEUS and grid-control)
- Control of Permanent Magnet Synchronous Motor with strongly nonlinear magnetic characteristics
- Modular and flexible Power Electronic Systems for prototyping and test stands

Several converter systems with different power levels up to 300kW have been developed at the ETI which can be used for various applications, e.g. converters for electrical machines, active-frond-ends, as DC-DC-Converter or in combination with electrical energy storage systems for their integration in the power grid. Their flexible configuration and adjustment of the signal processing allows a defined usage in test and prototype systems.



Single PCB converter (DC-Link voltage: 900V, max. output current: 130A, maximum power: 25kW)

Hybrid Electric Vehicles

The requirements for motors and power electronics as traction drives differ significantly from conventional designs for industrial applications. An optimized design of an electrical drive train can only be achieved in an interdisciplinary context. Therefore, the research fields are split into three focus areas:

- Mechanical Motor Design
- Power Drive System (motor, power electronics, mechanical drive train)
- Electromagnetic Motor Design

Three test stands have been set up for the characterization of prototypes and for parameterization and validation of simulations. With powers up to 250 kW, speeds up to 18,000 /min (or 30,000 /min with gearbox) and torques of up to 540 Nm they are an ideal match to the power range of hybrid and electric vehicles. Studies of the dynamics of electric motors, analyzes of drive cycles, development of control algorithms and many more tasks can be performed.

Motor test benches for hybrid and full-electric drive trains

Power Electronic Systems

Power Electronics are used in an increasing number of different applications. The optimized design of the power semiconductors and passives is one of the keys to comply with the requirements regarding energy and cost efficiency. The research topics focus on

- simulation, design and setup of new topologies
- optimization of power electronic systems
- investigation of new devices and materials

Additional test stands for medium voltage power electronics and the characterization of power semiconductors are in preparation. This will enhance the ETI test environment and enables new areas of research.

Battery-powered bus presented at IAA 2013.

Institute for Data Processing and Electronics (IPE)

The IPE of the Karlsruhe Institute of Technology (KIT) employs more than 120 researchers, technicians, PhD students and students. The IPE covers a wide range of research activities, including high end electronic detector systems for particle physics and high power Li Ion battery systems for stationary and mobile applications. The Li Ion battery system research is backed by forefront research on power electronic systems and components.

Thanks to its electronic packaging centre, researchers at the IPE are not only investigating new technologies but also innovate and transfer results in industrial

Thick-film based power module and copper wire bonds.

products and processes. Our machinery includes:

- high precision die bonding (< 1 µm resolution)
- automatic wedge/wedge and ball/wedge wire bonders (12.5 - 500 µm wires)
- thick-film processing line with screen printer and ovens
- lamination press for low-temperature silver sintering processes (LTJT)
- automatic SMD assembly, reflow and inspection systems

Automatic SMD assembly line.

Addressing the challenges of electric vehicle systems, renewable energy generation and storage, our key activities focus in research and development on the topics:

- innovative battery management systems
- highly integrated and efficient power electronic modules and inverter systems
- motor-integrated inverters for electric vehicles
- high-frequency half-bridges for wireless energy transfer

At the IPE, we develop, manufacture and characterise low inductive power electronic modules based on low-temperature sintering of wide band-gap power semiconductors. We meet thermal and electromagnetic design requirements by the beneficial use of copper thick-film substrates. A further important field of research is the development of highly reliable power electronic modules. To our industrial partners we offer comprehensive investigations of wire bond connections and die attach materials using our power cycling test stand.

Our vision is to optimize the integration of huge batteries, motors and power electronic systems.

Light Technology Institute (LTI)

The Light Technology Institute (LTI) is part of the Department of Electrical Engineering and Information Technology of the Karlsruhe Institute of Technology (KIT). It was founded in 1922 as the first Light Technology Institute in the world. Nowadays, 5 professors, 1 associate professor and 8 senior researchers supervise more than 60 Ph.D. students working at the institute.

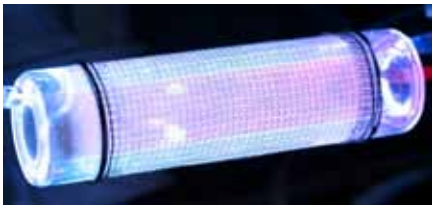
Prof. Dr. rer. nat. Uli Lemmer and Prof. Dr. rer. nat. Cornelius Neumann are the cooperative directors of the LTI.

The research at the LTI covers a wide range of activities including the investigation and utilization of light and light sources as:

- Plasma-Technologies
- Power-Electronics
- Optoelectronics
- Optical Technologies in Automobiles/ General Lighting
- Organic Photovoltaics
- Optical Antennas

Spatial-resolved spectroscopy of novel microwave-driven mercury-free energy saving lamps.

High-frequency resonant full-bridge inverter equipped with full-SiC-modules for 10 kW.



Laboratory sample of a pulse-driven Dielectric Barrier Discharge radiation source for disinfection purposes.

Power Electronics at the LTI

Within the department Light, ECG and Plasma Technologies, the Power Electronics Laboratory contributes electronic and power electronic equipment to achieve best operating conditions of sophisticated optical radiation sources. However, additional to light sources, the fields of research and development also cover:

- Electronic Control Gears (ECG) for all kind of light sources (plasma, LED)
- High-frequency switched-mode power supplies
- Microwave generators for mercury-free plasma lamps
- Grid-friendly PFC front-end ballasts for single and three-phase systems
- Characterization of power semiconductor switches (Si, SiC, GaN)
- Layout investigations on small to medium power transistor modules
- High-speed gate drive circuit design

The laboratory is equipped with latest measuring instruments, such as state of the art oscilloscopes, power meters and broadband high voltage and current probes. For device and circuit characterization, an impedance/network analyser is provided. Power semiconductor switches are statically and dynamically characterized using a unique thermally controlled test bench.

Our expertise in circuit topologies, magnetics design and semiconductor gate drive circuits is intended to be expanded to application areas as plasma surface treatment, inductive heating, wireless energy transfer and high power density applications.

The Department of Converter Technology develops solutions for the grid connection of renewable energy sources and energy storage, including the wired and wireless grid connection of electrical vehicles. We cover a power range from a few watts up to several megawatts. Our excellent competence is the design and dimensioning of power electronics converters, including the implementation of their control, for example DC / DC converters and inverters. In our concepts we follow a system oriented approach in order to find optimal solutions for each individual project/situation. Our research topics are new converter topologies, energy efficiency, reliability and new control algorithms.

Testing Laboratory for grid integration (Fault Ride Through Container)

Power Electronics and Components

The power electronics group's task is the development and optimization of circuits for switching power converters as well as components for renewable energy sources, energy storage and grid connection of electric vehicles. In addition to improve efficiency and reliability we also focus on the optimization of the volume-weight-cost of switching power converters. Our development laboratories are well equipped to perform demonstrations, investigate components as well as characterize and investigate final products.

Testing Centre for electromobility and battery converters

Power Converter Control

The converter control group designs and develops the control of power electronic converters, which are often used as a link between distributed generation plants and the electrical power grid. Our focus is on the development and optimization of control strategies and control algorithms that improve the behavior of the converter of on-grid-connected and off-grid-connected power plants thereby increasing efficiency. Using Hardware-in-the-loop and rapid-prototyping methods accelerates our development process.

Testing

Testing of generation units, static converters and power electronics is another essential part of the research activities at Fraunhofer IWES / Kassel. Within our accredited testing laboratories, we offer standard and customized tests and measurements together with characterization and simulation of power electronics and system components, with a particular focus on:

- Grid integration
- Performance and reliability
- Electromagnetic compatibility

Our services cover concept design and control systems as well as tests and measurements of all power electronics devices from sub kW to multi MW systems.

UNIKASSEL VERSITÄT

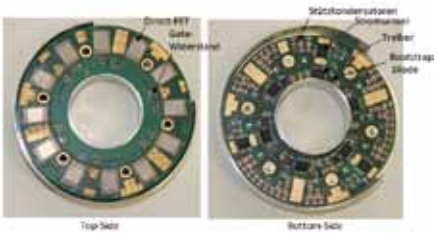
KDEE Kompetenzzentrum für Dezentrale Elektrische Energieversorgungstechnik

UNIVERSITY OF KASSEL

The Centre of Competence for Distributed Electric Power Technology (KDEE) was founded to offer a concentration point for the development of innovative technical designs within the university, enabling the transference of solutions at both device and system level to the industry. In terms of topics and personnel it operates in close connection with the chair of Electric Power Supply Systems (EVS). Power electronics-based converters are the most flexible and dynamic equipments for energy management in the current and future electrical grid. Their construction and control requires specialized knowledge, which will be concentrated and pursued on the long term. Hence, the KDEE will act as a partner for industrial and public-founded projects not only on the fundamental research level but also on industrial-oriented applications.

Teaching and research activities at the department EVS are focused not only on facilities and systems for electrical power supply but also on the development of power electronic components and devices for such systems. These include the development of methods to use renewable energy sources (e. g. solar energy, small-hydro power, biogas and wind) as well as power electronic converters for automotive applications. A close cooperation exists with the former "Institute for Solar Energy Technology" (ISET e. V.), today: Fraunhofer IWES (Institute for Wind Energy and Energy System Technology), which was founded 1988 by the former head of the EVS department Prof. Werner Kleinkauf as well as with SMA Solar Technology which has been a spin-off company of EVS/University of Kassel.

With currently about 30 employees, EVS and KDEE form a powerful research group focused on the topic of energy supply systems at the University of Kassel, diverse research possibilities and wide-ranging study contents.



Multiphase inverter for direct integration in motor housing operating at 140°C ambient temperature

Inverter board for direct integration on Pedelec

Main research areas:

Power electronic converters allow conditioning of energy with high flexibility and efficiency. This enables the integration of different energy sources and storages in a common energy system.

The main research areas of KDEE are:

- Power electronic converters for distributed and renewable energy applications, especially solar, wind power
- Automatized characterization of highly efficient power electronic semiconductors (Si, SiC, GaN) and also of magnetic materials (with precision calorimeter and high power amplifiers)
- Design of innovative magnetic components for highly efficient and compact power electronics
- Power electronic solutions (e.g. FACTs) for the grid integration of renewable energy sources
- Power electronics in automotive applications (e-car, hybrid car, auxiliary drives)

Highly efficient and compact three-phase fast battery charger (5kW/L with low-cost standard semiconductor devices within ECPE Project)

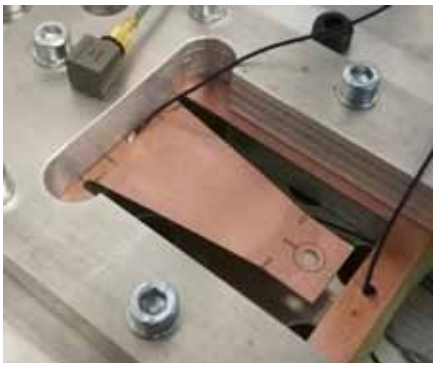
General Information

The University of Applied Sciences in Kempten is located in the south of Germany, close to the Bavarian Alps. The institution was founded in 1977 to establish a regional center for academic education in the Allgäu area. Today, the University of Applied Sciences Kempten has roughly 6000 students, of whom 1000 are enrolled at the department of Electrical Engineering in different Bachelor and Master programs.

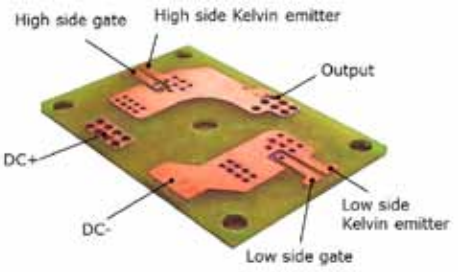
Laboratory for Electronics Integration

The Laboratory of Electronics Integration (EI-Lab) was founded in 2015 to promote applied research and education in the field of electronics packaging, micro-integration, and thermal management. Currently, the lab comprises an interdisciplinary team of seven scientists, engineers, and technicians. The team is supported by numerous students, who perform their student or thesis project within the lab. Both, public and industry funded research projects are carried out by the staff and concern the following topics:

1. **PCB embedding of power semiconductors:** Ongoing research projects focus on embedding of 1200V IGBT and diode chips in printed circuit boards. Reference applications are motor drives with nominal output powers in the range of 5 to 50 kW.



Demonstrator of PCB-based piezoelectric vibration energy harvester



1200V/25A PCB embedded IGBT half bridge fabricated at EI-Lab.

2. **Design and fabrication of PCB based microsystems:** Embedding of piezoelectric materials in printed circuit boards opens up the potential for many new, highly integrated, mini-/micro-electromechanical systems. A piezoelectric vibration energy harvester has been designed, fabricated, and tested as first proof-of-concept.

3. **Thermal management of (power) electronic systems:** The lab offers its expertise in heat transfer and CFD simulations for development and consulting activities for industry partners.

For these activities, the lab provides an extensive infrastructure. Core of the lab equipment is a prototyping line for printed circuit boards that comprises a circuit board plotter, spray etcher, via plater, and multilayer press. For semiconductor packaging the lab is equipped with a clean bench, sinter press, wire bonder, vacuum evaporation machine, and equipment for polymer casting. To characterize samples fabricated in the lab several optical microscopes, a scanning electron microscope and a test setup for power semiconductor characterization (static, dynamic, thermal) are available. State-of-the-art software tools for CAD, FEM/CFD, circuit design and analysis are used for designing lab-scale demonstrators.

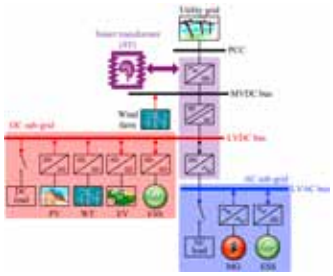
CHRISTIAN-ALBRECHTS-UNIVERSITY OF KIEL

In 2015 the Chair of Power Electronics comprised 20 people among PhD and Post-doc supervised by Prof. Marco Liserre, Head of the Chair, and Prof. Friedrich W. Fuchs. The Chair has already collected more than 7 million euro in new projects (in the last two years). The Chair is also member of CE Wind (Kompetenzzentrum Windenergie Schleswig-Holstein) and KLSH (Kompetenzzentrums Leistungselektronik Schleswig-Holstein).

Key research fields

The Chair of Power Electronics main focus areas are:

- DC/DC converters and Inverters for MW applications, with special focus on wind systems.
- Design for reliability and Active Thermal Control.
- Smart Grid: Grid identification, Smart Transformer and HVDC.
- DC/DC converters and drives for electric vehicles, aerospace and high-speed appliances.



Smart Transformer concept

The Chair has two large projects running in the following fields:

- Medium voltage impedance analysis for optimal power feed-in (BMBF grant, 2.300.000€, 2015-2018). The goal is the design and development of a 2 MW power converter to measure the impedance of the MV grid.
- Smart transformer (ERC consolidator grant, 2.000.000€, 2014-2019). The goal is to design a solid-state-transformer for distribution grid. A modular structure is studied to guarantee high efficiency and reliability.

In both projects, the Chair develops modular power converters with focus on high power density, efficiency and reliability.

Chair Laboratory Highlight

The **power electronics laboratory** features are:

- electric drives and power electronics test benches up to 90 kW;
- special thermal characterization setup for power electronics equipped with an IR Camera with positioning system and an optic fiber temperature measurement system;
- power electronics system test benches equipped with electronic loads, AC and DC sources up to 4 kV and 60 kW, oscilloscopes and power analyzers.
- electrical grid HIL and Power-HIL capabilities by means of Real Time Digital Simulator with power amplifier.
- Micro-grid and FACT facilities.

A new **medium voltage laboratory** is under development with facilities to test converter up to 1 MW of circulating power, 3 test cells with 10 kV connection and air/water cooling.

DC/DC Converters: 20 kW dual active bridge and quadruple active bridge

1 MW NPC Power stack for wind system

General Information

The University of Applied Sciences in Kiel is the largest Applied Science Institution in the State of Schleswig Holstein. In 2011 more than 6000 students were enrolled with more than 1000 students in the Faculty of Computer Science and Electrical Engineering. The Institute for Mechatronics as a part of the faculty is offering education and research participation for about 150 Bachelor and Master Students.

The Key Aspect is E-Mobility

The Institute for Mechatronics has a strong focus on E-Mobility and its hardware components which led to the establishment of the Schleswig Holstein Competence Centre for E-Mobility (www.fh-kiel.de/kesh). In research projects e.g. the daily use of electric vehicles (Peugeot Ion, EcoCarrier) is analyzed and a new battery management system is developed. 5 Professors in the Institute are offering specialized educational contents like electrical traction and drives, electrical circuit design, technical optics, mechanical design, system modeling and control techniques.

The Bonding and Joining Lab

Professor Ronald Eisele is part of the E-Mobility-Team and his courses and research capabilities in the labs are consisting of:

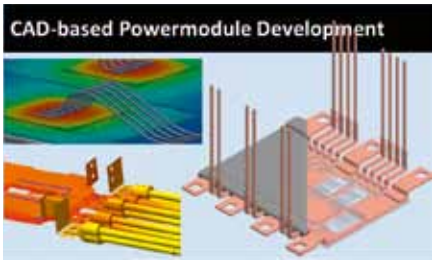
- Thermal modeling, simulation and design of systems and components
- Electrical and thermal design of powermodules
- Professional assembly processes for bonding joining tasks
- Testing and characterizing of power electronic components

These capabilities are also offered for industrial development demands e.g. in bilateral projects. By participating in regional and nationwide research projects these capabilities are constantly further developed.

The scientific team includes experienced engineers, Ph.D. Students (cooperative graduations with other universities), Bachelor and Master Students working on their theses.
The team is designing and manufacturing powermodule samples in industry-like quality by applying:

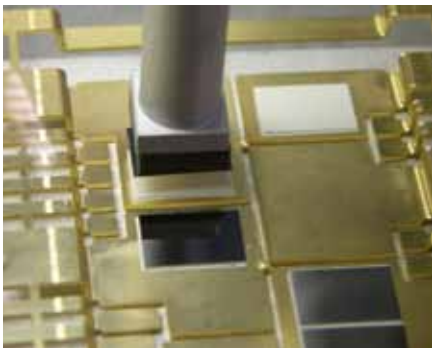
- Process-Development for Low-Temperature Sintering of power semiconductors and passive components, terminals, buffers and heatsinks
- Multiple design approaches based on different substrates (DBC, IMS, Leadframe)
- Final encapsulation in frames or hard epoxies

Bonding and Joining Technologies



CAD Power Module Development

In the bonding and joining labs the team is running a number of specially modified equipment in order to support the industrial partners in applying low temperature sintering. A very promising new investment and research target is the combination of sintering and Cu-heavy wire bonding (Orthodyne 3600+ new Cu-Version).


