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ECPE
European Center for
Power Electronics e.V.

ECPE Tutorial Programme

SILVER Cluster Management Excellence
DEDICATED TO CLUSTER EXCELLENCE

www.ecpe.org/events

Notice

Index

ECPE Network

ECPE European Center for Power Electronics e.V., founded in 2003, is the leading industry-driven Research Network in Europe with more than 200 member organisations, comprising Member Companies and Competence Centres.

Education, Research, Public Relations

As a European technology and innovation platform, ECPE is driving precompetitive joint research and develops research & technology roadmaps for a strategic research agenda with future research directions according to the demands of European power electronics industry.

The ECPE expert workshops and advanced training programme cover a wide range of current topics addressed especially to engineers from industry.

www.ecpe.org

Precompetitive Joint Research

Network-internal research is organized in the ECPE Joint Research Programme focussing mainly on power electronics in automotive and industrial systems as well as for renewable energies and smart grids.

Advanced Training

ECPE Workshops and Tutorials address a wide range of up-to date topics targeded especially at engineers in industry. In addition, a power electronics online course is available on the ECPE web site for members.

Public Relations

The ECPE public relations and lobbying activities to increase awareness of the role and importance of power electronics for Europe have two main directions, publicly funded research programmes addressing power electronics topics and future young engineers.

ECPE Tutorials and Workshops

ECPE Tutorials

small team of lecturers (typ. 2 – 5 tutorial speakers)
20 – 35 participants (classroom atmosphere)
tutorials are repeated annually with the same lecturers

Whilst the Workshops are mainly focusing on expert discussion, the **ECPE Tutorials** are addressing education and advanced training, with the target of helping engineers in industry entering a new job or function.

The number of participants of these two-day courses is normally limited to 35 persons to keep the classroom atmosphere. Furthermore, ECPE is offering **practical lab courses** in cooperation with Competence Centres e.g. on 'EMC Optimized Design' with Fraunhofer IZM in Berlin.

All presentations and discussions in English.

Tutorials | ECPE Member Companies:

- 25 % on each tutorial seat
- 1 free seat at each ECPE Online Tutorial

ECPE Workshops

about 20 invited speakers in a two-day event
with a typical presentation slot of 30 min
80 – 150 participants
unique events (topics can be repeated after some years)

The ECPE Workshops are addressing a wide range of up-to-date topics along the innovation and value chain of power electronics from materials, components and integration technologies up to system-related topics in various application fields of power electronics e.g. in automotive, industrial drives, renewable energies and electronic power grids.

These two-day Workshops provide a unique platform for networking talks and expert discussion.

All presentations and discussions in English.

Workshops | ECPE Member Companies:

- 3 seats free of charge

All programmes and registration forms are available on: ***www.ecpe.org/events***

Tutorial Topics

All presentations are available for download on: www.ecpe.org (for member companies only)

Theoretical Course

Practical Training

Introduction to Power Electronics

Programme

- **Electronic Basics**
- **General Basics of Power Electronics**
  - Components of Power Electronics
    - Passives
    - Semiconductors
  - Principle of converters
  - Switching Process
  - Gate Drive
- **Circuit Topologies**
  - DCDC Converter
    - Galvanically & not galvanically isolated
  - ACDC Rectifier
    - Diode rectifier
    - Active rectifier, PFC
    - Thyristor circuits
  - DCAC Inverter
    - Basics and control principles
    - Currents in transistors, diodes and DC link capacitors
- **EMC Considerations**
  - Introduction
  - EMC in power electronics
  - Design principals
- **Assembly Concepts**
  - Electrical design considerations
  - Thermal assembly concepts
- **Applications**
  - Automotive
  - Industry
  - Solar
  - Wind power

About:

With the advance of automation and increasing demands on energy efficiency, many industrial applications use closed-loop controlled drives based on power electronics. Power electronics also play a key role in feeding renewable energies from photovoltaic and wind power into the grid as well as coupling different voltage systems, e.g. battery energy storage systems.

This also applies to electromobility, both on the vehicle side with the drive converter and various power electronic converters in the car, as well as on the grid side with the charging infrastructure, e.g. for DC fast charging. The aim of the training is to convey the basic structure and above all the behaviour of power electronic components and circuits. The important circuit topologies are discussed and their use in various applications is shown.

Target Group:

The training is aimed at scientists, engineers and technicians who have no background in electrical engineering and especially in power electronics, and who want to acquire general knowledge of the basic behaviour and characteristics of power electronics. On the other hand, the training is also intended for users of power electronics who work more on a system level. Here the knowledge of the basics of power electronics helps to make the right decisions and measures.

Course Instructor:
- Hans-Peter Feustel, ECPE (DE)
- Prof. Dr. Wulf-Toke Franke, University of Southern Denmark (DK)

ECPE Member Companies:
- 25% discount on each seat

Power Semiconductor Devices & Technologies

Day 1:

- Introduction: From Power Electronic Applications to Power Devices
- Basics of Semiconductor & Device Physics
- Basics of Power Semiconductor Devices
- Power Diodes and Thyristors
- Si Power MOSFETs and Super Junction Devices
- Insulated Gate Bipolar Transistor (IGBT)
- Unipolar Wide Bandgap Devices (SiC, GaN)

Day 2:

- Packaging of Power Devices and Modules I & II
- Modelling and Virtual Prototyping I & II
- Integrated Power: Basics of Gate Drivers
- Gate Drivers with Galvanic Isolation (Medium and High Power), Integration in Smart Power Technologies
- Fully Integrated Gate Drivers (Low Power)
- Multi Chip Gate Drivers and Technologies; IPM and Single Chip Inverter; Gate Drivers for SiC- and GaN Devices

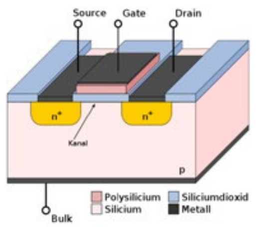
About:

The course starts with an overview on required power device properties and semiconductor material and device physics. Blocking capability of the devices, unipolar and bipolar current transport and gate control will be discussed. Diodes, MOSFETs and IGBTs will be treated in detail.

The superior properties of wide bandgap semiconductor materials for application and the expectations for the next years will be discussed. Also, issues concerning control, packaging and integration will be treated in the corresponding contributions. Basic principles of power electronic systems and the basics of intelligent IGBT / MOSFET control circuits will be demonstrated. MOS transistor and IGBT gate drivers for various fields of application are discussed in detail. A short overview of hybrid power electronic integration and the most relevant aspects (cooling, reliability, and EMC problems) will be presented.

Target Group:

The tutorial is aimed at engineers who are engaged in power electronics and want to improve their knowledge and understanding of power devices including the developments expected in near future.



