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Bodo´s Power Systems®

Electronics in Motion and Conversion

November 2022

PULSED INDUCTANCE MEASUREMENT

POWER CHOKE TESTER DPG10/20 SERIES

Inductance measurement from 0.1 A to 10 kA

KEY FEATURES

Measurement of the

- **Incremental inductance** $L_{inc}(i)$ and $L_{inc}(\int Udt)$
- **Secant inductance** $L_{sec}(i)$ and $L_{sec}(\int Udt)$
- **Flux linkage** $\psi(i)$
- **Magnetic co-energy** $W_{co}(i)$
- **Flux density** $B(i)$
- **DC resistance**

Also suitable for 3-phase inductors

WIDE RANGE OF MODELS

7 models available with maximum test current from 100A to 10000A and maximum pulse energy from 1350J to 15000J

KEY BENEFITS

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- **Lightweight, small and affordable price-point** despite of the high measuring current up to 10000A
- **High sample rate and very wide pulse width range** => suitable for all core materials

APPLICATIONS

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- **Development, research** and **quality inspection**
- **Routine tests** of small batch series and mass production

Technological leader in pulsed inductance measurement for 18 years

www.ed-k.de

Content

Bodo's Wide Bandgap Event Nov 29 – Dec 02, 2022
Registration is open at www.bodoswbg.com

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Bodo's 6th WBG Event

I can still remember how Bodo first thought of the idea of launching an event on Wide Bandgap Technology. That was back in November 2016, and the enormous potential of this technology was already clear to him then that wide bandgap semiconductors will become the key elements in future designs. And, as far as I remember, there were not many events covering WBG at this time.

Looking at the list of speakers from the initial event in 2017 it shows that nearly all companies from the first event are also taking part in this year's sixth edition, either under their original names or under the umbrella of a new organization. We have also noticed a constant increase in the number of sessions per event throughout the years, which shows the relevance and importance of Wide Bandgap in particular, and power electronics in general. This is evident from the number of delegates applying from a variety of industries. The event has welcomed visitors from all kinds of international companies over the years, such as Airbus, Audi, BMW, CISCO, Collins, Continental, Daimler, Ford, HUAWAI, Lear, LG, Milwaukee Tool, Siemens, SMA or Tata, to name just a few. The percentage of attendees from academia has always been high, which shows that the audience has just the right mix.

Registration for this year's virtual event, which takes place from November 29 to December 2, 2022, is now open at www.bodoswbg.com. You can expect four days of highly technical content and the opportunity to have your questions answered directly by the experts in live Q&As via Zoom. Best of all, you can use your existing account, that you use for any of the Bodo websites, so you don't have to create a new one. We now have over 40 companies who have confirmed their participation and/or sponsorship of the event, and I am pleased to announce that almost all of the slots in the program have been filled. We are intentionally holding a few spots open as we know there is always someone who 'likes to jump on the train at the last minute'! Please contact myself, or another team member if you are interested in any of the remaining opportunities to showcase your technology at this event – you won't regret it!

Bodo's magazine is delivered by postal service to all places in the world. It is the only magazine that spreads technical information on power electronics globally. We have EETech as a partner serving our clients in North America. If you speak the language, or just want to have a look, don't miss our Chinese version at bodospowerchina.com. An archive of my magazine with every single issue is available for free at my website bodospower.com.

My Green Power Tip for the Month:
Think very carefully about which devices you temporarily disconnect from the mains. It is always a good idea to save energy, but for some devices it is not useful and has the opposite effect. Some can even be damaged, such as certain types of TVs and screens!

Best regards

Events

WiPDA 2022
Redondo Beach, CA, USA November 7 – 9
https://wipda.org

BEVA 2022
Munich, Germany November 8 – 9
www.beva-europe.com

sps 2022
Nuremberg, Germany November 8 – 10
www.sps-exhibition.com

Thermal Management for EV/HEV 2022
Detroit, MI, USA November 15 – 17
www.automotive-iq.com
/events-ev-thermal-management-usa

electronica 2022
Munich, Germany November 15 – 18
https://electronica.de

SEMICON Europa 2022
Munich, Germany November 15 – 18
www.semiconeuropa.org

India Electronics Week 2022
Bengaluru, India November 23 – 25
www.indiaelectronicsweek.com

E|DPC 2022
Regensburg, Germany November 29 – 30
www.edpc.eu

Bodo's WBG Event 2022
online November 29 – December 02
www.bodoswbg.com

European Business Group awarded by Siemens Mobility with Supplier Award "Moving Beyond"

Mitsubishi Electric's Semiconductor European Business Group has been awarded by Siemens Mobility with the supplier award in the prestigious category "Moving Beyond". The decisive factor for winning this award was the development of a 3300 V Silicon Carbide Power Module to enable sustainable railway vehicle solutions for Siemens Mobility. Michael Peter, CEO of Siemens Mobility GmbH, explained during the award ceremony that the implementation of Mitsubishi Electric's 3300 V Silicon Carbide Power Semiconductor Module reduces the overall energy consumption of a train by 10%. "Mitsubishi Electric is setting new benchmarks with its Silicon Carbide technology and making an important contribution to the decarbonization of Siemens Mobility's rail vehicles", Michael Peter added. The award ceremony took place during the Innotrans trade fair on September 23, 2022 in Berlin.

Power semiconductors based on Silicon technology are used in railway vehicles from trams to high-speed trains for a long time. Silicon Carbide is continuously replacing conventional silicon power semiconductors in medium- and high-power applications. Silicon Carbide is a technology which enables manufacturers already today to develop highly efficient traction inverters, that are required for Hydrogen and battery driven trains, which replace old Diesel locomotives on not electrified railway lines. The regional train Mireo Plus B of Siemens Mobility is already contributing to this in the Baden-Württemberg town of Ortenau.

Our society faces the crucial task of accelerating decarbonization worldwide in all areas of transportation with urgency. With its Green Deal, the European Union has committed to becoming the first climate-neutral continent by 2050 with intermediate targets by 2030. This requires a high degree of electrification and the substitute of fossil fuels. This continuous transition must already take place today.

Strong partnerships of manufacturers and suppliers along the entire supply chain are needed to realize this transition. As a supplier of power semiconductors as key components, it is Mitsubishi Electric Semiconductor´s utmost objective to enable customers to bring efficient and sustainable solutions and products to market.

www.meu-semiconductor.eu

2023 Symposium on VLSI Technology & Circuits Announces Call for Papers

The 2023 Symposium on VLSI Technology & Circuits will deliver a convergence of technology and circuits for the microelectronics industry as a fully merged event to maximize the synergy across both domains. The 43rd Symposium on VLSI Technology & Circuits has announced a call for papers around the theme: "Rebooting Technology & Circuits for a Sustainable Future." The six-day conference program will be held at the Rihga Royal Hotel in Kyoto, Japan, from June 11-16, 2023.

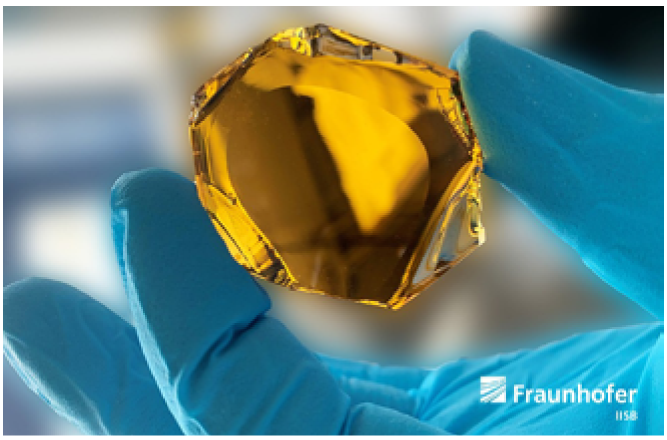
The Symposium will feature advanced VLSI technology developments, innovative circuit design, and the applications they enable, such as artificial intelligence, machine learning, IoT, wearable/ implantable biomedical applications, big data, cloud / edge computing, virtual reality (VR) / augmented reality (AR), robotics, and autonomous vehicles. The deadline for paper submissions to the Symposium is February 1, 2023 at 23:59 JST. Best Student Paper

Award for the Symposium is selected based on the quality of the papers and presentations. The recipient will receive a monetary award, travel cost support, and a certificate. For a paper to be reviewed for this award, the lead author and presenter of the paper must be enrolled as a full-time student at the time of submission, and must indicate on the web submission form that the paper is a student paper.

www.vlsisymposium.org

Aluminum Nitride Crystal with 43 mm Diameter

The Materials Department at Fraunhofer IISB has grown an aluminum nitride (AlN) crystal with a diameter of 43 mm in technol-



ogy-relevant quality. This result is a substantial step to reach the important milestone inside the BMBF funded project Leitban to demonstrate a 2 inch diameter AlN crystal by the end of 2022 and to deliver 2 inch AlN wafers to the consortium. This achievement was possible by the support of the BMBF FMD initiative. The availability of AlN crystals respectively AlN wafers in sufficient size and quality is the key for the manufacturing of high performance AlN-based electronic devices. Aluminum nitride as a semiconductor offers an extreme breakdown field strength, a high material quality, a low amount of defects and a very good thermal conductivity. Due to the special physical properties of AlN, AlN-based devices for power electronics can achieve a performance beyond that of silicon carbide (SiC) and gallium nitride (GaN). Thus, AlN is suitable for the processing of super-low loss power transistors and has the potential to become the most important Ultra Wide Band Gap (UWBG) semiconductor for power electronics in the future.

www.iisb.fraunhofer.de

Patented Switching Technique for Power Electronics Design

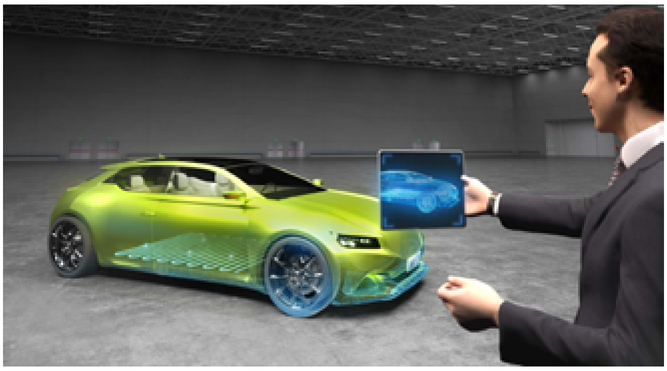
Pulsiv OSMIUM uses a patented method for converting AC to DC that involves charging/discharging a small storage capacitor without the need for a PFC inductor. This solution delivers high power factor, consistently high efficiency and an compact system design. Pulsiv OSMIUM technology can be used to improve overall system efficiency, optimize cost and contribute towards reducing global energy consumption.

The microcontroller family and supporting components can be combined with commodity flyback DC-DC converters to displace higher-cost LLC solutions. Pulsiv has demonstrated a universal input, single switch 150W flyback power supply design that delivers 97.5% average (99.5% peak) front-end efficiency while maintaining 90% at just 2W. A 240W interleaved flyback is currently being developed and work is underway to showcase reference designs with even higher power capability. Pulsiv OSMIUM microcontrollers (PSV-AD-150 and PSV-AD-250 sampling now) do not directly determine output power and can be used as a platform for any application requiring 1W to 10kW, by adjusting only three system components and connecting a suitable DC/DC converter.

Critical components in a Pulsiv OSMIUM circuit operate at low temperatures to extend their expected operating life, even under convection cooling. By regulating the flow of mains through a charging capacitor, Pulsiv has completely eliminated inrush current, meaning that manufacturers of industrial power supplies and LED lighting products can simplify their designs and reduce the cost of system installation. Finally, the technology supports Active Bridge Control, Configurable Hold-Up, X-Cap Discharge, HVDC Output Selection, a Power Consumption Indicator and Grid Failure Detection. These optional features can be selected as required to meet the needs of different end applications.

www.pulsiv.co.uk

Collaboration to Develop Software for Automotive Battery Management Systems



NXP® Semiconductors has joined forces with Elektrobit to co-develop the software platform that supports NXP's high-voltage battery management system (HVBMS) reference design. Using Elektrobit's Classic AUTOSAR tooling and software, the software platform of the HVBMS reference design eases the development of HVBMS architectures for electric vehicles (EVs) by abstracting the communication and controlling interactions between the BMS microcontroller and the battery cell controllers. As demand for battery-powered cars (EVs) continues to increase, so does the demand for improved performance, faster charging time, increased range and battery life, and improved safety. These demands drive rapid technological advancements in EV battery designs, especially for high voltages like 400V or 800V.

As these batteries become more powerful and complex, more sophisticated BMS architectures are needed to ensure the safety and reliability of EVs. NXP's HVBMS RD is a scalable ASIL D architecture composed of three modules: battery management unit (BMU), cell monitoring unit (CMU) and battery junction box (BJB).

NXP's wide portfolio of battery cell controllers, battery junction box devices, and devices for its electrical transport protocol link (ETPL), along with production grade software drivers for these silicon devices, makes it easier for OEMs and Tier 1 customers to enter the growing market of HVBMS and enables them to focus effort on their unique application features. Elektrobit has been collaborating with NXP for more than ten years. Utilizing Elektrobit's EB tresos (AutoCore, AutoCore OS, and RTE), NXP's reference application software and Complex Device Drivers (CDDs) are designed and integrated into NXP's HVBMS RD.

www.nxp.com

1200 Volt Rating on Vertical GaN Power Devices

ODYSSEY SEMI

Odyssey Semiconductor announced it reached the stated goal of 1200 volt rating on vertical GaN power field-effect transistors (FETs). The Company is now applying this validated technology to fabricate product samples in Q4 2022 for internal and customer evaluations, planned through Q1 2023.

"The importance of Odyssey achieving this milestone of 1200 Volt vertical GaN power devices cannot be over-emphasized," said Mark Davidson, Odyssey's Chief Executive Officer. "We are emerging from process and materials R&D to delivering products at voltages that lateral GaN can't practically reach with economics unattainable by silicon and silicon carbide. Our vertical GaN products will deliver high power conversion efficiency at almost 10x smaller than a silicon carbide transistor for the same application." "We are not just fabricating test structures. We're building product samples that customers need. Odyssey continues to close new commitments for product samples as customers gain a full understanding of the capabilities of Odyssey's power devices. The Company is uniquely positioned with the expertise and the IP portfolio to protect it. And with our own foundry in Ithaca, New York, we can innovate quickly and control our ability to supply products to customers," concluded Davidson.

www.odysseysemi.com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Go green+
Get more from your machine
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Efficient • Effective • Enabled
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PowerPros Live Video Application-Engineering Support

Power Integrations launched PowerPros℠, a live online video tech support service that enables power-supply designers to talk directly with members of Power Integrations' applications engineering team 24 hours a day, six days a week, anywhere in the world. Designers worldwide can share a video call with an expert power electronics engineer to discuss real engineering challenges – including full project design and debug – sharing bench-top test results.

Initially piloted during the pandemic to support Power Integrations' customers, the program has been expanded with new facilities, additional team members, extended hours and live video.

Trevor Hiatt, director of channel marketing at Power Integrations, said: "This is a technical solutions service where anyone can speak directly with an experienced application engineer any time of the day or night. The program has been very popular with customers, who rated the program 4.4 stars out of 5 with 93 percent of queries resolved within 72 hours. Some questions are simply a matter of pointing the enquirer to the right part of the datasheet, but many issues go much deeper. PowerPros staff advise on device and topology selection, review schematics and PCBs, help with transformer design, and do live design debugging."

Users of PowerPros can collaborate live with Power Integrations engineers to solve their design challenges in real-time using comprehensive bench instrumentation and design tools. Support is available for any of Power Integrations' extensive portfolio of power supply and driver products and a wide range of applications including industrial, appliance, home and building automation, metering, chargers and adapters, power tools, eMobility, motor drives and LED lighting.

www.power.com

Site for the Production of High-power Semiconductor Modules

Infineon Technologies has opened a factory in Cegléd, Hungary. The factory is dedicated to the assembly and testing of high-power semiconductor modules to drive the electrification of vehicles, which is key in the improvement of the world's CO 2 balance. In addition, Infineon has invested in further production capacities for high-power modules that enable green energy, from wind turbines and solar modules to energy-efficient drives.

"Infineon is pursuing a long-term growth path. Decarbonization and digitalization are driving demand for our semiconductor solutions," said Infineon's COO Rutger Wijburg. "Cegléd already has a strong track record in enabling green energy. The new manufacturing capacities will help Infineon accommodate the growing demand for electromobility applications. At Infineon, we have been investing in the future growth of electromobility from the earliest stage. Today our company is the key semiconductor enabler of the transition to green energy." The growth of electromobility is undisputed. Cars with fully or partially electrified drivetrains will account for more than 50 percent of cars produced by 2027, as per analyst forecasts.

Since its founding, Infineon has shown continuous commitment in Hungary and has now invested an additional 100 million EUR in the new fab, complemented by support from the Hungarian government. Tamás Szabó, Managing Director of Infineon Technologies Cegléd Kft. said, "Infineon has been present in Hungary for more than 25 years as a manufacturer of innovative semiconductor products, building on a highly reliable regional industrial infrastructure. Over the years, Infineon has gained a strong reputation in power modules, serving customers all over the world."

www.infineon.com

Swedish Maker of GaN-on-SiC Epitaxial Wafers to Boost Capacity

SweGaN has completed a Series A financing round totaling €12m. The financing was co-led by Intertech Ventures, Mount Wilson Ventures and leading European investor Atlantic Bridge, with participation by STOAF of Sweden and global fabless semiconductor leader MediaTek, forming a powerful global network from the US, Taiwan, and Europe. SweGaN's GaN semiconductor epitaxy process enables high performance and opens new applications in the multi-billion-dollar GaN-based RF and power markets. The company says that it's QuanFINE buffer-free GaN-on-SiC epitaxial wafers allow customers to reach new levels of device performance and reliability. The company has over 30 paying customers and is in qualification for a wide range of applications in Europe, the US and Asia.

The investment allows SweGaN to significantly increase production capacity to meet market demand from major suppliers of 5G base stations, defence radars, low-orbit satellite communications and on-board chargers in electric vehicles. Additionally, the financing funds empower the company's plans to expand its executive team and to boost engineering, sales, and production staff. In conjunction with the investment, SweGaN also announced the appointment of Jr-Tai 'Ted' Chen as CEO. Ted co-founded SweGaN in 2014 and invented the company's proprietary QuanFINE technology as its CTO.

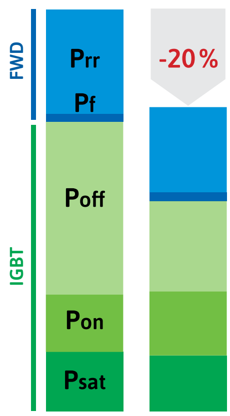
www.swegan.se

PrimePACK™ 7G IGBT Modules

Upgrading to 1200 A in PP2, 2400 A/1200 V & 2400 A/1700 V in PP3+ with RC-Technology

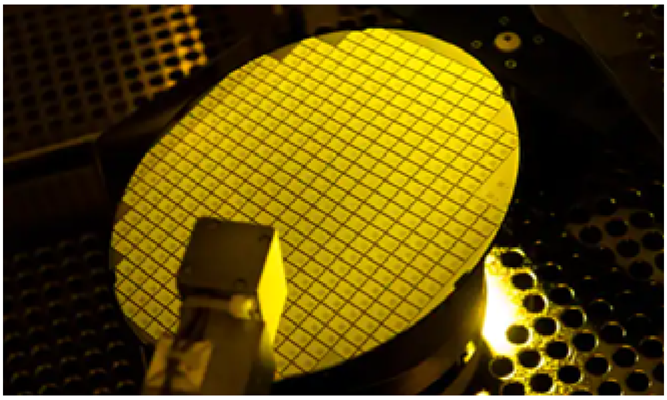
FEATURES

- Newly developed 7G IGBT & FWD
- Improved solder material for higher reliability
- Higher lifetime at same ΔT*j*
- Increased output power
- Higher power cycling capability
- Lower conducting and switching losses
- 2nd label with $V_{CE(sat)}$ and V_F classification for easier paralleling



Silicon Carbide Substrate Manufacturing Facility in Italy

STMicroelectronics will build an integrated Silicon Carbide (SiC) substrate manufacturing facility in Italy to support the increasing demand from ST's customers for SiC devices across automotive and industrial applications as they transition to electrification and seek higher efficiency. Production is expected to start in 2023, enabling a balanced supply of SiC substrate between internal and merchant supply.



The SiC substrate manufacturing facility, built at ST's Catania site in Italy alongside the existing SiC device manufacturing facility, will be a first of a kind in Europe for the production in volume of 150mm SiC epitaxial substrates, integrating all steps in the production flow. ST is committed to develop 200mm wafers in the next future.