Sintered die attach on Leadframe

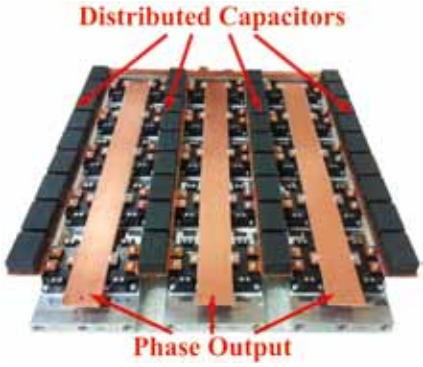
SiC MOSFETs in 750 V, 400 A inverter developed by Inmotion Technologies

Swedish ICT- Enabler of Cross-Border Collaborations

Acreo focuses on Sensors and Actuators, Digital Communication, Power Electronics and Life Science. Acreo is part of the Swedish ICT group and has total turnover of 22 M€ and 145 employees.

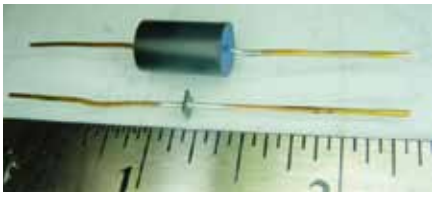
SiC Power Center – Promote implementation of SiC Power Electronics

The power electronics is becoming more efficient and smarter by integration with ICT. The vision of the future society encompasses integration of power electronics, SiC and ICT technologies in the structure and management of the multifaceted smart total electric energy system based on renewable energy sources. Some of the elements of the future energy system are electric energy generation, distribution and storage facilities, industrial infrastructure, mass transportation systems, e-mobility, intelligent houses and data servers. The SiC (silicon carbide) Power Center, led by Acreo, was founded in 2012 by Acreo Swedish ICT, KTH and Swerea Kimab. It provides a platform for cooperation between industry, research institutes and academia with main objective to promote introduction of SiC power electronics in the applications where high energy efficiency, compactness and high-temperature operation offer significant system advantages. The main objective of the cooperation is to explore the full potential of SiC electronics for future applications, increased competitiveness and sustainable development.



312 kVA inverter with 200 A, 1200 V half-bridge SiC MOSFET power modules built by KTH for Volvo

Acreo has been active in the field since 1993 covering all aspects of SiC technology from epitaxy to device design and manufacturing which resulted in an extensive knowledge base. Resources at Acreo include complete process line, electrical evaluation laboratory with high voltage, high current and EMC measurement capabilities and a high performance computing environment. CAD tools are available for the advanced design and simulation of electrical, electromagnetic, thermal, mechanical and optical devices and systems.



10 kV SiC PiN diode developed by Ascatron and Acreo for Alstom Power

SiC Power Center welcomes industry partners throughout the whole value chain. The center members today include some of Sweden's leading automotive, energy systems and power electronics companies: Alstom Power, Ascatron, Bombardier Transportation, Elektronik-Konsult, Eskilstuna ElektronikPartner, Inmotion Technologies, SEPS, Swerea IVF and Volvo AB.

The center organizes each year an International SiC Power Electronics Applications Workshop (ISiCPEAW) in May/June in Stockholm.

COLOGNE INSTITUTE FOR RENEWABLE ENERGY

Cologne Institute for Renewable Energy at Cologne University of Applied Sciences

The Cologne Institute for Renewable Energy (CIRE) is an association of currently 17 Professors plus Scientists within the fields of electrical engineering, mechanical engineering and resource management.
With 17 disciplines under one roof, CIRE combines interdisciplinary research and teaching dedicated to the technology and the implementation of renewable energy.
CIRE activities include a strong focus on Power Electronics and Electrical Drives with Prof. Lohner (Automation Engineering and Electrical Drives), Prof. Waffenschmidt (Electrical Grids) and Prof. Dick (Power Electronics and Electrical Drives) sharing laboratories, conducting research and common publications.

Converter Modulation and control Techniques

A research focus is on (resonant) DC-DC converters, e.g. as maximum power point tracker for PV. A major contribution was

a H-Bridge modulation strategy. It combines both pulse-frequency and phase-shift modulation improving the controllable voltage gain of a LLC-resonant circuit by less frequency variation. Pulse patterns are programmed directly on a flexible FPGA platform acting as rapid prototyping system for our setups.
Various PFC and DC-AC circuits are controlled by the same platform, including a 4-quadrant operation of an H-Bridge. Latter consists of Low-Side fast switching MOSFET's operating against SiC diodes, and of 50Hz operated High-Side IGBT's.

Magnetics

Inductive wireless-power systems for consumer applications are analyzed with special regard to the magnetic shielding material. Furthermore, a 500W wireless power transfer system was set up as part of the 2015 IEEE International Future Energy Challenge Competition.

A research project is on coupled inductors with H-Bridge being supposed to show material savings compared to classical inverter-legs with inductive output.

Such systems are analyzed in combination with the use of wide-bandgap power semiconductor devices.

Drives / Electromobility

A novel drive train concept based on the doubly rotating electrical machine is demonstrated as depicted. It allows a major increase in overall system efficiency in contrast to conventional drive train structures due to the connection of electric powertrain, double rotating electric motor and combustion engine, optimized for a certain operating point in terms of energy efficiency (2,9 l/100km, calculated from internal, not calibrated measurements of a 100km ride).

LUT
Lappeenranta
University of Technology

LAPPEENRANTA UNIVERSITY OF TECHNOLOGY (LUT)

LUT ENERGY Department of Electrical Engineering – Research Unit of Power Electronics for Energy Efficiency and Sustainability (PEES)

Finland has a strong, globally operating power electronics industry, and PEES at Lappeenranta University of Technology plays a significant role in the development of Finland's power electronics industry.

PEES has around 70 employees (5 professors, c. 15 postdoctoral researchers, and around 50 post-graduate students). The PEES research teams work in tight collaboration in various application areas of energy efficiency, energy conversion and conditioning of energy. The PEES core competencies are in electrical drives technology and in electricity power delivery systems and regulation markets.

General view

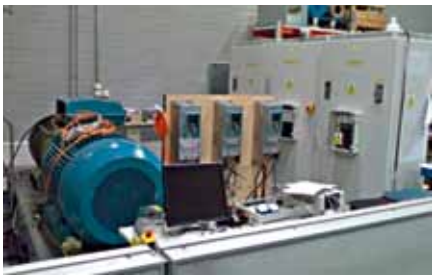
In the field of electrical drives technology (Prof. Juha Pyrhönen), the research achievements of high international level are related to permanent magnet technology, control methods and power electronics applications (linear drives, mobile drives, solid-rotor high-speed drives, AC drive technology, wind generators, model-based control of active magnet bearings, modulator control of power electronic devices, power line communication, medium-voltage converters, smart drives, fuel cells). The research achievements associated with electricity markets and power systems (Prof. Jarmo Partanen) include research activities related to low-voltage smart grids including for example new distribution arrangements based on DC systems or 1000 V AC systems, control of loads instead of production control, active energy storages, utilization of passenger electric cars in balancing the production and consumption in the grid and different distributed generation connected to the grid.

Power Electronics for Energy Efficient Energy Conversion Systems, Electric Energy Storages and Sustainability (PEECS)

PEECS is a PEES owned research program focusing on the most significant applications of power electronics technologies in industrial drives, distributed electricity generation, smart grids, transportation,

Drives test bench

and to some degree, domestic applications. PEECS contributes to energy efficiency enhancement and cost reductions by accurately controlling the electric power flow and storage applying intelligent power electronic control and by replacing mechanical or hydraulic systems



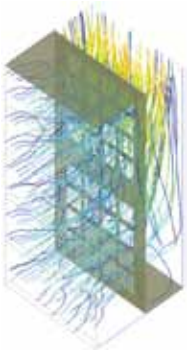
Medium voltage H-bridge inverter (3 kV) test setup

with electrical drives utilizing digital control algorithms. Our PEECS research infrastructure is inevitably the strongest in Finland in its own field. Research strength is assessed based on the number and productivity of the main researchers, scientific output, number of graduated doctors and international publications, especially, the quality of the power electronics and drives laboratory – Motorium Careliae (Figure 1), which on a European and even global scale has excellent research facilities with an infrastructure characterized by 300 m^2 of floor space (+ other laboratories), 1 MW power loss maximum, several test benches for motor drives up to 1 MW. The maximum speed available at 1 MW power is 12000 min-1.

Research Interests

The Power Electronics Laboratory (PEL) research interests are in the broad area of the electrical energy generation, conversion and storage. In particular, we are interested into high power electronics technologies for medium voltage applications, those operating with voltages in kV range, currents in kA range and powers in MW range. We believe that power electronics is one of the key-enabling technologies for the future energy systems, as it offers unprecedented flexibility for the integration and control of various electrical sources, storage elements or loads into the grid. This is equally valid for the present-day AC grids as well as for emerging concepts of DC grids, or inevitable mix of both in the near future.

To achieve controllable, reliable and efficient electrical energy conversion by means of advanced power electronic converters, we optimally use, but also influence and drive forward, advancements in different areas. These multidisciplinary considerations include: power semiconductors (e.g. Si, SiC, GaN), passive components (e.g. magnetics), insulation materials, mathematical modeling, simulations and optimization of power electronic systems, advanced control methods and tools (e.g. RT-HIL simulators), etc.



Cabinet thermal simulations

Facilities

To effectively support research activities, both low voltage and medium voltage experimental research facilities are available as integral part of the Power Electronics Laboratory. These include different low and medium voltage variable AC and DC sources, AC grid emulator, high power loads, electrical energy storage elements, medium voltage electric machines, partial discharge test setup, cooling units and several test bays with protective cages.

Collaborations

Our research activities are supported through various funding schemes from the public sector (e.g. SNSF, CTI, SFOE) as well as from industrial partners who seek research support in the field of power electronics.

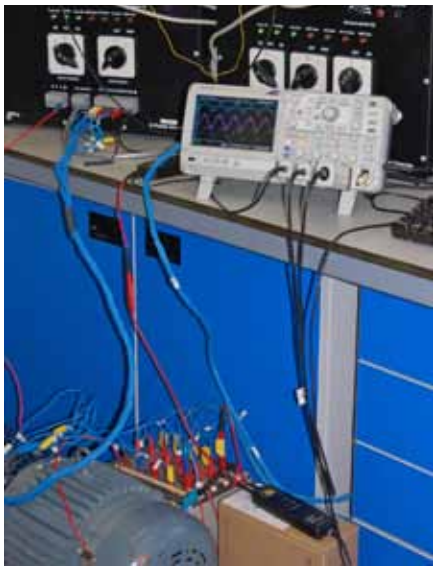
Keywords

- Electrical energy generation, conversion, storage
- Medium voltage applications
- High power electronic converters
- Modelling, simulation, design, optimization, control
- Power semiconductors, advanced magnetics
- High performance variable speed drives

MMC sub-module

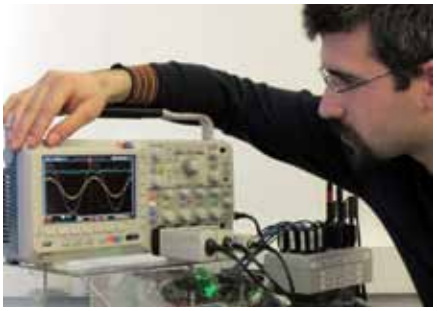
LIVERPOOL JOHN MOORES UNIVERSITY

Research in the area of electric machines and drives commenced at the Liverpool John Moores University in 1992. Located in the Faculty of Engineering and Technology, the Institute is situated in a vibrant and historic port city of Liverpool and operates under the auspices of the Research Centre for Electrical and Electronic Engineering. The research is conducted by three full-time academics, and, typically, five to ten PhD students and post-doctoral research associates. Visiting scholars from predominantly EU Universities are regularly hosted (on average, three per calendar year).



Testing of a five-phase machine in open-end winding configuration with dual inverter supply.

The main areas of activities are related to electric machine modelling, development of advanced control algorithms for variable-speed ac drives, and pulse-width modulation algorithms for multiphase and multilevel power electronic converters. Target application areas include (but are not limited to) general high-power industrial applications, locomotive traction, electric and hybrid electric vehicles, renewable energy generation (with emphasis on remote offshore wind generation using fully-rated power electronic converters), and microgrids.



EV's battery charging with unity power factor at the three-phase grid side.

Since the beginning of the 21st century the majority of research efforts has been directed toward electric machines and variable-speed drive systems of multiphase type (i.e., ac systems with more than three phases). A significant level of expertise has been acquired over the years in this area and most of the completed and current research projects (funded predominantly by the UK's Engineering and Physical Sciences Research Council, Qatar National Research Fund, and industry) has been/is related to this topic. A significant part of the research activities is carried out in cooperation with industrial partners and current collaborators include Ingeteam (Spain), BMW (Germany) and Infineon (Germany).

The research is conducted in a dedicated laboratory for advanced electric drive and power electronic converter testing. Control system development normally utilises either a dSpace platform or is based on Texas Instruments DSPs. The laboratory is equipped with unique pieces of equipment that enable a wide range of experimental investigations in the multiphase drive area:

- A range of multiphase machines: five-phase induction and synchronous reluctance machines, asymmetrical and symmetrical six-phase and nine-phase induction machines, and symmetrical nine-phase permanent magnet machines (with both near-sinusoidal and highly non-sinusoidal back emf).
- A range of multiphase power electronic converters: a multitude of two-level inverters with up to nine phases, two three-level neutral point clamped six-phase inverters, and a three-phase to nine-phase matrix converters.
- Advanced laboratory programmable ac and dc sources, e.g. a grid emulator Spitzenberger & Spies PAS2500 system, and Sorensen SG1600 high-power dc supplies.

An integrated on-board battery charger for EVs based on nine-phase power electronics and propulsion motor.

DTU Electrical Engineering at the Technical University of Denmark (DTU):

Power Electronics Engineering is an exciting area covering multi-disciplinary studies from energy conversion and power supplies to IC-design. DTU Electrical Engineering at the Technical University of Denmark is a world research leader in: High Efficiency Fuel Cell power Converters, Switch-Mode (class-D) Audio Amplifiers, Magnetic-less (piezoelectric transformer based) Switch-Mode Power Supplies, and Very High Frequency SMPS.

DTU Electrical Engineering:

We put special pride into linking theory and modelling to the experimental test & validation of results.

We are open for collaboration and new partnerships with companies and institutes. Our graduates are employed world-wide by companies, research centers, and authorities. We do collaboration projects with numerous domestic and international companies.

Power Electronics Research Areas:

The Power Electronics research focuses on physics, component and system level ranging from mega-Watt to milli-Watt. We also perform research within signal conditioning and electronics, as well as analogue and mixed-mode IC-design.

Ultra compact DC-DC converter design by DTU.

We have key competences in:

- Ultra-high efficiency power converters for fuel cells
- Switch-mode power supplies (SMPS)
- SMPS based on piezoelectric transformers
- Ultra-fast tracking power converter for RF amplifiers
- VHF SMPS
- Silicon carbide (SiC) and gallium nitride (GaN)
- Digital control of DC/DC converters
- Switch-mode audio power amplifiers - Class D
- Class-D and ultra low power radio receivers for hearing-aid applications
- IC design

LED driver comparison.
Left: DTU design. Right: Commercial product.

We provide Unique and Innovative Solutions:

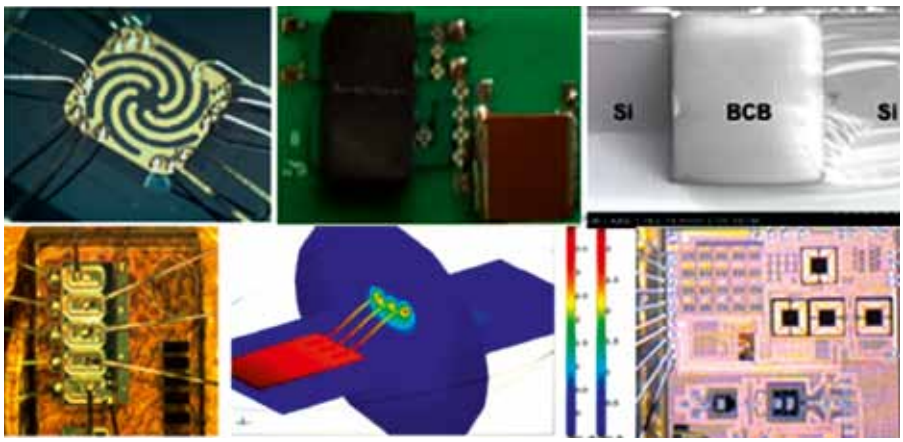
- 5 Start-up companies
- 30 Inventions and patent applications

Dual bidirectional input, single output fuel cell converter by DTU.

Laboratories:

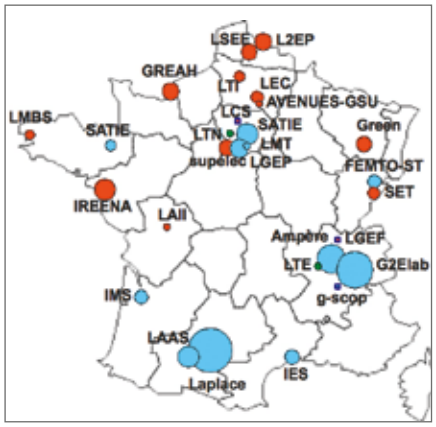
Our laboratories are equipped with state-of-the-art instrumentation and facilities enabling us to perform our research activities.

INSA – INSTITUT NATIONAL DES SCIENCES APPLIQUÉES LYON



Top from right to left: SiC 6.5kV LTThysristor, integrated passive system, 3D super-capacitor cell. Bottom from right to left: monolithic SiC converter, evaluation of EMC contribution, low power System-on-chip

SEEDS/ISP3D is a federation of 130 researchers form French electrical engineering labs. The researchers share a common but broad topic: integration of power systems in 3D. Five other researcher federations exist to work on the societal challenge of energy: this large group is untitled SEEDS as for Electrical and Power Electronic Systems in Societal Environment (www.seedsresearch.eu).