Technical Chair:

- Dr. Anton Mauder, Infineon Technologies (DE)
- Prof. Dr. Nando Kaminski, University of Bremen (DE)

ECPE Member Companies:

- 25% discount on each seat

Wide Bandgap User Training

Day 1:

- Introduction & Motivation for WBG Electronics
- Wide Bandgap Power Semiconductor Devices
- Design of WBG Electronics
- Integrating Fast Switching Semiconductors: The Era of Designing Parasitics
- Drivers & Control Circuitry for WBG Switches
- Testing Wide Bandgap Devices I (Focus on Chip)

Day 2:

- State of the Art Packaging
- Requirements for Inductive Components
- Temperature Challenges for Integrated Systems Due to High Power Density
- Testing Wide Bandgap Devices II (Focus on Packaging)

About:

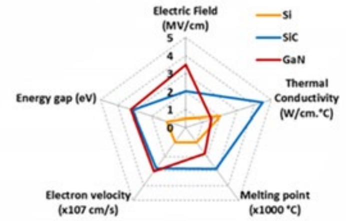
Wide bandgap semiconductors are the next generation of power electronics. The widespread programme is supposed to convey practical know-how to engineers working with SiC and GaN devices.

Efficient system integration is the key to exploiting the full potential of WBG semiconductors. Power electronics developers need to take into account that high switching speeds, high frequencies and high-power densities place special demands on the system components.

This 2-day tutorial addresses all aspects of WBG system integration from the choice of semiconductor components and design options to how to cope with parasitics, EMC and inductance at high switching frequencies. Another topic is test methods – both for electric tests of new power semiconductor components as for the robustness and reliability of modules and systems.

Target Group:

This tutorial is intended for engineers and technicians who work or plan to work with WBG devices.
Efficient system integration and practical aspects are core components of this course.



Technical Chair:

- Prof. Dr. Eckart Hoene, Fraunhofer IZM (DE)

ECPE Member Companies:

- 25% discount on each seat

Drivers and Control Circuitry for IGBTs and MOSFETs

Day 1:

- **View into an Inverter down to the Gate Driver**
- **Power Semiconductor Physics Device Physics**
- **Control of Power Semiconductors**
- **Aspects of Driver Supply Voltages**

Day 2:

- **Gate Driver Isolation and Isolation Coordination**
- **Advanced Gate Drive Approaches**
- **Data Acquisition at Gate Unit Level**
- **Gate Driver Protection Function**
- **Fast Switching and Common Mode Noise Immunity**

About:

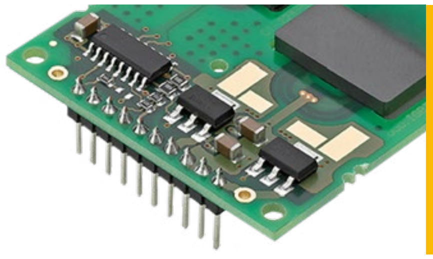
Drivers and control circuitry are the interface between the signal level and the power stage within a power electronic system. They are responsible for a safe operation of the power switches. Progress in microelectronics and in the implementation of cheap sensors allows to increase the functionality of gate drive units for MOSFETs and for IGBTs. Functions like gate current control, closer observation of voltages and of current slopes can be implemented on gate drivers at low incremental cost.

Advanced solutions for the isolation barrier with enhanced bi-directional communication can lead to completely new possibilities.

In the context of the development and adoption of innovative Wide-Band-Gap semiconductors, new challenges concerning robust operation at very fast switching speed and frequencies also need to be addressed in order to attain the expected gains at system level.

Target Group:

The training provides circuit designers with the requirements for drivers, the knowledge of how drivers work and the necessary component knowledge.



Technical Chair:
- Prof. Dr. Martin Pfost, Technical University of Dortmund (DE)

ECPE Member Companies:
- 25% discount on each seat

Hands on Training | Use and Assessment of Power Device Models in Power Electronic Simulation

Programme

- **Introductory Remarks**
- **Hands on Training: 'Power Device Models and the Data Sheet'**
  - DC characteristics of power devices (IGBT, MOSFET, Diode)
  - Gate charge and capacitance evaluation circuits
  - Transient characteristics
- **Hands on Training: 'Power Device Models inside Application Circuits'**
  - Control schemes with controlled voltage / current sources
  - Single ended resonant topology with two-point current control (induction cooker)
  - H-Bridge with PWM control

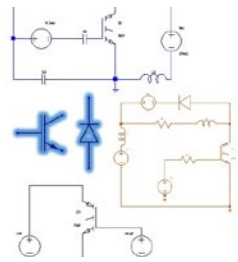
About:

Compact simulation models of power devices that are available from manufacturers are aimed for supporting virtual prototyping purposes in power electronics - the acceleration of system development processes. Applied power device models have to have high-level accuracy. This 'hands on training' allows you to evaluate/use compact power device models for IGBTs, diodes and MOSFETs via a brief description of power device models and data sheets with an introduction to the simulation software LTSPICE (trial available from Analog Devices: ***https://www.analog.com/en/design-center/design-tools-and-calculators/ltspice-simulator.html***).

You will assess standard data sheet related simulation circuits (and the models used), through correlation to the data sheet values. Performance of power device models will be shown by some application circuits through the innovative use of controlled sources.

Target Group:

Who should attend? Engineers, starting their career in power circuit design or simulation; device developers interested in power electronic system evaluation; students with a background in power electronics. The attendees should have LTSPICE on their notebook ready to use. Model libraries and test circuits needed for this tutorial will be distributed in advance.



Technical Chair:
- Dr. Peter Türkes, Consultant (DE)

ECPE Member Companies:
- 25% discount on each seat

Passives in Power Electronics: Magnetic Component Design and Simulation

Day 1:

- Magnetics Design
- Practical Applications in Power Supply Design
- High Frequency Considerations

Day 2:

- High Frequency Planar Magnetics for Power Conversion
- Modelling and Simulation of Magnetic Components
- High Frequency Materials for Advanced Magnetics

About:

High efficiency and power-dense converters are key to the growth of telecommunications, automotive, aerospace and data processing industries. High-frequency (HF) operation leads to a reduction in magnetics size and an increase in power density. The tutorial covers the fundamentals of magnetic component design (inductors and transformers), optimized inductor design incl. Flyback converter, transformer design optimized to core and winding loss, optimized design to HF loss with non-sinusoidal currents, fringing, interleaving and litz wire, practical designs of Forward, PushPull and LLC resonant converters, planar magnetics for low profile, automated assembly and predictable parasitics incl. wireless power transfer.