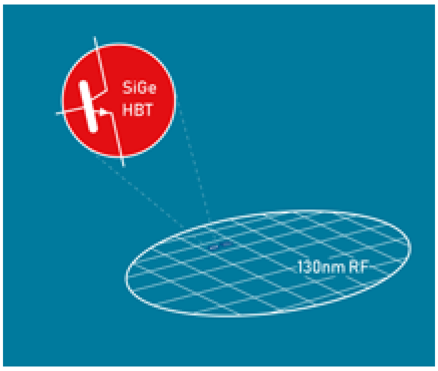
This project is a key step in advancing ST's vertical integration strategy for its SiC business. The investment of €730 million over five years will be supported financially by the State of Italy in the framework of the National Recovery and Resilience Plan and it will create around 700 direct additional jobs at full build-out.

"ST is transforming its global manufacturing operations, with additional capacity in 300mm manufacturing and a strong focus on wide bandgap semiconductors to support its $20+B revenue ambition. We are expanding our operations in Catania, the center of our power semiconductor expertise and where we already have integrated research, development and manufacturing of SiC with strong collaboration with Italian research entities, universities and suppliers" said Jean-Marc Chery, President and Chief Executive Officer of STMicroelectronics.

www.st.com

Agreement Leads to 130 nm SiGe BiCMOS Platform

X-FAB Silicon Foundries has announced a further expansion of its longstanding partnership with the Leibniz Institute for High Performance Microelectronics (IHP). As part of a new agreement, X-FAB will now license IHP's SiGe technology. It will mean the performance benefits of this technology can be brought to high-volume customers. Significantly strengthening the X-FAB technology portfolio, the newly created 130 nm platform provides a solution attaining the elevated performance parameters needed to address next generation communication requirements. Examples of areas benefiting from this technology include Wi-Fi 6 (and future Wi-Fi 7) access points, plus next generation cellular infrastructure (in particular



5G mmW and emerging 6G standards) and vehicle-to-vehicle (V2V) communication. This technology will also be pivotal in the development of +100 GHz radar systems, for use in both automotive and consumer applications.

This license agreement follows on from the collaborative work that began in 2021, where X-FAB's copper backend was added to IHP's SG13S and SG13G2 frontend technologies to boost the bandwidth figures that could be supported. In relation to this innovative SiGe platform, X-FAB is set to start engaging with selected early adopters on prototyping projects during Q4 2022. An early-access PDK is available enabling Prototyping, while volume manufacturing will happen at X-FAB France, the company's facility near Paris.

www.xfab.com

PLECS Conference 2022 – Insights Into Real-Time Simulation

At the PLECS conference in Zurich, leading industrial companies presented their various implementations of real-time simulation with PLECS and the RT Box. The speakers showed how PLECS was successfully used to automatically generate models and controls in

their rapid prototyping process. The speed of the simulations was well appreciated. In addition, the RT Box proved to be very versatile: ALSTOM's Dr. Ing. Roberto Aceiton used the compact RT Box in a home-office environment during the pandemic, while Schindler integrated the RT Box into highly automated systems running overnight simulations of various elevator failure modes. Between the presentations, there were lively discussions on the various features of real-time simulation.

The conference ended with a look into the future of PLECS: Wolfgang Hammer from Plexim presented future features, such as the "comment out" function to disable components for a simulation run and a difference viewer to compare two models.

One question remained for the participants: When will the next PLECS conference take place? Orhan Toker, Vice President of Plexim, says "There will be for sure another PLECS conference in 1-2 years.".

www.plexim.com

Accreditation for Calibration of DC Current Transducers

Danisense announced its accreditation to ISO/IEC 17025:2017, the quality management system and main standard for testing and calibration laboratories. This means that the company can now offer ISO 17025 accredited DC calibration of DCCTs up to 21kA. The ISO 17025 accreditation was awarded to Danisense by the Danish national accreditation body, DANAK.

ISO 17025 accreditation means that the laboratory has met the Management Requirements and Technical Requirements of the internationally-recognized ISO 17025 standard, and is deemed technically competent to produce calibration and testing results. Now Danisense can ship new current sense transducers with the ISO 17025 calibration authority, saving customers a long and painful process and much administrative time and effort.

Explains Loic Moreau, Sales & Marketing Director at Danisense: "The Danisense laboratory was first built in 2017. We have since gained knowledge in the field of metrology, particularly high accuracy DCCT calibration. We have continuedly improved our methods and equipment, and the laboratory has been used to support the development of high-end DCCTs for particle accelerators, MRI scanners, green energy applications like windmills, electric vehicles and many other applications."

ISO 17025 accreditation means that the laboratory has met the Management Requirements and Technical Requirements of the internationally-recognized ISO 17025 standard, and is deemed technically competent to produce calibration and testing results. Now Danisense can ship new current sense transducers with the ISO 17025 calibration authority, saving customers a long and painful process and much administrative time and effort.

www.danisense.com

GaN HEMT Device Performance

Oxford Instruments alongside its research partner Industrial Technology Research Institute (ITRI) can share technology developments that will benefit key hyper-growth electric vehicle, datacentre and 5G markets. The technology developments allow critical transistor components to operate at higher voltages which increases performance and reliability, while also achieving a safer and more energy efficient (normally off 'E-mode') operation compared to existing devices. The GaN (gallium nitride) HEMT device architecture is defined by a recessed and insulated gate junction into the AlGaN layer, and this device is referred to as GaN MISHEMT.

In September 2021, Oxford Instruments Plasma Technology and ITRI announced a cooperative research program for next-gen compound semiconductors. This latest breakthrough is an example of that collaboration delivering on its goal of accelerating technology to benefit the partners, their regions and wider global markets. Since that announcement, Oxford Instruments has also unveiled an exclusive supply deal with Laytec, who's endpoint technology is used to control the GaN MISHEMT recess gate depth. Recess depth accuracy and repeatability is critical to tune the device performance characteristics, and LayTec's technology is designed specifically for this application achieves target depth accuracy of ±0.5nm. ITRI provides pilot production and value-added services, including process verification and product development. ITRI's integration services, especially this GaN development project, have proved incredibly beneficial, which quickly proved out the higher performance of GaN MISHEMT and provided a lower risk and faster route to market for the device.

www.oxinst.com

SVP of Product Dieter Liesabeths

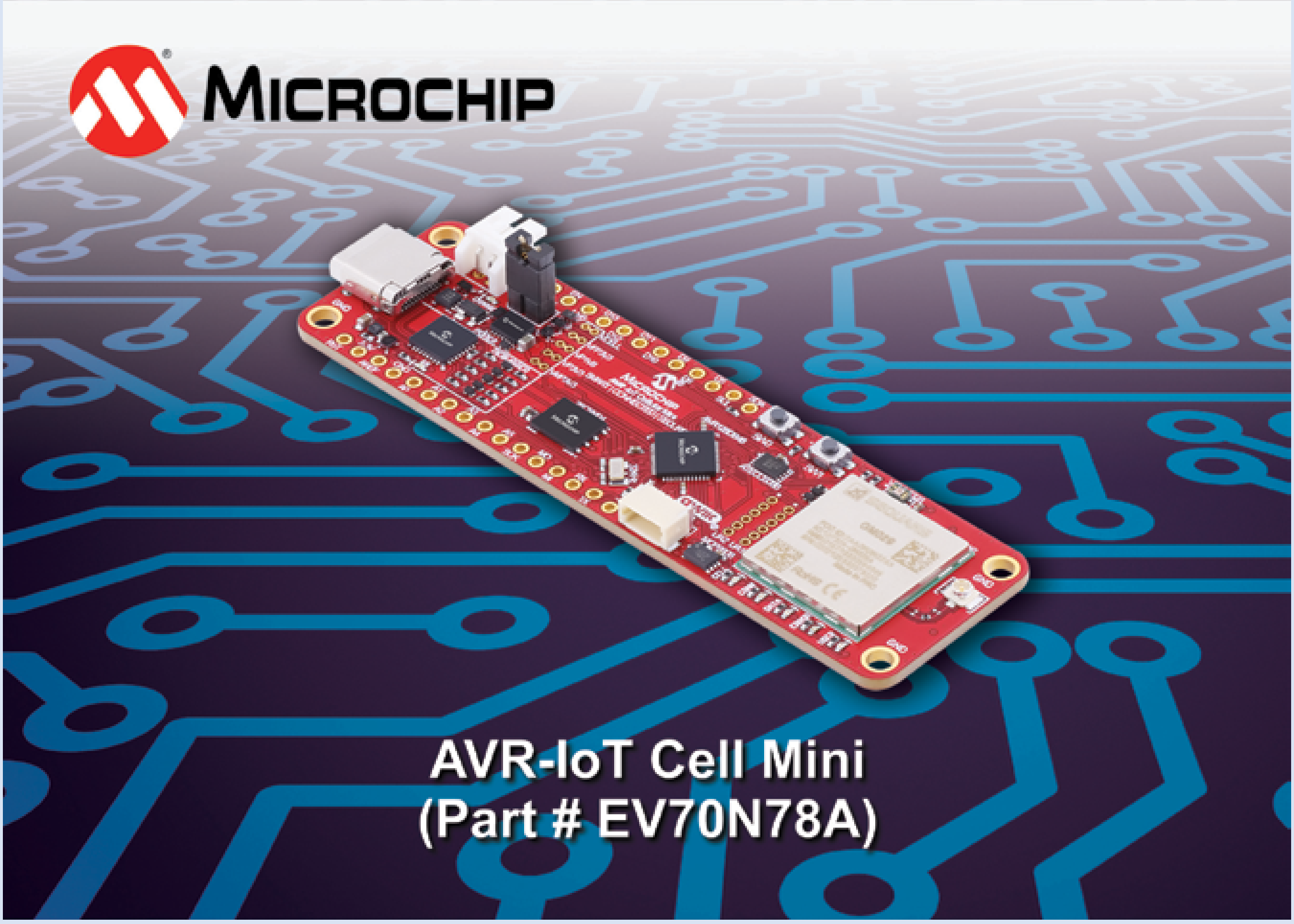
VisIC Technologies is happy to announce that Dipl.-Ing. (TH) Dieter Liesabeths is joining the company as a Senior Vice President of Product. With over 30 years of experience in the semiconductor industry, Dieter will drive the adaptation of GaN power devices in the automotive and industrial fields. In the last 12 years, Dieter was a front-row leader in Europe to drive the conversion from Silicon to WBG, and in his new position he will lead the next generation semiconductors revolution with VisIC's D3GaN (Direct-Drive D-Mode) technology.

"With his long-term experience in wide band gap power semiconductors combined with his excellent knowledge of the automotive market, Dieter is the ideal candidate to extend our management team, expand our footprint in the automotive industry, and lead the transition from Silicon to GaN for the next generation of the electrical drive train and on-board chargers," says Tamara Baksht, CEO of VisIC Technologies Inc. "I'm happy to join VisIC Technologies LTD. as SVP of Product, as VisIC's D3GaN will leverage the development of the next generation of power devices, which will make electrical drive trains more affordable while providing longer range and lower power consumption compared with other wide band gap materials like SiC", says Dieter Liesabeths, SVP Product at VisIC Technologies.

www.visic-tech.com

Win a Microchip AVR-IoT Cellular Mini

Win a Microchip AVR-IoT Cellular Mini (EV70N78A) from Bodo's Power and if you don't win, receive 15% off your next purchase plus Free Shipping.



The AVR-IoT Cellular Mini development board is a development board based on the AVR128DB48 8-bit microcontroller (MCU). This solution provides a robust platform to start building sensor and actuator nodes on 5G narrowband IoT networks. The AVR-IoT Cellular Mini Development Board is a small form factor board making it an ideal solution for developers who want to connect IoT devices to an available 5G network. This is an essential feature for devices on the go or located in remote areas with limited availability of Long Range (LoRa®) networks or other Low Power Wide Area Network (LPWAN) solutions.

Customers can tap into the flexibility and ease of design offered in the latest AVR128DB48 8-bit MCU family, including security protection with Microchip's ATECC608 CryptoAuthentication™ device. The ATECC608 device can easily be configured to most major cloud service providers through Microchip's IoT Provisioning Tool.

The AVR-IoT Cellular Mini Development Board comes pre-configured to send data from on-board light and temperature sensors to the cloud, viewable using Microchip's sandbox portal. The sandbox portal provides customers with the ability to track and monitor their device in real time from a remote location.

This functionality covers the core requirements of many applications in various industries including agriculture, industrial and energy, as well as consumer spaces such as transportation of goods, alarm systems, building automation and remote monitoring.

To provide an even easier, more efficient and more cost-effective solution for developers to connect IoT devices to 5G using the AVR128DB48 MCU, Microchip partnered with Sequans to include its Monarch 2 GM02S single-chip radio equipped with 5G LTE-M and narrowband IoT. Microchip also partnered with Truphone to provide the SIM card for cellular service that offers reliable coverage worldwide. For your chance to win a Microchip AVR-IoT Cellular Mini or receive 15% off your next Microchip purchase and Free Shipping, visit https://page.microchip.com/Bodo-Mini.html and enter your details in the online entry form.

www.microchip.com

The True Cost of Global Energy

By Dr. Alex Lidow, CEO, Efficient Power Conversion

EPC's mission is to make GaN power devices that are higher performance and lower cost compared to silicon. GaN devices increase power density, improve efficiency and enable new applications and with the rising cost of energy globally, it is no surprise that the adoption rate of our GaN devices is accelerating dramatically.

Developing economies are struggling to build energy infrastructure to support industry and bring power to far flung villages. At the same time, industrialized economies are straining to balance conflicting demands for more power while decreasing the environmental impact. Finding ways to meet rising demand for energy without plundering natural resources, poses one of our greatest global challenges and provides one of our greatest opportunities to impact sustainability.

There are multiple costs associated with energy. These costs include the cost of generation, distribution, storage, conversion, consumption, and cleanup. Each of these costs varies with the type of energy and the way it is used.

The cost of generating electricity varies widely from fossil fuels to renewable sources such as wind and solar, or nuclear fission. The cost of distribution and storage for each of these is also vastly different. For example, the cost of storage for renewables can be high when there is no sunshine or wind.

The cost of conversion is also very different for fossil fuels compared with electricity supplied to a server farm. This is an area where wide bandgap (WBG) semiconductors can have a significant impact. The higher speed, lower production cost, smaller size, and lower resistances contribute to better electricity utilization but also to changing topologies that can result in huge savings.

The cost of consuming fuels also differs greatly depending upon the specific usage and is another area where WBG semiconductors can have an impact. Our customers have shown that by using GaN we can save about 30% of the energy used by power supplies and about 20% of the energy produced by more efficient solar panels.

Finally, the cost of cleanup and reclamation of electricity can dramatically impact the total "cost of ownership." For example, the cleanup of the environment from coal usage is worse than natural gas, and solar panels are better than gasoline backup generators. The reclamation of all the electrical equipment we have also needs to be accounted for. Consider the costs associated with recycling vs landfills. Is there a better way to recycle and neutralize the environmental impact of all the electrical gadgets that we have come to consider as almost disposable? The cost of cleanup is frequently not adequately factored into the total cost as it is deferred into the future and creates artificially low costs for certain types of energy that might have higher cleanup costs than others.

Distorting the true cost of the energy we consume can lead to poor choices that have long-term adverse impacts. Factoring in the true cost of energy will promote energy choices that are the most environmentally and socially responsible. Energy efficiency can directly increase global standards of living and the emergence of wide bandgap semiconductors can contribute significantly. Wide band gap semiconductors, particularly GaN will save a large amount of our energy consumption and make way for an improved global standard of living and a cleaner environment.

Alex Lidow will be delivering the GaN Keynote at Bodo's Wideband Gap event on 30th November 2023 where he will discuss 'GaN IC Roadmaps for Motor Drives, DC-DC Converters, and Lidar Systems'.

About the Author

Alex Lidow is CEO and co-founder of Efficient Power Conversion Corporation (EPC). Since 1977 Dr. Lidow has been dedicated to making power conversion more efficient upon the belief that this will reduce the harm to our environment from energy production and consumption.

In order to pursue this mission, in 1977 he joined International Rectifier as an R&D engineer. In 1978 he co-invented the HEXFET power MOSFET, a power transistor that launched the modern power conversion market and displaced the aging bipolar transistor. Royalties from these patents brought in more than $900M over the years, and International Rectifier, prior to being acquired was the largest producer of power MOSFETs in the world. Over the 30 years Dr. Lidow was at IRF, his responsibilities grew. He progressed to the head of R&D, head of manufacturing, head of sales and marketing, and finally CEO for 12 years.

Dr. Lidow holds many patents in power semiconductor technology, including basic patents in power MOSFETs as well as in GaN FETs. He has authored numerous publications on related subjects, and recently co-authored the first textbook on GaN transistors, "GaN Transistors for Efficient Power Conversion", now in its third edition published by John Wiley and Sons.

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High-Power Solutions for Critical Applications

I had the chance to talk to Vito Savino from ABB Power Conversion about their recently introduced series of High- and Low-Power DC/DC Converters and what applications are targeted for these products.

By Bodo Arlt, Publishing Editor, Bodo's Power Systems

Bodo: What is your area within ABB and then can you tell me about your history back to AT&T Bell Lab?

Vito: Sure. Currently, I lead the data center and wireline segment for ABB Power Conversion, which is a division underneath the ABB Electrification umbrella. Our business has a long-established history centered on our telecom-based, mission-critical expertise. This includes back when we were part of Bell Labs, where we helped to power the infrastructure needs of AT&T. I actually started my career in this field in 1988, at AT&T Bell Labs Power Systems division before the Lucent Technologies spin-off. And while we remain grounded in our telecom roots, we're now also designing, developing, and delivering power products, solutions, and services across a broad range of industries, including communications, networking, and transportation infrastructure, as well as industrial applications such as advanced manufacturing, electric utilities, and process industries. Regardless of industry or application, our mission is to provide high-quality, reliable, and efficient power that meets our customers' evolving needs.

Bodo: We are talking about widely used quarter brick power converters. Is there a DOSA standard for these quarter brick DC/DC power converters?

Vito: Yes, our Barracuda-series converters comply with Digital Open Standard Alliance's (DOSA'S) guidelines. Although the organization has been inactive for close to a decade now, its guidelines are still the industry standard, and we recognize the value of maintaining those baseline requirements.

Bodo: Can you give us a more detailed overview of the target applications for your product and the specific requirements you want to meet with it?

Vito: Our high-power Barracuda-series converters are designed to be used for computer servers, data network equipment, 5G wireless infrastructure, robotics, test equipment, and other industrial applications. To facilitate these applications, we ensure our converters feature high efficiencies and high power densities.

Bodo: You also talk about critical applications. What exactly do you mean by critical?

Vito: When we talk about "critical applications," we're really talking about any use case for which downtime or repairs would be very costly or impactful. It's things like wireless communications and internet infrastructure, data centers that keep servers online, supercomputers, and automated testing solutions in factories.

Bodo: What classifications do these products meet? Do you do medical-grade supplies?

Vito: Our high-power Barracuda-series converters meet IPC 9592B Class II Category 2 standards and are EMI Class B. They comply with RoHS Directive 2011/65/EU, amended Directive (EU) 2015/863, and REACH Directive (EC) No 1907/2006. They also have some external filtering, meet global safety standards, and support PMBus deployments. While these converters are not medical grade, we do have other products that adhere to those specifications.

Bodo: Can you point out the main differences between the high-power and low-power versions of the Barracuda products?

Vito: input-voltage range of our Barracuda isolated bus converters is loosely centered around 48VDC — for example, 36-75V for telecom deployments or 40-60V for computing. Our high-power line includes eighth- and quarter-brick versions, which can deliver between 150 and 1500W at 10.4-12VDC out, with optional PMBus capabilities for digital communications. Our low-power Barracuda line delivers from 15 to 120W at 12, 5, or 3.3V outputs. The low-power versions are also available in smaller footprints, including 1x1-inch, DOSA sixteenth-brick modules as well as eighth-brick converters.

Bodo: You offer analog and digital solutions. Can you specify the applications for each?

Vito: Most of our products have digital controls, but we give system designers a choice to better meet their needs. It's not so much about specific applications as it is about the client's preferences. For example, we offer digital controls for PMBus deployments that use a serial communications bus for supervision. Similarly, some high-end original equipment manager (OEM) products, such as servers and network switches, include system controllers that monitor and control individual power supplies. Other applications use a simple "analog" interface to each power supply. These analog options typically include an on/off switch, trim, and remote-output-voltage sensors.

Bodo: Wide bandgap devices are serving for higher efficiency. What are your plans?

Vito: We're continuing to explore and experiment with wide bandgap solutions for future products. While these solutions make some significant performance improvements possible, they cost more and their availability can be limited. Of course, there are cases where silicon may be a better choice at this time and for current applications. Still, the improvements enabled with wide bandgap technology are certainly enticing. We're working to evaluate where the performance gains outweigh potential barriers.