Map of labs involved in SEEDS/ISP3D group in France

Research areas

SEEDS/ISP3D group focus many areas related to integration of power systems. It starts from materials for magnetic integrated devices, high dielectric ceramics, powders for alternative brazing of chips in power module or special fluid for integrated active cooling. Integration of devices deals with passive devices (capacitors, inductance, transformer, super-cap, battery cell), high-voltage wide band-gap devices and high temperature SOI devices. Functional integration is experimented on silicon up to double-face circuits. Efforts concern alternative interconnection solutions of chips in a 3D manner in a module.

Many results have been obtained on converter architectures that benefit from 3D integration like magnetically coupled polyphase converters. Converter architectures are experimented to improve safety of service and failure-mode operation.

SiC-JFET based inverter for 300°C ambient temperature operation

Analyses of failure modes are carried out on industrial and lab-scale modules to feed research on lifetime prediction of assemblies. Tests focus industrial applications in standard temperature range or advanced power cores in extended temperature range.

Innovative cooling approaches are proposed within the semiconductor or at package level. Passive cooling is addressed as well as active cooling based on special fluids and motion schemes. Wide bandgap devices are addressed for high voltage applications and higher ambient temperature. SiC, GaN and diamond are experimented and different levels of integration are considered. Power devices have been tested between -75°C to 300°C and more. Development of dedicated drivers is hot topic. CMOS SOI technology has been selected and various driver test chips have already been tested from -90°C to 300°C, mainly in an attempt to exhibit failure modes apart from functional verification. Low-power monolithic integration receives a lot of attention and challenging system-on-chips have been demonstrated.

The Center of Industrial Electronics (CEI) is a research center at the Universidad Politécnica de Madrid (UPM) created to generate knowledge and develop applications related to Industrial Electronics, in cooperation with industry partners.

CEI activities focus on electronic system designs, both analog and digital. Research lines are related to **power electronics**, **power quality** and **embedded systems**.

Strong Industrial Program

CEI is recognized for its strong industrial program and the large number of direct collaborations with industry, worldwide. The funding scheme is a combination of public funds and direct contracts with International industry partners in **Europe** (ABB, Airbus, Alcatel, Boeing, Bosch, EADS, Crisa, Fagor, Indra, Philips Hearing Implants, Premo, Sedecal, Sener, Siemens, Thales Alenia Space, Tecnobit), **USA** (Ansoft/Ansys, Agere Systems, APEX, GE, Enpirion, Intel), **China** (SISC, Huawei), and **Australia** (Cochlear).

Power Electronics activities at CEI are related to Power Supply Systems of any nature, ranging from low power (5mW) in cochlear implants to high power (100kW) X-ray applications. Most of the activities deal with DC-DC, AC-DC or DC-AC conversion. CEI researchers have strong expertise in the following areas:

- **Powering Digital ICs**
- **Powering RF amplifiers**
- **Renewable Energy converters: Grid, Batteries & PV panels**
- **Automotive, Aircraft and Space applications**
- **Wireless Power**
- **Control, Modeling, Design & Optimization Tools**

Knowledge in power electronics is of a matrix nature, where a technology developed for a specific application may be adapted for another application. Supplying energy for biomedical, aerospace, low power ICs or high power PV plants share some core technologies. Examples of this are digital and non-linear controls, fast-dynamic techniques, multi-phase converters, modeling of magnetic components, optimization algorithms, etc..

Education & research

Young researchers are of fundamental importance in a University research center. Besides the Master and Doctoral Programs, and besides the specific research projects, we organize at CEI our **"Annual Meeting"**, where students and industry partners share results and discuss their visión on the future of power electronics. This interaction facilitates technology transfer from university through people, and a real synchronization between industry and academia.

Research Topics

Focus

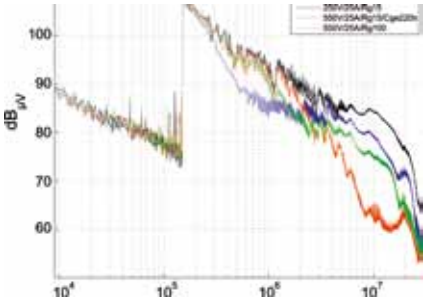
Research is focused on new power semiconductor devices in power electronic circuits and systems: To make circuit and system design appropriately profit from the rapid development of devices coming rather close to ideal switches, a basic physical understanding of their operation is required. On the other hand, device development taking into account major circuit or application-related requirements can facilitate usage of the components optimised this way. To achieve viable results in this respect, theoretical calculations and simulations need to be complemented by experimental work in laboratory.

The interaction between component, circuit and system is influenced on such different levels as circuit elements including parasitics, drivers, control methods and operational conditions of the system. To a large extent, power supplies or electric drives are investigated, aiming at applications such as in the fields of electric grid with HVDC, renewable energy, automotive electronics, welding sources or appliances.

Topic EMC

The switching slopes of the power semiconductors cause conducted and radiated emissions of the system which need to be limited according to standards to avoid disturbances of the power electronic or other equipment. The propagation of these disturbances is strongly influenced by capacitive and inductive parasitic elements, thus a detailed investigation of power section – comprising mechanical construction, semiconductor devices and their control – is required to achieve an optimisation.

Power section with driver and filter circuits of an experimental converter



Measured conducted emissionsof a converter over frequency under different conditions

Topic Reliability

Power semiconductor devices typically consist of a chip which is packaged in a structure of several conductive and isolating layers. Several known mechanisms limit lifetime. Those can be triggered by operational conditions, e. g. load cycles leading to thermo-mechanical stress and subsequent fatigue. Again, the requirements defined by increasingly demanding applications – e.g. cycles in traction, electromobility or wind generators – need to be determined and appropriately applied to the devices' capabilities as qualified in standardised tests.

Equipment for reliability tests

Research Environment

With a mixed team of experienced and young scientists and a state-of-the-art infrastructure of power electronic laboratories and computer equipment with relevant simulation software, a variety of research projects in the aforementioned fields have successfully been carried out. Students are involved, providing them an education to become the next generation of experts in the field of power electronics with its increasing importance as key technology for energy efficiency and usage of electrical energy generated from renewable sources.

The School of Electrical and Electronic Engineering

The Faculty of Engineering and Physical Sciences at the University of Manchester (formerly UMIST) has a strong tradition of collaboration with industry, encompassing sponsored research and commercial application of results. Its School of Electrical and Electronic Engineering has an exceptionally high proportion of postgraduate activity. The Manchester Centre for Electrical Energy (MCEE) combines the activities of the University's Electrical Energy and Power Systems (EEPS) Group and the Power Conversion (PC) Group. It has 19 academic staff with approximately 60 PhD students and 20 RAs and research staff. During the past 40 years, it has established itself as one of the longest continuously active university-based research centres in electrical power engineering anywhere in the world. The School houses the National Grid Centre for High Voltage Research and the Rolls Royce University Technology Centre in Electrical Engineering for Extreme Environments.

Power Conversion Group

Power electronics research at Manchester is principally based in the Power Conversion Group which is active in many areas, undertaking both fundamental and applied research that covers:

The Intelligent Electrical Power Networks Evaluation Facility (IEPNEF) Control Room

- Power Electronics Enabled Electrical Systems for Aircraft, Vehicles and Marine
- Wind Turbine Systems and Condition Monitoring
- Power Electronics in Powers Systems (HVDC, FACTS and Custom Power)
- Converter Circuits and Systems
- Motor Drivers and Actuators
- Superconducting Devices
- Supercapacitor and Battery-Based Energy Storage Systems

The Rolls-Royce UTC

Rolls-Royce opened a new University Technology Centre (UTC) at the University of Manchester in 2004 to pursue research into innovative electrical technologies for aerospace, marine and energy applications.

The Centre designs electrical systems for air, sea and land vehicles which operate in 'extreme environments' like those experienced by planes at altitudes of 60,000ft and by ships in freezing waters. The Centre houses a state of the art laboratory – the Intelligent Electrical Power Networks Evaluation Facility (IEPNEF) – in which all of these conditions can be tested.

This major Rolls-Royce £1M plus facility has been installed as part of a national project to devise and develop more-electric technologies for future aircraft, marine and land-based vehicles.

Testing on a Fuel-Cell Powered Taxi

Multi-Phase Marine Converter Testing

Univerza v Mariboru

FERI Fakulteta za elektrotehniko, računalništvo in informatiko

UNIVERSITY OF MARIBOR

Research Areas

Institute of Robotics is a part of the Faculty of Electric Engineering and Computer Science, University of Maribor, Slovenia. We are not simply a classroom university professors and lab-locked researchers, but always have a strong demand for proving our value outside of the environment and societies in which we cooperate.

The main focuses of our research work are in the fields of:

- Electric motors (control and modulations, high speed, sensorless),
- Power electronics inverters (DC-DC, DC-AC in AC-DC, control, measurements, simulations, thermal management, EMC, design of HF magnetic components),
- Alternative energy sources (photovoltaics, fuel cells, TEG),
- Mechatronics (robotics, haptics, position and force control),
- Automotive industry (processes, functional safety, batteries, BMS, power / energy management, drivetrains for EV and HEV),
- Rapid control prototyping (HIL systems, dynamic emulations of loads, model-based design),
- Programming (microcontrollers in C, Matlab, and SciLab; FPGA in Verilog and VHDL).

Our goal is and has always been to be a valuable partner of the industry and research groups, both local and international. We were and are involved in several international and local research projects, among which the following are the most important:

- HYSIS (Fuel Cell Hybrid Vehicle System Component Development, www.hysys.de, Coordinator: Daimler Chrysler, Germany),
- Hi-SEPS (Highly Integrated Combustion Electric Propulsion System, www.hi-ceps.eu, Coordinator: CRF, Italy),
- HYPSTAIR (Development and Validation of the Hybrid Propulsion System Components and Sub-System for Electrical Aircraft, www.hypstair.eu, Coordinator: Pipistrel, Slovenia),
- AUTOUNIVERSE (Automotive Quality Universities, Erasmus+, http://www.automotive-quality-universities.eu/, Coordinator: TU Ostrava, Czech Republic),
- EVA4green (Ecological Safe Vehicle for green mobility, Coordinator: SiEVA, Slovenia, Slovenian government funded).

Laboratory facilities

To ensure the high-quality research work and evaluation of research results, our group has at its disposal the following equipment:

- Spectrum analyzer,
- Single- and three-phase LISN (9 kHz – 30 MHz, suitable for AC and DC powered EUT),
- Single-path LISN (DC to 60 Hz),
- AC/DC current probes amplifiers (750 A peak),
- High voltage differential probes (200 MHz, slew rates up to 275 V/ns at 1/250 gain, ±1500 V),
- Circuit board plotter and plating system,
- Fuel cell (1.2 kW PEMFC),

- 3D printer,
- dSPACE system for testing electrical drives with induction machines,
- Bidirectional 50kW inverter system for 3ph AC electrical motors.
- DC-power source (0-600V, 0-16A, 0-10kW)
- AC or DC power source (1ph, 0-150V,55A; 3ph, 0-260V,18A; DC, 0-210V,30A)
- AC electronic load (Voltage 50-300V, 0-45A, Power 0-4.5kW, Resistance 1.11Ω-2.5kΩ.

Overview

IK4-IKERLAN is the leading Applied Technology Centre in Spain in terms of technology transfer rate to the industry (60% of our 19M€ income was generated by contract research with industry). With a staff of over 250 people, IK4-IKERLAN offers its clients R+D services spanning the entire innovation cycle, from the idea or concept to the industrialization stage, combining and integrating different cutting-edge technologies.

100kVA Full SiC converter

European Dimension

Since 1985, we have been increasingly active in the European Union Framework Programmes for R&D. During the whole of FP7 and H2020, we have participated in 43 funded projects, representing a total volume of 18,8M€ in grants. These projects have allowed us to collaborate with some of the finest research centres and universities in Europe, as well as with the most innovative companies, to jointly enhance the state-of-art in different fields of science and technology.

Power Electronics and Energy Storage

More than 30 full-time researchers (10 of them with a PhD) and 7 PhD students specialized in the design, development and materialization of power converters, electric machines and storage systems. With a clear solution-oriented and multidisciplinary approach (electrical, mechanical, SW, electronics, thermal engineering and control), the team has a vast experience on the design and development of customized solutions and systems integration for railway, elevation, renewable energy and power system industries. The main current research area is the multiparameter integration (reliability, availability, power density and cost) of:

- Power Electronics Converters: using latest semiconductors, such as SiC and GaN devices, and topologies.
- Magnetic Power Devices: medium-frequency medium-voltage transformers, inductive power transfer systems and permanent magnet synchronous machines.
- Electrical Energy Storage Systems: Li-ion battery and UltraCapacitor (UC) based systems (battery pack and BMS), including chargers, application-integration and control.

3kVA contactless battery charger

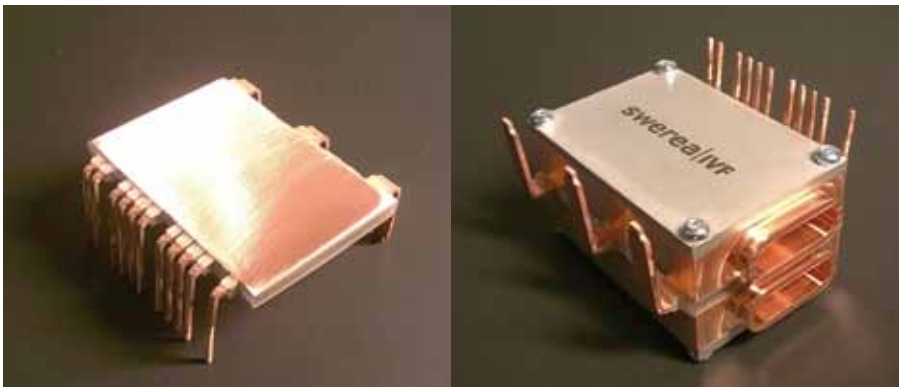
Some references

- Railway traction converters for 3kV/1.5kV and 750V catenary lines up to 1,5MVA (CAF)
- UC energy storage system for catenary-less tramways (CAF), elevators (ORONA) and Pitch system (GE)
- Up to 6MVA modular power converters for locomotives (CAF)
- 400kVA medium-frequency transformer (750V-3kV) for train-trams (CAF)
- Tramway converters using SiC devices (CAF)
- Li-ion energy storage system for grid-connected applications (CEGASA, ACCIONA)
- Grid-connected converters for electrical distribution enhancement up to 150kVA (ORMAZABAL)
- Traction converters for hybrid and full electric buses (VECTIA)
- Up to 50kVA contactless power transfer system (CAF)

6.5kV-750A IGBTs based Half Bridge module

SWEREA IVF AB

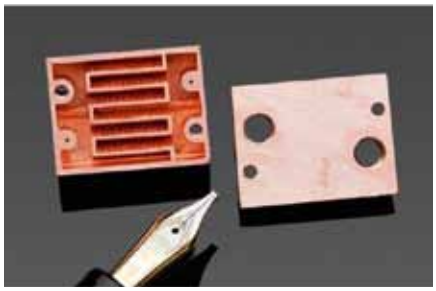
The research institute Swerea IVF is a subsidiary of the Swerea group, a conglomerate of Swedish research institutes within the fields of materials, process, product, and production technology. Swerea IVF's staff of about 150 carries out applied research, offer qualified research and consultancy services and have extensive experience of participating in international projects, as well as of initiating and coordinating them. The main goal of Swerea IVF is to assist in the rapid introduction of new technologies and methods to practical use in our customers' operations. Our customers include industrial companies as well as public institutions that turn to us to develop their future resource efficient products and processes.



SiC packaging concept with double sided cooling and water jet formed vias

Electronics Packaging and Reliability

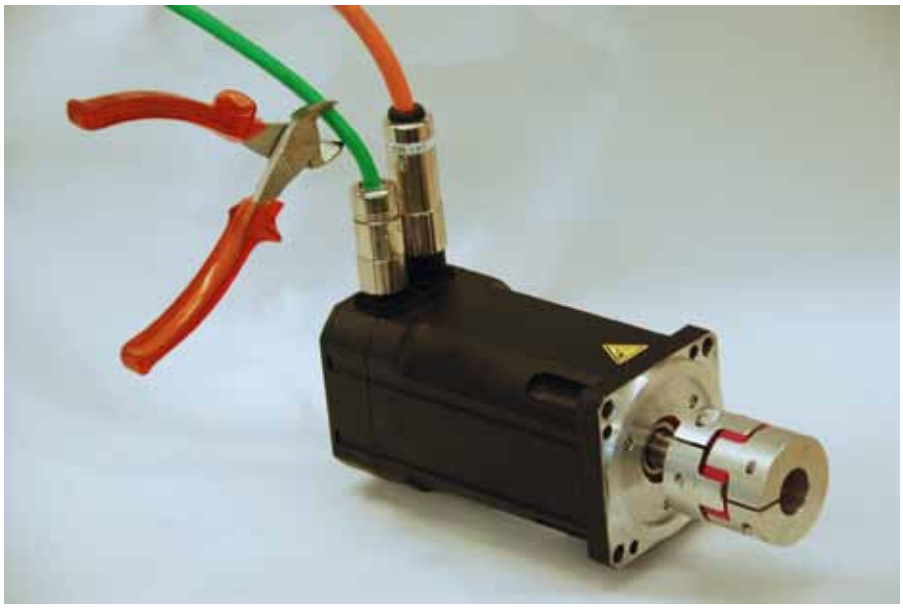
Swerea IVF has more than 25 years experience in electronics packaging and reliability. Materials and failure analysis, both on destructive and destructive, are important tools in the reliability assessment. To that end we maintain sample preparation, testing, and analysis labs including SEM, Scanning Acoustic Microscopy, and Micro Focus X-ray equipment. We assess the reliability of new packaging concepts in research projects as well as for specific products, notably field returns, at the request of individual companies.


Direct manufacturing from powder of Cu cooler for SiC application


Full 3-D freedom in part manufacturing

One example of a strong research effort is Swerea IVF's activities since 1997 in the area of Dye-sensitized solar cells and Perovskite solar cells which focus on the development of materials, manufacturing processes, upscaling and reliability testing of prototypes where we are working in a close collaboration with the Royal Institute of Technology in Stockholm (KTH), Uppsala University, and Dyenamo AB.