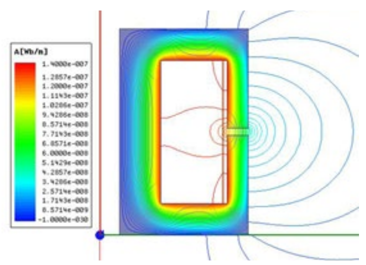
Simulated approach/numeric models will be presented for easy application of the tutorial contents to common designs including an overview of available permeable materials for HF.

Target Group:

Students looking to develop magnetic circuit theory using practical applications, higher frequencies and modern materials, electronic circuit design engineers looking to understand loss mechanisms through calculation and simulation, magnetic circuit design engineers looking to develop products through use of alternative materials and techniques for higher efficiency and reduced volume.

Prior knowledge:

Basic understanding of the principles of electric circuit theory and electro-magnetism.techniques for higher efficiency and reduced volume.



Technical Chair:
- Prof. Dr. Ger Hurley, Nat. Univ. of Ireland (IRE)
- Prof. Dr. Ziwei Ouyang, Technical University of Denmark (DK)

ECPE Member Companies:
- 25% discount on each seat

Power Electronics Packaging

Day 1:

- Introduction to Power Electronics Packaging
- Packaging Materials
- Materials Properties and Reliability Aspects
- Backside Interconnect Technologies
- Frontside Interconnect Technologies
- Encapsulation and Housing
- Discrete Power Semiconductors

Day 2:

- Power Modules
- Basics of Thermal Management
- Cooling of High Power Systems
- Low and Medium Power Systems
- Failure Mechanisms
- Lifetime and Reliability Testing
- WBG Packaging

About:

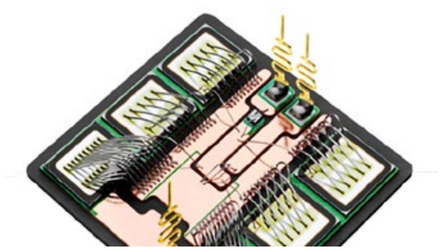
In Power Electronics packaging one has to deal with handling high voltages and currents as well as handling electrical losses with the required heat dissipation. Basic features of power electronics packaging including functions, materials and thermal management are covered in the tutorial.

The packaging of components and modules as well as the converter level packaging is covered starting from low power discrete and monolithic solutions up to hundreds of kW converters. Power electronics packaging is discussed in a system environment focussing on cooling techniques and thermal interface materials. The shortcomings and bottlenecks of state-of-the-art packaging will be discussed and the emerging interconnection and integration technologies that aim to address these challenges will be reviewed.

Since there is a dominant impact of packaging on the reliability of components and systems, one session is devoted to failure mechanisms and reliability testing.

Target Group:

This tutorial is aimed at engineers who are engaged in power electronics and want to improve their knowledge and understanding of power electronics packaging including ongoing developments and future trends.



Technical Chair:
- Prof. Dr. Uwe Scheuermann, Semikron Elektronik (DE)

ECPE Member Companies:
- 25% discount on each seat

Thermal Engineering of Power Electronic Systems Part I: Thermal Design and Verification

Day 1:

- **Heat: Basics, Examples, Heat-Exchange – I & II**
- **First Steps of a Converter Design**
- **Thermal Measurements I**
- **Thermal Network Simulation**
- **Introduction to Finite Element Simulation**

Day 2:

- **Thermal Measurements II**
- **Practical Training: Thermal Simulations with three options:**
  - Thermal Network Simulation (LTspice™)
  - CFD Thermal System Simulation with Finite Element Method
  - Modelling a Power Board with 3D CFD Thermal Analysis (Simulation and Measurement)

Thermal Engineering of Power Electronic Systems Part II: Thermal Management and Reliability (next page)

About:

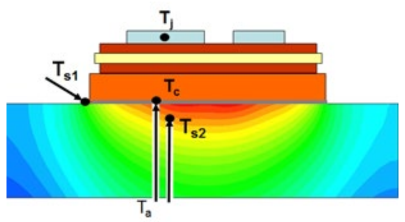
Thermal engineering of power electronic systems is a key to achieve high performance and reliability. We will thermally design and validate a power electronic inverter (100 kW SEMIKUBE IGBT converter) with additional thermal sensors.
Part 1: A review of the basic theory of heat transfer is followed by the calculation of losses in a voltage source inverter. For selected stationary operating conditions, the expected device temperatures of the sample converter will be calculated from datasheet values. Online tools to facilitate this process will be demonstrated. Participants can choose between FEM simulations and equivalent thermal network calculation with LTspice™ to simulate these operating conditions. The results are compared to thermal measurements using thermocouples and an IR camera.
A 3rd practical training group will deal with modelling of a power board with 3D CFD thermal analysis.

Target Group:

Power system designers, young engineers, researchers, and developers

Prior knowledge:

The attendees should have basic knowledge on power semiconductor devices and power electronics systems.



Technical Chair:

- Prof. Dr. Uwe Scheuermann, Semikron Elektronik (DE)

ECPE Member Companies:

- 25% discount on each seat

Thermal Engineering of Power Electronic Systems Part II: Thermal Management and Reliability

Day 1:

- **Short Summary of the Results of Tutorial Part 1**
- **Semiconductor-Level Thermal and Electrical Failure Mechanism**
- **Temperature and Reliability: Package-Level Failure Mechanisms I & II**
- **Thermo-/Damage-Sensitive Electrical Parameters**
- **Thermal Impedance Measurement – Preparation / Introduction to Experiment / Results and Interpretation**

Day 2:

- **Design for Reliability**
- **Lifetime Models based on Power Cycling Test**
- **Mission Profile based Lifetime Estimation**
- **Electro-Thermal and Thermo-Mechanical Simulation**
- **Thermal Simulation of Complex Power Packages Considering Reliability Issues**
- **Cooling Technologies – Overview**
- **TIM Materials**

Thermal Engineering of Power Electronic Systems Part I: Thermal Design and Verification (previous page)

About:

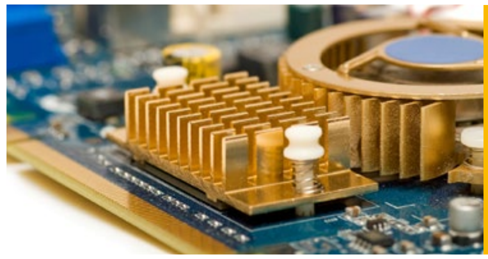
Thermal engineering of power electronic systems is a key to achieve high performance and reliability. We will thermally design and validate a power electronic inverter (100 kW SEMIKUBE IGBT converter) with additional thermal sensors. The attendees should have basic knowledge on power semiconductor devices and power electronics systems.
Part 2: Failure mechanisms, both at semiconductor and package levels will be introduced. Thermo-/damage-sensitive parameters will be discussed, including theoretical background of thermal impedance measurement. A practical experiment about measurement of thermal impedance will be shown. We will continue with a concrete design for reliability concepts, and go on with lifetime estimation, based on both power cycling and mission-profile approaches. Advanced electro-thermal and thermo-mechanical simulation will be followed by an overview about cooling systems.