Bodo: A not-so-serious question: ABB's isolated, regulated board-mounted power converters all have names like species of fish. What's the idea?

Vito: Yes—and some dangerous fish at that! Those names—Barracuda, Hammerhead, Orca, and so on—were chosen long ago. I couldn't tell you what the thought process was at the time, but I like to think they are intended to showcase the reliability and power of ABB Power Conversion's products.

Bodo: Thank you Vito. Looking forward to seeing you at one of the upcoming events.

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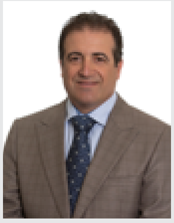

Vito Savino *is the data center and wireline segment leader for ABB Power Conversion, where he works with data center and telecommunications customers to provide advanced solutions for their dynamic power challenges.*

LEM Celebrates 50 Years of Leading the World in Electrical Measurement

Ingenuity and inspiration have been the watchwords for LEM over the last 50 years as it has pushed the boundaries of electrical measurement technology to become a global leader. Electronics design engineers and system design engineers in such sectors as automotive, automation, renewables and charging infrastructures have come to rely on LEM's solutions for energy and mobility that combine optimal performance with unrivalled levels of reliability and safety.

By Maxime Rau, Vice President Sales Excellence, LEM

The half century since LEM was founded in Geneva has been marked by the company now moving into a brand new global Headquater in the same city. Representing LEM's continual investment in the next generation of technologies and talent, the building is a symbol of the company's commitment to the future based on the legacy it developed over the past five decades.

LEM has always led the way. The company's drive to develop innovative solutions to meet demanding market requirements initially bore fruit in 1973, when the first ever current sensors were installed on Swiss trams to enable them to operate more smoothly. More recently, it has culminated in LEM developing world-beating expertise in PCB-mounted current sensors. This will be a major focus at Electronica.

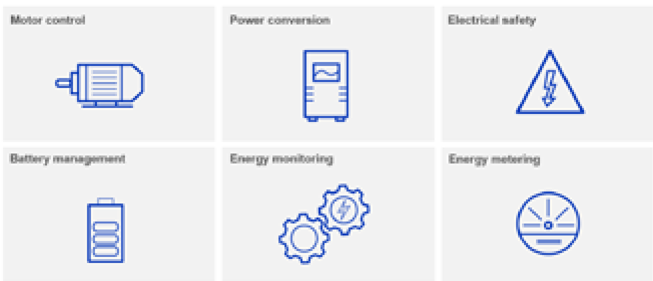

Figure 1: LEM sensors and solutions play a key role in 6 areas

LEM is drawing inspiration for the future from the numerous ground-breaking successes of its past. Through a range of technological and product firsts, as well as its exponential expansion into wider world markets, the company is driven in every aspect of its operations by ingenuity – being genuinely original and inventive to meet the changing needs of customers. Ingenuity – "a particularly clever way of thinking" – is also backed up by teamwork and close co-operation with every party within the supply chain in order to satisfy every challenge it is asked to meet.

Says Jean-Pierre Etter, LEM's founder and CEO of LEM up to 1989: "Ingenuity is a response that comes from demand. Ingenuity is a mindset, accepting a way of thinking differently, listening to one's instincts, and working on practical solutions that are needed. Above all, it is about accepting that by working together and with the customer we are certain to arrive at the right solution."

Focusing on the company's raison d'être, Jean-Pierre adds: "Customers wanted customised products, so we developed products together with them. Afterwards, they viewed these sensors as their own. There was always significant investment in R&D, but to grow and to produce high volumes at lower prices, we had to invest even more in production. We needed automated production, which required machine engineering and production engineers as well."

Hand-in-hand with ingenuity within LEM are boundless energy and dynamism which enable it to identify trends and opportunities to develop cutting-edge products that tend to be world-firsts. The company is not just about selling tens of millions of electrical sensors (66m in 2021 compared to 37m in 2015) but is increasingly concerned with enabling customers – and society in general – to move towards a more sustainable future by focusing on energy, mobility, digitisation and automation.

Continual improvement

The need for continual improvement is in LEM's DNA – standing still is not an option, as can be seen by the constant drive to create the market's best sensors for such applications as automation, railway and traction, automotive, renewable energy, energy distribution and high precision. With a global presence that stretches across 15 countries, LEM doesn't just use its extensive R&D capabilities to develop innovative solutions for customers, it also has to satisfy their specific requirements regarding volume, price and quality. In recent years, LEM has committed to investing between 8% and 9% of sales revenues into R&D.

Of course, new product development relies on sound financial support and investment and a long-term vision from shareholders, so it is fitting that LEM has also announced record annual results in its 50th year of operation, despite the extreme economic challenges of recent years. The pandemic caused significant disruption to supply chains around the world that had an effect on a range of industry sectors but LEM has been sufficiently flexible to adapt so that it remains ahead of the situation and continues to serve its customer base effectively. There are still some supply chain constraints, especially in terms of semiconductors, due to various pandemic lockdowns in China for example, yet LEM has reported a top line sales growth of 24.1% . These figures are not just impressive in their own right, they also underline what LEM has been able to achieve in the face of a global post-pandemic economic recovery. Some areas have seen sales increase significantly above the average – for example, 34.6% growth in the rest of the world outside Europe, China and North America. Indeed, global orders went up for LEM by more than 56% in one year, valued at around 100m Swiss Francs a quarter.

Figure 2: An unparalleled product portfolio

Erik Rehmann, GVA expert for Quality Management

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A changing world offering new markets and opportunities for integrated current sensors

Integrated current sensors (ICSs) were developed by LEM to meet the growing demand for smaller, smarter and cheaper solutions. A key feature of ICSs is that they are able to combine such characteristics as high performance, low form factor, cost-effectiveness, robustness, reliability and safety. This has made them ideal for use in robotics as well as low-power, high-volume applications such as drones and even e-bikes.

Indeed, such megatrends as electrification and decarbonisation present significant opportunities for LEM to grow still further across a range of industry segments that are allied to current measurement, such as power electronics, which are expected to open up major new markets for LEM.

One of the biggest megatrends that will drive substantial growth for the company in the immediate future is the increasing adoption and development of electric vehicles (EVs), which opens up new avenues for current sensors. The rapidly growing demand for EVs leads to an associated demand for more current measuring points (which LEM satisfies with a range of products, including the recently launched HC16, CAB and HSTBV) as well as a new charging infrastructure with the challenges of metering (met by the DCBM 400/600 DC meters). For example, DC fast-charging stations for electric vehicles deliver power to the car battery directly and quickly, which is vital for extending the distance that EVs can travel. The AC/DC power module enables the conversion from AC to DC and sensors ensure the control loop function, which regulates the stability and power of power modules. With the DCBM, LEM has become one of the first companies in the world to introduce integrated functions and a certified software solution for billing electricity for fast charger users.

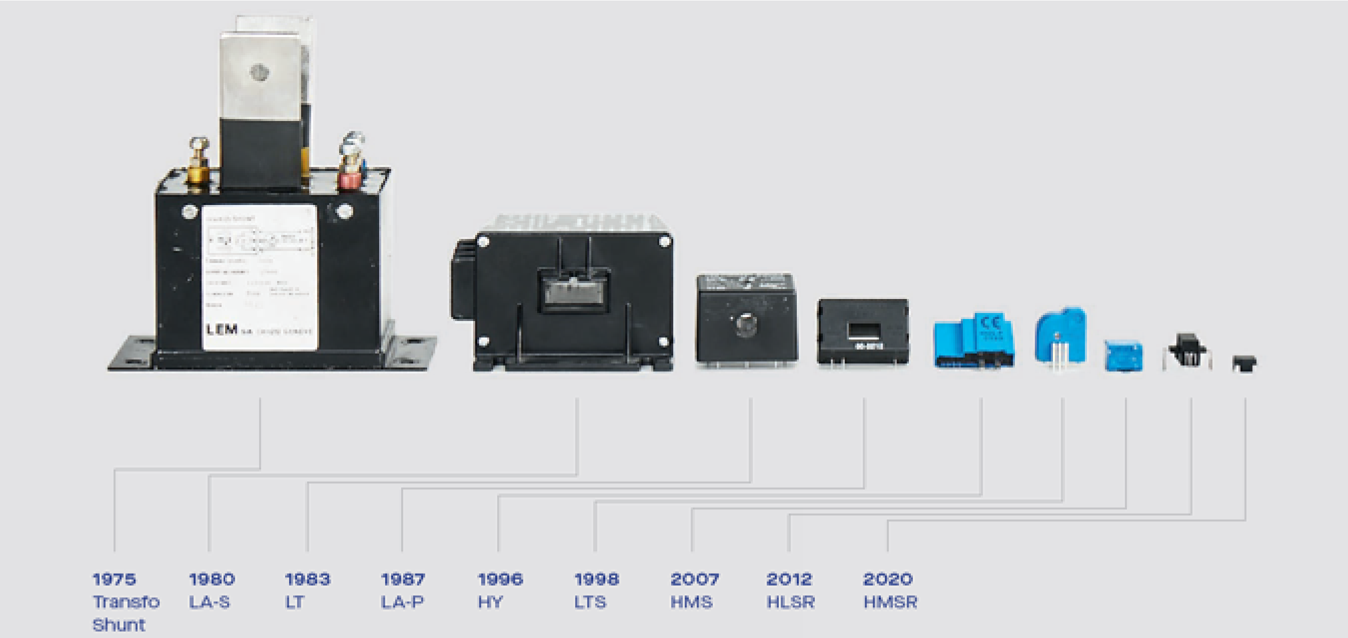

Figure 3: LEM sensors miniturization over time

For example, the newly launched HMSR series mixes superior performance levels with substantial robustness. The HMSR AN analog version offers best-in-class accuracy while the digital HMSR DA delivers high-resolution Sigma Delta digital bistream output. Key features of both devices include a 75A measurement range, reinforced isolation with 8mm Cr/Cl to 4.95kV (IEC60950-1), 20kA lightning tests, and outstanding robustness against external magnetic fields.

Electrification, e-mobility, smart grids, LEM addresses the megatrends

One of the megatrends that such ICSs are designed to address is electrification – the growing demand for smaller and smarter current sensors in such industries as heating, ventilation and air conditioning (HVAC) as well as the aforementioned robotics and renewable energy. Automation and energy-saving applications have been among the main growth drivers for LEM's sales and the company's latest product family of ICSs for small drives and robotics has proved particularly popular. The HMSR ICSs are simply the latest innovation in the continuous evolution (and miniaturisation) of sensors that have not just met the demand for more compact product design but have also been responsible for driving the market forward.

Figure 4: LEM HMSR DA, the first ICS with Sigma Delta bitstream digital output

Figure 5: LEM DCBM, certified metering for DC chargers

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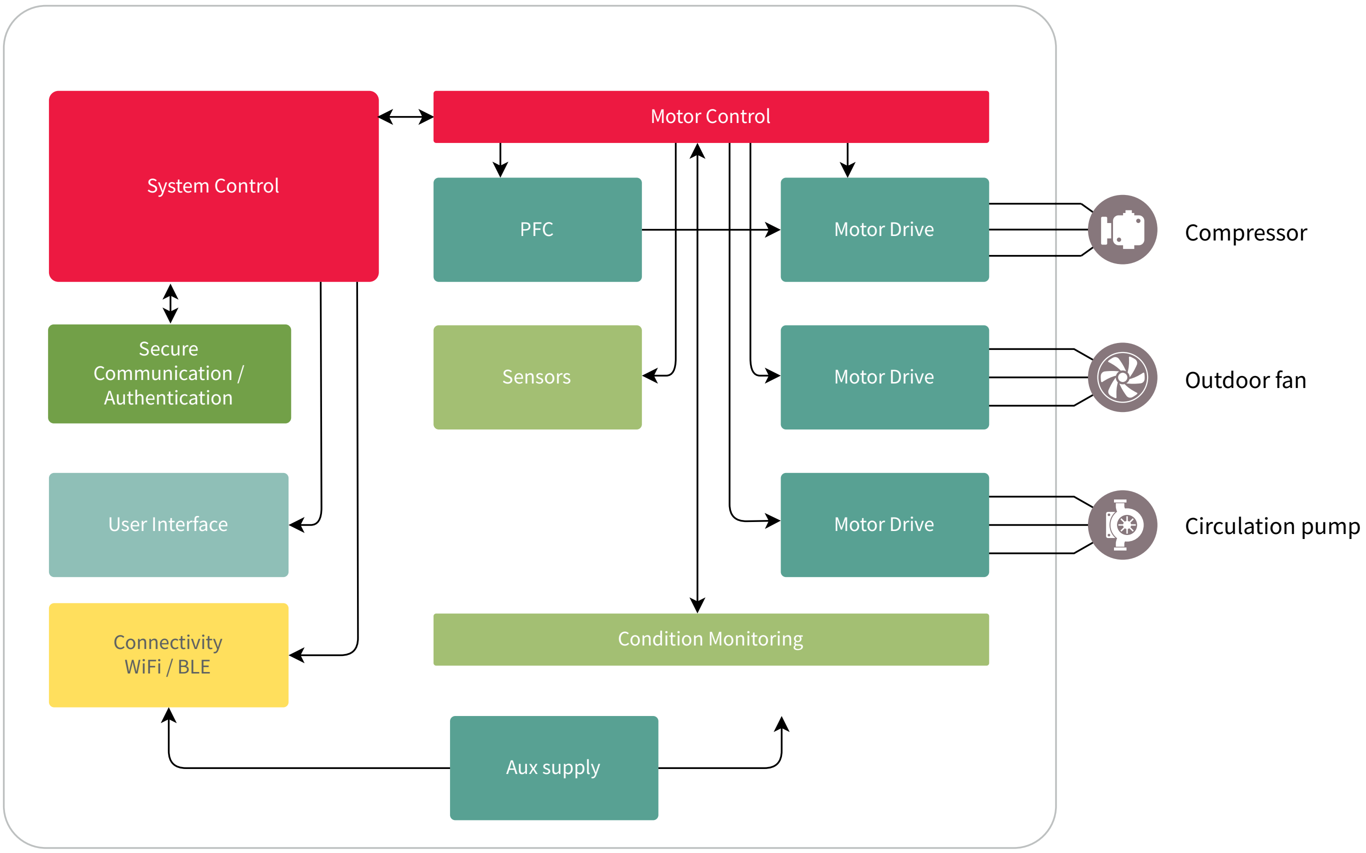

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The increased demand for EVs from consumers has seen LEM's sales in the automotive sector rise by nearly 11% in the last financial year. Because LEM's products have been designed for use in many makes of EV that have entered the market in recent years, the company has seen its market share in China grow by an impressive 31.7%. LEM remains in a market-leading position around the world and is well placed to make the most of the growth opportunities that will come from an international drive to have EVs make up 25% of all new cars by 2025 (and by 2028 half of all annual car production to use hybrid and electric powertrains).

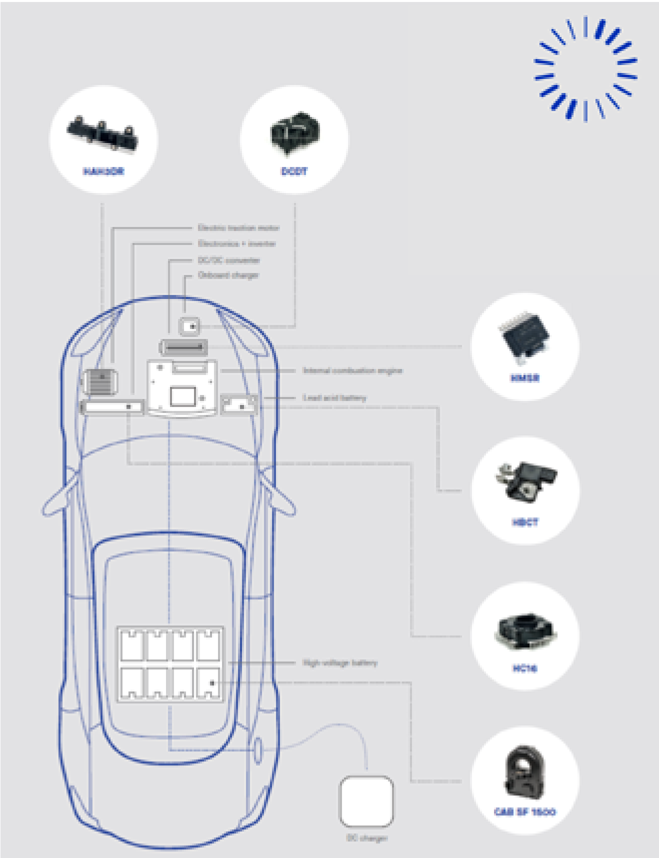

Figure 6: LEM sensors in a DC charging station

LEM believes that the market for current sensors in the EV market will grow from the 125m current phases measured in 2020 to around 450m by 2028. This means increased demand for onboard chargers (OBCs), DC meters and DC/DC converters for energy distribution and management of hybrid and electric powertrains. There is also a greater associated focus on electrical safety because customer protection is enhanced by the ability to detect current leakage – especially important when dealing with battery voltage levels of up to 800V. At the same time, more accurate information can be provided to drivers through more efficient battery management systems that can measure a battery's state of charge (SoC) and state of health (SoH).

Further growth in the market for LEM's current sensors is also expected to come from the move towards driverless cars where sensors will play a vital role in ensuring on-board safety systems offer maximum protection to all passengers in a vehicle. Sensors will form part of a driverless vehicle's automated driving assistance system (ADAS) which is required to operate to the ISO 26262 standard.

LEM is continuing to evaluate sensor technologies of the future, such as high density applications, based around silicon carbide (SiC) and gallium nitride (GaN) which facilitate the higher switching frequencies required in the automotive sector where high performance levels are vital.

A new market for current sensing solutions is the 'smart grid'. With millions of EVs on the road and the move towards decarbonising the world's energy systems, there is growing demand for terawatts of renewable energy capacity. However, the intermittent nature of wind and solar energy requires grid operators to build flexibility into their systems. At the same time, the rapid growth of distributed energy resources (DERs) is decentralising networks and increasing the complexity of their operation. The solution is a 'smart grid' that is able to integrate intermittent renewable energies and DERs. LEM offers best-in-class solutions for meet the demands of utilities and equipment manufacturers in this area, including providing sensors that measure electrical parameters along networks, enabling grid operators to monitor, control and automate operation of the grid.

Looking at the next 50 years

While it is undoubtedly useful to look back, LEM owes its huge success to looking to the future and planning ahead. Over the coming years, from its bases in Geneva, Lyon and Beijing where it has a strong R&D base, the company will continue to develop innovative and advanced products for use in such areas as drives, residual current detection, high precision and semiconductors. LEM is expanding its embedded software capabilities to develop smarter products for traction, DC metering for EV fast-charging stations and automotive battery management systems. The company is also developing R&D capabilities in Sofia, with a particular focus on embedded software.

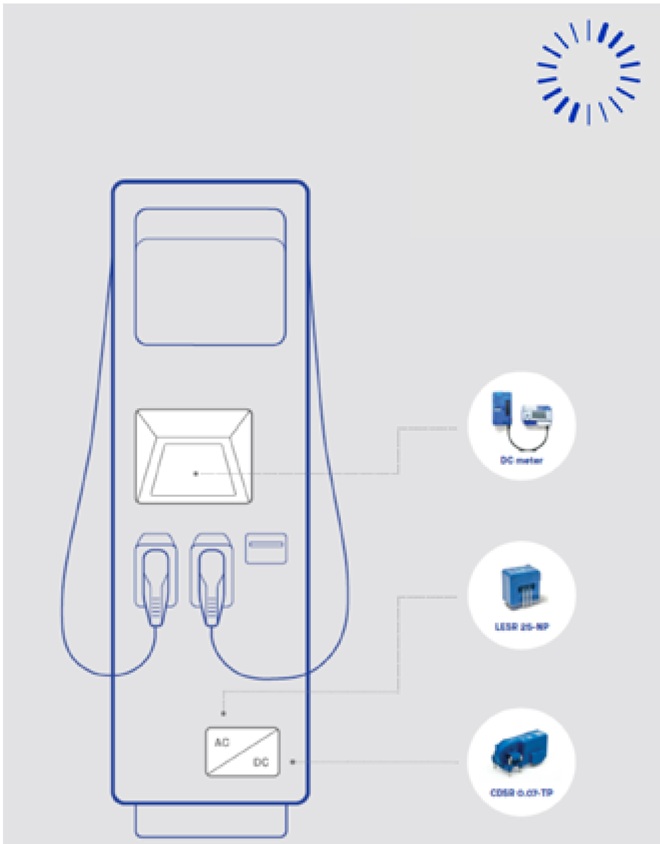

Figure 7: LEM sensors and solutions in a DC charging station

In Europe and Asia, LEM's specialists will also focus on creating such new and advanced systems as embedded software development and validation as well as the pre-development of technologies and innovative applications of the company's products, including algorithms for intelligent battery management. Dedicated innovation teams at both sites will continue to work with universities and technical institutions in a partnership strategy that has proved to be highly successful in driving technology forward.
Indeed, LEM has already begun to make substantial increases in the resources of R&D teams around the world, including doubling the size of the ICS R&D team, which has been enhanced with special-

ists from the semiconductor industry. This move will enable LEM to bring more research and development in-house and become even stronger in the disciplines of design, test development and applications support.