The Electronics group together with the ceramics experts in the Department of Materials performs research within the area of high performance electronics with ceramic packaging solutions. In the past 5 years the research has had strong focus on high temperature applications of GaN sensors, packaging of thermoelectric materials and SiC power electronics. Swerea IVF to this end works with additive direct manufacturing technologies for packaging which allows highly integrated power electronics and cooling solutions. Recent power electronics packaging research focuses on a solution with stacked structures that allows for double sided cooling. Swerea IVF was coordinator of the recently finished FP 7 project COSIVU, focusing on an electric wheel motor drive system with SiC power electronics.



Electrical Drive Systems and Power Electronics

Besides the typical topics of electrical drive systems, like the different types of electrical machines, their operation and control, the chair works also on sensorless control of electrical drives, on predictive control of converters and on Hardware-in-the-Loop-systems for Power Electronics.

The wide range of research and teaching areas makes the chair of Electrical Drive Systems and Power Electronics at Technische Universität München the best basis for a future-oriented education in terms of systems and drive engineering.

Key Research Fields & Competence Areas:

- Optimization strategies to identify mechatronical systems
- Non-linear, adaptive (time variant) control of mechatronic multivariable (multiple-input, multiple-output) control systems
- Sensorless control of Induction machines
- Predictive control of multilevel inverters
- Predictive control of Induction machines
- Flatness based predictive control of electrical drives

Institute Highlights:

- Great modern laboratory
- Hardware-in-the-Loop-systems for Power Electronics
- Practical education on modern hardware and software
- Brand new control and inverter technology
- Real-time-system for inverter control
- Broad performance capacity in the field of drive systems

Professor:

Ralph M. Kennel was born in 1955 at Kaiserslautern (Germany). In 1979 he got his diploma degree and in 1984 his Dr.-Ing. (Ph.D.) degree from the University of Kaiserslautern. Until 1999 he worked on several positions with Robert BOSCH GmbH (Germany). From 1994 to 1999 Dr. Kennel was appointed Visiting Professor at the University of Newcastle-upon-Tyne (England, UK). From 1999 - 2008 he was Professor for Electrical Machines and Drives at Wuppertal University (Germany). Since 2008 he is Professor for Electrical Drive systems and Power Electronics at Technische Universtät München. His main interests today are: Sensorless control of AC drives, predictive control of power electronics and Hardware-in-the-Loop systems.

Dr. Kennel is a Senior Member of IEEE, a Fellow of IEE and a Chartered Engineer in the UK. Within IEEE he is Treasurer of the Germany Section as well as ECCE Global Partnership Chair of the Power Electronics society (PELS).

IPEC is focused on High Power Converter Systems for application in

- Energy transmission and Energy distribution
- (Wind power, solar power, solar-thermic power, DC-Super grid)
- Large electric drives (Traction,electric ships, electric aircraft)
- Electric vehicle drives (LEV, electric passenger cars)

and new Converter architectures enabling

- Modular, scalable hardware
- Fault tolerant operation
- Fully digital control and integrated sensors

These systems are developed and investigated thoroughly with respect to industrial feasibility. The equipment at IPEC includes laboratories for investigation of High Power Converters up to 20kV in the MW-Range and Electric Drives up to 1kV in the 100kW-Range.

Advanced Multilevel-Converters for High- and Medium-Voltage

High Voltage Direct Current Transmission (HVDC) is becoming a key enabling technology for the integration of regenerative sources into the grid. While the conventional AC-Networks are getting more and more inefficient or unstable under the new conditons, an electronically controlled DC-Grid will be extremely valuable.

Advanced Multilevel-Converters are the most promising systems for these requirements. New concepts, suitable for these applications, are developed at IPEC (E.g.: Modular Multilevel Converter, M2C). Research is concentrated on industrial scalability, safety, fault tolerant operation and the digital control system. At the control side, the new systems offer vastly extended degrees of freedom. Therefore, many research projects are focused on new digital control schemes, for improved exploitation of these new possibilities.

Large Drives with Medium-Voltage represent another important field for Modular Multilevel Converters, applied e.g. for industrial drives and electric Ships.

Ultra light converters for mobile applications (MHF)

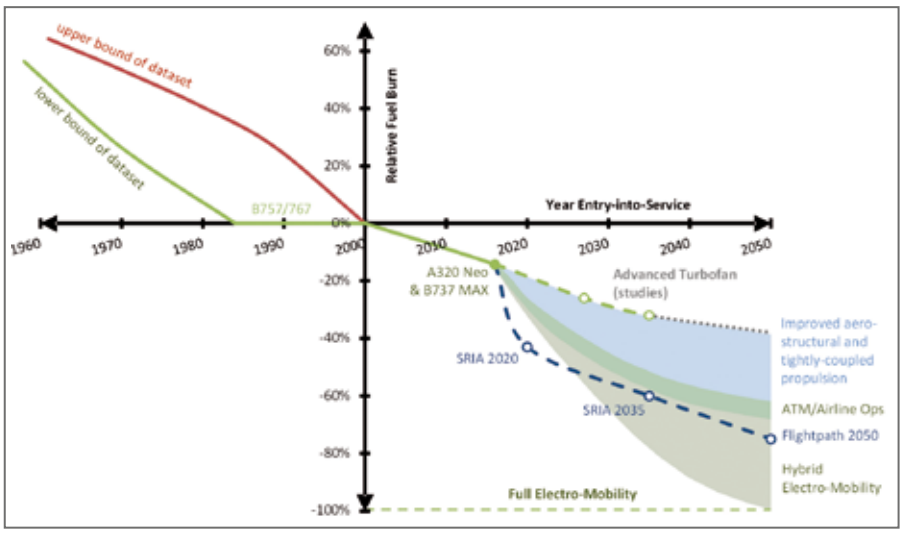
The successful development results of Multilevel-Converter for the High Power range has led to a significant extension of research projects , focused on mobile applications. In this area, industrial scalability ,modularity of the hardware and fault tolerant operation are very important, too. Additionally, ultra light weight and minimized space are essential points. These requirements are best met by new multilevel topologies, which allow for the elimination of passive filters. New converter topologies (MHF) enabling and integrated contol and sensors are developed and investigated in several research projects.

Interdisciplinary think-tank for the future of aviation

Bauhaus Luftfahrt is an interdisciplinary research institution funded by the four aerospace companies Airbus Group, Industrieanlagen-Betriebsgesellschaft (IABG), Liebherr-Aerospace and MTU Aero Engines as well as grants of the Bavarian Ministry for Economic Affairs, Media, Energy and Technology. The non-profit association is an internationally-oriented think tank. The team of around 50 employees deals with the future of mobility in general and with the future of air travel in particular. The goal of the research work is to consider the complex system of aviation from different points of view. In every project, the technical, economic, social and ecological aspects are considered holistically.

Energy technologies for future aircraft

A key research focus at Bauhaus Luftfahrt are novel energy and power conversion technologies that will help aviation realize the important emission savings imposed by political roadmaps such as Flightpath 2050. In particular, Bauhaus Luftfahrt is studying the potential of electrically powered flight: While at present universally-electric aircraft only exist in the ultra-light category, modern commercial airliners already have many more electric subsystems than their predecessors, with a future tendency to increase both electrical power levels and voltage ratings.



Aviation industry goals and technology options for future transport aircraft with ultra-low emissions.

Challenges to airborne power electronics

Evidently, to move from there into the power range of electric propulsion for passenger aircraft, important research questions must be addressed: Should the aircraft's power architecture rely on DC or AC components? How can the required redundancy levels be achieved? Which materials are most suitable to design power electronic controllers for MW-level electric motors? How can we improve or optimize power, weight and volume ratios within mobile applications? Researchers at Bauhaus Luftfahrt are working to address these questions from a fundamental point of view, using physics-based models of power electronic components and engineering knowledge of the aircraft as an integrated system to identify alternatives that could conceivably meet tomorrow's requirements. Strict attention is paid to the fact that visionary concepts and strategies are also always application-oriented and technically feasible, giving rise to concepts such as Bauhaus Luftfahrt's 2012 pre-concept study "Ce-Liner" of a universally-electric short-to-medium range aircraft for 189 passengers.

In 2012, Bauhaus Luftfahrt unveiled the pre-concept study "Ce-Liner" for a universally-electric short-to-medium range aircraft seating up to 189 passengers.

NEWCASTLE UNIVERSITY UPON TYNE

Newcastle University can trace its origins back to 1834 and is now in the top 1% of world universities (QS World Rankings). We are member of the Russell Group, the association of the 20 leading research-intensive UK universities and we have one of the largest European Union research portfolios in the UK. The Electrical Power Research Group (EP) is UK's most active academic research institution in research on novel electromagnetic devices, power-dense power electronics and derived systems, estimation and control methods and advanced smart grids. Research activities cover various applications such as small low-cost drives for household applications to high efficient high power multilevel converters. EP is very active in automotive, aerospace and smart grid applications, working closely together with OEMs, Tier 1 and Tier 2 suppliers on new cost-effective solutions. The Group comprises 14 members of academic staff, supported by approximately 22 Research Associates and 50 PhD students, with a strong record on publications, patents and exploitations. 60% of our project funding comes directly from industry and EP's role is to assist industry in the creation and maintenance of market lead new products.

High efficient drive for a solar powered plane

Power module for a fault tolerant drive

Example 1: Power dc/dc converter – Project ongoing. This project addresses the need to build smaller passive components for power dc/dc converters. Traditional techniques are making use of high switching frequency devices or are developing new materials to reduce the size of passive components. Regrettably, these solutions are leading to high cost and suffer from the unknown of reliability data. EP developed a step-change in designing dc/dc converters by introducing new design rules. These design rules led to a new and simple control method that keeps the output voltage and inductor current stable even at a reduced inductor size. Work presented so far shows a reduction in the inductor size of a dc/dc converter by 50% only by changing the control algorithm but without the use of new materials or increasing the switching frequency. Therefore this technique is seen as a cost-effective method to reduce the size and weight of passive components.

Example 2: Lifetime enhancement of power modules – Project ongoing. The lifetime of power modules is determined by the junction temperature cycle. In order to increase the lifetime the junction temperature swing must be reduced. EP has developed a power module adopter that can be placed between the baseplate of the power module and cooling element. This adopter is changing the local thermal impedance actively for each individual chip. This allows full active control of the junction temperature for each chip, thus reducing the temperature swing. A 30% reduction of the temperature swing can be observed with the potential to go up to 70%. The adopter communicates with the gate drive circuit directly and impinges the cooling fluid in a controlled manner without the use of a mechanical pump.

Inverter for a doubly-fed induction generator

The Power Electronics, Machines and Control (PEMC) Group is one of largest university centres of its kind worldwide with 16 academics (6 Full Professors, 3 Associate and 7 Assistant Professors) dedicated to the field. The research team also includes ca. 45 Postdoctoral Contract Research Fellows and 64 PhD students. Funding for the Group's research (current portfolio ca. €28M) comes from a diverse range of national/international agencies and industry. The Group coordinates the EPSRC National Centre for Power Electronics, a UK-wide activity supported by an investment of ca. €30M over 7 years including capital equipment and research funding.

The PEMC main research laboratory at University Park Campus.

Core technology expertise of the Group covers 4 main areas:

- Power Electronic Energy Conversion, Conditioning and Control
- Power Electronics Integration, Packaging, Thermal Management and Reliability
- Motor Drives and Motor Control
- Electrical Machines.

The Group strategy is to sustain an in-house, internationally renowned research capability and portfolio spanning the entire range from power device and component technology to complete power conversion systems. The PEMC Group collaborates closely with complementary groups at Nottingham, and with a number of other Groups in the UK and worldwide. Research activities cover basic technology (e.g. component physical characterisation and technology validation) to applied research (e.g. professionally engineered advanced technology demonstrator hardware for aerospace industries).

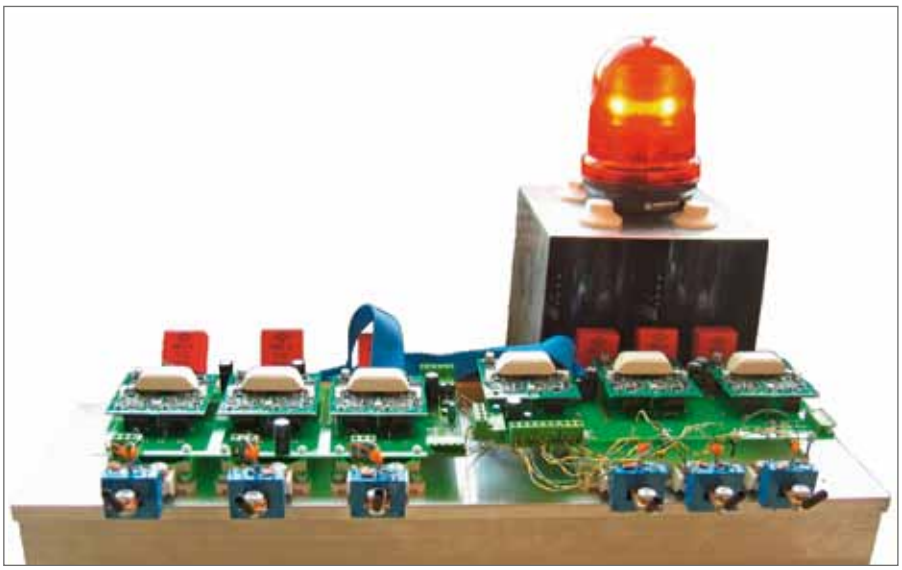
The PEMC Group has very strong links with industry, both nationally and internationally, ranging from component suppliers to OEMs, where it applies its core technology expertise to application oriented research. The portfolio of applications is currently orientated towards aerospace, renewable/sustainable energy and future energy networks, but it continually evolves to reflect new opportunities and challenges. Other significant industrial collaborations exist in marine systems, industrial drive systems and power conversion for high power RF sources.
Research in the Group is underpinned by world class experimental and workshop facilities allowing realistic practical validation of novel components and systems. Work up to 1MVA (continuous) is possible. State-of-the-art specialist facilities exist for power device and packaging research, as well as reliability studies, for in-house prototype electrical machine construction and testing (up to 120,000rpm) and for power converter construction. Dedicated electronic supplies provide emulation of aircraft generation systems up to 270kVA. Extensive modelling capabilities also exist with expertise in most of the established specialist simulation and CAD environments. Reflecting the Group's success, investments from internal and external sources for infrastructure developments and equipment have continued and increased, leading among others to the creation of a dedicated multi-disciplinary Aerospace Research Centre (ARC) and the FlexElec Laboratory, dedicated to research in microgrids and HVDC.

A team of Group members developed the winning 2015 MotoE series race bike!

TECHNISCHE HOCHSCHULE NÜRNBERG
INSTITUT ELSYS

UNIVERSITY OF APPLIED SCIENCES NUREMBERG, GEORG SIMON OHM

The Institute of Power Electronic Systems ELSYS at the University of applied Sciences Nuremberg, Georg Simon Ohm is headed by Prof. Norbert Grass and Prof. Armin Dietz and has about 20 employees. The Institute works in cooperative research and development projects with industrial partners. Main areas of work are **power electronic systems up to 300 kVA, control and diagnostics** and interfacing power electronic systems to **information technology**. With high efficiency and power management as well as power quality analysis ELSYS contributes to energy conservation and against global warming by means of power electronics. Students are involved in research projects, thus they are practically trained to work in industrial research projects.



Key Research Fields & Competence Areas

Platform Technology for Power Electronic Systems

- Power platforms up to 200 kVA, 1000 A
- Control platforms based on microcontrollers, DSPs and FPGA
- Object Oriented Control Framework for DSP
- Data communication modules

Power Electronics in the Loop and Drive-Test-Systems

- Electronic loads up to 200 kVA
- Dynamic load emulation
- Drive test benches up to 100 kW

Drive Systems, Smart Grids and E-Mobility

- Grid control and interfacing of vehicles
- Power quality issues
- High Efficiency Drives

Institute Highlights, Examples, Equipment

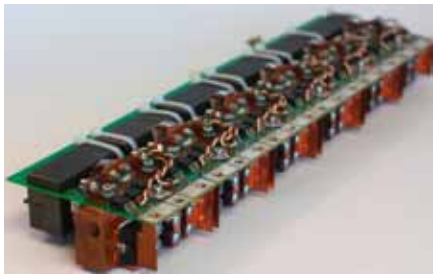
- High efficient electrical drives
- Control of Reactive Power and Harmonics in a real existing LV grid with integrated data communication
- Power electronic control and driver concepts
- Model based software development
- Texas Instruments DSP platform
- Infineon XC 167 and XC2000 platform
- Xilinx FPGA platform
- Equipment for power quality analysis
- IR camera for thermal design verification

Staff, Expertise & Research Areas

The team of scientific co-workers, senior engineers and technicians of about 20 persons is headed by Prof. Joachim Böcker. Before his appointment in 2003, Prof. Böcker gained 13 years of experience in industrial research and development with AEG and Daimler. The department is focusing on three main areas: power electronics, electrical drives and energy management. The nature of the projects varies from basic research to applied research in cooperation with various industrial partners.

Power Electronics

Challenges to be solved are application-specific energy conversion, control and distribution - always aiming to improve the system performance with respect to efficiency, volume, weight and dynamics. Currently considered applications are power supplies for data centres, electric spot welding, chargers for EVs/HEVs, DC/DC converters in power distribution systems, piezo electric drives and piezo electric assisted cutting and bonding applications.



Converter for electric spot welding

Thermal modelling of electrical drives

Main Topics

- Soft and hard switching techniques for isolating and non-isolating topologies
- Power semiconductors (Si, SiC, GaN) switching loss characterisation
- Control concepts for PFC rectifiers and resonant converters

Electrical Drives

Application areas cover traction drives for EVs/HEVs, servo drives for industrial applications, wind power generators and high speed drives for turbo compressors and machine tools.
Principal objectives are improvement of the drive system performance and optimized utilisation of energy and resources. Recently also the improvement of system reliability and safety level are targeted.

Main Topics

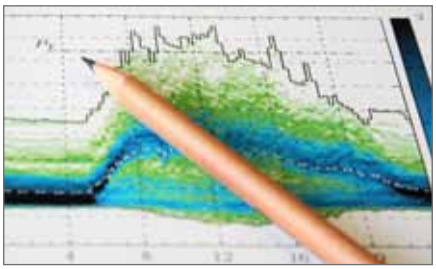
- Various controller (e.g. FOC, DTC, MPC) and observer concepts
- Modelling and simulation, HiL, dynamic co-simulation (FEA & time-domain)
- Thermal modelling and system identification
- Model-based fault detection and management (e.g. fault-tolerant control)

Energy Management

Aspects for reduction of supply costs, the increase of total system efficiency and in general the most economic use of energy are investigated.
Typical applications within the focus are: industrial microgrids, loads in the domestic area, EVs/HEVs and hybrid energy storage systems.