Target Group:

Power system designers, young engineers, researchers and developers

Prior knowledge:

The attendees should have basic knowledge on power semiconductor devices and power electronics systems. Having attended the first part is helpful.



Technical Chair:

- Prof. Dr. Uwe Scheuermann, Semikron Elektronik (DE)

ECPE Member Companies:

- 25% discount on each seat

EMC in Power Electronics

Day 1:

- **Introduction – Warming up with examples**
- **Power Electronics as High Frequency Technology**
- **EMC Fundamentals**
- **Interference Sources and Mechanisms**
- **Handling Interference: Filtering or Shielding**
- **Interference Simulation**
- **Return Currents**
- **Filter Components and their Properties**

Day 2:

- **Filtering of Common Mode Interference**
- **EMC-Design for Drive Systems**
- **Design Rules for PCBs**
- **Ground Plane Design**
- **Which EMI questions can be solved more efficiently using simulation tools?**
- **EMI of Power Modules**
- **Using Stray Elements for Reducing EMC Issues**
- **Design Methods for Passive Filters**

About:

Advantages in semiconductor technology drive power electronics to higher efficiencies and compact systems designs. This progress comes along with increasing effort to comply with EMC requirements. Integration as a response to the market demands intensifies the challenges. With dense placement electromagnetic coupling between components raises influence on system behaviour. The design becomes more complex and leads to significantly higher development costs.

The EMC in Power Electronics tutorial is a response to the increasing importance of EMC. It provides an overview on EMC phenomena and introduces methodologies to handle EMC questions. The tutorial is intended for the training of young engineers and engineers from neighbouring disciplines.

Target Group:

Young engineers and engineers in industry entering a new field.

Technical Chair:
- Prof. Dr. Eckart Hoene, Fraunhofer IZM (DE)
- Prof. Dr. Jean-Luc Schanen, Grenoble Institute of Technology - G2ELab (FR)
- Lex de Rijck, Acradac EMC Training and Consultancy (NL)

ECPE Member Companies:
- 25% discount on each seat

ECPE Lab Course EMC Optimised Design (Parasitics in Power Electronics)

Day 1:

- **1st Lab Session**
  A circuit board of an inverter working with 40V and 15A is provided as test object. A check of function will be carried out by the attendees using typical laboratory equipment. Goal is to find out all design mistakes and if possible, to find work arounds.
- **2nd Lab Session**
  The work of the first session will be continued. Electrical components and soldering materials are offered for modification of the circuit board.
- **Discussion of the first results**

Day 2:

- **3rd Lab Session**
  The functionally optimised Circuit Board will be additionally measured for conducted emissions. Dependencies between conducted emissions and the bad layout will be carried out.
- **4th Review of Lab Sessions**
  Review & common analysis of failures on the Circuit Board.
- **5th Part Presentations**
  - Design Strategies on Board Level
  - Parasitic Effects: Design of Commutation Cells & Filters
  - Power Module Design for Lower Emissions

About:

When designing power electronic circuits often electromagnetic properties of layout and construction prevent a proper function.

This lab course is intended to give an insight into the underlying effects by directly carrying out experiments. By investigating the function of a badly designed circuit in the lab a feeling for common mistakes and measurement methods to point them out is given.

There is the possibility to modify the circuits and to improve their performance directly.

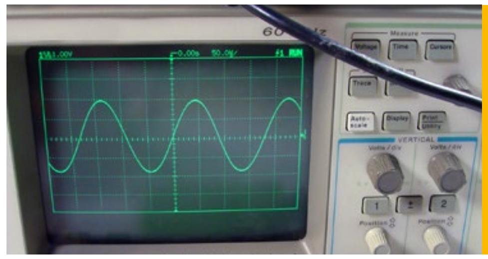
Different examples for good solutions are shown and finally every attendant has the chance to develop an own design that will be checked by the course instructors for electromagnetic quality. Examples from daily business are also welcome.

Target Group:

Circuit designers, researchers, students

Prior knowledge:

Having already designed circuits and having a basic knowledge of lab equipment is helpful.



Technical Chair:
- Prof. Dr. Eckart Hoene, Fraunhofer IZM (DE)

ECPE Member Companies:
- 25% discount on each seat

Power Circuits for Clean Switching and Low Losses

Day 1:

- **Power Semiconductors Switching Inductive Load and Parasitic Inductance**
- **Geometry of Conductors and their Inductance – Determination and Evaluation**
- **Parasitic Inductance – Effecting Switching Characteristics and Stress Factors of Power Semiconductors**
- **Turn-off Behaviour of Bipolar Devices – IGBT and Diode: Influence of DC-Voltage, Current and Gate Control**
- **Parasitic Inductance – Effecting Current Sharing of Paralleled Power Devices**

Day 2:

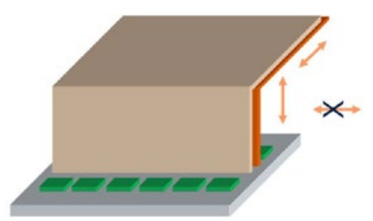
- **Case Study II: Asymmetric Paralleling and Discussion**
- **Parasitic Inductance – Effecting System Losses**
- **Oscillations in DC-Bus**
- **Parasitic Inductance meets Parasitic Resistance**
- **Gate Inductance**
- **Parasitic Capacitance and Aspects of EMI**
- **Clean Switching of WBG Devices – Part I & II**
- **Clean Switching of SiC Devices**
- **Measuring Challenges and Solutions**
- **Benefit of Circuits with Low Parasitic Inductance**

About:

In power electronics, power density and current density are continuously rising, and parasitic inductance and resistance become a limiting factor.
Overvoltage during switching is only one problem. For bipolar power semiconductors like IGBTs and freewheeling diodes, parasitic inductance causes disadvantageous current waveforms. When considering power semiconductors in parallel, the current sharing of controlled devices like IGBT, MOSFET and JFET can be affected by the presence of small parasitic inductances. In the control circuit it decouples driver and the gates of the devices leading to increased short circuit current.
The tutorial covers the basics of switching inductive loads and the discussion of related waveforms and their effects. Geometries of conductors and system design for low parasitic inductance and good current sharing will be another main part.

Target Group:

System designers, researchers, students.