LEM is also investing in next-generation technologies that will support the growing market penetration of intelligent sensors for energy measurement. These investments are a direct response to increased demands in such areas as semiconductors, metering, electromobility and smart grid applications. Manufacturing facilities will also become more localised to minimise supply chain issues and shorten time-to-market timelines for LEM's products. At the same time, a new production plant in Malaysia is expected to begin production in early 2024.

For 50 years, LEM's customers have been pushing boundaries and inspiring the company to develop some of the most sophisticated sensors in the world. Indeed, it is customer demand that has driven LEM to improve to the point that its engineers, R&D personnel, managers and directors are acknowledged as being among the world's most respected experts in electrical measurement.

The industries that LEM's products operate in are highly fluid and change rapidly, with regular technology breakthroughs and newly emerging market opportunities. However, LEM is not just about feeding markets with solutions to problems. The company is also acutely conscious of its responsibilities to society because only by developing innovative products can it enable many industrial sectors around the world to become more efficient in terms of energy consumption and minimising their impact on planet Earth. In line with this approach, LEM itself is looking closely at how it can reduce its own carbon footprint, with the aim of becoming CO2 neutral inscope 1 and scope 2 emissions by 2025 and CO2 neutral in all three scopes by 2040.

According to those responsible for driving forward LEM's continued success in electrical measurement technology, the company's long-term prospects remain incredibly strong, especially because of the megatrends mentioned above that will drive the demand for state-of-the-art sensors – particularly in solar power, electric vehicles and e-mobility.

In a joint statement, Andreas Hürlimann, Chairman of the Board of Directors, and Chief Executive Officer Frank Rehfeld say: "The last couple of years have certainly been tough for many markets but our talented teams around the world have demonstrated again their commitment, ingenuity and resilience in the face of multiple challenges. Our excellent performance is also the result of the trusted relationships we have developed with customers, suppliers and business partners. We relish the opportunities to work together and bring to market new innovative products. Ultimately, all of us at LEM are inspired by a common purpose – helping our customers and society accelerate the transition to a sustainable future. We have come a long way since 1972 and we remain as enthusiastic as ever regarding LEM's prospects for the next 50 years!"

Both add: "We are at the very core of major technical efforts to decarbonise the world. We are a key enabler in this, it drives our structural growth and provides plenty of emerging opportunities. LEM employees and customers are also key enablers of the carbon-free energy systems of the future. We can all make a major contribution to the challenges that lie ahead."

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Short Circuit Tests with 4th Generation SiC MOSFETs in a Power Module for xEV Main Inverters

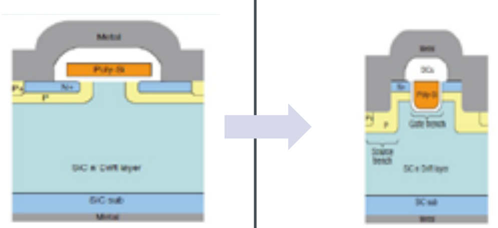
An Application Example for xEV applications

Since the benefits of SiC power semiconductors for electric powertrains are proven, SiC power semiconductors are quickly attracting attention as a next-generation technology. Higher efficiency of SiC MOSFETs compared to Si IGBTs lead to longer driving distances or smaller high voltage batteries, bringing benefits to the consumer. ROHM is one of the SiC pioneers and announced its 4th generation of SiC MOSFETs for multiple applications this year.

By Kevin Lenz and Vikneswaran Thayumanasamy, ROHM Semiconductor Europe

ROHMs 4th generation in xEV

Since ROHM obtained qualification under the AEC-Q101 automotive standard for SiC in 2012, the company has built a track record for SiC MOSFETs, primarily in automotive chargers and DC/DC converters. ROHM presented the 1st trench based SiC MOSFET already in 2015. The experience in process and field design helped to create the newest generation with a 40% reduced Rdson compared to the previous trench-based generation.



	Planar	Trench
Pros	• Easy process	• Low channel resistance • Higher potential to shrink chip size • Lower A*R_{ON}
Cons	• Low channel mobility • Difficult to shrink chip size • Higher A*R_{ON}	• Slightly complicated process than planar process → Needed know-how • Electric field concentration at the bottom of trench gate

Figure 1: Planar vs. Trench

ROHM's latest 4th Gen SiC MOSFETs deliver low ON-resistance per unit area through advanced technology utilizing a trench gate structure. At the same time parasitic capacitance, the source of switching loss, has been reduced. This translates to a 40% performance improvement in drift layer resistance and 50% lower switching loss compared with 3rd Gen SiC MOSFETs. Switching loss in particular account for more than 70% of the losses generated by SiC MOSFETs in traction inverter applications, so minimizing this can contribute to significantly improved efficiency. [Tamegai]

Incidentally, superior response enables higher frequency operation, leading to smaller heatsink, capacitors, and other components used to smooth out the waveforms of voltage and current. And as the size of these components greatly affect the size of the inverter, they also contribute to greater miniaturization. SiC's high temperature resistance is also advantageous to downsizing. Compared to silicon power semiconductors, SiC enables stable performance at temperature exceeding 100°C (actually up to 175°C but the package and wiring cannot withstand this), allowing the cooling structure to be simplified by changing from water to air cooling and reducing the size of the heat sinks. [Tamegai]

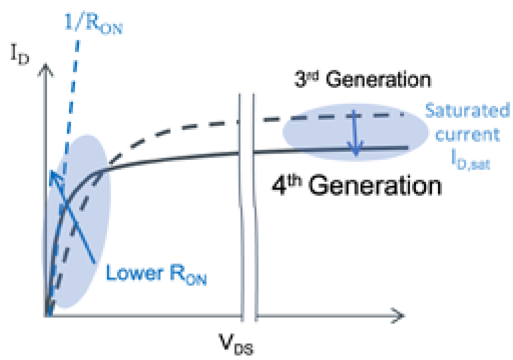


Figure 2: Optimized Short Circuit behavior

Short Circuit Tests

ECPE's guideline AQG 324 describe two short circuit scenarios which should be qualified on power module level [AQG 324]:

1. A Short circuit when no current was flowing before a.k.a. Short Circuit Type 1
2. A failure under load a.k.a. Short Circuit Type 2

Due to their high short circuit current and lower short circuit withstand time in comparison with Si-IGBTs, SiC MOSFETs require a fast and precise short circuit detection method. For this purpose, experimental short circuit detection and protection results of a newly developed power module using the conventional drain source monitoring method (a.k.a. DESAT) are presented at [PCIM 22].
The device under test used for this investigation was a power module for e-powertrain applications equipped with ROHM's newest generation of SiC trench MOSFETs.

Expectations 4th Gen in SC

ROHM's latest 4th Gen SiC MOSFETs reduce loss without compromising durability and reliability (short-circuit withstand time). Together with a low inductive power module design this promise an ideal solution for e-vehicle traction inverters.

Device under Test and Test setup

In ROHMs Power lab in Willich/Germany short circuit tests with 4th Gen were performed and presented at [PCIM 22]. A Power module from Semikron was used and a Gate driver testboard based on ROHMs Gate Driver BM6112 (20A output DESAT detection and Advanced Soft turn off) was developed to perform the tests.

The device under test (eMPack module from Semikron) was equipped with 4th Gen SiC MOSFET dies. It includes six switches (three half bridges) and was specifically developed for automotive traction inverters [4]. Blocking voltage of the semiconductors is 1200 V, the module's rated current is 780 A. A very low stray inductance has been realized through an innovative internal assembly and connection method to the DC-link capacitor. [PCIM 22]

To detect a Short Circuit the short circuit desaturation detection (DESAT) method was used. After DESAT is triggered, the so called Advanced Soft Turn Off (ASTO) is used to turn off the device quickly and safely.

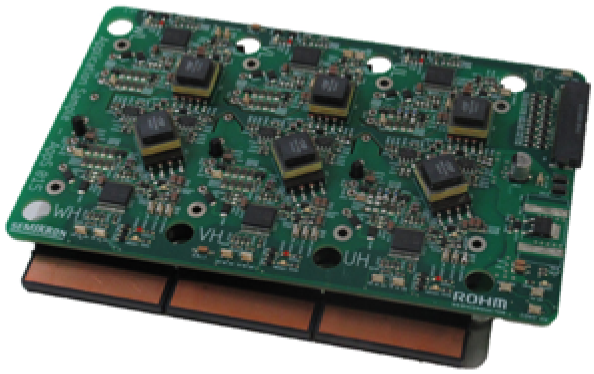


Figure 3: Testboard BM6112 for eMPack: "EMPACK6CHGD-EVK-301" with six GDIC BM6112FV for IGBT and SiC MOSFET, Vgson/off: 18V/0V

Test results

Before we present our results, we like to explain the Gate driver settings. Even if ROHMs 4th generation SiC MOSFETs are designed to withstand higher short circuit withstand times, we defined our goal based on market typical requirements. The market trend for DESAT detection circuits is to turn off a short circuit within 1.5-2µs.

Per definition the short circuit time is between the 10% of ISC during turn on and 10% of IC during turn off.

There are in general two gate driver design criteria which play a role in managing the short circuit time:

1. DESAT detection time
   Goal: tradeoff between detection speed and sensitivity
   Parameters: R1, R2, R3, D1 (pic. 4, left)
2. Turn off slope:
   Goal: tradeoff between turn off time and overvoltage due to parasitic L * di/dt
   Parameters: ASTO feature: R_PROOUT1 for ~160ns after DESAT is detected and R_PROOUT for the rest of the turn of slope (pic. 4, right)

We adjusted the gate driver board (picture 3 and 4) in a way that we first evaluated the DESAT with a hard short circuit (like type 1). We tested different soft turn off scenarios:

STO: Soft turn off
(R_PROOUT1=10Ω, R_PROOUT2=open)

ASTO: Advanced Soft Turn off
ASTO1: fast turn off
(R_PROOUT1=10Ω, R_PROOUT2=1.2Ω)
ASTO2: optimized ASTO
(R_PROOUT1=10Ω, R_PROOUT2=2.7Ω)

With ASTO1 design, the shortest t_{SC} was archived. However, the peak voltage upon turn off is with 1156 V which provides a low safety margin for a 1200V rated power device.

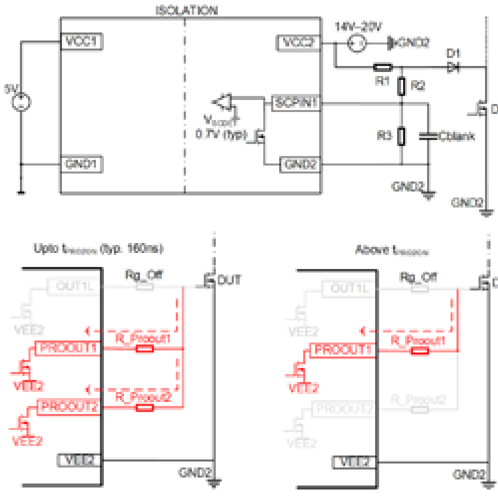
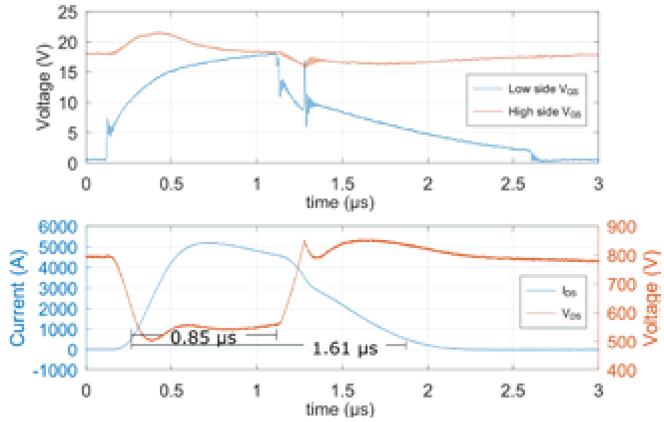


Figure 4: Top: DESAT detection in BM6112 [datasheet BM6112], bottom: ASTO [PCIM 2022]



Type of Soft turn-off	$V_{DS,pk}$ [V]	t_d [ns]	t_{SC} [µs]	E_{SC} [J]
ASTO1	1156	850	1.34	2.88
STO	854	850	2.01	4.26
ASTO2	856	850	1.61	3.31

Figure 5: top: SC type 1 with ASTO 2, bottom: results with ASTO1: fast turn off, ASTO2: slow turn off

With STO and ASTO2 the overvoltage can be significantly reduced to an overshoot of less than 60V and thus a very good safety margin. The SC time with conventional soft turn off (STO) was around 2us with an overvoltage of 56V. ASTO2 achieve a shorter SC time (1.6us) and similar overvoltage levels as STO. Using ASTO2 is clearly a benefit since neither of SC time and overvoltage are compromised, henceforth will be used for further measurements shown in this article.

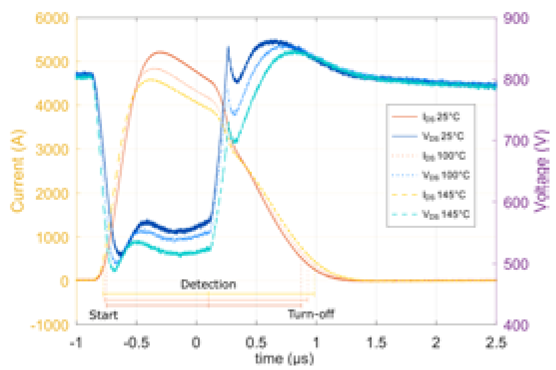


Figure 6: Short circuit Type 1

Second step was the evaluation of temperature's influence for both, SC type 1 and 2 using ASTO2.

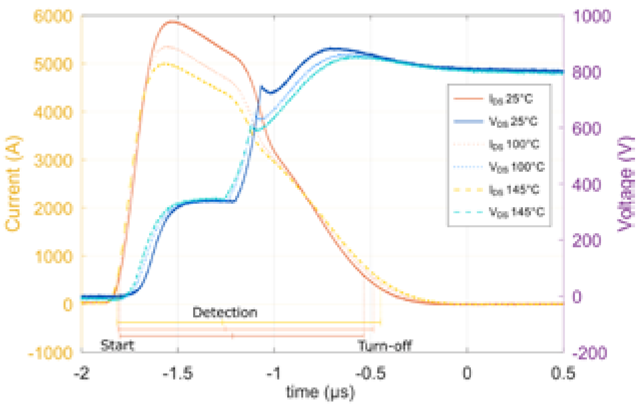


Figure 7: Short circuit type 2

Targets of the investigation:
Influence of temperature on

- td (DESAT detection time)
- tsc (short circuit time)
- Esc (short circuit energy)

Turning off the short circuit in both SC cases was possible within 2us. The gate driver detected independent of temperature, SC type I within 870ns and SC Type 2 within 550ns. The power device was also safely turned off within 1.7us in case of SC Type I and 1.3us in case of SC Type 2.

Conclusion

ROHMs newest SiC MOSFETs generation performs very well in a short circuit. The short circuit current of the 1200V MOSFET is round six times of the rated current in the device under test. A target SC time less than 2us was achievable and with an optimized Gate driver design (DESAT and ASTO) the overvoltage upon turn off was also less than 60V. With an optimized Gate Driver design (using DESAT and ASTO) it was possible to switch the short circuit off within 1.6µs by getting less then 60V overvoltage peak.

The combination of ROHMs 4th Gen SiC MOSFET in Semikron's eMPack and ROHMs Gate Driver BM6112 are developed for automotive power train applications and bring xEV designs on the highest level of performance and robustness.

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[AQG 324]; ECPE Guideline AQG 324, Release 03.1/2021

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Acknowledgement

It was a pleasure to collaborate with Ingo Rabl and Jürgen Engstler from Semikron on this investigation. Thanks also to our colleagues from headquarters, especially Yoichi Tamegai, Akifumo Enomoto and Naoyuki Kizu.

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www.rohm.com

DAB Calculations for a 3kW Battery Charger Application & Magnetics Design

The dual active bridge (DAB) topology is currently raising a lot of interest from the power electronics community. Its bidirectional nature, soft switching and high efficiency features make the DAB a perfect candidate for high power applications like battery energy storage systems. Galvanic isolation is normally required and achieved by using a transformer between the isolated and non-isolated sides. In this article, the basic calculations and tools to design a 3kW transformer for a 48V LiFePO4 pack are presented.

By Sotiris Zorbas, Power Electronic Engineer, Frenetic

Basics

In Figure 1, the basic DAB configuration is shown in the Frenetic Circuit Simulator. In simple terms, it is two full bridges with a transformer that separates them in the middle, and with symmetry being one of the characteristics of this topology. It's easily inferred that, with proper control, power can be bidirectionally transferred from any of the bridges to the other. Notice that the transformer is modeled as an ideal transformer in parallel with a certain magnetizing inductance and a series leakage inductance. In the DAB topology, the leakage inductance is a key specification parameter.

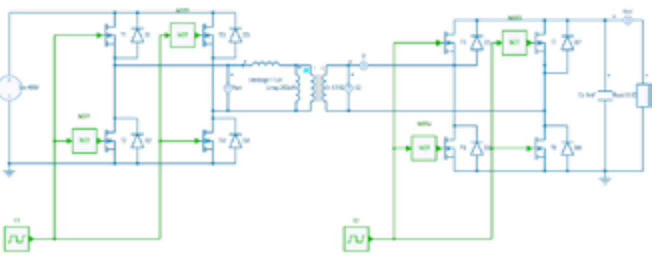

Figure 1: The basic DAB configuration

Controlling a DAB

In Figure 1, C1 and C2 control modules drive each bridge independently, having the same frequency. C1 or C2 can introduce a phase shift between signals, controlling their respective bridge. There is also the option of a third phase shift between C1-C2. Therefore, there are three phases in total that can be controlled.

We have the Single (SPS), Dual (DPS) and Triple Phase Shift (TPS) control methods, where naming implies the number of free variables for control. The simplest case is SPS, where the phase shift between C1 and C2 is the one manipulated. SPS is easy to use and has high efficiency with ZVS, in particular at heavy load, acceptable current stress, and relatively low reactive power when the output-input voltage gain is close to one. Also, the phase shift between mosfets in each bridge is fixed at 180° for both C1 and C2. To achieve the best performance throughout the wide power and voltage range, DPS has been developed, particularly to maintain ZVS and restrict the switching current at the medium load. In DPS, the phase shift between the legs of a bridge is not necessarily fixed at 180° but is the same for both C1 and C2. In TPS, C1 can have a different phase shift than C2 and it is advantageous at light load or even no-load condition securing ZVS for all switches.

SPS control method

SPS is the easiest control method to implement. Of course, there are disadvantages if compared to DPS or even TPS, but efficiency and ZVS for all mosfets are not in this list. Therefore, SPS is a reasonable choice for a charger application, at least.

As mentioned above, the leakage inductance is a key spec parameter. In a DAB, the leakage inductance, which can be increased by introducing a series shim inductor, controls the limit of the maximum available power for transfer.

For SPS:

$$L_{lk} = \frac{T_{sw}(1-D)DV_{in}V_o n}{2P_{\max}} \quad (1)$$

and

$$D = \frac{phase\_shift}{\pi} \quad (2)$$

Where D is the parameter with values 0 to +/-1 indicating a phase shift between C1-C2 from 0° up to +/-180°.

Worth mentioning that in (1) the term D (1-D) actually controls the power output, given that the other parameters like L_{lk}, n (transformer turns ratio), V_{in} or V_o stay the same. This term maximizes its value at D=0.5, which translates using (2) into a 90° phase shift. More or less phase shift than 90° will result in lower output power. If the sign of D is negative, that implies a negative phase shift and means that the power travels the other way.
In theory $90°C \leq D\pi \leq -90°C$ is all it's needed to control the maximum power output and its flow, but in reality the practice is to design for max power output at a +/- 60°-70° phase shift, limiting the reactive currents inside the bridge that would result in unnecessary losses. The higher the phase shift, the higher the reactive currents, thus the rms currents and the losses in the bridges.