Main Topics

- Model predictive control
- Analysis and prediction of power profiles
- Optimal component/system dimensioning



Energy management

Laboratory

Well equipped with high-performance measuring equipment to solve different measurement challenges.

Electric Motor Test Beds

- Air-conditioned motor test cabin with load machines up to 250 kW
- RCP hardware (DSP/FPGA-based)
- Rotor telemetry system

Power Electronic Test Beds

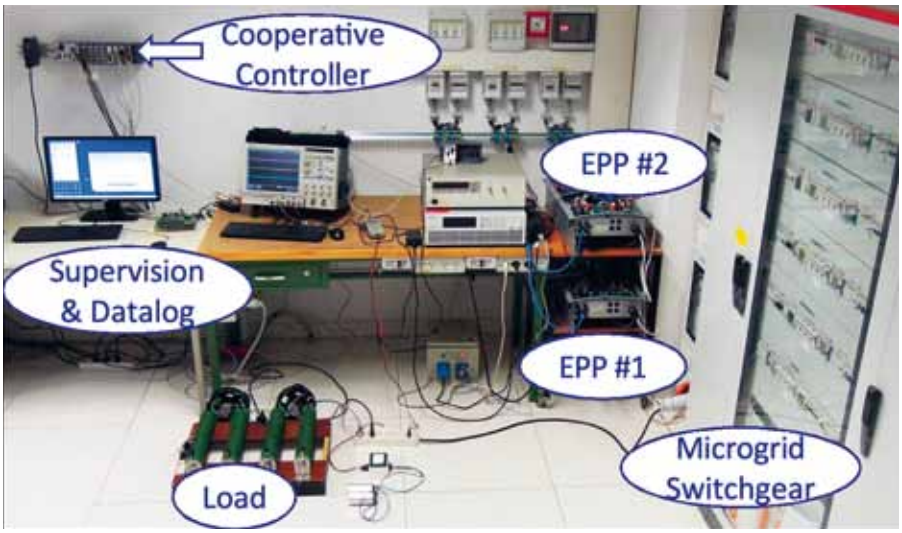
- Programmable power supplies/sinks
- Power semiconductor characterisation test beds
- Calorimetric power loss measurement

UNIVERSITÀ DEGLI STUDI DI PADOVA

UNIVERSITY OF PADOVA

Power Electronics Laboratory

The Power Electronics Laboratory (PEL) of the University of Padova performs state-of-art research in several areas of industrial and consumer power electronics. It has been active since the early 80's in development of topologies and control strategies for energy conversion. The research group includes three full professors, three associate professors and one assistant professor, plus several Ph.D. students and research fellows. Main current research areas are the following.



Power Device Technology

As new power devices appear, their performance characterization becomes a major research topic. PEL is particularly involved with reliability studies of new power semiconductors, i.e., SiC and GaN power devices as well as Si-based components.

Digital Control

Digital control of switching power supplies is a mainstream research topic at PEL, mainly targeting the study and development of fast, highly optimized and integration-oriented digital controllers for high-frequency DC/DC converters. Recent projects focus on digital control of automotive LED drivers with fast dimming capabilities, smart power management solutions for energy harvesting systems, and online efficiency optimization techniques for resonant topologies.

Renewable energy

Development of new converter topologies and control techniques for full exploitation of renewable energy sources is another key activity, with special focus on interface converters for photovoltaic generators, batteries and PEM fuel cells.

Solid State Lighting

Design of line-fed converters for lighting is a traditional research area for PEL. Recently, focus was on the development of novel converter solutions for LED lamps, in particular those based on high-frequency resonant converters.

Smart grids

PEL participates to a multi-disciplinary research team including experts in Power Systems, Control, Telecom, Economics, and Measurement. The group mission is to perform cutting-edge research on smart micro-grid technology, particularly on:

- Online and optimal policies for control of distributed micro-generation, real-time cooperative control of active elements, real-time power scheduling for distributed prosumers.
- Optimum control of distributed energy storage to meet grid requirements while maximizing the exploitation and lifetime of batteries.
- Real-time simulation and HIL testing real-time control algorithms in the smart micro-grid experimental facility.
- Communication paradigms for SG control and monitoring.

Activities of the Faculty of Electrical Engineering (FEE) are directed towards continuous development in research as well as in education. Full support is given to research grant applications and to prestigious research projects. Participation in EU projects and projects coordinated by the national technology centers is encouraged. FEE has a long standing tradition in cooperation with industry. Five faculty departments offer their research and development capacities, expertise and technical equipment to partners from industry in both the Czech Republic and abroad. The list of industrial and research references can be provided on demand.

At present, R&D activities at FEE are concentrated into a new research center **"Regional Innovation Centre for Electrical Engineering (RICE)"**. Construction of RICE infrastructure was funded from the European Regional Development Fund (ERDF) and started in October 2010 with budget of 25 mil. EUR. The centre offers excellent research infrastructure such as a medium-voltage hall laboratory/testing facility of power electronics and transportation systems for testing up to 31 kV / 4 MW, special laboratories focused on material research particularly in organic-based sensors, including a so-called "clean room", special microscopic laboratory, or X-ray diagnostics. Therefore, RICE is able to secure the whole research process – from basic research, through development, up to prototyping and full test coverage of functional samples.

Institute Highlights:

- Research on new drive concepts and advanced technologies for a new generation of transport systems with special regard to traction vehicles.
- Power electronics and electrical drives.
- Materials research with a main focus on organic-based electronics, smart sensors and multi-sensor systems.
- Control systems for transport technology and power engineering.
- Research on new equipment and technologies for more efficient energy conservation in the fields of power and heat generation, mining, heavy engineering industry and nuclear energy production.
- Development of advanced nuclear technologies, including, for example, special detectors used in nuclear power engineering and space research
- System diagnostics and identification – research and development of new diagnostic methods. Complex systems for automatic testing of equipment functionality and reliability
- Research and development of innovative solutions of physical fields and their mutual interactions.
- Certified test laboratory (EMC, etc.). Full test coverage during product development.

INSTITUTE OF INFORMATION THEORY AND AUTOMATION (UTIA)

Mission

The Institute is involved in fundamental as well as applied research in computer science, artificial intelligence, stochastic informatics, systems and control theory, signal and image processing, pattern recognition, and econometrics. It contributes to increasing the level of knowledge and education and to applications of research results in practice. The Institute publishes the journal Kybernetika.

UTIA's Building in Prague

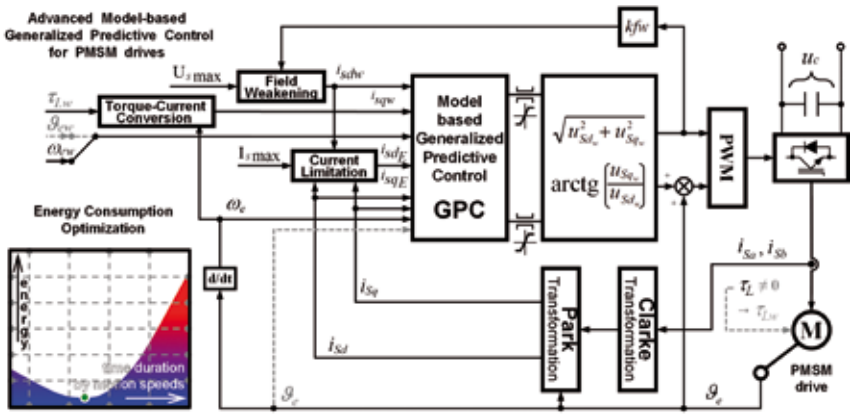
Key Relevant Research Fields and Competence Areas

- Control & Decision Making Theory: adaptive control, prediction and estimation for industrial applications.
- Signal Processing: digital processing, parallel algorithms and architectures, field-programmable gate arrays.
- Image Processing: image fusion, recognition, content-based retrieval.
- Pattern Recognition: statistical model – based pattern recognition, modelling of random fields for scene interpretation.

The interplay between theory and limited computing power is the common issue linking various domains.

Institute Highlights

- Wide international cooperation activities, EU-funded projects, bilateral agreements & contracts: http://www.utia.cz/grants
- Long-term R&D in concepts, theory, algorithms, software & applications: http://www.utia.cz/research



Adaptive Systems

The Adaptive Systems' Department focuses predominantly on the design of decision-making systems. Decades of research have brought a lot of conceptual, theoretical, and algorithmic results. This "know-how" serves to resolve national and international research projects with industry and government partners: http://www.utia.cz/AS/partners

The topics of interest include control of technological processes, drive control, industrial robotics, and automotive applications with focus on system modelling, data analysis and estimation. The applicability of adaptive systems is currently being extended towards complex scenarios of adaptive systems in accord with the main stream of the research towards decentralized control of large-scale systems and normative decision-making.

Dynamometer with rated power of 160 kW in Laboratory of Power Electronics

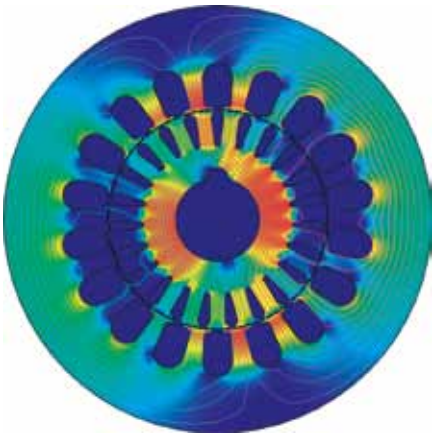
Department of Electrical Engineering and Electrophysics

The Department of Electrical Engineering and Electrophysics of the Institute of Thermomechanics AS CR, v. v. i. is engaged in the analysis and modeling of electric drives and rotating machines along with the experimental verification of the achieved results. The most important methods for the conversion of mechanical energy into electrical energy and vice versa are analyzed. Research is also focused on current problems connected with the circuit structures of power electronic converters and algorithms of the digital control and diagnostics of these converters. The mutual effects of power electronic converters with both the machines that are supplied from them and the supply networks to which they are connected are analyzed.

Considerable attention has been paid to systems with multi-phase machines in recent years. The use of such machines can lead to improving the energy efficiency and the reliability of electric drives. The goal of increasing the reliability of variable-speed drives is to propose measures for keeping the drive in operation even if some of its components fail. A related area of research is the compensation of unbalanced three-phase power supplies of semiconductor converters that can, in practice, result in the significant deterioration of the operating characteristics of electric drives.

Advanced control algorithms of AC drives are developed and tested experimentally with prospective utilization in industry and traction. A power supply from multilevel frequency converters is developed for these drives. Studies focus on the unfavorable high-frequency phenomena (EMI) due to operation of the converters. Models of the individual components of the drives, also valid for high frequencies, are proposed and experimentally verified. As far as the electromagnetic compatibility (EMC) in electric power engineering and the quality of electrical energy are concerned, algorithms are developed to control the active power filters with the goal being to compensate for higher harmonics, unbalanced loads, power factor and flicker, and to control energy flows in transmission, distribution, and industrial networks.

The Department has at its disposal several laboratories for measurement on electric machines and drives up to the output of 160 kW. The laboratories are equipped with several dynamometers, a number of high-quality measuring devices and modular control systems as well as with equipment for EMC measurements.



Modeling of magnetic field distribution in electric machine

ROBERT BOSCH CENTER FOR POWER ELECTRONICS – RBZ

Exterior view of the rbz in Reutlingen

The rbz – a research and teaching network

The Robert Bosch Center for Power Electronics (rbz) is a research and teaching network established in 2009 in which the Bosch Group, Reutlingen University and the University of Stuttgart have joined forces. This unique cooperation is the first of its kind in Germany.

In order to set up and operate the rbz, the Bosch Group, the state of Baden-Württemberg and the universities committed themselves to invest more than 30 million Euros over the next ten years for new chairs and infrastructure. The Robert Bosch Center for Power Electronics has branches in Reutlingen and Stuttgart. At the rbz students can take Bachelor's and Master's degree programs that focus on power- and microelectronics. They can study in Stuttgart or Reutlingen, depending on the program chosen. There is also the possibility of studying for a doctorate.

The rbz in Reutlingen

At the rbz in Reutlingen three new chairs have been established. These professors are responsible for teaching in the Master's program for Power Electronics and Microelectronics as well as for conducting research in these fields.

Prof. Dr.-Ing. Martin Pfost, professor for Power Electronics, was working for eleven years at Infineon Technologies in Munich and Bucharest at different positions in GaAs-, SiGe- and Si-power-technology modeling and safe operating area simulation.

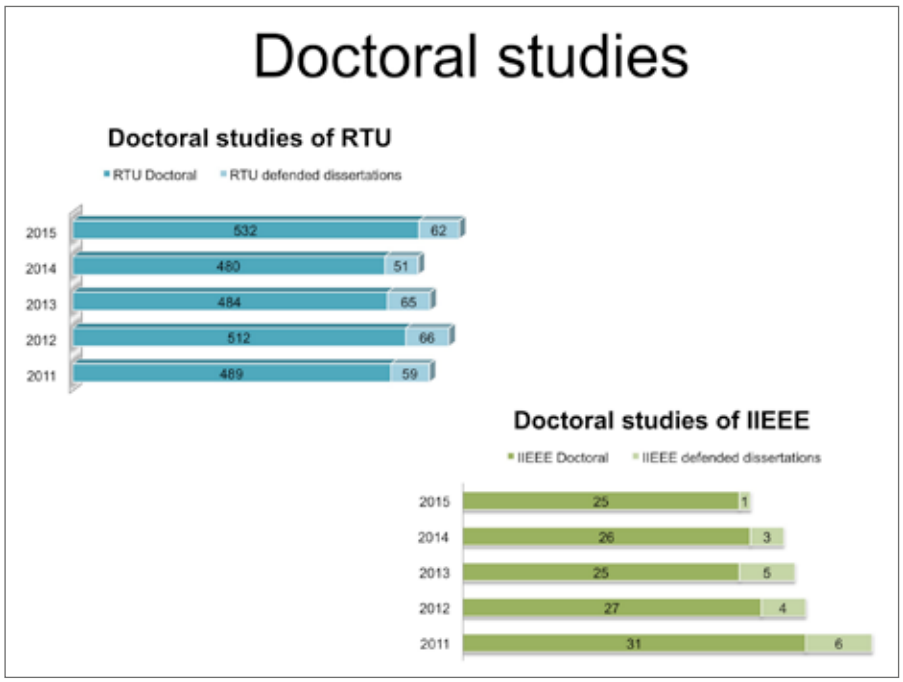
Prof. Dr.-Ing. Jürgen Scheible, professor for Electronic Design Automation, gained over 18 years of working experience at Robert Bosch GmbH where he was in charge of layout design and methodology, improvement of design flows, tool management and ASIC layout design.

Prof. Dr.-Ing. Bernhard Wicht, professor for Integrated Circuit Design, also came straight from the industry. At Texas Instruments, Freising, he was working as analog ASIC designer and design manager for power & networking.

Their research interests comprise characterization, modeling, and optimization of power semiconductors and power electronic systems, methods for automation of ASIC layout design, IC design with focus on power management, gate drivers, motor control, energy efficiency, low-power, ESD and EMC. Many research projects from these fields have already been started. Some are concerned with the prediction of safe operating area and lifetime modeling of advanced power semiconductors. Other projects deal with improved layout generators and constraint-driven design methodologies, DC converters operating in the MHz range as well as optimized gate drivers. More topics not mentioned here are addressed in ongoing research activities.


Students working in one of the laboratories

More than 20 Ph.D. students are involved in several research projects, projects with public funding and in collaboration with industry. Further growth is expected.



Starting from 1987 Institute's of Industrial Electronics and Electrical Engineering is one of biggest among 35 institutes of Riga Technical University.

Main research lines:

- Energy-saving multifunctional energy converters and their control systems;
- Smart transport systems and their control;
- Smart electrical technologies and energy-efficient production automation.

Institute annually publishes 80 to 90 scientific articles; arranges RTUCON annual international scientific conference; issues periodical scientific journal „Electrical, Control and Communication Engineering"; has realized more than 25 projects, fulfilled industrial research tasks.

IIEEE collaborates with other scientific institutions industrie enterprises all over the world.

Institute of Industrial Electronics and Electrical Technologies carries out professional studies within bachelor's master's and doctoral programmes in smart elektrotechnology specialties:

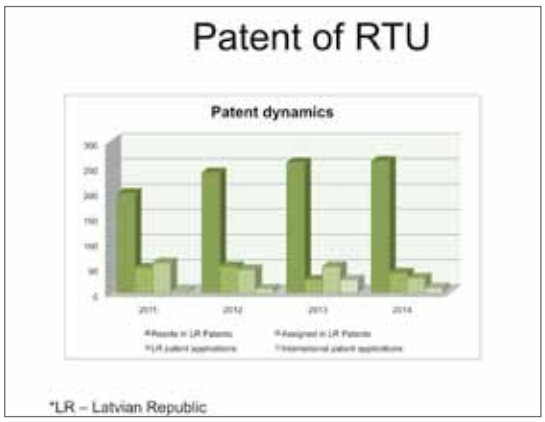
- Adaptronics;
- Computer control of electrical technologies.

Our researchers continuously develop and create a new knowledge in all types of converters, energy flow measurement and IKT application programs for optimal reduction of losses.

Various „electronic transformers" are used in DC micronetworks that operate in existing AC networks environment. There were few and still are ongoing some big and noticeable projects.

For example:

- In October enden project Development of Training Network for Improving Education in Energy Saving. The projec contributed education process in such aspects of this topics energy saving like enhancement of energy efficiency, use of renewable sources. Project's coordinator – Riga Technical University.
- Automation and Robotics for EUropean Sustainable manufacturing (AREUS) are still on run and include ten partner organizations from Germany, Sweden, Finland, Denmark and Latvia. Aim is to develop smart, green solutions for industrial robotics – and demonstrate their viability for industrial production with great efficiency in energy and cost reduction while incurring the lowest possible eco-footprints!