Technical Chair:
- Dr. Reinhold Bayerer, Physics of Power Electronics (DE)
- Prof. Dr. Thomas Basler, Chemnitz University of Technology (DE)

ECPE Member Companies:
- 25% discount on each seat

Testing and Electrical Characterization of Power Semiconductor Devices - Basics

Day 1: (Theory)

- **Introduction to Double Pulse Measurement**
- **Measurement of Fast-Switching Operation with Wide Bandgap Transistors**
- **Calorimetric Measurement of the Switching Loss Power of Resonant Converters**
- **Current Measurement**
- **Challenges of Measuring GaN-Based Half-Bridge Switching Loss**
- **Measuring On-state Capacitance**
- **Working Safety and Practical Tips for Measuring**

Day 2: (Practical Lab Course optional)

- **Introduction and Outline**
- **EPC-LabSafety Instructions**
- **Practical Measurements in the Lab**
  - Double Pulse measurements of Si, SiC and GaN
  - Dynamic Current Measurement
  - Determining Switching Losses with Calorimetric Measurements
  - Dynamic Voltage measurement of Fast-Switching GaN Half Bridge Board
  - Dynamic characterization of SiC Diodes

About:

The dynamic properties of fast-switching power semiconductor devices can only be measured properly if the power semiconductors are integrated in well designed and well-known custom circuits and test setups.

Relevant measuring techniques including dynamic measurements will be presented that can be used to test and characterize power semiconductor devices. The lectures can optionally be supplemented by attending a following practical course. There the participants can perform measurements in small groups under supervision. **Objectives:**

- Knowledge of relevant physical quantities for testing or characterization of fast-switching power semiconductor devices
- Competence to interpret the corresponding information in standards and data sheets
- Knowledge of possible measuring techniques and their behaviour
- Competence for the conception and execution of measurements

Target Group:

Young engineers, PhD students, engineers in industry entering a new field.

Prior knowledge:

This tutorial requires basic knowledge in power semiconductor characterization e. g. with static measurements.

Technical Chair:
- Prof. Dr. Ingmar Kallfass, University of Stuttgart (DE)

ECPE Member Companies:
- 25% discount on each seat

Testing Automotive Power Modules according to the ECPE Guideline AQG 324

Day 1:

- Introduction and Motivation
- SiC-Based Power Modules in AQG 324
- Mapping of Relevant Standards
- Characterizing Module Testing
- Lifetime Testing: Temperature Tests
- Lifetime Testing I (PC Principles)

Day 2:

- Lifetime Testing II (HT Principles)
- Mechanical Tests
- Test Documentation and Outlook

About:

The ECPE Guideline AQG 324 is prepared and released by the ECPE Working Group ´Automotive Power Module Qualification´ comprising ECPE member companies from the automotive supply chain. The original version is based on the supply specification LV 324.

The described tests concern the module design as well as the qualification of devices on module level (i.e. the assembly) but not the qualification of semiconductor chips or manufacturing processes. The requirements, test conditions and tests presented in the tutorial essentially refer to power modules based on Si power semiconductors while wide bandgap power semiconductors (e.g. SiC or GaN) are addressed but not yet fully covered by the Guideline.

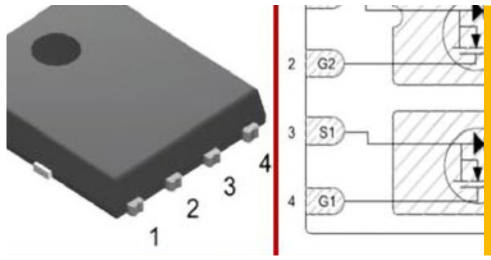
The Tutorial with speakers from the AQG 324 Core Team will give practical information and advice how to test power modules according to the AQG 324 Guideline under comparable conditions.

Target Group:

It aims at direct users from beginners to senior experts coming from power module suppliers, automotive tier 1 suppliers or test service and equipment providers.

Prior knowledge:

Background in power device and module theory.



Technical Chair:
- Dr. Martin Rittner, Robert Bosch (DE) Chairman of the AQG 324 Working Group

ECPE Member Companies:
- 25% discount on each seat

Model Predictive Control for Power Electronics, Drives and Power Grid Applications

Day 1:

- Introduction and basic concepts
- Mathematical background
- Numerical optimization in MPC
- MPC for drives
- MPC for electrical power grid

Day 2:

- MPC for grid-connected converters
- MPC for photovoltaic inverters
- Algorithms and embedded implementation of MPC
- Advanced MPC concepts

About:

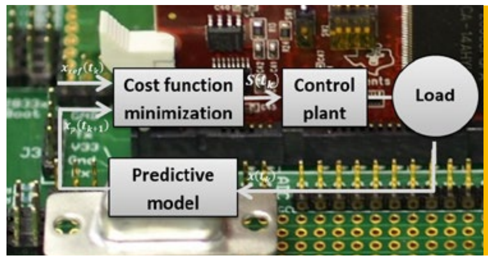
MPC is a conceptually simple yet powerful methodology to control power converters, electric drives and large systems. MPC provides advantages over traditional controllers by intuitively handling a large variety of control problems by directly incorporating system constraints and requirements. MPC controllers are inherently stable and easy to implement and so advances in processing power of digital signal processors have promoted MPC into commercial applications.

The tutorial aims to introduce basic MPC principles to formulate (mathematically) and solve (optimally) the control problem, discuss practical challenges in MPC of drives, grid connected converters, PV inverters and electrical power grids with examples.

Practical implementation guidelines for hardware, software, programming methods and suitable design tools will be demonstrated for advanced MPC concepts on examples.

Target Group:

Developer of power electronic assemblies and systems; Developers of control systems for power electronic systems, drive systems and electrical power grids



Technical Chair:
- Prof. Dr. Tobias Geyer, ABB System Drives (CH)
- Prof. Dr. Ralph Kennel, Technical University of Munich (DE)

ECPE Member Companies:
- 25% discount on each seat

Function and Design of Multilevel and Multicell Converters

Day 1:

- Topologies for Multilevel Converters
- Power Semiconductors for Multilevel Converters
- 3L-NPC Basics I
- 3L-NPC Basics II
- Further 3L-Topologies

Day 2:

- Modular Multilevel Converter (MMC)
- Cascaded H-Bridge Converter
- Flying Capacitor Topologies
- Stacked Multicell Converter

About:

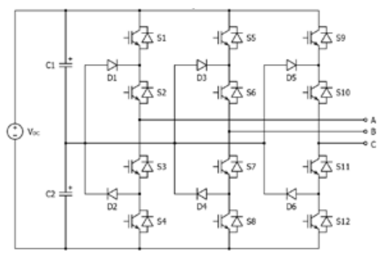
As opposed to 2-Level converters, multilevel converters feature several voltage steps with the advantages of the use of power semiconductors not rated for the full DC link voltage, whilst avoiding series connection of switches. Higher system voltages (AC and DC) with improved efficiency and reduced THD at high frequency are possible.