Another useful formula is the output to input voltage ratio:

$$d = \frac{nV_o}{V_{in}} \quad (3)$$

V_o: is the output voltage
V_{in}: is the input voltage
n: is the transformer turns ratio (Vpr/Vsec)

ZVS areas

The SPS topology offers full zero-voltage switching for all x8 switches, when operating under certain conditions. Unfortunately, turn-off losses exist, but the mosfet driving circuitry can effectively minimize them. That said, targeting an efficiency goal of 95-97% design is within reach. That effort is however compromised if the DAB doesn't experience ZVS. The following equations describe the necessary phase shift to achieve ZVS in the two bridges:

$$D > \frac{d-1}{2d} + \frac{2\sqrt{L_{lk}C_{eq\_i}}}{Td} \qquad (4)$$

$$D > \frac{1-d}{2} + \frac{2d\sqrt{L_{lk}C_{eq\_o}}}{T} \qquad (5)$$

L_{lK}: transformer leakage inductance (or the sum of transformer leakage and the inductance of a series inductor to increase the total available inductance).
C_{eq_i}: Input bridge equivalent mosfet Coss + transformer parasitic capacitance
C_{eq_o}: Output bridge equivalent mosfet Coss + transformer parasitic capacitance
T: switching period
Using (4)(5), graphs similar to the one presented in Figure 2 are obtained.

Notice the "ZVS zone" in Figure 2. Equation (4) describes the "leading FB" condition to achieve ZVS and marks the upper boundaries in Figure 2, above the d=1 line. Respectively, equation (5) sets the necessary condition for the ZVS of the lagging bridge. Choosing a phase shift that satisfies both equations means that ZVS is achieved in all switches. This implies a minimum D, thus a minimum power output as described in (1).

Also, when the phase shift is low, in a light load scenario, there is a strict margin for ZVS operation. Keeping the d ratio close to 1 is the way to solve this problem and maintain ZVS. In a battery charging application, there is a mode of constant voltage until power goes down as the battery approaches its full charge drawing less and less power from the DAB. That's a light load scenario in this application.

Table 1 is the specs table for the charger application. As mentioned, the value of d (output to input voltage ratio) should be as close as possible to 1, especially at light loads, to stay within the ZVS zones, so the turns ratio should be selected accordingly.

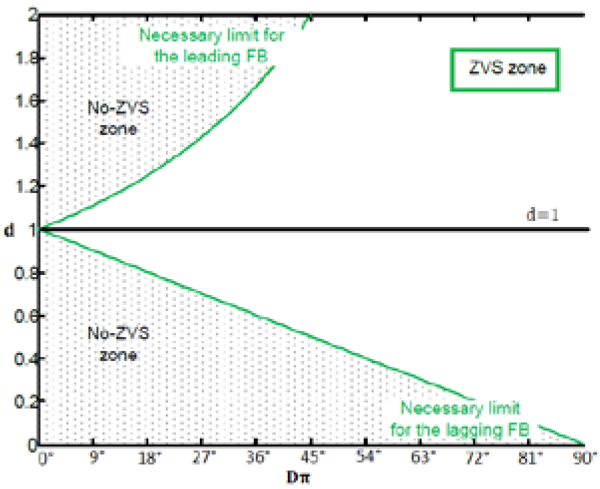

Figure 2: ZVS areas in SPS

When the battery voltage is high (i.e., an almost charged battery pack) the turns ratio should result in a d=1 value. Solving (1) for a maximum output voltage of 54V, n=8.5. On the other hand, when the battery is discharged (47V) with a selected n=8.5, then d=1.14. For manufacturing reasons n=8 was finally selected.

The leakage inductance is given from (1), choosing a maximum phase shift at 60° or Dmax=60°/180° = 0.33, then Llk=52uH. The minimum power at which ZVS is achieved highly depends on the Coss of the mosfets in each full bridge leg. Taking a typical case of 200pF of leg capacitance on the HV bridge (primary winding) and

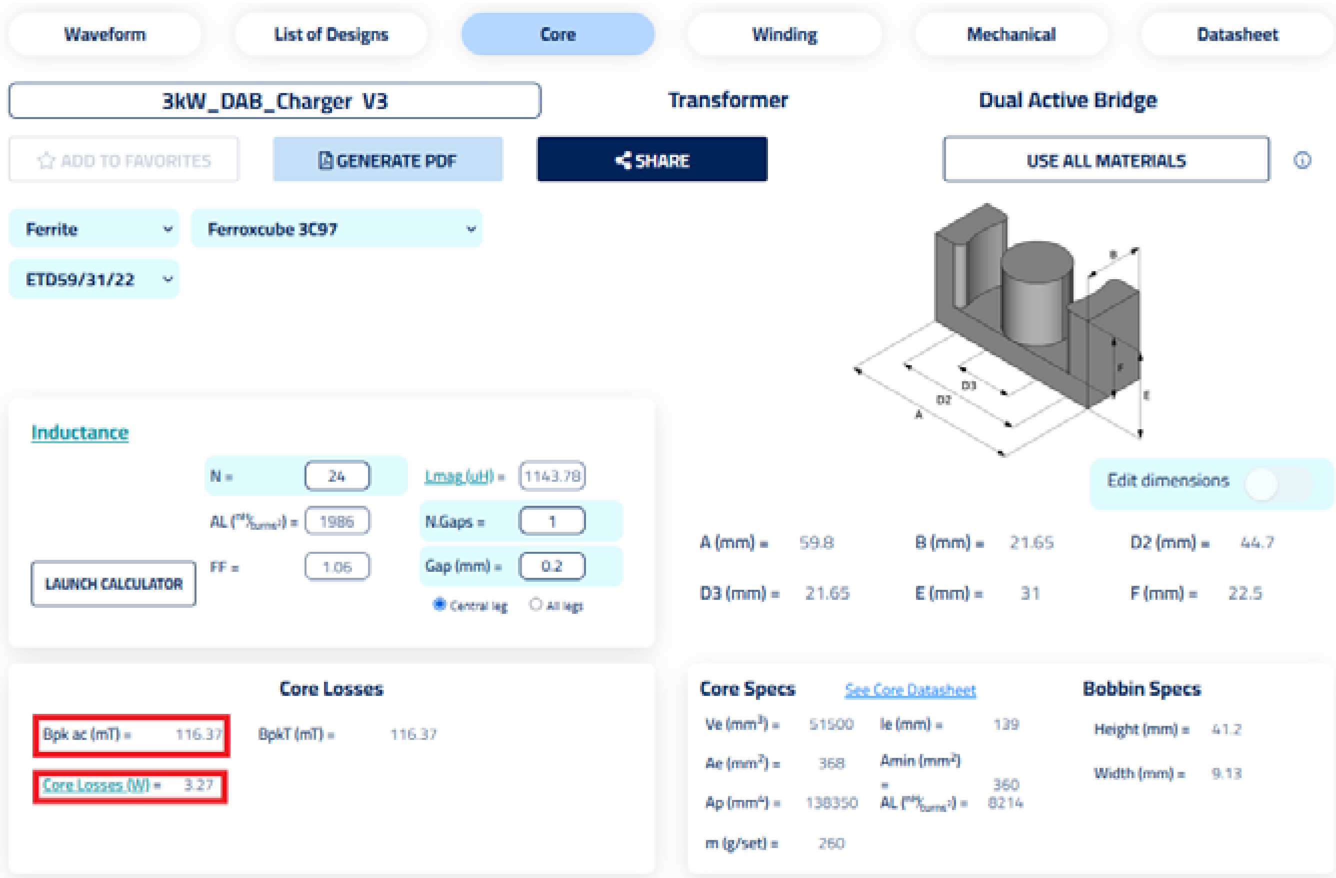

Figure 3: Transformer core selection and losses

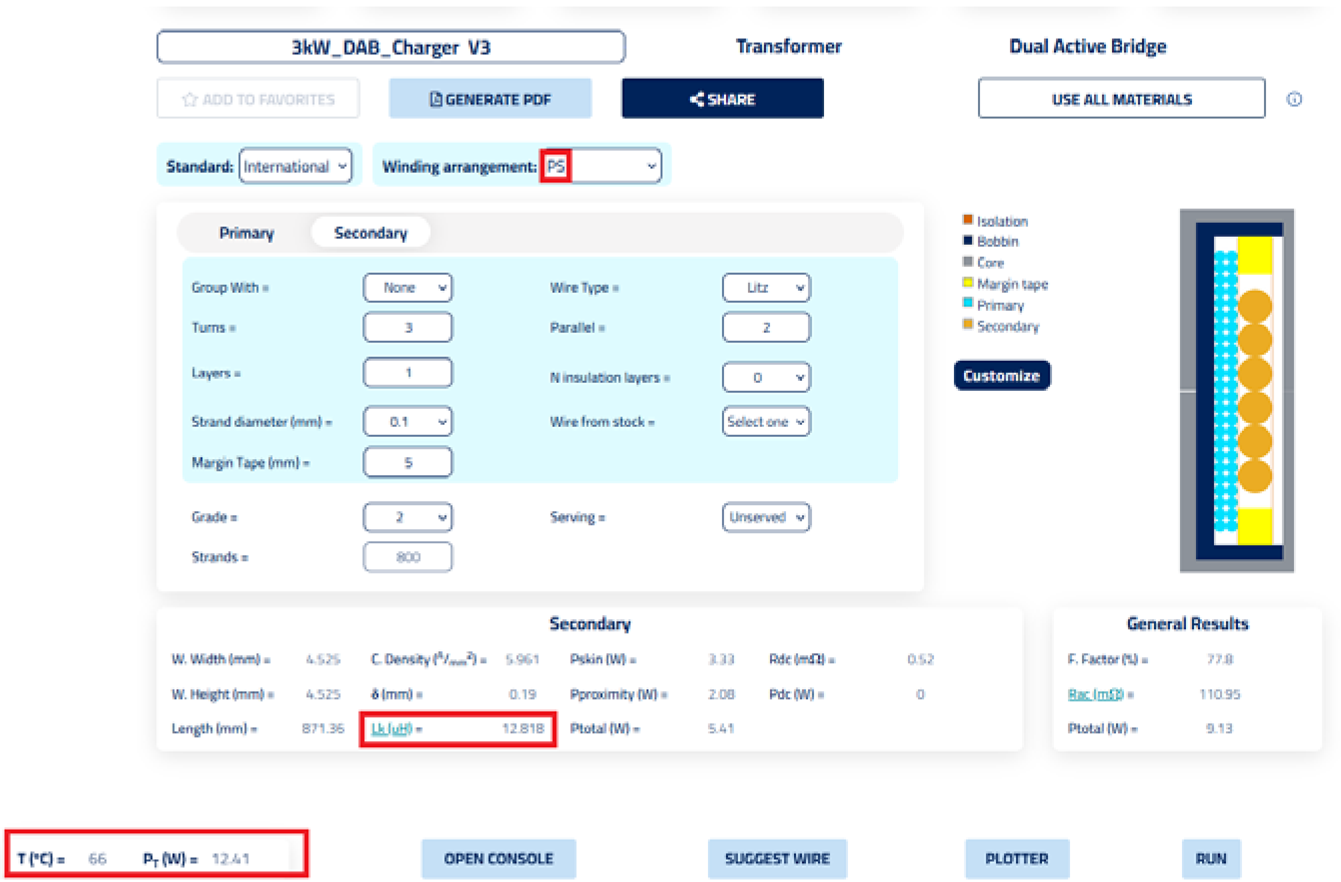

Figure 4: Transformer windings and losses

2000pF at the LV bridge (secondary winding) from (4)(5) to achieve ZVS in all switches the minimum power output should be between 620W and 1230W when the battery voltage moves from 47V up to 54V.

Magnetics design

All the necessary parameters to model and choose the transformer and/or shim inductor are now known. The parameters of Table 1 are given as input to Frenetic Online and in Figure 4 the core selection is ongoing. The important parameters of the core, marked in red, are calculated in real time as

DAB charger example	
Parameters	Value
V_{in}	400V
V_{out}	47-54V
P_{max}	3kW
f_{sw}	100kHz
n	8
L_{lk}	52uH

Table 1: 3kW DAB specs

the engineer finetunes the gap of the ferrite cores, the number of turns in the primary winding etc. A ETD59/31/22, C97 material core was chosen, with a 0.2mm gap and 24 turns on the primary winding. A flux density swing at 116mT and core losses at 3.27W are acceptable.

In Figure 4, the transformer windings are chosen. The PS (P: primary, S: secondary) winding arrangement keeps the layer number down, achieving low proximity losses. Two primary windings (180strands x 0.071mm Litz wire) of 24 turns are connected in parallel at the pins and for the secondary two (800strands x 0.1mm Litz wire) wires are wounded together in a bifilar manner. Keeping the current density for the primary and secondary winding at a maximum of 5-7A/mm2 is a good rule of thumb. The AI tool has calculated a 12.8uH of leakage inductance for this transformer configuration. Given the fact that 52uH of leakage inductance is needed, a shim inductor of 39.2uH can be placed in series with the transformer. A different winding strategy like the two-chamber approach will have more leakage current for the same gapped core. However, in order to keep the total losses of the transformer low, a more conservative approach was chosen as a first iteration. Notice the yellow areas marking the position of margin tapes to keep a creepage distance at 5mm between windings. Choosing margin and insulation (between layers) tape with a CTI index >600V the design complies with IEC61558-1 standard for a reinforced isolation transformer. Finally, the total losses of the transformer at 3kW of power output are calculated at 12.4W, with a hotspot temperature of 66°C in a 25°C ambient room temperature environment.

Conclusion

In this article, the basic theory of the dual active bridge was presented, in order to design a 3kW DAB transformer used in a 48V LiFePO4 pack battery charging application. The SPS control method was analyzed focusing on identifying the ZVS operating areas of the leading and lagging bridge. The battery voltage during high and low state of charge was taken as input to properly select the transformer turns ratio. After deriving all necessary specs, Frenetic Online was used to simulate and design the transformer.

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www.frenetic.ai

Current Sensing Technology for System with SiC and GaN Power Devices.

The author of this article, Asahi Kasei Microdevices (AKM) is a leading company of magnetic sensors and audio products. AKM holds 70% worldwide share of the Hall element market in the magnetic sensor field, and "velvet sound$_{TM}$" is famous in the audio field. AKM also produces current sensors with III-V group semiconductor Hall elements, "Currentier$_{TM}$" that is the only one in the world. In this article, we introduce coreless current sensor "Currentier$_{TM}$" and discuss the best current sensing methods for systems with SiC and GaN power devices.

By Miho ONUMA, Asahi Kasei Microdevices Corp.
Takahisa SHIKAMA, Asahi Kasei Microdevices Europe GmbH.

Introduction.

Recently, for improving energy efficiency against the backdrop of SDGs, SiC and GaN power devices are widely adopted instead of Si power devices. Current sensing is indispensable for the control of power devices, and the requirement of current sensing is also changing due to the change in the power device trend described above. In the following chapters, we are going to discuss requirements of current sensing in systems with SiC or GaN, introduce our coreless current sensor "Currentier$_{TM}$", which is the optimum current sensing to satisfy all of the requirement and compare solutions addressing the requirement.

Requirements of current sensing in systems with SiC or GaN.

- **Fast response and high accuracy for both to detect overcurrent and to control the system.**

Current sensors detect the overcurrent when power devices make short-circuit. The short-circuit tolerance of SiC or GaN is shorter than that of the conventional Si. So Current sensors on a system with power devices of SiC or GaN need to detect the overcurrent much faster than when they work with Si. For example, GaN devices require an immediate shutdown within 600 nsec once the system is detecting the overcurrent. In this case, overcurrent detection time of the current sensor is required to be less than 300 nsec.

An accurate current measurement at high frequency is also important on the system with SiC or GaN. SiC or GaN devices allow systems to use higher switching frequency, which makes it possible to downsize passive components. The accurate and fast response current sensing helps a controller to manage the power device working efficiently at high speed. In the system with Si-based power devices, 3 to 5µsec response time would have been sufficient, but on the other hand, with SiC and GaN power devices, less than 300nsec would be required. The requirement for the accuracy would be higher is better.

- **Wide current range sensing.**

The transition of power devices to SiC and GaN makes it possible to increase the power density compared to Si, and requires wider measurement range on current sensors. For example, an on-board charger (OBC) utilizing SiC power devices has a peak current of 100 A_{peak} flowing inside them due to expanding drive range. The higher the power density is, the wider the current measurement range needs to be.

- **Isolation property, and small heat generation.**

Using higher voltage and higher current with SiC or GaN power device, system designers will use current sensor supporting galvanic isolation and having low heat generation. Those properties are inevitable to see at any system design. The current sensor having UL standard for isolation and low heat generation would help them to develop a safe product and reduce system size without consuming time of the designers.

Best solution of this topic is "Currentier$_{TM}$".

"Currentier$_{TM}$" is AKM's magnetic coreless current sensor. Figure.1 shows internal structure of "Currentier$_{TM}$". It combines AKM's key technologies of "Hall element", "packaging" and "ASIC".

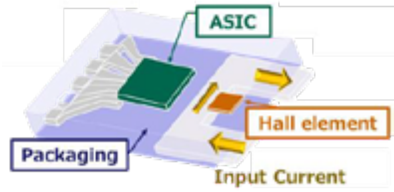

Figure.1 Internal structure of Currentier$_{TM}$

Hall elements in "Currentier$_{TM}$" use III-V group compound semiconductor. III-V group Hall element has good S/N. It enables fast response (<300 nsec). In addition, it has a wide linear range, making it possible to measure large current more than 100 A_{peak}. Also, it is robust for strong magnetic field.

Although one of well-known cons of the Hall elements is strong temperature dependency, the ASIC technology of AKM cultivated in audio product is utilized to compensate it. Total accuracy of "Currentier$_{TM}$" is ±0.4 %F.S (0-90 °C).

The package technology realizes a primary conductor resistance of 0.3mΩ, which results in very low heat generation. Furthermore, "Currentier$_{TM}$" doesn't require isolation power supply, and its clearance and creepage distance of 8mm are compliant to UL61800-5-1. "Currentier$_{TM}$" meets all the performance requirements to control systems with SiC and GaN power devices, and is a promising solution in the several systems. For example, PFC circuit and DCDC circuit are mainly used for switching power supplies used in servers, and various control modes are used in each circuit to improve energy efficiency. For controlling the CRM mode used in PFC circuit and to achieve ZVS in DCDC circuit with LLC methods utilizing SiC or GaN power devices, it is required to detect zero current of inductor quickly and accurately. So fast response and high accurate current sensing would be required.

Discussion: Is it impossible with other current sensing methods to meet all requirements?

Table.1 shows the requirements for current sensing in this topic and performance of each current sensing.

(1) Shunt resistor. This well-known technology applies simple principle and is widely used with Si power devices. However, the shunt resistor with isolation amplifier can't achieve the fast response required in the system with SiC or GaN. Also, the difficulties to apply it with SiC or GaN are establishing compatibility between low heat generation and high accuracy at high speed. To suppress heat generation, low resistance would be needed, but the inductance of the shunt resistor causes output error at high speed due to its LdI/dt. Furthermore, this solution needs both isolation and non-isolation power supplies. As a result, the system become more complex and bigger.

(2) Current transformer (CT). This requires single non-isolation power supply and satisfies low heat generation. However, in order to achieve fast response time, the size of the CT would be larger. In addition, the accuracy of CT depends on magnetic hysteresis.

(3) Cored type magnetic sensors. It satisfies performance such as fast response, good accuracy, measuring large current, isolation, and low heat generation. The disadvantage is large size and cost due to bulky magnetic core.

(4) Coreless type magnetic sensors. The coreless current sensors realize small size, good cost efficiency, and good isolation property with only non-isolation power supply. These sensors normally use Si Hall elements or xMR elements.

   1. The Si Hall elements have a wide linear range of output and robustness for strong magnetic field. But it's difficult to realize fast response due to 20times lower S/N specification than III-V group Hall element.
   2. The xMR elements realize a fast response due to its good S/N. But because of narrow linearity range of output and lack of robustness for strong magnetic field, they cannot measure large current required in the system with SiC and GaN power devices.

Even though any devices can be used to control a Si power device, they can't satisfy all requirements for controlling a SiC or GaN power device.

Conclusion:

"Currentier$_{TM}$" is a coreless current sensor using a III-V group compound semiconductor Hall element as a magnetic sensor, and it is an ideal solution for controlling systems with SiC and GaN power devices. If you would like to know more information about this type of sensor, please check the web site of AKM.com (https://www.akm.com), or contact to akmeu-info@asahi-kasei.eu.

Table.1 Summary of requirement for current sensing and performance of each current sensing.

Requirement for system of SiC or GaN		Currentier	(1)Shunt Current Sensing with Isolation Amp	(2)Current Transformer	(4)-1 Coreless type Si-Hall	(4)-2 Coreless type xMR
Response time	<300 nsec	**<300 nsec**	>2 μsec	>1 μsec Trade-off with size.	3-5 μsec	300 nsec
Measurement range	>100A_{peak}	**>100 A_{peak}**	<50 A_{peak}	<65 A_{peak}	<65 A_{peak}	<65 A_{peak}
Isolation property	Galvanic isolation	**Galvanic isolation**	Galvanic isolation (Need isolation power supply with isolation Amp)	Galvanic isolation	Galvanic isolation	Galvanic isolation
Heat generation (Resistance value)	As small as possible	**Low heat generation (0.3 mΩ)**	Large heat generation (>1 mΩ)	Low heat generation (0.1 mΩ)	Middle heat generation(<1 mΩ)	Middle heat generation(<1 mΩ)
Accuracy	As good as possible	**±0.4 % (0-90 ℃)**	Inductance of shunt resistance causes error with high switching frequency.	No good due to magnetic hysteresis	±1 %	±1 %

Currentier's values are technically achievable but not an actual product.