ROMA TRE
UNIVERSITÀ DEGLI STUDI

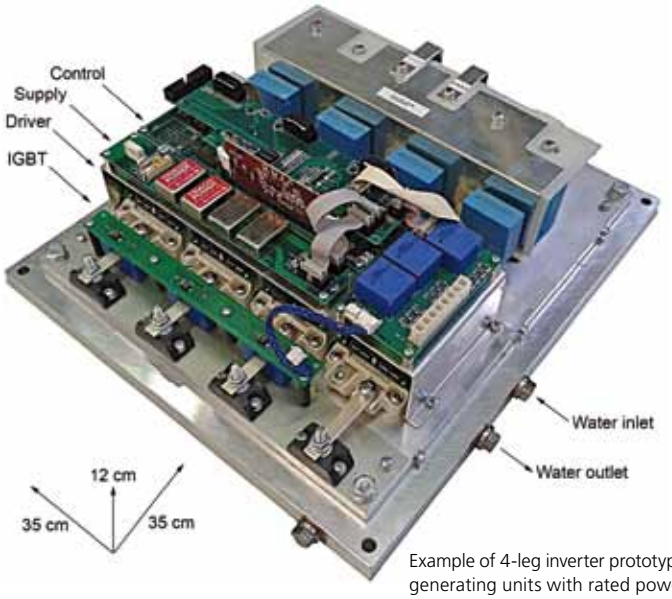
PED LAB OF UNIVERSITA' DEGLI STUDI ROMA TRE

Research Areas

The Power Electronics and Electric Drives (PED) Laboratory is one of the main important laboratory facilities of the Department of Engineering at the University Roma Tre.

The main interests and research activities being carried on within the areas of Power Electronics and Electrical Drives relate to the design and control of power electronic converters, electrical machines and drives for both propulsion systems and distributed electric power generation. In particular, the activities refer to several themes being linked each other as the study of novel algorithms for the implementation of electrical drives regulation and control systems, design and prototypal construction of power electronic converters for both grid connected and stand alone applications, investigation of optimal criteria for thermal and electromagnetic design of both conventional and axial-flux permanent-magnet synchronous machines, analysis and experimental testing of electromagnetic compatibility in electric drives.

Recent advances and trends in power electronics are focused on integration of devices as well of functions, reduction of weight, size and cost, and improvement of systems efficiency. To this purposes at the PED Lab research is addressed to high-frequency, high-efficiency power converter technology, advanced analog and digital control techniques, high performance electric drives design for power management and other applications.

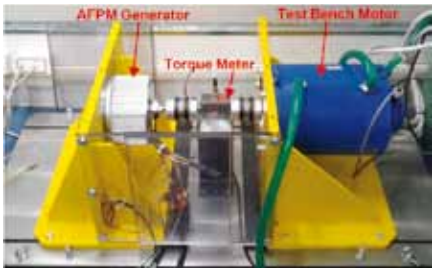


Example of 4-leg inverter prototype for distributed generating units with rated power of 40 kVA

The research activities are typically performed in strong connection with either private companies or research centers, the achieved results have been published through numerous scientific papers on the most recognized international journals as well
conference proceedings.

Laboratory Facilities

The laboratory is fully furnished with powermeters, digital scopes, thermal analyzers to perform experimental testing with controlled energy sources in both AC and DC and the following main equipment



High Speed Electric Drives test bench

- Electric Drives test bench with 4-quadrant 3-phase front-end power converter, rated 6000 rev/min, 60kW, 400Nm up to 1500 rev/min.
- High Speed Electric Drives test bench with 4-quadrant 3-phase front-end power converter, rated 20000 rev/min, 40Nm.
- 0-200kW resistive and non-linear loads.
- 16.7F – 252V supercapacitors tank.
- Fully equipped EMC chamber.

The Institute of Electrical Power Engineering at the University of Rostock is engaged in extensive research in the area of medium and high power semiconductors and their application in inverters for electrical drives and energy transmission. An excellent equipped laboratory with newest test benches, measuring techniques and state-of-the-art simulation tools offers research on emerging topics like Silicon Carbide, Reverse-Conducting IGBTs, multilevel inverters, HVDC grids and inverters, grid stability and control and hybrid vehicles. Currently fifteen scientific employees are exploring exciting topics in the area of power electronics. Some research topics are:

- Power Semiconductors: electrical and thermal characterization of Reverse-Conducting IGBTs, detailed analysis of the switching behavior of IGBTs like self-turn on/off, short-circuit behavior of IGBTs and diodes especially in inverter operation, switching behavior of Silicon Carbide MOSFETs/JFETs and their application in modules, lifetime estimation in wind power applications, device simulation
- HV gate drive units: design of special high-voltage (up to 6,5 kV) gate drive units, advanced gate drives with FPGAs for Reverse-Conducting IGBTs, gate drives for improved short-circuit behavior
- Multilevel/HVDC: hardware-based inverter control with scaled low-voltage test benches of multilevel inverters (3L-(A/AA)NPC, 3L-T-Type, C5LC, Hybrid 7L), modulation of modular multilevel converters
- Influence of inverters on the grid: improved inverter control for offshore grids, Fault Ride Through behavior of wind generators with 50 kW test bench, grid oscillations with electronic loads, scaled low-voltage grid with several wind generators and HVDCs
- Automotive drive test bench: 400 V hybrid test bench with dSpace engine/inverter control and load machine, 48 V/15 kW test bench for mild hybrid engines
- Education and training of succeeding electrical engineers (B.Sc., M.Sc., PhD)

UNIVERSITY OF SEVILLE

The University of Seville Power Electronics Group

The Power Electronics Group (PEG) is a Research Laboratory that belongs to the Electronic Technology Group (GTE) of the University of Seville (Spain). The PEG is an international research centre for power electronics and industrial applications. The Group is formed by around 8 academic staff, 4 post-doctoral and PhD researchers, and a grant portfolio of €3M. Its strategy focuses on the energy and transportation sectors with an important activity in the renewable energy fields. The activities range from basic technology research to applied research, culminating with industrial prototypes development.

Our main R+D topics are:

- Power Converter Topologies and Control
- Power Electronics for the Integration of Renewable Energy Systems
- Grid codes requirements
- Energy Storage Systems: Last generation batteries, supercapacitors, flywheels
- Transmission, Distribution and Micro-Grid Power Electronics (HVDC, FACTS)
- Power Electronics for Electrical and Hybrid Vehicles Transportation Systems
- Aerospace Applications

We can highlight facilities such as:

- Wind Power Test Bench
- Photovoltaic Inverters Test Bench
- Fuel Cell Conditioning Test Bench
- Flywheel Test Bench
- New Technology Batteries
- FACTS. Test Bench (UPFC, STATCOM, Active Filter)
- HVDC IGBT based (1MW on schedule)
- Several Multilevel Converters (NPC, Cascade, Multiphase)

The power electronics group at KTH currently has two seniors, prof. Hans-Peter Nee and assoc. prof. Staffan Norrga. In addition, a number of adjoint faculty members from industry contribute to research and teaching, and also serve as a link between KTH and our industrial partners. There are typically 10-15 Ph. D. students and postdoctoral researchers in the group. Our research activities mainly fall in two categories – high power electronics and wide bandgap power semiconductor applications.

High power electronics

High power electronics concern large scale power conversion with converters in the range of tens of megawatts up to gigawatts. Typical applications range from large motor drives and railway power supplies to high voltage direct current (HVDC) links used for long distance power transmission.

KTH has for many decades conducted research into this field, starting out already in the era of mercury-arc valves. In later years, research has been focused on modular multilevel converters (MMCs) since

these are rapidly being adopted in many applications that are important for our industrial partners.

System aspects of MMCs are studied in several projects. This includes research into several new converter topologies, for instance to allow for the converters to be compatible with HVDC grids. Also control and modulation of MMCs is investigated by the group. Schemes enabling lower losses and increased performance have been devised and verified by experiments on down-scaled prototypes.

The group is also investigating alternative semiconductor choices for high power converters. One track concerns converter cells based on gate commutated thyristors (GCTs), which can offer great benefits in terms of cost and power losses. Our lab enables full-scale testing of converter cells up to several MVA.

Wide-bandgap power semiconductor applications

The group has been performing research on silicon carbide (SiC) power electronics for almost 20 years. Topics that have been covered include: inverters employing massive parallel connection and diode-less operation, gate drivers for various devices including solutions for normally-ON devices, short-circuit protection of SiC transistors, investigations regarding various reliability issues of SiC MOSFETs. Also, power electronics for operation at extreme temperatures – beyond 600 C – is being studied. Furthermore, the study of high-voltage devices in SiC has recently been initiated. The work is organized as two parallel activities, where one is focused on modelling and testing of devices, and the other is focused on submodule design for high-power, high-voltage converters. Both activities are still in the build-up phase, but preliminary results indicate that bipolar devices with ratings of 30 kV can provide significant advantages both from a loss perspective and by reducing the complexity of the converter. Great reductions in converter size are also foreseen.

Universität Stuttgart

Institut für Leistungselektronik und Elektrische Antriebe ILEA

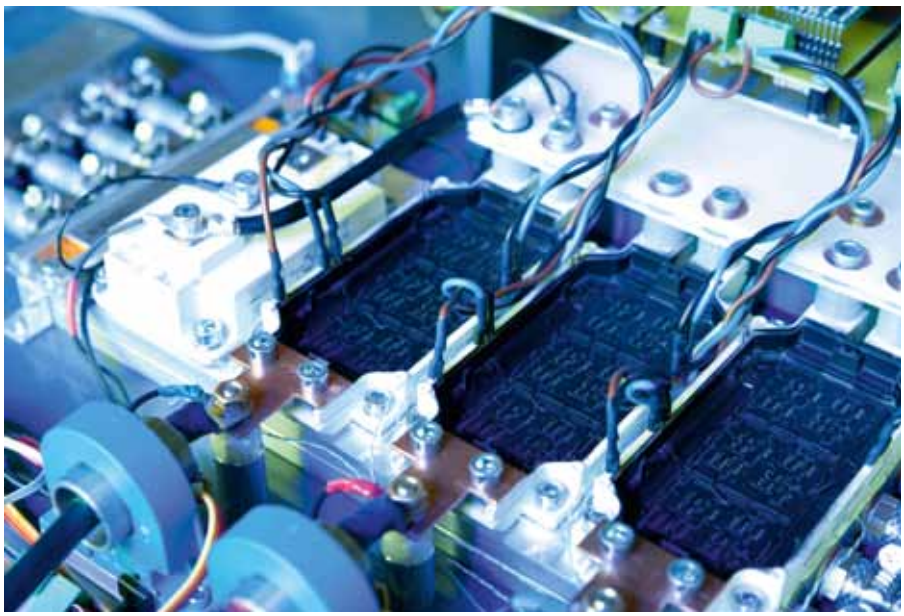
INSTITUTE FOR POWER ELECTRONICS AND ELECTRICAL DRIVES UNIVERSITY OF STUTTGART

Research and education

The Institute for Power Electronics and Electrical Drives is in the faculty of computer science and electrical engineering, University of Stuttgart, responsible for the subjects power electronic, automatic control and electrical drives in research and education. Actual focused topics in the scientific activities are

- Power electronics and electrical drives for automotive traction applications,
- Methods for sensorless position measuring at electrical machines,
- Energy efficient drives in industrial automation,
- Reliability of power electronic systems,
- Circuit topologies and advanced modulation schemes for power converters and special current sources for technical processes,
- Power electronic emulation of electrical machines and power line systems,
- Contactless power transmission systems for mobile applications,
- High current sensors with excellent dynamic performance.

In the mentioned fields the scientific staff possess many years of experience in research and development, both in industrial as well as scientific environment. Research outcome is continuously published at conferences and journals and becomes part of education. The institute is part of the Robert Bosch Centre for Power Electronics (RBZ).



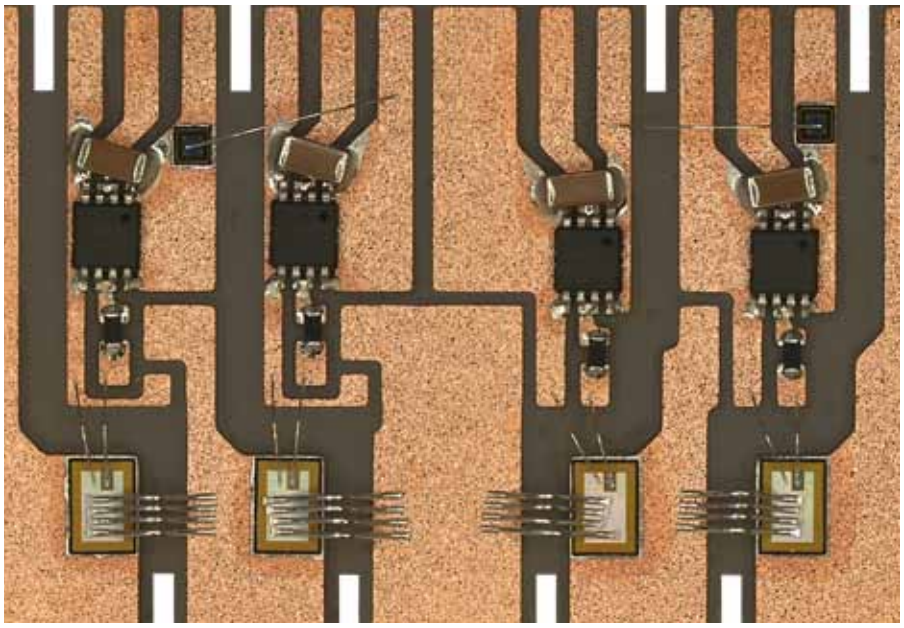
Experiment to analyse the thermal behaviour of the power semiconductors in an automotive traction inverter

Technical facilities

The Institute for Power Electronics and Electrical Drives is equipped with

- Laboratory with ca. 20 workplaces for research and education,
- Laboratory for electrical drives with rated power up to 250 kW,
- Heating oven for thermal measurement and analysis
- Software-tool for simulation in time- and frequency domain
- Multiphysics FEM simulation-tool
- Development tools for microprocessor- and DSP systems
- Development tools for programmable logic devices
- CAD-Tool for circuit design and PCB routing
- Workstation for SMT assembling
- Laboratory workshop, equipped for manufacturing prototypes of electrical machines, heat sinks and precision components for sensors.

Test bench for a high speed drive

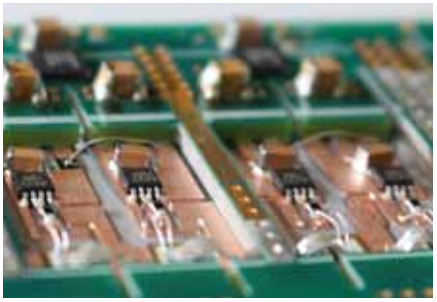


"Multi-chip-module (MCM)":
Full bridge (1.2kV SiC MOSFETs), gate drivers and bootstrap supply on an AlN DBC substrate.

The Institute of Robust Power Semiconductor Systems (ILH) has been established in 2013 at the University of Stuttgart in the frame of the Robert Bosch Center for Power Electronics (rbz).

The ILH conducts research on power semiconductor integrated circuits and modules using wide bandgap power semiconductors (GaN, SiC) with a focus on:

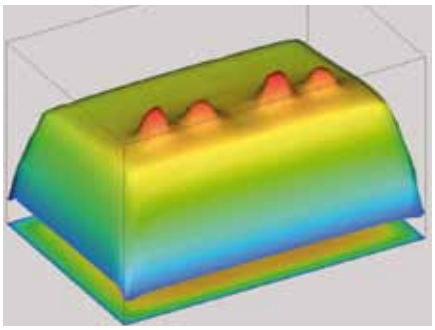
- Characterization and modeling of power semiconductor devices
- Integration, packaging and assembly of power semiconductor circuits and modules
- Efficiency, power density and robustness of power semiconductor systems.



Multi-chip-module (MCM) soldered on a printed circuit board (PCB) for low-inductive connection of dc-link for fast-switching converters.

Characterization and Modeling

The ILH concentrates research on development of equivalent circuit based transistor models for SiC and GaN power devices. Characterization and modeling of the static and dynamic characteristics of modern wide bandgap power semiconductors is a key requirement for the successful design of power converters, integrated circuits and systems. In addition to electrical simulation, electro-thermal co-simulation improves the simulation and design of power modules and systems.



Electro-thermal co-simulation of full bridge multi-chip-module.

Integration, Packaging and Assembly Technology

High power density and high switching frequencies impose stringent requirements on packaging technologies. By appropriate approaches such as 3D packaging, parasitic effects that are caused by packages, substrates and layouts, can be systematically influenced and reduced.

Efficiency, Power Density and Robustness

Approaches to increase the power density are the hybrid and monolithic integration of gate-driver and power converter circuits, as well as active and passive components. To ensure robustness of the systems, the thermal behavior and EMC of power modules is studied and optimized.

TALLINN UNIVERSITY OF TECHNOLOGY

POWER GROUP ELECTRONICS

TALLINN UNIVERSITY OF TECHNOLOGY

Power Electronics Group
Department of Electrical Engineering
Tallinn University of Technology

Research in the Group is focused on the development and experimental validation of new state of the art power electronic converters for such demanding applications as renewable energy systems, rolling stock, automotive and telecom. Key research directions include synthesis of new converter topologies, development of special control and protection algorithms, implementation of new components and elaboration of design guidelines to further improve the efficiency, power density, reliability and flexibility of the on-market power electronic converters. Other research activities are concentrated on the development of power flow control algorithms and new supervision, fault detection, protection and communication methods for the electronic power distribution grids (Micro- and SmartGrids).

Key Research Fields & Competence Areas:

Research and development of power electronic converters for renewable energy systems:

- Power conditioning units for fuel cells and solar panels
- Integrated multiport converters for hydrogen based long- term energy storages
- Power electronic transformers (solid state transformers)
- Interface converters for small- or medium-scale wind turbines

Research and development of power electronic converters and auxiliary systems for rolling stock applications:

- Traction and auxiliary converters for light rail vehicles
- High-voltage IGBT based converters for electric and diesel-electric locomotives and/or trains
- Remote control, diagnostics and data communication systems

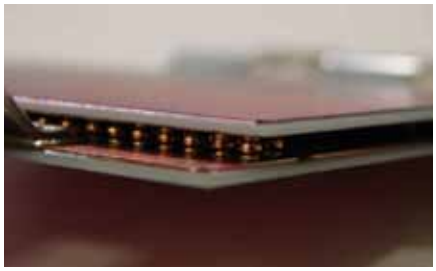
Research of advanced converter topologies (Z-source converters, high gain step-up converters, etc.) and state of the art components (SiC, GaN and GaAs semiconductors), planar magnetics, high-voltage IGBTs, etc.