3- and 5-Level converter topologies have been introduced for demanding applications like PV/Wind inverters, UPS, MV drives and active filters/split DC link topologies to gain advantages of improved EMI behaviour/efficiency/higher bandwidth, use of cost-efficient power semiconductors at lower voltage ratings, reduction of passive filters (improved power density) and improved availability using redundant components.

The training develops competencies allowing the professional design, rating and implementation of multilevel/multicell converter-based systems.

Target Group:

The tutorial is designed for R&D engineers, system designers, project managers and (PhD) students interested in power electronic converters and systems, especially for grid and drive applications.



Technical Chair:

- Prof. Dr. Marc Hiller, Karlsruhe Institute of Technology (KIT) (DE)
- Prof. Dr. Thierry Meynard, University Toulouse (FR)

ECPE Member Companies:

- 25% discount on each seat

High-Performance Power Electronics

Day 1:

- Introduction to High-Precision Applications
- Academic Session 1: Non-Linearities in Passive and Active Components
- Academic Session 2: Topologies & Filtering
- Academic Session 3: Modulation & Compensation
- Industry Session 1: High-Precision in Semiconductor Lithography

Day 2:

- Industry Session 2: High-Precision Current Sensing using Flux-Gate Technology
- Industry Session 3: High-Precision in Medical Imaging
- Industry Session 4: Developing Gradient Amplifiers for MRI
- Academic Session 4: High-def Audio Amplifiers

About:

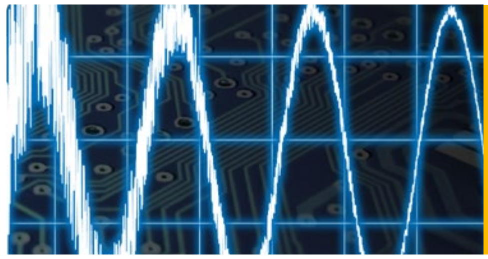
Power amplifiers are used in high-precision applications such as high accuracy positioning systems (semiconductor lithography where any error in the current translates to a positioning error), Magnetic Resonance Imaging - where current errors directly relate to image distortion, audio amplifiers, electron microscopy etc.

Most of these applications require high voltages and currents (up to MW levels), while maximum current and voltage errors are in the ppm range. In comparison, inverters for grid applications are found in the same power range, but with a THD of a few percent. High precision applications typically require much larger bandwidths (up to 100s of kHz) with almost zero phase delay, making modelling and control very important topics as well. Such challenges require the engineer to take a very different design approach compared to the design of traction inverters, for example.

Target Group:

This tutorial is aimed at engineers and researchers who are engaged in power electronics and want to improve their background knowledge and understanding of high precision systems and converters, including recent developments and future trends.

Various academic sessions cover a range of fundamental topics such as component modelling, topologies, and compensation techniques. Industry sessions are included to give detailed insight in the challenges and solutions for several state-of-the-art high-tech applications.



Technical Chair:

- Dr. Bas Vermulst, Eindhoven University of Technology (NL)

ECPE Member Companies:

- 25% discount on each seat

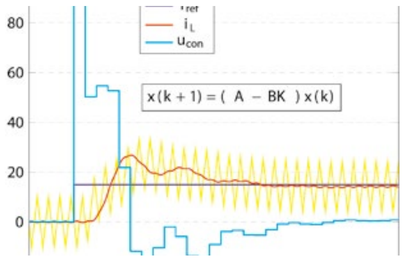
Digital Control | Modelling and Feedback Design in State-Space

Day 1:

- ODEs, State-Space and Initial Value Problems
- The Matrix Exponential
- Introduction to PLECS and Octave
- **EXERCISE**
- Modelling in State-Space
- **EXERCISE**
- Switched Systems with Blanking Time
- **EXERCISE**
- Brief Introduction to Numerical Integrators
- **EXERCISE**
- Concatenation of Linear Systems
- Opt.: Multi Megawatt Lab tour (1hour) at Fraunhofer ISE

Day 2:

- State-Space Modelling of LCL Filter, Discretization
- State-Space Controllers and Pole Placement
- **EXERCISE**
- Controller, Prefilter and Feedforward Control
- **EXERCISE**
- Controller Integrator
- **EXERCISE**
- Robustness and Damping Time Constants
- **EXERCISE**
- Actuator Limitation and Anti-Windup
- **EXERCISE**
- Resonant Controller Integrator (SOGI)



About:

- State-space control methods are now state-of-art for power electronics applications. Their superior dynamic behaviour over PI schemes makes them preferable when it comes to fast and accurate converter control (whilst keeping low computational complexity), due to the increase in harmonics and disturbance behaviour requirements. The tutorial provides structured guidelines for state-feedback implementation of current or voltage tracking issues, outlining strategies such as: Clarify the linear ordinary differential equations, eigenvalues and eigenvectors used (and their connection to stability), accurate modelling and simulations of continuous and discrete systems, design of robust state feedback controllers for typical applications (such as prefilter, feedforward and integral action implementation.

The tutorial will consist of assisted hands-on exercises with Plexim PLECS® and GNU Octave.

Target Group:

This tutorial is specifically designed for engineers and scientists who want to build up or improve their skills in power electronics control.

Technical Chair:
- Benjamin Stickan, Fraunhofer ISE (DE)

ECPE Member Companies:
- 25% discount on each seat

Further new tutorials in 2022 (planned)

For more information, please check: ***www.ecpe.org***

- **ECPE Tutorial: Isolation Coordination**
- **Reliability of Power Electronic Systems**

Speakers

Thomas Basler received his Diploma in Electrical Engineering from Chemnitz University of Technology in 2009. At the beginning of 2014 he received his PhD. His thesis is about short-circuit and surge-current ruggedness of IGBTs. 2014 he joined Infineon Technologies AG, Neubiberg, Germany, where he worked on the development of SiC MOSFETs, diodes and Si IGBTs. In April 2020, he has taken over the Chair of Power Electronics at TU Chemnitz as a Professor.

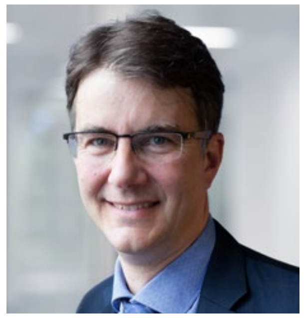
Reinhold Bayerer studied physics at the Technical University of Darmstadt, Germany and completed in 1979. He continued at this University as Research Associate and achieved his doctor's degree in physics in 1985. He works in the field of IGBT Modules since then. He contributed to the fields of packaging technology, low inductance module design, test and application engineering, driver electronics, as well as manufacturing engineering. Until retirement in July 2018, he was Fellow for physics of power modules and working at Infineon Technologies in Warstein, Germany. Today, he is available as consultant in physics of power electronics.