What Your Medical Device Battery Vendor Is Not Telling You

The growth of the internet of medical things is one of many trends that is both driving and being driven by the proliferation of small, inexpensive batteries and cells. Battery and cell vendors provide data sheets that include various graphs describing the performance of their products, and they are generally honest about the data that they include on the graph. However, there are some key facts that the vendors will not tell you, and these facts can make a dramatic difference in the efficacy of your medical device and the risk you assume when you specify a particular battery for your device.

By Brad Jolly, Senior Applications Engineer, Keysight Technologies

What the battery and cell vendors tell you

Most batteries or cells include a data sheet with a few graphs depicting the performance of the product. Here is an example of the type of chart that a data sheet might include. Note that this chart is for illustrative purposes only and is not intended to depict any real battery.

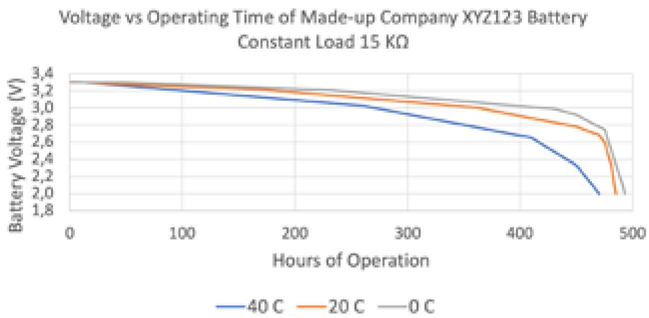

Figure 1: Sample chart of information that might be included in a battery or cell data sheet (does not represent any real product).

In this case, the lines all begin at 3.3 volts and stop at 2.0 volts, which is when our pretend vendor defines their battery as being depleted. Note that there are three different lines, illustrating the voltage delivered by the aging battery at different temperatures. In this case, the temperatures are 0, 20, and 40 degrees Celsius, but different vendors will specify performance at different temperatures.

This data clearly shows that the battery lasts between 450 and 500 hours at the three tested temperatures. Assuming that your device is operated between 15 and 25 degrees Celsius, can you conservatively specify the lifetime of your device as 400 hours? The answer is no, you cannot rely on this value. The runtime of your device may be much shorter or much longer than the values shown, and to ensure the efficacy of your device and reduce risk to patients, you must take several factors into account.

Variability of manufacturing process

When you look at a chart like the one above, what exactly is it showing you? Is it the minimum guaranteed life of every single cell or that type of battery the manufacturer will ship? Is it the best value they obtained from a set of 25 batteries they tested? Does it represent the mean performance of 100 batteries from different lots produced on different days in different factories? Is it some sort of median performance? And suppose that it is the mean or median of a large set of batteries. What does the distribution look like? A set of batteries with runtimes that vary from 459.8 to 460.2 hours may have a slightly lower mean or median than a set of batteries with runtimes that vary from 410 to 540 hours, but which one would you trust in your medical device?

Derating due to transportation and storage

The minute a battery is removed from its charging station, it begins to lose capacity due to self-discharge. This is usually relatively small, and most manufacturers will specify an average charge loss during storage as a percentage of battery capacity per year. Often these numbers are small, around 2% lost per year, but it is important to recognize that there are usually temperature and humidity conditions associated with this number, and this number is only an average. It would not be impossible for an individual cell or battery to lose much more capacity during storage if the battery is near the tail of the manufacturing distribution or if the environmental conditions in which the battery is stored are less than ideal.

The actual current consumption profile of your device

The estimated battery life in a data sheet is usually based on some sort of standard current or load. Other than a simple pen flashlight, most medical devices do not behave as constant loads and will consume charge at widely varying rates. For example, a connected medical device may spend most of its time in a low-current (microamps) sleep mode, and then wake up once every minute to take a quick, 30-ms measurement (milliamps) before returning to sleep. Perhaps the device transmits data wirelessly to a central device or access point in an operation that consumes 10 mA over 50 or 100 milliseconds once every 30 minutes. Some devices may spend charge to flash an LED, run an encryption processor, or send a signal to turn on an actuator. It is obviously impossible for a battery vendor to know the current profile of every device. You must measure your actual device to determine how it consumes charge. Your device may spend enough time in low-power sleep modes that its expected life far exceeds the value shown on the data sheet.

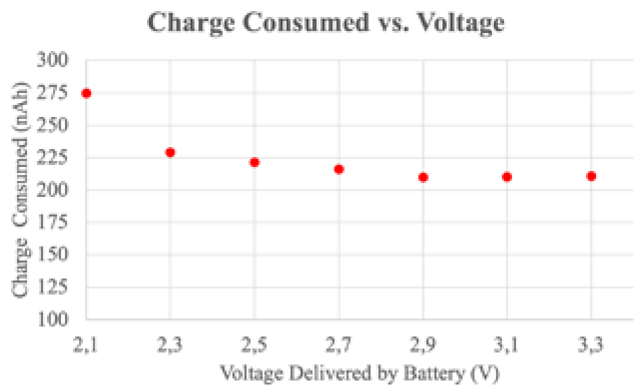

Figure 2: Charge consumed by an IoT device for a fixed operation at different supply voltages, as measured on a Keysight X8721A IoT device battery life optimization solution.

Varying charge consumption as voltage declines
A connected medical device may continue to operate with efficacy as the voltage delivered by the primary cell or battery declines, but you cannot assume that the charge consumption remains constant. In some cases, a subsystem or component that requires a fixed amount of power may draw more current to compensate for the declining voltage. In other cases, a subsystem or component may be operating near the low end of its power range and may have to go through a retry loop once or more to succeed in performing its function. It would be unreasonable to expect the battery or cell vendor to know exactly how every medical device is going to consume charge as the voltage declines over time. To ensure efficacy and reduce patient risk, it is prudent to use a source-measure unit to measure charge consumption for several operational cycles at various levels of battery depletion so that you are not surprised by field failures, short battery life, and related issues reported in post-market surveillance.

Conclusion
Most battery and cell vendors provide accurate information that is helpful in explaining how a battery or cell will behave under various loads and environmental conditions. However, this information does not account for the distribution of performance or the fact that the current levels in a connected medical device can vary by several orders of magnitude. To reduce risk to patients and ensure the efficacy and safety of connected medical devices, engineers should test their device and monitor its current profile at different voltages to know how their device will behave as the battery moves toward depletion.

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Fully-Protected Half-Bridge Power ICs Enable Motor-Integrated Inverters

Navitas' GaNSense™ technology provide size and loss savings to enable integration of the inverter with the motor

By Alfred Hesener, Senior Director Industrial and Consumer, Navitas Semiconductor

Motor Drives: Next Generation Solutions to "Electrify Our World™"
Motor drives consume nearly 50% of the electricity produced in Europe [1]. Governments have therefore created regulations and standards to make sure electricity is consumed as efficiently as possible with the least impact and disruptions to the electrical supply grid. Variable speed drives (VSD) are now common in the industry as they reduce energy usage up to 90% compared to older constant-speed induction motors [2], whilst having the added benefits of reduced motor size, improved dynamic performance and reliability.
Standards such as IEC 61000 were created to support the electrical supply grid in terms of immunity and emissions of electrical equipment, as large inductive loads presented by motor drives can significantly impact local-grid stability. To address these standards, various techniques have been implemented in the motor-drive system, including active power-factor correction (PFC), which modulates the distorted wave back into a sinusoidal wave to maximize real power from the grid supply.

GaN Improves Both Performance and Cost
Gallium nitride (GaN) is a wide-bandgap semiconductor which offers superior characteristics compared to older silicon equivalents, including the ability to switch up to 20x faster and increase power density by over 3x times. Implementing GaN power devices into a motor-drive system for PFC and inverter stages provides a significant reduction in power losses, and size, enabling the integration of the inverter with the motor. In this article, a 400 W reference design for a motor integrated inverter created by Navitas is explained in detail.

GaN FETs do not have any reverse recovery charge, which allows for extremely fast switching, resulting in 4-5 x lower switching losses than silicon IGBTS and MOSFETs and approximately 50% reduction in total power losses. This reduction in power translates to reduced dissipated heat from the device, allowing heatsinks to be reduced in size - or even eliminated in lower power drives. In 2021, the cost of heatsink-grade machined aluminum reached a 13-year high, with a price of around $8/kg, so minimizing heatsink requirements allows significant savings on the total system cost. In addition, lower shipping costs result due to reduced system weight.

The combination of extremely low switching losses and no reverse recovery enables a new degree of freedom in switching frequencies, but also thermal design for VSDs. Motor-integrated inverters have difficult operating conditions, apart from vibrations and strong magnetic fields the ambient temperature can be quite elevated, making cooling of the power semiconductors tricky, so it is best to start off with a power switch that does not produce a lot of heat to begin with.

Integration Improves Efficiency, Control, and Robustness for Motor Drives
GaNSense™ technology integrate the performance of GaN power with driver, protection, and dynamic-sensing capabilities, making them ideal for high-reliability motor-drive applications. The optimized gate-drive circuit with associated voltage regulator and protection circuits, such as over-temperature and over-current detection has the autonomous ability to self-protect. All these features are fully integrated, resulting in the superior performance with highest reliability. The input signal can be controlled with a simple digital signal, eliminating external components, and reducing PCB area. This becomes beneficial for compact motor drives, where the complete electronic system can fit in the motor housing.

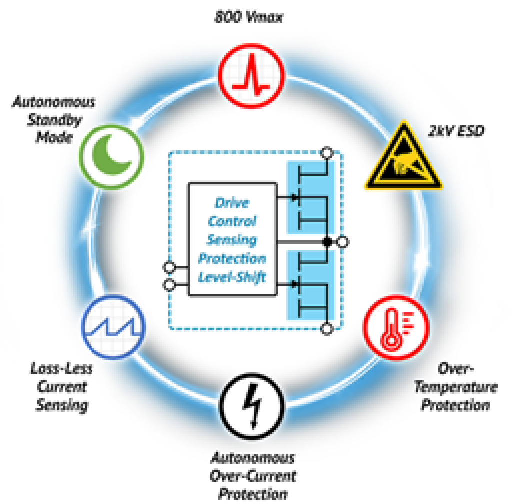

Figure 1: Simplified block diagram of a fully integrated GaNFast IC with GaNSense technology from Navitas

Compared to discrete silicon or discrete GaN approaches, GaNSense™ technology can 'detect and protect' in only 30 ns - 6x faster than silicon or GaN discretes, improving system-level reliability. More details are explained in Application note AN015.

Integration of temperature control on the power switches offers higher precision and real-time sensing compared to a traditional low-precision temperature sensor on a heatsink. This is critical for motor-integrated drive applications that cannot easily be serviced, and where – especially in industrial settings – highest reliability and uptime are expected. The built-in over-temperature protection circuit will turn off the GaN IC when set temperatures are exceeded, enabling fast protection of the system.

The benefit of loss-less current sensing in GaNSense technology eliminates the need for large and expensive shunt resistors, significantly reducing system size and cost, whilst maintaining fast over-current protection for system robustness as required in industrial motor drives for factory automation.

Additionally, the total component count is lowered, yielding a significantly lower FIT (failures in time) rate and improvement in

system reliability. Navitas recently announced a 20-year limited warranty on its products, which is an industry first to highlight their exceptional reliability.

Navitas is introducing a full family of GaN power ICs in half-bridge topology, as can be seen in table 1. As multiple different GaN power half-bridge ICs with different RDSON values exist that are pin-compatible, the design is easily scalable up or down in power.

Part #	Type	$V_{DS(CONT)}$ (V)	$V_{DS(TRAN)}$ (V)	$R_{DS(ON)}$ (mΩ, typ)	Package	Status
NV6247	Half-Bridge	650	800	160/160	PQFN 6x8	Production
NV6245C	Half-Bridge			275/275	PQFN 6x8	Engineering

Table 1: GaN power IC portfolio in half-bridge topology from Navitas

All the new half-bridge products come in space-saving PQFN packages for very good thermal connection to the PCB and low parasitic inductance and resistance, and show the same robustness and reliability as Navitas' single power switches, in particular high transient voltage capability (650V continuous, 800V transient). They are covered by the recently announced 20-year warranty. Further information on the performance and robustness of the products can be found in their respective datasheets [3] and dedicated Application Note AN-018 at www.navitassemi.com [5].

Reference design for motor-integrated inverter

The availability of GaN power ICs in half-bridge topology enables the implementation of very compact motor inverters, as shown in figure 2.

This inverter consists of three half-bridge GaN power ICs from Navitas, the new NV6247. It contains the input logic, level shifter, voltage regulators and gate drivers, and the current and temperature sense circuits, as well as the bootstrap supply. As a result, the external component count is very small.

The schematic for one of the three legs of the inverter is shown below in Figure 3. Shown is the circuit for the second phase, with all three phases being identical. The main component is the NV6247, integrating the two power switches in half-bridge configuration, as well as the gate drivers and their regulators, and the input logic labeled "PWM". A built-in bootstrap circuit is used to provide the gate drive power to the high-side driver. Also included is a level shifter, so that the input signals can be ground-referenced, making this device a digitally-controllable power stage in the best sense of the word.

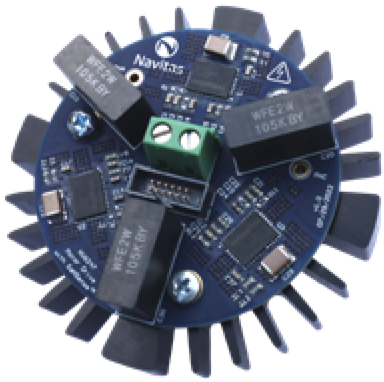

Figure 2: Circular PCB with a 400W motor inverter power stage that attaches to the back of a BLDC motor, with a diameter of 56mm

Furthermore, several sensing functions are included. First, the current flowing through the internal low-side GaN power FET is sensed internally and then converted to a current at the current sensing output pin (CS). Second, the junction temperature is sensed with a circuit on the gate driver and used to turn off the power switches when too hot.

The IC pins include the drain of the high-side GaN power FET (VIN, connected to VBUS), the half-bridge mid-point switched node (VSW, connected to PHB), the source of the low-side GaN power FET and IC GND (PGND), low-side IC supply (VCC), low-side gate drive supply (VDDL), low-side turn-on dV/dt control (RDDL), low-side 5V supply (5VL), low-side referenced PWM inputs (INL, INH), low-side current sensing output (CS), auto-standby enable input (/STBY), high-side supply (VB), high-side gate drive supply (VDDH), and high-side 5V supply (5VH). The external low-side components around the IC include VCC supply capacitor (CVCC) connected between VCC pin and PGND, VDDL supply capacitor (CVDDL) connected between VDDL pin and PGND, turn-on dV/dt set resistor (RDDL) connected between VDDL pin and RDDL pin, current sense amplitude set resistor (RSET) connected between CS pin and PGND, 5V supply capacitor (C5VL) connected between 5VL pin and PGND, and auto-standby enable pin (/STBY) connected to PGND to enable auto-standby mode or connected to 5VL to disable auto-standby mode. The external high-side components around the IC include VB supply capacitor (CVB) connected between VB pin and VSW, VDDH supply capacitor (CVDDH) connected between VDDH pin and VSW, and 5V supply capacitor (C5VH) connected between 5VH pin and VSW. The high side VB, 5VH and VDDH bypass capacitors must be chosen carefully to accommodate various system considerations such as high side wake up time, high side hold up time and standby power. On the right side, the VBUS blocking caps can be seen, and the PCB allows the use of film or electrolytic caps. Their purpose is to dampen any kind of ringing that might occur because of parasitic inductance in the supply and the switching action, since the board is designed for DC input. Finally, R17 and C18 can be used to dampen ringing on the switch nodes, as it might be caused by long cables and their inductance, and are optional.

It is important to note that the switching speed of the power switches can be adjusted with an external resistor (R7 in this case). While slowing down the switching speed does increase switching losses,

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the impact is not large as the switching losses are very low to begin with. That way, the switching speed can be adjusted to whatever the motor needs, and the resulting EMI can be tuned to comply with all required regulations and EMI filter components can be downsized. A value of 50Ω is a good starting point.

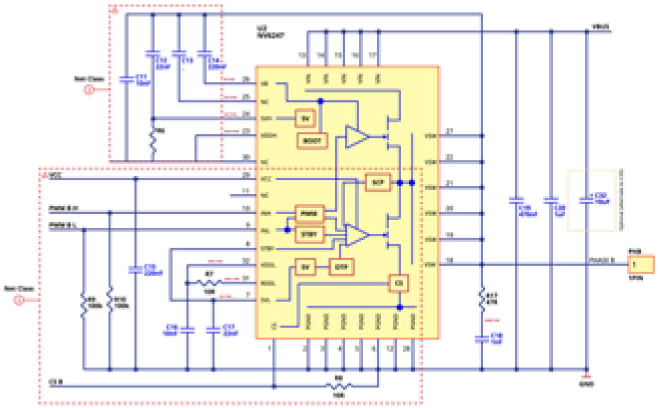

Figure 3: Schematic of one of the three inverter legs, showing that in addition to the GaN power IC very few external components are needed

The resistor on the CS pin (R8) can be set as needed by the microcontroller and its ADC input, to scale the voltage appropriately. However, If the voltage on this pin exceeds 1.9V, the overcurrent protection is triggered. It needs to be noted that the choice of the resistor on the CS pin will affect both the voltage corresponding to the current in the power stage, as well as the overcurrent protection.

The auto standby mode is designed to reduce the power consumption of the NV6247 when it is not switching. If no more input pulses are detected for a time longer than ~90 µs, the IC will automatically enter low power standby mode. This will disable the gate drive and other internal circuitry and reduce the VCC supply current to a low level. When the INL pulses restart, the IC will wake up after a delay (typically around 450ns) at the first rising edge of the INL input and enter normal operating mode again.

Performance results

The inverter has been designed and built in Navitas application engineering labs, and full design documentation will be made available. It has been tested along with a BLDC motor and mechanical load under the following operating conditions: DC input voltage 300 V, ambient temperature 25°C, FOC (field oriented control) algorithm with a switching frequency of 20 kHz. The thermal resistance from PCB to ambient has been measured with ~12.5 K/W. Figure 4 shows the resulting inverter efficiency (electrical output power versus input power, not considering the motor efficiency), which is approaching 99% for output power of 300 W. While the efficiency of the inverter usually is much better than the motor efficiency, it is still important to understand the losses produced in the inverter, in order to design the cooling system accordingly. With a power dissipation of <3W at full load, the heatsink can be reduced a lot, and the thermal design of the system is much easier, eventually avoiding a lot of manual assembly work usually associated with attaching large heatsinks. The two curves shown correspond to different settings for the slew rate (red = 20 V/ns, blue = 40 V/ns), the difference being rather small.

Figure 5 shows the temperatures across the PCB while operating the inverter at an output load of 300W. With ambient temperature of 25°C, the package surface temperature stays below 60°C, not surprising given the very low losses. As the PQFN power switches are thermally well connected to the PCB, the maximum power output is thermally limited by the allowable PCB temperature, usually 105°C. The GaN power switches themselves do tolerate much higher temperatures, and as a result this design offers both exceptional reliability as well as great robustness for abnormal operating conditions like output short-circuit or rotor stall, that may drive the power switch temperature up very quickly until the controller or the built-in overtemperature protection circuit can react.