Our Highlights:

- Well experienced and dynamic team of young researchers and engineers
- Long-lasting experience in applied design of power electronic converters for different power ranges and applications
- Strong relations and cooperation with Estonian and Baltic industrial companies
- Strong relations with European universities and research institutions
- Modern laboratory facilities and infrastructure:
  - Small-scale Microgrid with alternative and renewable energy sources for research and teaching
  - Fast prototyping tools for speedy assembling and experimental verification of new ideas and concepts
  - EMC laboratory
  - Up-to-date simulation tools
- Project-based PhD programs with research oriented theses
- Active participation in EU funded programs and joint research projects

PRIMES has been identified as a platform of the competitiveness center Aerospace Valley in order to enhance the strengths of the area specializing in the industry of embedded systems.

Industrial members are gathered in an « association Loi 1901 », linked by a permanent contract to academic laboratories. PRIMES offers means to industrial companies: ALSTOM Transport, EADS IW, SAFRAN, Schneider Electric, and SMEs: SCT, CIRTEM, Boostec, Aquitaine Electronic, CISSOID, TM4, CALYOS, aPSI3D, and French academic laboratories: LGP, LAPLACE, LAAS, Latep and CIRIMAT.



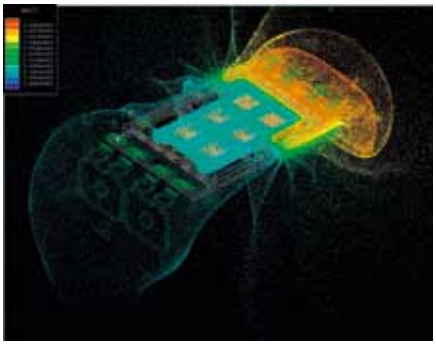
The main objectives of PRIMES are these two fundamental topics:

- Technology of **integration** of power converters (Design and manufacturing of demonstrator; Validation of basic technologies; Integration numeric-power);
- **Architecture**, system and technology management for electrical energy storage in fixed or onboard systems.

PRIMES is succeeding to the **PEARL** Laboratory and take the benefit of its 10 last years of experience in applied research as well as in the use of very highly equipped platform.

One of the major challenges for Primes is to enable the maturity of new industrial channel aiming at the manufacturing of new wide gap components that could be sold to the transport Industries (aeronautics, railway, automotive) as well as to the industrials dealing with the management of energy, with facilities to design, develop and test integrated power converters and test power systems like traction drives or any inboard systems.
In particular, PRIMES puts a huge effort in developing virtual **prototyping** solutions for power electronic systems, combined to a prototyping and characterization platform to be able to **design, simulate, manufacture** and **characterize** new power module technologies.

In a technological point of view, PRIMES has developed several integration technologies, for insulating or conductive materials to electrical system topologies. PRIMES has experience and is certified for the industrial development of power switches for avionic/aerospace applications and be confident with innovative interconnect, packaging and cooling solutions. PRIMES includes a power switch manufacturer of proven experience in the avionic domain (linked to AeroSpace Valley competitively Pole), and is equipped and resourced to provide the type and number of innovative power modules required for any program.



PRIMES is a key platform for power integration innovations in Europe.

POWER ELECTRONICS INNOVATION CENTER OF POLITECNICO DI TORINO (POLITO)

Mission

The Power Electronics Innovation Center (PEIC) main goal is to provide efficient and reliable power conversion solutions for strategic applications, such as hybrid and electrical vehicles, infrastructures for electrical battery charging, more electric aircraft, electrical energy production from renewables and advanced production systems for industry.

Description

The PEIC is a newly created inter-departmental laboratory located in five POLITO departments (Energy, Electronic and Telecommunications, Mechanical and Aerospace Engineering, Applied Science and Technology and Control and Computer Engineering). The PEIC team consists of 60 researchers belonging to different cultural areas. As a result, the center will rely on a common ground of multi-disciplinary knowledge and testing environment.

WBG converter prototype for the transmitter coil of a wireless charger while driving.

Research Topics

- Wide-band gap (WBG) converters, having high power density, efficiency and reliability at a competitive cost and complaint with the EMC constraints.
- 3D integration of power electronics in electromagnetic actuators for electromechanical energy conversion systems
- Power devices and modules packaging technologies, sensor integration and electromagnetic-thermal-mechanical modeling and simulation.
- Internet of Power (IoP) applied to power converters open to the cloud by means of innovative bidirectional optical transmission.
- Reliability of power electronic components and converters and dependability of power conversion systems.
- Modeling and simulation of electrical energy systems.
- Electromagnetic compatibility
- Systems on Chip (SoC) and integrated circuits for smart power.
- Sensorless control and plug-in control of electrical drives.
- Advanced testing of motor drives.
- Diagnostics and prognostics of electromechanical systems.
- Design of electrical machines and actuators, including mechanical gearbox.

Test rig for testing of electrical motors.

Academic –Industry Cooperation

The PEIC gives a particular attention to national and international collaborations with universities, companies and other engineering organizations. The PEIC members have an important experience in technology transfer to companies for new products.

750 kVA inverter for testing of aircraft generators.

Education

Politecnico di Torino is a leading technical university in Italy and it has a recognized position in electrical and electronic engineering. The PEIC will have a decisive impact on the PhD education and in general on the training of future experts in power electronics.

Laboratory facilities

The PEIC will invest in the next two years about 2 million Euros on key testing equipment that will be integrated with the existing one in the following laboratories:

- Enertronica laboratory.
- Power electronics laboratory.
- Servo actuators laboratory.
- Materials and microsystems laboratory.
- Microelectronics EMC laboratory
- Optical transmission laboratory.

Materials and Microsystems Lab cleanroom.

High Bandwidth hysteresisgraph for characterization of 1D and 2D iron losses in soft magnetic materials

About IRT

Institute for Technological Research (IRT) Saint-Exupéry is part of the IRT Initiative launched in France to boost high value competitive technological sectors.
IRT Saint-Exupéry is an interdisciplinary thematic institute that develops economic sectors related to aerospace and embedded systems through a balanced strategic public-private partnership. For this, it manages research programs coupled with technology platforms, conducts research and development projects at international level; contributes to the engineering of initial and continuous trainings (qualifying professional training and/or degree delivering); and ensures the exploitation of the obtained results.

The institute is located in two main French aerospace clusters: Toulouse and Bordeaux. By the end of 2015 IRT Saint-Exupéry had more than 80 researchers coming from Industry (secondment) and public sectors (part time researchers) as well as around 50 Ph.D. and Post-Doctorate fellows.

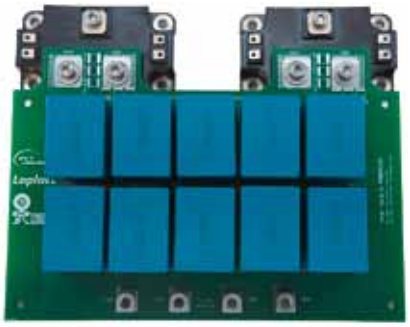
More Electrical Aircrafts Department

In addition to the departments of Materials and Embedded Systems, IRT Saint-Exupéry host the More Electrical Aircraft Department, which conducts different research projects related to the replacement of hydraulic and pneumatics technologies by electrical ones. The aim is to develop technologies to reduce the weight and volume of every element of the electrical system taking into account all constraints (EMI, reliability, cost,…).

Key Projects and Research Topics

Integration of electromechanical chain

- Iron losses characterization for design of high performance machines and magnetic components
- Characterization of switching losses of wide bandgap semiconductors
- Thermal modelling and optimization of high performance cooling systems for power converters
- Design and fabrication of high performance SiC power modules
- Integration and EMI characterization of high performance electromechanical chain



Circuit for characterization of switching losses of 1200V/100A SiC module

Robustness and reliability

- Characterization and modeling of the effects of ageing on EMC behavior of COTS analog and digital components
- Reliability modelling of microelectronics parts
- Radiation effects modelling on GaN Normally-off technologies
- Characterization of partial discharge and gaseous breakdown in aeronautic environment
- Characterization and standardization of aeronautical testing electric arc

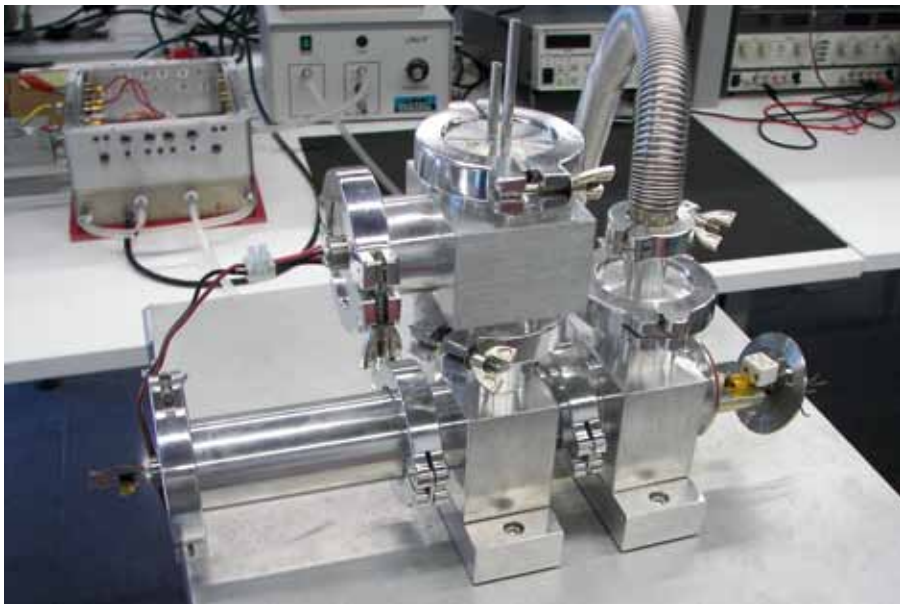
Energy storage systems

- Modelling of aging process of high and low temperature fuel cells and batteries.
- Development of diagnostic tool for maintenance of fuel cells and batteries.

Partial discharge detection in motor stator bobbin

UNIVERSITY OF VALENCIA

The Instrumentation and Industrial Electronic Laboratory (LEII), with its 16 staff members, has two divisions: Power Electronics Division and Electronic Instrumentation Division. The Power Electronics Division is responsible for power electronics education at the University of Valencia and carries out government and industry projects. Research activities cover various areas related with high-efficiency power converters: power electronics for e-Mobility infrastructure, aerospace power systems, high power resonant converters for industrial applications, advanced control techniques and power devices characterization.

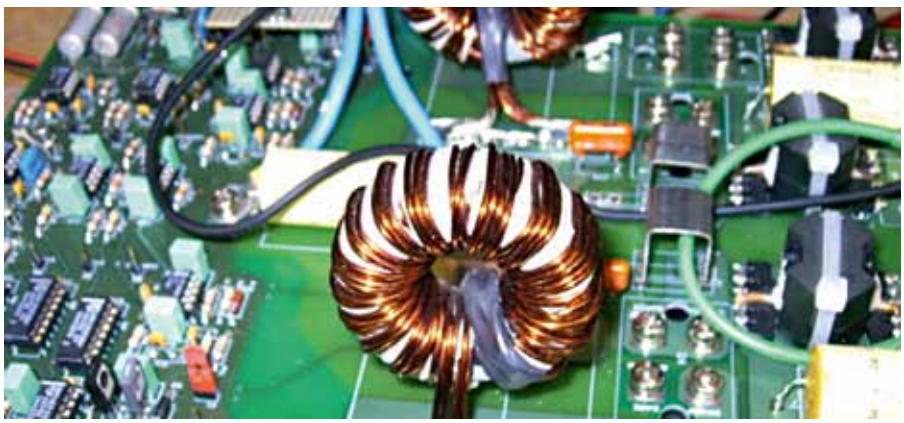


Key Research Fields & Competence Areas:

- e-Mobility Infrastructure
  Ultrafast high power DC chargers, inductive chargers
- Aerospace Power Converters
  Battery charge/discharge regulators, solar array regulators, power supplies.
- High Power Resonant Converters
  Industrial induction heating, high voltage applications
- Advanced Control Techniques
  Non-linear control and vector control (DSP) focused on renewable applications
- Power Electronic Devices
  Static, dynamic and thermal characterization of passive and active devices (Si, SiC)

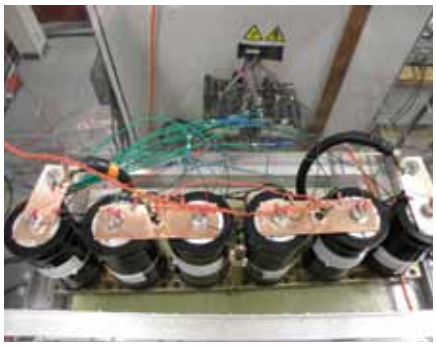
Institute Highlights:

- Powerful Lab-facilities
  Gain-phase and impedance analysers, 1ph and 3ph AC and DC power sources, dynamic power loads, EMI test tools, climatic chamber, and electronic simulation tools.
- Power Semiconductor Test-Bench
  Large temperature range (-170°C to 400°C), high voltage and high current setup.



The laboratory

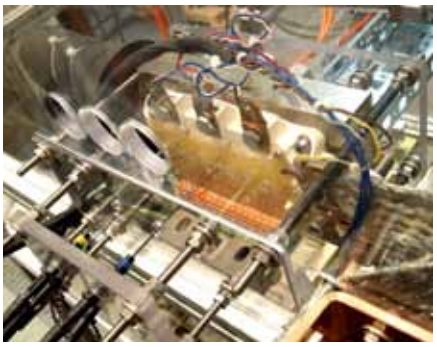
The Laboratory of New Technologies is a lab of the IFSTTAR institute. Its proficiency concerns the power electronics applied to transport systems, traction applications (automotive and railway) and electric actuators (aircraft), with a technological approach of components (semi-conductors, ultra-capacitors, fuel cells,…). The global approach is to contribute to the knowledge of the behavior of new devices subjected to their usage conditions, to study their integration in the transport modes and to promote the development of electric and hybrid transport systems. It is involved in original research in the domain of the reliability testing of power semiconductor devices, the storage of electrical energy for urban transport systems and the integration and interface systems of fuel cell generators.



Key research fields

Robustness & Reliability of Power semiconductor devices and integrated systems

Investigations are especially conducted for high voltage and high temperature power semiconductor devices and power modules. In this field, the research focus is in one hand the assessment of power devices lifetime and on other hand on the understanding of the physical mechanisms of degradation and aging phenomena of power IGBT modules and new wide band gap based semiconductor devices (SiC, GaN).



Reliability of Energy storage systems for transport applications (Ultra-Caps)

Works concern the behavior of ultra-cap devices and systems against ageing by successive charge and discharge cycles. The goal is the understanding of their behavior in usage conditions. Effects of test parameters (temperature, voltage, current, ...) are evaluated in order to highlight the key factors involved in failure modes and to control the reliability and security of the energy storage systems.

Fuel Cell generator systems for transport applications

The research activities conducted on fuel cell generators are closely linked with

actual contexts of electrical vehicle and reduction in greenhouse gas emission. The focus is done on experimentation and integration of fuel cell systems in the transport environment (characterization, performance improvement, endurance, reliability and diagnostics). It is also considered degradation modes and fault tolerance of fuel cells.

Competence areas

- Reliability testing (ageing tests by power cycling, thermal cycling)
- Search for ageing indicators (damage detection)
- Si (power IGBT modules) and WBG (SiC and GaN) devices
- Electrical characterization in high power range (4kV-6kA from –40°C to 125°C, 20A-6kV @250°C)
- Thermal characterizations (Rth, Zth, transient thermal analyses,…)
- IR thermography
- Physics of failure (Failure analyses, failure mechanism investigations)
- Multi-physic modeling (electro-thermal, thermo-mechanical)

AUSTRIAN INSTITUTE OF TECHNOLOGY

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY

About AIT
Austrian Institute of Technology

The AIT Austrian Institute of Technology, Austria's largest non-university research institute is among the European research institutes a specialist in the key infrastructure issues of the future. AIT provides research and technological development to realize basic innovations for the next generation of infrastructure related technologies in the fields of energy, mobility, digital safety & security and health & environment.

Research Focus in the Field of Power Electronics

As an industry partner AIT focusses on design and validation methodologies using rapid prototyping as well as laboratory environment to lower design costs, and to increase development speed. This includes:

- Modelling and design of Smart Grid components, electric vehicle drives and battery systems
- Loss modelling, thermal design (CFD) and electro-magnetic design of power electronics and electric machines (FEA)
- Rapid prototyping and integrated design of components and controls for Smart Grid applications and electric vehicle powertrains involving hardware-in-the-loop-(HIL)-technologies
- Reliability of power electronic and energy storage systems

AIT Energy, Smart Electricity Systems and Technologies Laboratory, (SmartEST)

AIT Mobility, Dual-Inverter for Hybrid Electric Vehicle

Laboratories
SmartEST

- 3 independent laboratory grids with variable impedances for up to 1000 kVA, flexible star point configuration and grounding systems
- 2 independent grid simulators: 0 to 480 V 3-ph AC, 800 kVA
- 3-ph balanced or unbalanced operation
- Facilities grid compliance tests
- Environmental simulation:
  - LxWxH: 3.6 m x 2.6 m x 2.8 m
  - Temp.: -40° C to +120° C
  - Humidity: 10 % to 98 % r.H.
- Multicore real-time simulators
- P-HIL and C-HIL at full power in a closed control loop
- Configurable PV 48.6 kWp

High Power

- Low-voltage, high-current up to 150 kA, 700 V and 15 kA, 1500 V
- Medium-voltage tests up to 120 MVA
- DC tests up to 30 kA

High Voltage

- AC up to 600 kV / 1.5A

Electric Drives

- Synchronized acquisition of electrical, thermal and mechanical measurement data
- Real-time HIL for drive cycle control, vehicle emulation, etc.
- Several data-bus interfaces
- CAN-restbus simulation
- Several dynamometers,
  - Pmax = 280 kW (at 3500 rpm),
  - nmax = 22000 rpm (at 100 kW)
- DC supplies, sinusoidal AC supplies, and drive inverters
  - Voltage up to 1.8 kV
  - Power up to 600 kW
- Control of cooling conditions, from -50° C to 220° C.