Hans-Peter Feustel studied electrical engineering with a focus on energy technology at the University of Applied Sciences Würzburg-Schweinfurt. After completing his university education in 1978, he worked for a drive technology company for 17 years, developing power electronics for use in machine tools. He has been with Temic, now part of Continental, since 1995, where he developed power electronics for automotive applications. Numerous products for hybrid and electric vehicles have been developed and brought to mass-production under his leadership. From 2010 to 2018 he worked as Principal Technical Expert Power Electronics for Continental throughout the group. Mr. Feustel has been retired since 2018.

Speakers

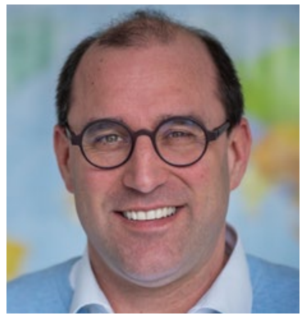
Wulf-Toke Franke has studied electronics at the Christian-Albrechts-Universität of Kiel and received his PhD in the field of power electronics. Between 2011 and 2013 he worked as a technology engineer in the research group of Danfoss Solar Inverters. In 2014 he joint Danfoss Silicon Power with focus on power stack development and research projects. In December 2017 he was appointed to an associate professorship at the just founded Center for Industrial Electronics at the University of Southern Denmark. His research interests are in the field of the reliability of modern power devices and their applications.

Tobias Geyer received the Dipl.-Ing. degree in electrical engineering, the Ph.D. in control engineering and the Habilitation degree in power electronics from ETH Zurich in the years 2000, 2005 and 2017, respectively. Having worked for GE Global Research in Germany, the University of Auckland in New Zealand and ABB Corporate Research in Switzerland, Dr. Geyer joined in 2020 ABB's medium-voltage drives business as R&D platform manager of the ACS6080. He teaches a regular course at ETH Zurich, and was appointed as an extraordinary professor at Stellenbosch University in South Africa from 2017 until 2023.



Eckart Hoene studied Electrical Engineering at the Technical University Berlin, where he received his Dipl.-Ing degree. He joined the Fraunhofer Institute for reliability and Microintegration in 1997 and worked as scientific assistant on EMC in power electronics. This was also the topic of his PhD degree he received from the TU Berlin in 2001. Since then, he worked at the Fraunhofer IZM as post-doc and group leader for the power electronics group. Main topics are semiconductor packaging and EMC. He published over 30 scientific and technical papers.

William Gerard Hurley received the B.E. degree in Electrical Engineering from the National University of Ireland, Cork in 1974, the M.S. degree in Electrical Engineering from the Massachusetts Institute of Technology, Cambridge MA, in 1976, the PhD degree from the National University of Ireland, Galway in 1988 and the higher doctorate D.Eng. degree based on his publications in 2010. He worked for Honeywell Controls in Canada and for Ontario Hydro. He lectured at the University of Limerick, Ireland and was professor of Electrical Engineering at the National university of Ireland, Galway. He is professor emeritus of Electrical Engineering at the National University of Ireland, Galway.



Ingmar Kallfass received the Dipl.-Ing. degree in Electrical Engineering from University of Stuttgart in 2000, and the Dr.-Ing. degree from University of Ulm in 2005. In 2001, he worked as a visiting researcher at the National University of Ireland, Dublin. In 2002, he joined the department of Electron Devices and Circuits of University of Ulm as a teaching and research assistant. In 2005, he joined the Fraunhofer Institute for Applied Solid-State Physics. From 2009 to 2012, he was a professor at the Karlsruhe Institute of Technology. Since 2013, he holds the chair for Robust Power Semiconductor Systems at the University of Stuttgart, where his major fields of research are compound semiconductor-based circuits and systems for power and microwave electronics.

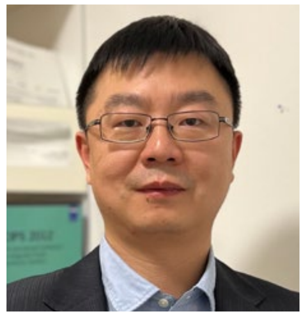
Nando Kaminski received the Dipl. Ing. (1994) and Dr. Ing. (2001) from University of Bremen. He was PhD-candidate at the Daimler-Benz research institute in Frankfurt am Main, where he worked on SiC power devices. From 1998 until 2008 he was with ABB Switzerland. He worked on IGBTs, IGCTs, diodes, packaging, and reliability and finally he became head of the IGBT module fab. 2008 he joined the University of Bremen as full professor. His research interests include alternative semiconductors, material basics, device concepts, simulation, packaging, reliability, influence of parasitics, and EMC.

Ralph M. Kennel got his diploma degree Dr.-Ing. (Ph.D.) from the University of Kaiserslautern. From 1983 to 1999 he worked on several positions with Robert BOSCH GmbH. Until 1997 he was responsible for the development of servo drives. Between 1997 and 1999 he was responsible for „Advanced and Product Development of Fractional Horsepower Motors" in automotive applications. From 1994 to 1999 Dr. Kennel was appointed Visiting Professor at the University of Newcastle-upon-Tyne (England, UK). From 1999 - 2008 he was Prof. for Electrical Machines and Drives at Wuppertal University (Germany). Since 2008 he is Prof. for Electrical Drive systems and PE at Technical University Munich (Germany). His main interests today are: Sensorless control of AC drives, predictive control of power electronics and Hardware-in-the-Loop systems.

Anton Mauder studied electrical engineering and received his PhD in 1996 from the Technical University Munich. He joined Siemens Semiconductor Group, now Infineon Technologies AG in Munich, Germany, and started his work in the product development of IGBT modules. From 1998 to 2004 his focus was the technology development of bipolar power semiconductor devices where he developed innovative freewheeling diodes and led several IGBT and diode development projects. During this time he participated in the development of SiC diodes. From 2005 to 2015 he worked as a project leader in the technology development of high voltage MOS power transistors. Since begin of 2015 he is leading projects in the technology development of IGBTs.

Thierry A. Meynard became a Doctor of the Institut National Polytechnique de Toulouse, France, in 1988 and he is now Directeur de Recherches at the CNRS and IEEE fellow. He has been part-time consultant with Cirtem from 2000 to 2016, founded the company 'Power Design Technologies' in 2016 and 'EIRL Thierry Meynard' in 2020. T.A. Meynard is co-inventor of several topologies of multilevel converter : 'Flying capacitor', 'Stacked MultiCell', '5LANPC', 'AC/AC chopper', 'xPlexed'. These topologies ar used used in a wide range of industrial applications from several watts to several megaWatts by ABB, Alstom, Cirtem, General Electric, Schneider Electric, iCergi, Nidec, SolarEdge,ViSic, EPC, Infineon, Texas Instruments, ...