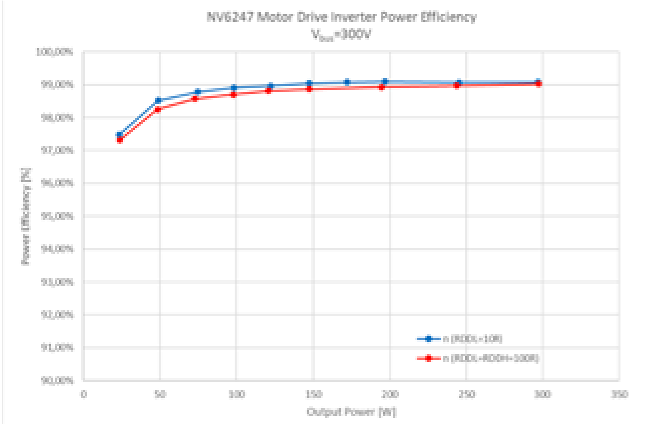

Figure 4: Inverter efficiency across the whole output power range is approaching 99%

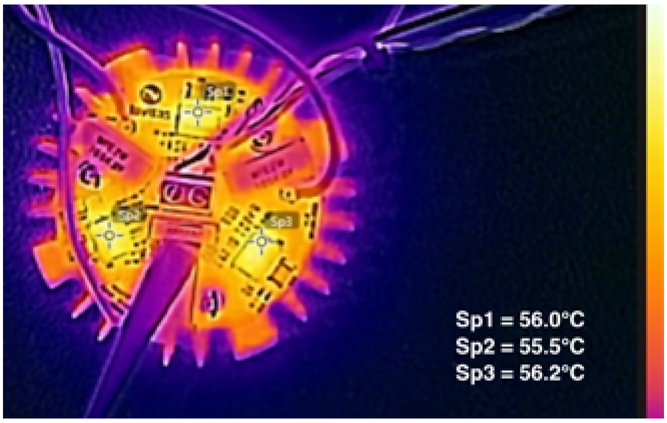

Figure 5: Thermal scan of the inverter board, showing the comparatively low surface temperatures due to the low losses of the inverter

Summary: GaNSense™ half-bridge ICs Drive Up Efficiency and Lower Cost

Every motor has different requirements, but the trends are in the same direction: improved efficiency, better performance, and lower cost. GaNSense™ half-bridge ICs enable higher system efficiencies and improve performance, whilst reducing total cost of ownership of the complete system. GaNSense™ half-bridge ICs offer the highest level of integration - drive, power, protection, and sensing to enable motor-integrated inverters with great performance and reliability.

References:

[1] ec.europa.eu, "Electric motors and variable speed drives"
[2] Engie, "5 Reasons to Install Energy-Saving VFDs"
[3] www.navitassemi.com
[4] Navitas Semiconductor, Application note AN-015, Dec 2021
[5] Navitas Semiconductor, Application note AN-018, Dec 2021
[6] Navitas Semiconductor, "GaNFast™ Power IC Solutions for EV, Solar & Industrial", Bodo's Wide Bandgap Event, Dec 2021

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Beyond MLCCs – the Rise of the Silicon Capacitor

High-Density E-CAP Devices Address Performance, Size and Noise Challenges of Data-Intensive Applications

Passive components remain a crucial element in power hungry and data-intensive applications. And, as the end of the Moore's Law journey for traditional semiconductors and other factors prompted the development of new technologies such as silicon carbide (SiC) and gallium nitride (GaN), so too there is a need for capacitors to do the same and address new performance challenges.

By Mukund Krishna, Senior Manager, Product Marketing, Empower Semiconductor

Whether used for energy storage, power decoupling or tuning and filtering, capacitors are critical components in every electronic design. Nowadays, multi-layer ceramic capacitors (MLCCs) have become ubiquitous, being deployed in everything from smart phones to electronic content-laden vehicles, As a result, the market for these miniature components is predicted to reach five trillion devices by 2025[1].

However, they are reaching the end of the road as a suitable solution to many designer's needs.

Silicon capacitors are one way that engineers can address the latest design problems in terms of performance, size, stability and susceptibility to threats such as vibration, temperature, and electrical noise. Empower Semiconductor's E-CAP technology is an example of how capacitors are keeping pace with advances in other component types.

Increasing Application Challenges for MLCCs

MLCCs have been great servants and workhorses for the electronics industry and their existence has been, and indeed will continue to be, important for many applications. But it is a fact that the direction of travel of some designs is increasingly exposing their limitations.

As data rates increase so do power requirements, and the need to address these in space envelopes that are typically getting smaller even as end applications incorporate more processing power and functionalities raises the spectre of problems associated with noise and thermals.

Look inside many pieces of modern equipment and you will see a lot of board space occupied by MLCCs. The number of these tiny off-the-shelf devices is dictated by the high-power, data hungry nature of the applications. This is often further exacerbated by the requirement to not only extend the frequency bandwidth response of the design, but also guarantee the effective capacitance value once all deratings due to voltage, operating temperature and ageing are accounted for. To mitigate these requirements, more and more devices are traditionally added to the circuitry.

Ultimately the combination of these factors means the long-serving MLCC is often no longer an elegant, viable or sensible solution.

Other specifications that become more of an issue as end application power and frequency increase, are Equivalent Series Resistance (ESR) and Equivalent Series Inductance (ESL). In simple designs, the low values of these parasitics that move the capacitor value away from being 'pure' – i.e. what it says on the can / package – have little or no impact on performance and reliability. However, as power and frequency are increased, efficiency can be impacted and unexpected performance and results seen.

As a result, designers are actively seeking alternatives, one of which is the silicon capacitor.

Introducing High-Performance Silicon Capacitors

As power goes up and available space reduces, the spotlight falls on power density.

Silicon capacitors offer significantly increased power density, as illustrated by Empower's E-Cap technology, which typically offers five times the capacitance density possible with MLCCs.

E-CAP integrates what would have previously required multiple discrete components onto a single die in a single package. This dramatically reduces component count and can give a valuable five to seven times reduction in board real estate required for a given capacitive solution. BoM and total cost of ownership (due to single rather than multiple component insertions) are also cut back.

Interconnects made on the die within a package as opposed to on the PCB mean that the reliability and ruggedness of this approach are also better.

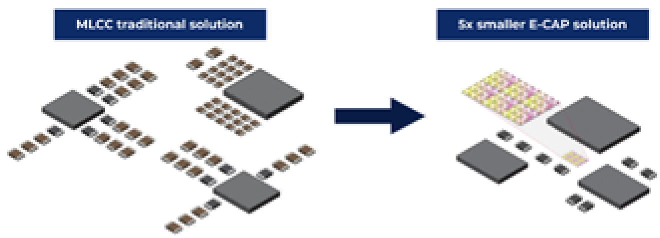

Figure 1: E-CAP solutions offer 5x capacitance density versus traditional MLCCs

In terms of both electrical and physical specifications, no two applications are the same, so the ability to source integrated solutions that are customized for specific needs is appealing to design engineers. From an electrical perspective, E-CAP usefully allows matched capacitance values ranging from 75 picofarads (pF) to 5 microfarads (µF) (@2V) to be integrated into an array.

Passives have often been 'afterthoughts' to the key processing technology and, as a result, the shape of the available board space once major components have been placed may not be regular nor the enclosure height very generous. This means that the flexibility to offer an integrated package that matches the application requirements is vital. E-CAP solutions can take account of the X and Y dimensions on the designer's wish list and with an overall package height down to just 50µm, headspace is less likely to be an issue. Additionally, packaging interconnect options based on bumps, pads or pillars allow designers to choose the best solution based on system constraints.

Integrated and versatile form factors also facilitate innovative approaches to locating capacitors - for example, 'in-package' and 'under-package' SoCs and in PCB filtering and bypass applications.

As mentioned, with power and data intensity increasing in a

smaller space envelope, performance issues can emerge, many of which are due to derating. In this area, silicon capacitors are less needy and cause minimal design headaches for engineers used to working with MLCCs.
For example, temperature de-rating for MLCCs can be in excess of 10% up to 85°C, while de-rating for the effects of ageing can be in the order of 5 to 10% over 10,000 hours operation. In a discrete MLCC solution, this can necessitate additional components with the associated cost and layout issues that presents. In contrast, E-CAPs are barely impacted by temperature and ageing and so, do not require over-design to mitigate effects. In addition, they require no AC or DC bias de-rating.

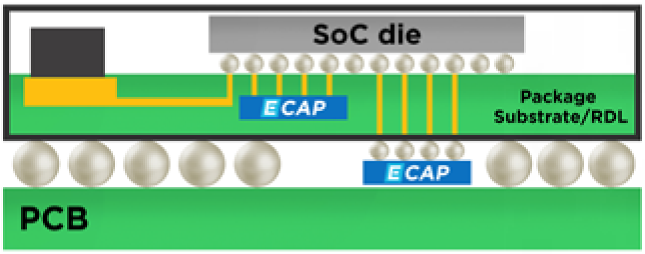

Figure 2: Small size and electrical and mechanical robustness open up alternative mounting options for integrated silicon capacitor solutions

While ESR and ESL parasitic characteristics become a potential issue with MLCCs as power and frequency increase, silicon capacitor solutions exhibit these at much lower levels removing uncertainty around performance. In addition, although Empower's E-CAPs have lower nominal capacitance, their superior frequency response and ESL over MLCCs results in lower impedance at high frequencies.

Custom Parts with Low Risk

The desire for shortened design cycles to get compelling new products to market quickly leads to the perennial choice of 'make versus buy' (custom versus off-the-shelf) solutions. MLCCs clearly fall into the latter category but thanks to an optimized design flow, custom silicon capacitor solutions can still help designers deliver within tight timescales.
Empower, for example, based on learnings from the development and launch of its Integrated Voltage Regulator (IVR) technology, has developed a process to smoothly take customer requirements for E-CAP solutions from concept to production.

Parameter	Standard MLCC	E-CAP
Temperature de-rating	~11% up to 85°C	Negligible - ~0.3% (measured in ppm/K) - equivalent to C0G
DC bias de-rating	44% @ 3V	None
Aging	~5-10%/10k hrs	<0.001%/10k hrs
ESL	>100pH (100nF)	<10pH (100nF)

Table 1: Compared to standard MLCCs, E-CAP technology almost entirely removes the need to consider de-rating

At the beginning of the process this means a clear definition of technical requirements and application constraints, which then leads to a custom design proposal that can quickly move to design and the fabrication of engineering samples. The predictable performance of E-CAP due to minimal parasitics and the robust nature of an integrated package containing multiple capacitive elements, removes the risk from the process, resulting in parts that are tightly aligned to application needs.

[1] https://blog.techdesign.com/2020-mlcc-demand-and-supply-analysis/

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Practical Guidelines for the Litz Wire Selection and AC Copper Losses Estimation – Part 1

Applied to Resonant Power Magnetics used in Automotive Converters

Litz wire conductors are well known and massively used in magnetic components dedicated to power electronic applications to reduce copper losses versus frequency. However, their modelization could remain complex or not fully fixed for an accurate prediction of the final temperature rise in the windings of switching transformers or resonant inductors. The best wire selection and an accurate computing of its losses remain at first position for high power density converters optimization.

By Patrick Fouassier & Benoit Battail, PREMO FRANCE Inductive Components R&D

The increasing market of electrical and plug-in hybrid vehicles requires powerful embedded switch-mode power supplies (figure 1) including large inductive devices as well as for AC/DC high voltage battery chargers of some 7-11-22kW (figure 2a) and DC/DC 400-800V/14V converters of a few kW (figure 2b) to supply in energy conventional low voltage equipment (lighting and air-conditioning systems, ECUs, radio-set, GPS…).

The magnetic components used in such power electronic assemblies generally count for 1/4th to 1/3rd in volume, weight, and cost within such devices. Therefore, their optimization in terms of power density is fully mandatory till the limit of an acceptable efficiency and temperature rise depending also on the cooling strategy [1]. For transformers and inductors used in such parts, low loss ferrite cores and Litz wire windings are mostly selected. The best Litz wire selection remains a must for copper losses reduction versus frequency.

Figure 1: 7-11kW OBC + 2.4kW/14V DCDC presented by BOSCH Mobility Solutions [2]

This article will first summarize well known properties of Litz wire by highlighting special care and tips in its selection (part 1). The modelization approach of such conductors will be then discussed and the models available in FEA simulation tools will be compared. Eventually, a few words and references about the equivalent thermal conductivity that can be assigned to a given Litz wire will be introduced to help in thermal simulation (part 2).

Litz Wire Advantage and Selection

Frequency Impact on the Wire Choice

Why Litz wire for conductors? It is well known that frequency effects in metal can affect a lot the losses in it when carrying an alternative current. Three major effects are identified as eddy currents, proximity effect and fringing flux effect. The first is related to the self-induced magnetic field around a

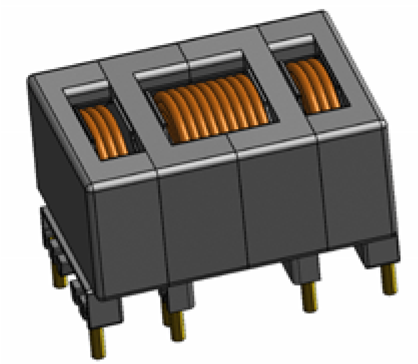

Figure 2a: PREMO 11kW CLLLC magnetic module before potting

Figure 2b: PREMO HV/LV 2kW DCDC transformer as a ready-to-plug solution

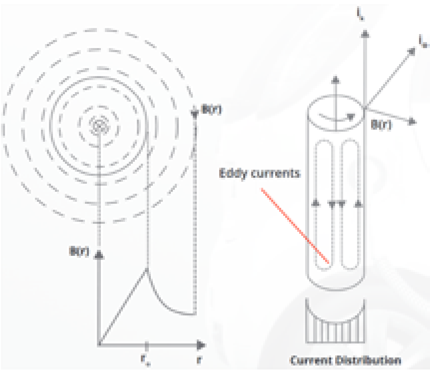

Figure 3a: Eddy currents

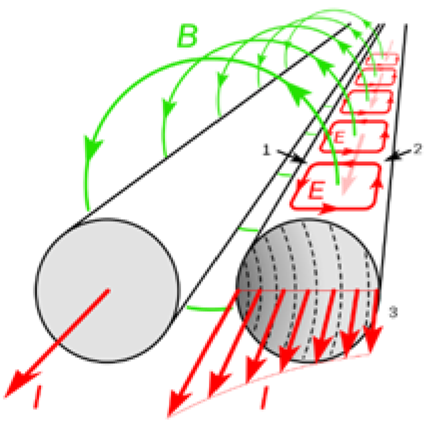

Figure 3b: Proximity effect

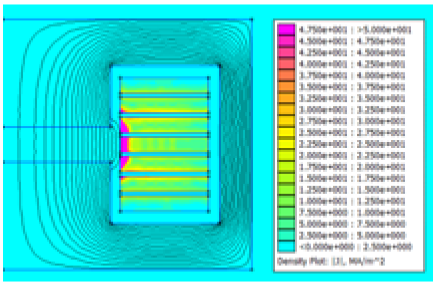

Figure 3c: Current density inside a conductor including fringing flux effect from an airgap

conductor that generates eddy currents circulating principally on its outer surface to try to cancel the effect that has given life to it (figure 3a). Proximity effect is something similar but related to the same effect into conductors in the neighborhood (figure 3b). Each turn perturbates the surrounding ones and is also influenced by them. The third effect can be related to the presence of any external magnetic field with time variation as it is the case from airgaps cut in cores to fix some precise inductance value (figure 3c).

A key parameter to quantify this perturbating current distribution over the surface of the conductor is the skin depth expressed as below (figure 4). It is well admitted that the first choice for the conductor diameter must always remain below 2δ (dconductor < 2δ) not to see a noticeable increase of its resistance. For instance, an easy calculation at 7δ diameter leads to twice the DCR value (figure 5).

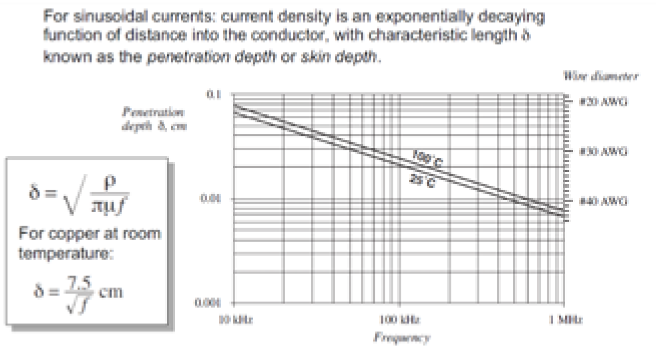

Figure 4: Skin depth in copper (apply 6.6 instead of 7.5 coefficient at 100°C)

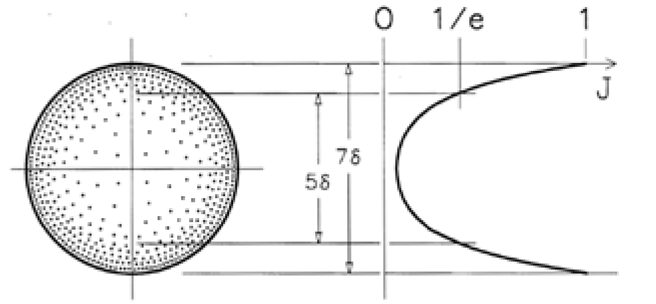

Figure 5: 7δ Diameter Conductor shows an AC Resistance of twice the DC value

The above considerations are valid for a single conductor. However, these simple formulas and concepts clearly illustrate that, according to the current to drive through the winding, parallelization of small conductors will be a must. They can be just wound multi-filar that it is not a good solution either for proximity effect between conductors or process optimization. Litz wire characterizes this parallelization plus a twisting versus length so that each strand passes equally through each position on inside and outside of the bundle (figure 6). This prevents circulation of currents between strands by reducing proximity effects.

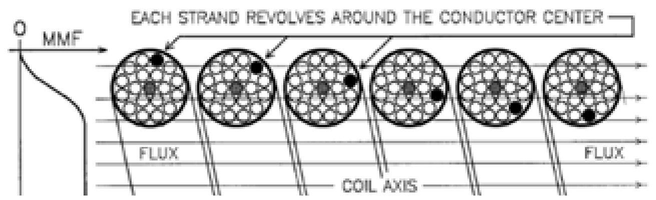

Figure 6: Litz wire for proximity effect reduction between thin strands

It is particularly true when the component is submitted to a high frequency switching with high current variations (example: resonant chokes with full wave excitation). Of course, other design considerations will be important to reduce the copper losses at the minimum, as the winding structure (bifilar, concentric, multi-level interleaving…) or the core design (single or multigap…).

From a practical standpoint, it is not always easy to quantify the increase of copper losses versus frequency. For a 2-winding transformer, it can be possible to have an overview of the total AC copper losses by measuring its impedance versus frequency viewed from the primary side with the secondary shorted. Here, the core has normally no influence on the Rac measurement (ampere-turns cancelation or with remaining fully negligible magnetic induction) which is not the case for single chokes where such measurement must be taken with a lot of precaution because representative of core+copper losses at the end.

Below is an example considering a 2.3mm Litz wire diameter of different strandings (figure 7). We can clearly notice the improvement in the 100-200kHz operating region when the strand is of a lower diameter even if in some cases it could lead to higher estimated DC losses. As a matter of fact, the total copper cross-section can differ according to the number of strands assembled for a same overall diameter. So, a compromise to find can exist between the strands thickness and the number to twist together.

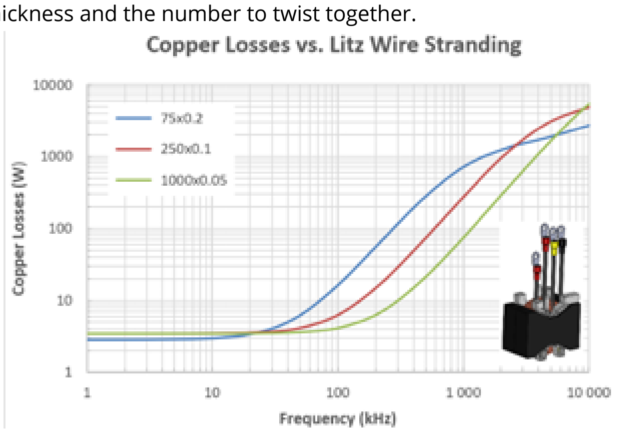

Figure 7: AC copper losses in a transformer acc. to the Litz wire selection

Fr = Rac/Rdc is a coefficient of interest that could be set as a design rule for given technologies and stranding (table 1). It shows the increase of copper losses vs. frequency depending on the wire and winding arrangements. The below table proposes some coefficients that can be applied for the total copper losses estimation with a good Litz wire selection for the windings. Of course, if the harmonics content of the current waveform is high, a more accurate study shall be performed.

Transformer Type with Optimized Litz Strand	OBC LLC 3.5kW	DCDC HV/LV PSFB ZVS 3kW – 1x Interleaving	DCDC HV/LV PSFB ZVS 3kW – 2x Interleaving
Fr = Rac/Rdc	1.2 to 2 @100-250kHz	3 to 5 @100-150kHz	2 to 3 @100-150kHz

Table 1: Optimized Fr coefficients for some given topologies/technologies

The strand diameter selection can have a big impact on the real total AC copper losses of transformers or chokes wound by Litz wire. From such statements, the strand diameter must be optimized to keep the Fr ratio as low as possible without maximizing the cost of the product by expensive Litz wire application or too challenging interleaving process in the winding construction.

Generally speaking, and because of the skin effect, the higher the operating frequency, the thinner the nominal single wire diameter.

The Litz wire suppliers [3] often proposes a table of recommended use according to the frequency range (table 2). It can be good to introduce some margins to consider the possible harmonics content of the current waveform which could be high for phase-shift half- or full-bridge ZVS topologies as well as for LLC/CLLLC in some cases.