Batteries

- Cell characterisation, and modelling
- BMS development and tests
- Safety and abuse tests at cell, module and system level
- Environmental simulations
- Endurance and aging tests

The Institute of Energy Systems and Electrical Drives was merged in 2011 from the institute of "Electrical power systems", "Electrical drives and machines" and the "Energy economics group". Our department is active in the area of the design of electric machines, as well as their regulation. Of course the power electronics may not be disregarded in the drive technology.

Due to the trend of repairing components just before a problem arises, monitoring is also a topic in our field of research. One domain is the monitoring of induction machines where the squirrel cage is examined for a breaking bar. In the view of life time, the inverter's weakest component is the DC link capacitor. So another domain is the monitoring of these capacitors of an inverter without additional components in the power path of the inverter.

Fig.: Dental drive with INFORM

The main focus of our research is the highly dynamically sensorless control of permanent magnet synchronous machines (PMSM). Sensorless means you do not need any mechanical speed or position sensor. At high speed we use the well known back EMF method. At low speed and at standstill this model will not work due to the lack of the stator voltage. So we developed the so called INFORM method which uses the machine itself as a sensor. Therefore some test pulses are applied to the machine and the response can be used to calculate the actual angular speed of the motor shaft which is needed for a field orientated control of the PMSM. Latest developments are aimed to include these test pules into the normal operating mode. So the noise of the INFORM test pulses will be negligible.

Fig.: Prototype inverter design

The INFORM method is independent of the size of the motor. As an example for small drive applications, we implemented the INFORM method together with a dental company in their products. So we solved their former problem of damaged Hall sensors during high temperature sterilization (Hall sensors can be used for the field orientated control of the PMSM). Now they are able to cover the whole range of speed with one drive and can serve additional applications where full control of speed and torque is needed. As a high torque application example, we designed a traction machine for propulsion with the scope of good sensorless properties. So the drive is able to be highly overloaded and even be controlled without sensor. In the figure the 4kNm prototype is shown.

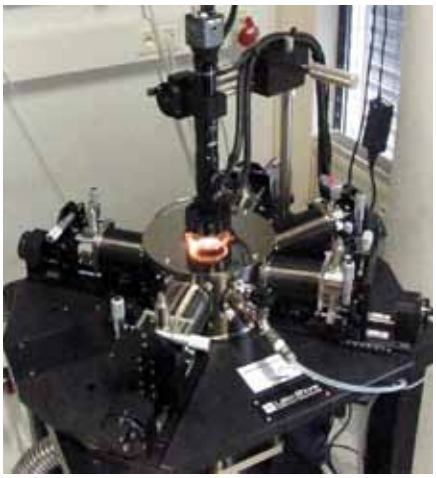
Fig.: 4000 Nm traction drive

As mentioned, the INFORM method is independent of the size of the machine. We are able to control small machines with a few mNm at very wide speed range up to torque motors in the range of several kNm at low speed. Therefore no speed or position sensor is needed even at low speed and standstill.

KAI KOMPETENZZENTRUM AUTOMOBIL- UND INDUSTRIEELEKTRONIK GMBH

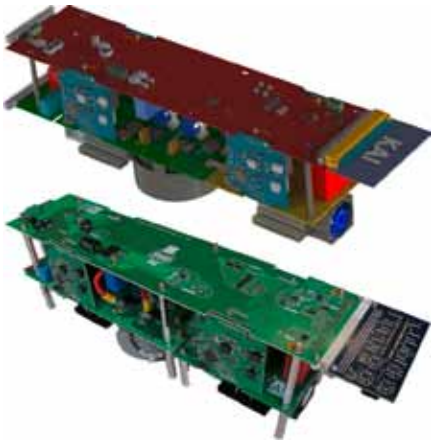
Overview

KAI is an industrial research center in Villach, Austria, founded in 2006 and owned by Infineon Technologies Austria AG. We are focused on power electronics reliability, test concept development, advanced semiconductor materials research, statistical lifetime modeling, data science and multi-physics FEM simulation. Our proven experience in the coordination of interdisciplinary research projects is complemented by an international network of industrial and academic partners.



Key Research Areas

- Physical understanding of microscopic defects and their role in power semiconductor reliability
- Temperature dependent mechanical properties of metals and interfaces for stress-optimized multilayer structures



- Analysis and prevention of semiconductor surface corrosion mechanisms
- Thermo-mechanical fatigue robustness of power device interconnect structures under cyclic stress
- Electro-thermal and mechanical device and system analysis with state of the art FEM simulation
- Application relevant stress test concepts and development of automated real-time test systems
- Verification methodology, functional safety and failure rate estimation
- Application demonstrators and novel design solutions for power systems
- Application of Data Analytics and Machine Learning to support decision making in semiconductor manufacturing

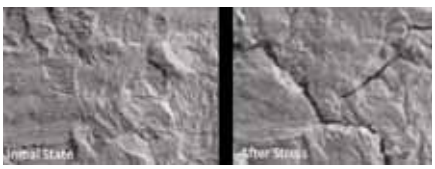
Main Competences

Our scope of research covers all aspects of power semiconductor performance and reliability in the application fields of automotive and industrial power conversion. We investigate the newest discrete and integrated power devices, advanced materials, cutting-edge technologies and applications.

We develop new methods for application-relevant stress testing of power devices, from the latest generation of automotive smart switches to novel SiC and GaN power semiconductors for efficient power conversion, to identify known and new failure modes and find underlying physical degradation mechanisms.

In close cooperation with our academic research partners we have developed strong competences in understanding and quantifying relevant physical fatigue and damage effects, providing models and parameters for the numerical simulation and a mathematical formulation of lifetime models.

Based on a profound understanding of material and device ageing and degradation, we are able to propose advanced solutions in technology and product design, as well as new methods to verify the improved reliability of innovative power semiconductor technologies and products.



Warsaw University of Technology, Faculty of Electrical Engineering, Institute of Control and Industrial Electronics

Research activities

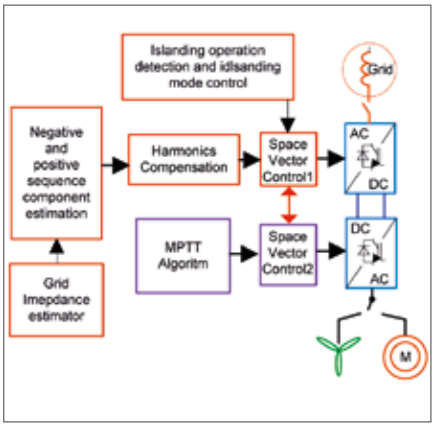
- Control of multilevel converters - active filters, rectifiers, inverters
- Converters topologies
- Power generation based on renewable energies, PV, wind turbines, ocean waves
- Adjustable speed generation autonomous and grid connected
- Autonomous Double Fed Induction Generators (ADFIG –DFIG)
- Control of microgrids
- Control of multiphase machines
- Operation of converters at distorted and unbalanced grid
- DSP and FPGA systems
- Silicon carbide devices and converters
- Reactive power compensators
- Reactive power compensation of cage induction generators
- Intelligent building control
- Artificial neural network based control of repetitive process
- ECO vehicle technologies
- Energy storage based on batteries and supercapaciotrs
- Personal Rapid Transit
- Contactless energy transfer
- Multi-oscillatory LQ regulators for a 3-phase 4-wire inverter with an L3nC output filter

Test set of generation 60 KVA system including DFIG, induction and synchronous generator driven by Diesel Engine

- Sensorless control of permanent magnet axial flux machine
- Converter control of compensation induction generator reactive power

Scientific and industrial projects:

- Single-phase 5.5kW high efficiency and transformerless DC/AC converters for PV panels
- Investigation of simplified topology for three-level NPC AC/DC/AC converter for wind turbines
- Low speed small wind turbine with energy storage module for distributed generation
- Transformerless four-leg three-level converter for renewable energy systems
- Development of AC/DC converters resistant to grid disturbances in disperse grid 5-400 kVA
- Global maximum power point searching algorithms for photovoltaic power plant connected to grid through five-level ANPC converter
- High Power Impulse Magnetron Sputtering feeders for application in semiconductor, medical and solar industry
- Application of bidirectional AC-DC-AC converter (45kW-200kW) with back-spin control for high pressure pumping stations
- Application of three-level npc bidirectional AC-DC-AC converter 800kW operating at wide range variation of grid voltage
- Smart microgrid - renewable energy sources for uninterruptible and high efficiency power supply in local grid
- Fault tolerant control algorithms of Multi-phase Energy Generation System
- Predictive control of four-legs three-level Flying Capacitors Converter for Shunt Active Power Filter
- Development of multi-objective optimization procedures for modern AC-DC converters in particular for renewable/ distributed energy systems
- Intelligent controller of 60 kVA generation system with induction generator



Power conversion systems

WARWICK
THE UNIVERSITY OF WARWICK

UNIVERSITY OF WARWICK

Warwick University is home to the Energy Conversion Research Group where leading research on power electronics is performed. Significant investment from the UK government and industry has contributed to the development of a silicon carbide dedicated cleanroom and a power electronics laboratory. Research into power electronics for automotive and energy transmission/distributtion systems has recently been funded leading to a centre of excellence in power electronics. The Energy Conversion Research Group at Warwick University is engaged in the following research activities

Silicon Carbide:

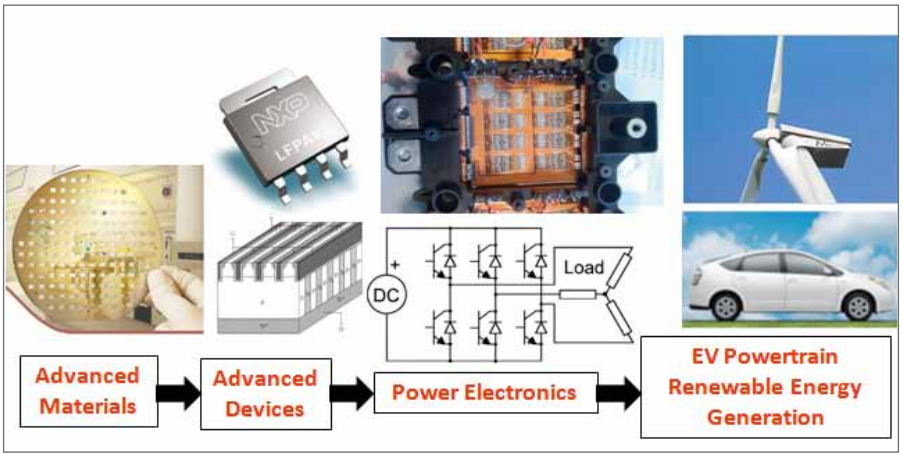
The European Regional Development Fund together with the West-Mindlands Regional Development Agency have invested over £10 million into the development of a silicon carbide dedicated processing facility at Warwick University. Using wide bandgap semiconductors like silicon carbide, significant improvements in the efficiency of energy conversion can be achieved. Energy efficient power converters for automotive and power systems based on silicon carbide are continously being demonstrated.

Vehicle Electrical Systems Integration:

This project was funded by the British government to the tune of over £3 million. The project involves the development and optimization of Electric Vehicle systems architecture for improved energy conversion and management. Research into silicon carbide. Prof. Mawby is leading a consortium of several UK universities in delivering this project.

High Voltage SiC Devices for the Future Grid:

Warwick University has also recieved funding from the British government to develop the SiC power devices for the future electrical grid. With the increased integration of renewable energy into the grid, advanced power electronics will be required to ensure stability, controllability and flexibility especially since energy sources are intermittent and unpredictable.



Advanced Packaing Technology:

The Energy conversion group at Warwick University also conducts research into advanced packaging solutions for high temperature/high frequency applications. The packaging cleanroom has recently been opened for this purpose.

Converteam/Royal Academy of Engineering Research Chair:

Prof. Phil Mawby occupies a Royal Academy of Engineering Chair as well as a Converteam Research Chair. He is the founder of the Energy Conversion Research Group at Warwick University and has worked with several industrial partners in the automotive and renewable energy sectors. He is principal investigator of several projects funded by the government and industry.

SWISS FEDERAL INSTITUE OF TECHNOLOGY ZURICH

Keywords

- Ultra-compact / efficient light-weight power electronic converter systems
- Extreme environment power converters and drives
- Self-sensing super high-speed and eco-intelligent drive systems
- Magnetic bearings / Bearingless motors
- Hybrid actuators
- Advanced multi-objective predictive control schemes and control stability analysis
- Magnetic components and materials modeling
- Multi-domain modeling / Multi-objective (Pareto) optimization

Typical application areas:

- IT power supplies / UPS
- Renewable energy / PV
- Automotive systems / EV battery charging
- More-Electric Aircraft (MEA)
- Industry automation
- Medical systems
- Semiconductor / chemical / pharmaceutical industry.

29 Ph.D. Students
4 PostDocs

Research Focus

The research at the Power Electronic Systems Laboratory (PES) addresses challenges in power electronics and mechatronics that have a fundamental or generic nature. The considerations are on a system-oriented basis. Proposed concepts should allow a translation into future innovative industrial products. Motor and actuator concepts, converter topologies, power semiconductor technologies, modulation schemes, control methods, thermal management, and EMI filtering are seen as coupled issues rather than treated in a sequential manner. Circuit-oriented simulation and FEM- and PEEC-based analysis of the mechanical, electromagnetic, and thermal behavior are integrated into the research and design process. Furthermore, multi-objective optimizations are performed in order to identify the Pareto performance limit concerning efficiency, power density, and costs.

The main areas of research are currently

- novel concepts of PWM rectifier systems with low effects on the mains
- highly compact / efficient electromagnetically integrated DC/DC converter systems
- novel isolated / non-isolated AC/AC PWM (matrix) converter topologies
- ultra high speed drives, magnetic and hybrid air bearings, bearingless motors
- multi-domain / scale modeling, abstraction, simulation, and multi-objective optimization.

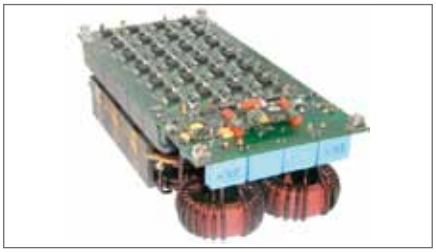
Ultra-efficient / compact automotive DC/DC converter; 99% @ 40kW/dm^3.

World record speed drive systems; 100W @ 1'000'000 rpm.

In each research area, a comprehensive experimental verification of the proposed theoretical concepts is provided that employs the latest Si and SiC (GaN) power semiconductor and high performance digital signal processing technology. The investigations are currently carried out by 29 Ph.D. students and 4 Postdocs under full or partial funding by international industry partners.

Future Extensions of Research Scope

- Medium-frequency medium-voltage DC/DC converters / Solid-state transformers
- Inductive power transfer
- DC distribution systems
- Micro power electronics / Power supply on chip
- Virtual Prototyping.



Ultra-high efficiency 3.3kW 1-ph. PFC rectifier; (efficiency at rated power: 99,4 %).

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Research Areas

The new Institute for High Power Electronic Systems (HPE) founded in 2010 at the ETH Zurich focuses its research on high power converter systems operating from low to high voltage levels and power levels from kW to MW range. The research is based on a comprehensive system-oriented view including all aspects of power electronics and related topics. With the attained research results the development of future innovative products and also the exploitation of new application areas by power electronic systems should be enabled. The major research areas are:

- Novel topologies & modulation concepts
- Advanced passives (E.g. integrated cooling concepts, integrated EMI filtering, ultra low loss, low acoustic noise, advanced isolation design…)
- New control methods
- Energy storage systems
- Multi-domain modelling:
  - Electrical
  - Magnetical
  - Insulation Design
  - Thermal
  - EMI
  - Reliability
- Multi-objective, mission profile oriented optimization

The multi-domain modelling of the converter systems enables a comprehensive optimisation at the system- as well as at the component-level, for example for maximal efficiency, ultra high power density or high reliability. Based on the mission profile, the system design is optimally adapted to the requirements minimising raw material usage and costs. Also multiple objectives as for example the system volume and losses can be considered at the same time. This results in a Pareto Front or Surface as shown for example in fig. 1 where different designs of modular multilevel converters for medium voltage battery energy storage systems are compared. Based on these Pareto Fronts different topologies, modulations, and also technologies can be compared. With the models and the optimization also the industrial design process could be significantly accelerated enabling a shorter time-to-market.

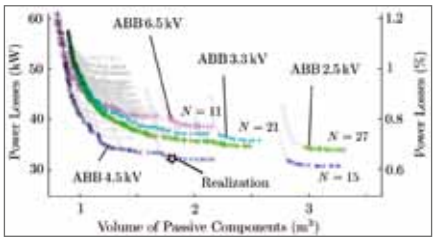

Fig.1 Example of a Pareto Front in the volume – power loss plane for a modular multilevel converter (M2C), where different semiconductor technologies and number of modules N are considered. The Pareto-Front defines the maximal achievable performance for a compromise between system volume and efficiency

Laboratory Facilities

For validating the models and the optimization procedures, prototype systems based on cutting edge technology are designed and built. An example is given in fig. 2 showing a prototype of a module for a 250kW modular multi-level converter (M2C) with an AC voltage of 9kV and a DC voltage of 35kV. The design of the converter system is optimized for a high power density and efficiency. The converter system is controlled via a newly developed serial bus system, which synchronizes the switching period of all modules within +/-5ns.

For performing experiments, a fully equipped laboratory with the following energy sources is available:

- 0..400V / 250KVA
- 0..800V / 250KVA
- 0..25kVAC / 250KVA
- 0..35kVDC / 250VDC (bidirectional)
- 0..2kVDC / 100kW (bidirectional)
- 400V arbitrary AC source

Additionally, a faraday cage for shielding and partial discharge tests as well as different water and air cooling facilities and a 2t crane are available.

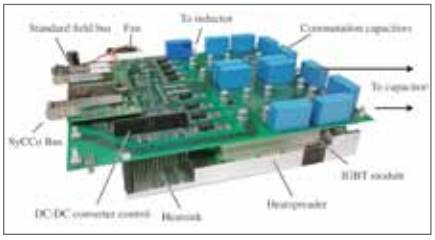

Fig. 2 Prototype of a module for a 250kW M2C bidirectional rectifier system for connecting a 9kV AC grid to 35kV DC test loads. The module voltage is 2.2kV and the IGBTs in the module switch at a frequency of 1kHz.

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