Speakers



Ziwei Ouyang received his PhD degree from Technical University of Denmark (DTU) in 2011. From 2011 to 2013, he was a postdoc researcher at DTU. From 2013 to 2016, he was appointed as an assistant professor at the same department. Since from April 2016, he is an associate professor at DTU. His research areas focus on high-frequency magnetics modeling and integration, high-density high-efficiency power converters, PV battery energy storage system, and wireless charging etc.

Martin Pfost received the Dipl.-Ing. and Dr.-Ing. degrees in electrical engineering from the Ruhr-University Bochum, Germany. In 1999, he joined Infineon Technologies, Munich, working on GaAs- and SiGe-HBTs. During 2004-2010 he was concerned with device characterization and electro-thermal simulations of power semiconductors, working from 2008-2010 in the Design Center Bucharest, Romania. In 2010, he became Professor at the Robert Bosch Center for power electronics at Reutlingen University, Germany. From 2015 - 2016, he was with the Institute of Mechatronics, University of Innsbruck, Austria. Since 2016, he is chair holder for energy conversion at the TU Dortmund University, Germany.

Lex de Rijk My name is Lex de Rijck and I founded Acradac EMC Training and Consultancy in October 2015. Before that I worked at Philips. During my whole career, I always enjoyed Electromagnetic Compatibility (and still do) and found it a very interesting subject. Over the years I more and more realized that EMC is not just important to comply with legislation, but above all is essential to make a robust product that is not hampered in its functionality by internal EMC problems. In my present day job I give EMC consultancy and EMC courses in a variety of companies with a wide spectrum of products, including power electronics. I also am Technical Advisor EMC in the Power Electronics group of the Eindhoven University of Technology. I have been a course instructor in the EMC-tutorial of the ECPE since 2011.

Martin Rittner is senior expert for power electronics assembly and interconnection technologies in the Corporate Research unit of Bosch. He studied Physics at the University of Stuttgart and received his diploma in Nuclear Physics in 1994. Afterwards he did his PhD thesis in the field of Semiconductor Physics at the same university. Since working as research employee in the Corporate Research sector of Bosch in 2001 he attended several German and EU public funded projects in the field of electronics packaging and assembly technologies for automotive and power electronics applications.

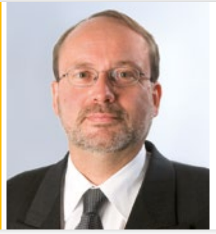
Jean-Luc Schanen is Professor at Grenoble Institute of Technology. He is deputy director of the engineering school Energy, Water and Environment, and member of the Grenoble Electrical Engineering Laboratory (G2ELab). His research activity is focused on EMC of Power Electronics systems. His group develops models and tools for Power Converters optimization.

Uwe Scheuermann has been active in the field of power electronic for 25 years. He worked for SEMIKRON in the development and qualification of power modules and is currently responsible for reliability of components. He is a member of several program committees of international conferences, has published more than 70 papers in the field of power electronics and is co-author of the textbook "Semiconductor Power Devices". Since 2006, he serves as a lecturer at FAU Erlangen/Nuremberg, where he became an honorary professor in the field of electrical engineering in 2014.

Peter Türkes received his diploma and doctoral degrees in physics from Erlangen University/Erlangen Germany in 1979 and 1983 respectively. He has more than 30 years of experience in the power device development and compact power device modelling business. He is now using his experience for consulting and training purposes. In 1984 he was a postdoctoral research associate at the Laboratory of Atomic and Solid-State Physics (LASSP)/ Cornell University Ithaca NY/USA doing research on the low temperature thermal properties of thermo-electric boron carbide. From 1985 to 2000 he was with the 'Corporate Technology Department' of SIEMENS AG/ Munich working on power device physics related topics. In 2000 he switched to the power device development department of Infineon Technologies where he was responsible for power device compact- and thermal modelling issues until December 2018.

Bas Vermulst Bas Vermulst received his BSc, MSc and PhD degrees in Electrical Engineering from Eindhoven University of Technology (TU/e), specializing in power electronic converters. He was a design engineer and system architect for Prodrive Technologies between 2010 and 2016. After, he joined Eindhoven University of Technology as full-time Assistant Professor, where he focuses on research in high-performance power electronic converters and systems.

ECPE Staff



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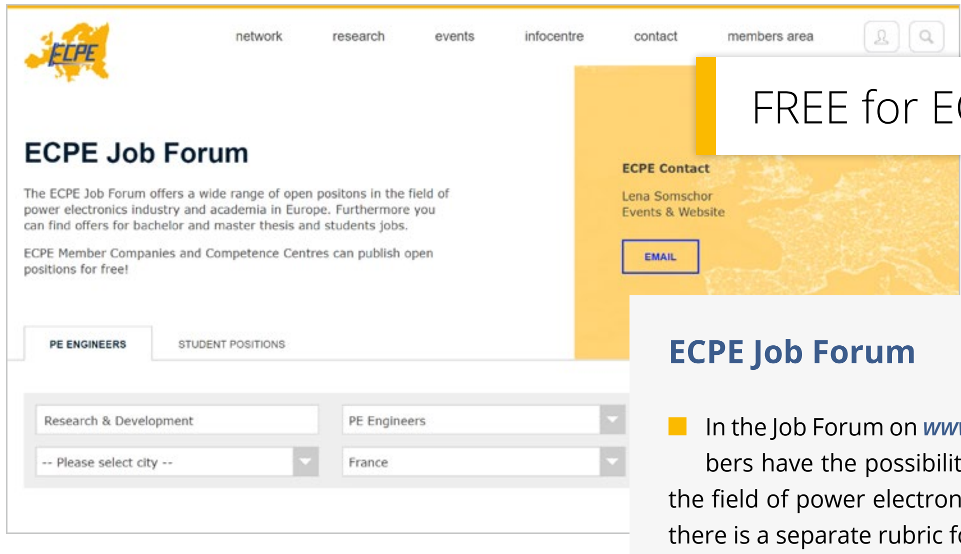
ECPE Job Forum



FREE for ECPE Members

ECPE Job Forum

- In the Job Forum on *www.ecpe.org/jobs* network members have the possibility to publish open positions in the field of power electronics free of charge. In addition, there is a separate rubric for student positions for practical trainings, master thesis or working students.

Visit the ECPE Job Forum on: ***www.ecpe.org/jobs***

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