Range of Frequency (kHz)		Nominal Diameter of Single Wire (mm)	
From	To	From	To
0.06	1	0.4	0.25
1	10	0.25	0.2
10	20	0.2	0.125
20	50	0.125	0.1
50	100	0.1	0.08
100	200	0.08	0.063
200	350	0.063	0.05
350	850	0.05	0.04
850	1400	0.04	0.03
1400	3000	0.03	0.02

Table 2: Strand diameter selection for Litz wire

In Litz wires, to consider a minimum interaction between several bundle diameters with δ skin depth, and in a simplified way, the maximum single wire diameter should be smaller or equal of nearly a third of δ (dstrand < δ/3). Example: F = 200kHz, δ = 0.148mm => dstrand ≈ 0.050mm.

Current Density and Number of Strands

When the strand diameter is selected, the number to consider will depend on the acceptable current density in the windings of the magnetic devices. Even if the total copper losses and the hotspot temperature shall be determined afterwards, some additional design rules can be preliminary applied to confirm a possible diameter of the final conductor to use (table 3).

Construction

Litz wires cannot be only defined by the stranding. Other parameters of importance are the bunching and the twisting (table 4). As a matter of fact, the bunching (ex. : 50x5 vs. 10x5x5...) and its direction (S or Z at different levels) could affect a lot the frequency behavior (figure 8). The twisting (number of rotations per meter or lay length or pitch) is normally calibrated to have at least 3 rotations along the mean turn length of the winding ; this is to balance the best proximity effect cancellation.

Component Type and Cooling Concept	J (A/mm²)
Big Power (tens of kW)Transformer, No Cooling	2-3
Big Power (tens of kW) Transformer, Air-blow	3-6
kW-range Transformer fixed on a Water-cooled Plate	7-10
Fully Potted Transformer in a Water-cooled Cavity	10-15

Table 3: Applicable current density per size and cooling

Conductor	Bare wire diameter (mm)	0.10
	Tolerance (mm)	±0.003
No. Of strand		250
Bunching		50x5
Single wire	Enamel Thickness (≥mm)	0.008
	overall diameter (≤mm)	0.117
Litz wire	No. of lay (Ts/m)	30±5
	Lay direction	S
Taped wire	Overlap [%]	67±3
	Max. overall diameter (≤mm)	2.287
	Break - down Voltage (≥v)	4000
	Film layer thickness for two sides (mm)	0.15
	Width of the tape (±0.5mm)	12
	Thickness of the film (±0.003mm)	0.025
	Electric Resistance DC (≤Ω/km, 20°C)	9.61

Table 4: Example of Litz wire complete specification (source: SUNTEK WIRE)

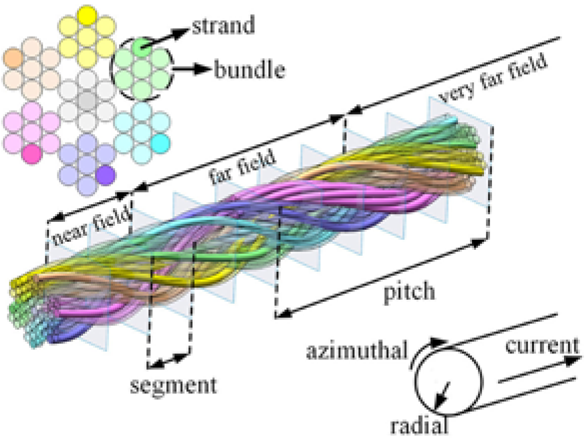

Figure 8: Litz wire bunching and twisting

Some rules can be applied for the bunching definition. The maximum number of strands at first bundle level (N1,max) can be given by the below formula [4] where δ is the skin depth at the defined operating frequency and temperature, and ds is the selected strand diameter:

$$N_{1,max} = 4\frac{\delta^2}{d_s}$$

Bundles are then twisted together by groups of 3, 4 or 5 maximum. If the total required number of strands is over this second level assembling, the process is repeated on one more level.

Example: 1600 strands of δ/4 diameter should be packed as a 5x5x64 Litz wire (64 strands per bundle, 5 bundles twisted together, and this twisted again 5 times).

Dimensions

Depending on the internal structure of the Litz wire, some packing factors can be found in the literature. These packing factors (tables 5a/b) can be used to roughly estimate the wire diameter using the following formula [5]:

$$D = \sqrt{N_s}.d_s.\rho$$

With D the overall diameter of the Litz wire, ds the diameter of the strands, and p the packing factor for Ns strands.

Elektrisola Packing Factors	
# of Wires	Factor
3 - 12:	1.25
16:	1.26
20:	1.27
25 - 400:	1.28

Table 5a: Packing factors for different number of strands (source: ELEKTRISOLA)

Another parameter that will impact the overall diameter is the type of insulation. The following section will be dedicated to the presentation of the different technologies, possible application, and advantages of each.

Isolation and Certifications

When the copper distribution is fully defined for the best performance in the application, criteria for the isolation must be added. Of course, the strands are isolated as common enameled wires and the same standard and grades applied. Thermal class is F/155°C

Litz Construction	Single End Wire Size	Packing Factor
n/##	48 - 20 AWG	1.155
n/n/## or n/n/n/##	48 - 33 AWG	1.155
5xn/## or 3xn/##	48 - 20 AWG	1.236
5xn/n/## or 3xn/n/##	48 - 33 AWG	1.236
5x5xn/## or 5x3xn/##	48 - 44 AWG	1.271
	43 - 33 AWG	1.328
	32 - 20 AWG	1.398
5x5xn/n/## or 5x3xn/n/##	48 - 44 AWG	1.271
	43 - 33 AWG	1.363
5x5x5xn/## or 5x5x3xn/##	48 - 44 AWG	1.271
	43 - 33 AWG	1.363
	32 - 20 AWG	1.536
5x5x5xn/n/## or 5x5x3xn/n/##	48 - 33 AWG	1.363
n = Number of Strands in bunch	## = AWG Size of individual strands	

Table 5b: Packing factor for different Litz wire structures (source: RUBBADUE)

or solderable H/180°C according to IEC 85 in most of the cases. Varnish thickness is normally according to grade 1 to offer a limited overall diameter as well as an easier solderability when connecting all the strands together at the outputs (by tinning, electrical soldering, or hot-crimping methods…).

Litz wire often offers a serving for protection or enhanced isolation between turns, layers, or windings (figure 9). It could be:

- A serving by single or double layer of silk or nylon if the self-isolation of the strand by enamel could be not enough. This is the cheapest and more suitable choice for low withstanding voltages. When using this type of wire, varnishing the winding or even the finished product can help because the silk or nylon textile can absorb the varnish and provide a more robust isolation. Applying the varnish under vacuum process would be preferred to improve the reliability and reproducibility.

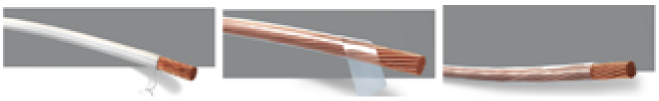

Figure 9: Served / taped / extruded Litz wires from ELKTRISOLA manufacturer

- An overlapping by tape, which can be PET/PEN/Mylar/polyimide… These wires can achieve better dielectric strengths. The definition of the insulating film will depend on the thermal class and required dielectric strength. The overlapping is one of the parameters than can be modified to fix the performances. At 50%, it enables 2 layers of isolation at any length on the wire whereas a tighter 67% overlapping leads to 3 layers. These overlapping techniques are a way to answer to safety standards that require multi-layer of thin film isolation (IEC 60950-1, IEC 61558-1/-2-16…). Some well-known suppliers even propose fully VDE or UL certified construction according to this technique [6].
- It exists other isolation structures by plastic extrusion around the conductor [7]. It can be made of Teflon, or polyester or of any other suitable material. Here also, 2-layer or 3-layer extrusion can be imagined as in double-insulated (DIW) or triple-insulated wires (TIW).

Cost Consideration in Automotive Industry

The use of Litz wire in wire wound products increases cost and decreases amount of copper within the core window. Depending on the expected performances vs. frequency and level of isolation it could have a huge weight in the cost breakdown of the final product [8]. However, it remains today the first choice in resonant wire-wound inductive components used in some kW to tens of kW automotive converters where heating and efficiency come always under the scope of power density increase.

This article is the first one in a two-part series. Please visit us at electronica, Stand 231 Hall A5.

Resource Materials and Citations

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About the Authors

Patrick Fouassier, Principal Engineer, PREMO FRANCE R&D Manager, Inductive Components

Patrick holds a degree in Engineering as well as a PhD in Electrical Engineering. He has more than 20 years of experience in magnetic components related to signal and power electronics.

He studied at Grenoble INPG/ENSE3 engineering school and did his thesis in the G2ELab close to the Alps. After his prior position as R&D Manager at MICROSPIRE (now part of EXXELIA Group), a French company oriented towards professional markets like defense, avionics, and space, he joined the Spanish PREMO Group in 2008 when participating in the creation of the PREMO FRANCE office located in the Grenoble area.

Now his activity within his team is fully focused on the development and project management of innovative solutions for the automotive sector with fully optimized components for battery chargers and DC/DC converters from some kW to tens of kW used in new electrical and hybrid cars.

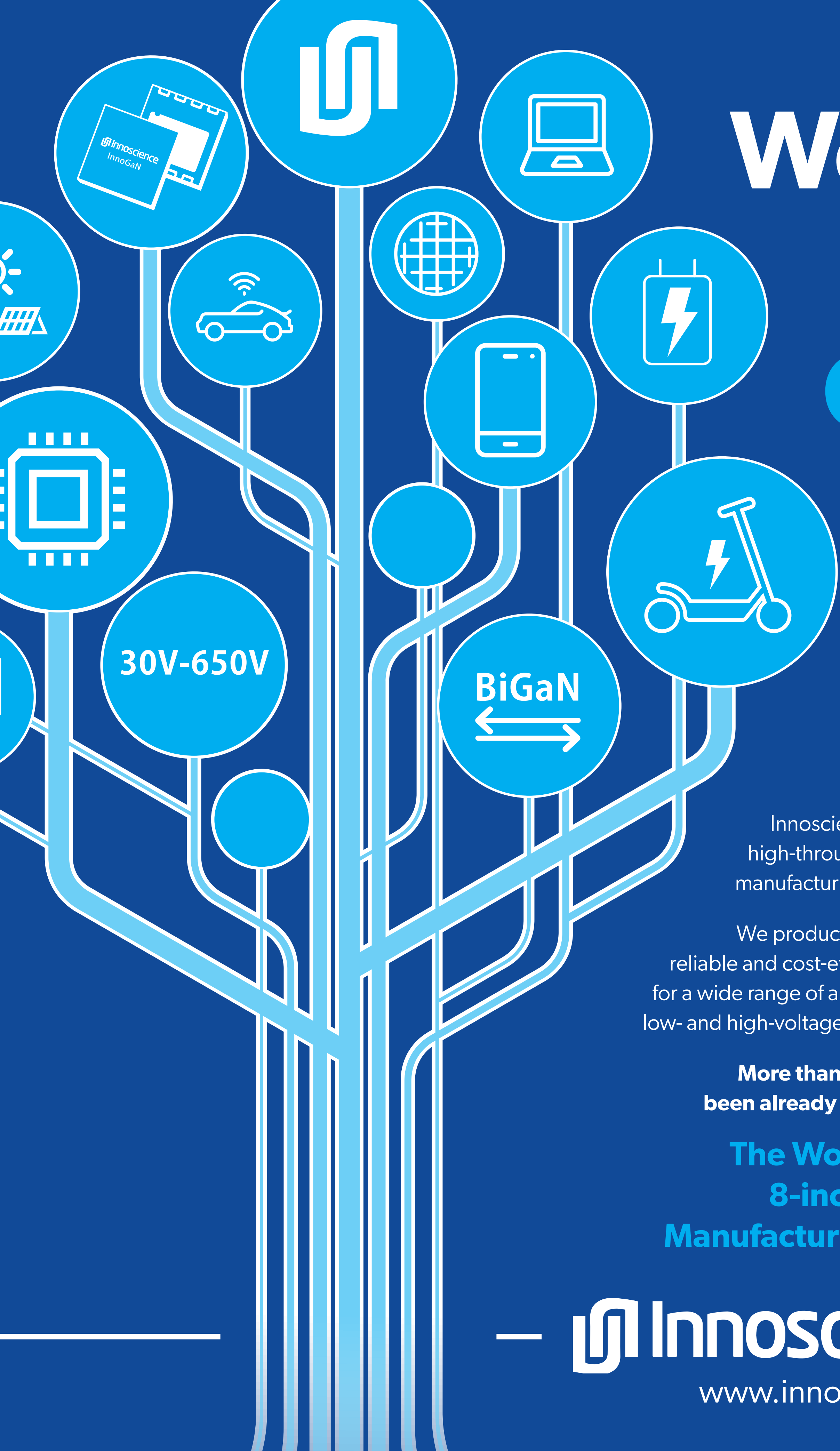
His R&D expertise is renowned on a worldwide scale and in a fully multidisciplinary context from customer technical support to internal training.

Benoit Battail, R&D Engineer, PREMO FRANCE, Inductive Components

Benoit has a degree in Electrical Engineering specialized in power electronics from the UGA / Grenoble INP ENSE3 school.

He followed his 4th year internship at the department of cybernetics engineering of NTNU Trondheim working on modelling and simulating the wireless charging for submarine applications.

He has been now working with PREMO for 3 years in the design of complex solutions of magnetic components for power electronic converters embedded in EVs.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How MCUs Can Unlock the Full Potential of Electrification Designs

Not too long ago, widespread adoption of electric vehicles (EVs) was nothing but science fiction. Once thought too expensive or impractical, we are now in the midst of an EV revolution driven by OEMs' desire to achieve zero emissions and explore alternative energy sources. Many car manufacturers have gone all-in by pledging all-EV lineups in the next 10 to 15 years.

By Sean Murphy – Marketing Lead for HEV/EV, Texas Instruments

Despite this momentum, we stand at an inflection point. EVs have made significant steps toward mainstream acceptance as drivers are looking for lower energy cost per mile and a fun driving experience that EVs can deliver. However, EVs are currently more expensive compared to internal combustion engine vehicles. There are also some concerns from drivers around range anxiety given the existing lack of charging stations, low driving range per charge, and the long charging time to get a full battery.

At the heart of every EV are power electronics systems: a traction inverter, onboard charger and high-voltage DC/DC converter, as shown in Figure 1. The performance of these systems will help define the acceleration and success of EV adoption in the coming years, as they directly impact an EV's driving performance, cost, driving range, and charge time. The demand for more performance from these systems directly translates to demand for more microcontroller (MCU) performance, in terms of both real-time control and advanced computing.

Figure 1: The EV powertrain, including: traction inverter, high-voltage DC/DC, and onboard charger

Our new high-performance Sitara AM263 MCUs are the latest addition to the Sitara MCU family, and can help customers make progress in advancing the processing technology behind EVs. Sitara AM263 MCUs are the first devices in the Sitara MCU portfolio that pair the real-time control subsystem originated in C2000 MCUs with the Sitara multicore Arm® architecture to meet the dynamic performance demands needed for motor and digital power control applications.

By combining real-time control and more than 3,000 Dhrystone million-instructions-per-second (DMIPS) computing performance, the AM263 MCU family can help reduce size and weight of the motor and mechanical enclosures as well as system cost, increasing driving range and helping to make EVs more affordable. The AM263 MCU family naturally leverages and extends the benefits of the C2000 real-time MCUs to offer even more options for EV powertrain applications.

For example:

- In traction inverters, AM263 MCUs enable higher motor speeds (>30,000 rpm), which can reduce motor size by as much as 36% and increase driving range by 15%.
- The MCU's ability to run at higher switching frequencies (>1 MHz) unlocks the potential for the use of wide-bandgap technologies such as silicon carbide (SiC) and gallium nitride (GaN), increasing power density and efficiency and thereby increasing driving range.
- More cores and peripherals enable the integration of multiple functions and reduce both the number of field-effect transistors in a system and mechanical enclosures, significantly reducing cost and weight of enclosures and magnetics.
- AM263 family incorporates functional safety features that enable up to Automotive Safety Integrity Level (ASIL) D, E-Safety Vehicle Intrusion Protected Applications (EVITA) hardware security module full version, Automotive Open System Architecture (AUTOSAR) support, and communication peripherals to help reduce system bill of materials with a single chip.

With EVs and renewable energy comes the need for an extensive charging infrastructure and energy storage systems, as pictured in Figure 2. To be as common and as quick as a gas station, these systems need to be more efficient and higher power. The fundamental concept of these systems is power conversion, which enables grid-to-vehicle and vehicle-to-grid energy transfer in charging stations. And in energy storage systems, power conversion enables the storing of energy in batteries when demand is low and delivers it to the grid when demand is high, or when the renewable energy source is not generating. The real-time control subsystem integrated in the AM263 family delivers the necessary precision to lead the power conversion industry into the future. For example, with the AM263 MCU family you can now achieve:

- Faster charging time. Achieving higher levels of switching frequency, higher inverter efficiency (99%), and less power loss, AM263x helps to deliver faster and higher power conversion.
- Improved output power quality for electric grid compatibility. Advanced analog control peripherals enables higher precision for lower latency, lower total harmonic distortion (THD) and higher output power quality in solar inverters.
- Reduced system size and cost. Multiple Arm® cores enables complex control topologies and reduces the system size and BOM cost by integrating functions.

Figure 2: Electrification extends beyond EVs to charging stations and renewable energy storage

The world around us is changing. Environmental and regulatory pressures for zero-emission vehicles and renewable energy sources are accelerating EV production, but widespread adoption will require increased affordability, efficiency and performance. Sitara AM263 MCUs, including the AM2634-Q1 and AM2634 devices, help deliver on the demands of these next-generation architectures. Get started with the AM263 family today and explore our application note, “AM263 for Traction Inverters”, and our easy-to-use MCU+ software development kit (SDK), or create and implement examples in just minutes with our TMDSCNC263 evaluation module (EVM) and MCU+ Academy.

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Reduce Costs in the Long Run: Use the Same Qualified Parts for Both Positive and Negative Output DC-to-DC Converters

One relatively easy way for manufacturers to reduce the cost of electronic components is by using the same designs or components for disparate applications. The cost savings manifest not only in the obvious bulk procurement of identical parts, but also in minimizing the number of required qualification processes. Qualification is especially critical for the transportation industry – particularly for automobile manufacturers. Usually it is an expensive process involving testing for ruggedness, reliability, and longevity of units.

By Victor Khasiev, Senior Applications Engineer, Analog Devices

This article shows how to use the same components—an IC controller and power train—in two very different topologies: a common buck converter and in an inverting buck-boost converter. The component requirements are explored for the inverting buck-boost converter by specifically examining the reverse voltage fluctuation on the output of the inverting buck-boost, and ways to use the least expensive polarized capacitors in this topology. As a result, a simple and cost-effective solution for designing positive buck and negative buck-boost converters using the same IC is presented.

Positive Output, Buck Converter

The electrical schematic of the positive output, buck converter is presented in Figure 1. The converter generates a stable V_{OUT} of 5 V at 15 A from the input voltage V_{IN} range of 5 V to 38 V. The power train includes modulating (high-side) MOSFETs Q1 and Q2, rectifying (low-side) MOSFETs Q3 and Q4, inductor L1, a combination of the electrolytic and ceramic input filter capacitors C_{IN1} and C_{IN2}, and a similar combination of capacitors for the output filter and the controller.

The resistor RS can be used as a current-sense element if the peak current mode controller is employed, or as part of the short-circuit protection circuitry in voltage mode control. The input capacitors CIN1 and CIN2 are terminated to GND; however, the optional CIN3 and CIN4 are terminated to the output and are employed in the negative buck-boost solution. The functionality of buck converters is widely studied and easily obtainable. In this article, we just briefly note voltage and current stress on the power train components. It is relevant to the preliminary selection of components in new designs and rough evaluation of the existing solutions. Assuming continuous conduction mode (CCM) operation, the following expressions can be used.

$$D = \frac{V_{OUT}}{V_{IN}} \quad \textit{Duty cycle}$$

$$V_{DS} = V_{IN} \quad \textit{Maximum voltage stress on Q1 through Q4 and L1}$$

$$I_L = I_{OUT} + 0.5 \times \Delta I \quad \textit{Inductor L1 peak current, where } \Delta I \textit{ is peak-to-peak ripple current.}$$

Negative Output, Negative Buck-Boost Converter

The schematic of the negative buck-boost converter presented in Figure 2 is similar to the buck converter schematic in Figure 1. Notably, both use the same components for the power train, interconnections, and controller. Differences arise in the grounding of the controller, switching MOSFETs, and input/output filter. The ground of these inverting converter components is $-V_{OUT}$. The inductor L1 is terminated to the system (input) ground.

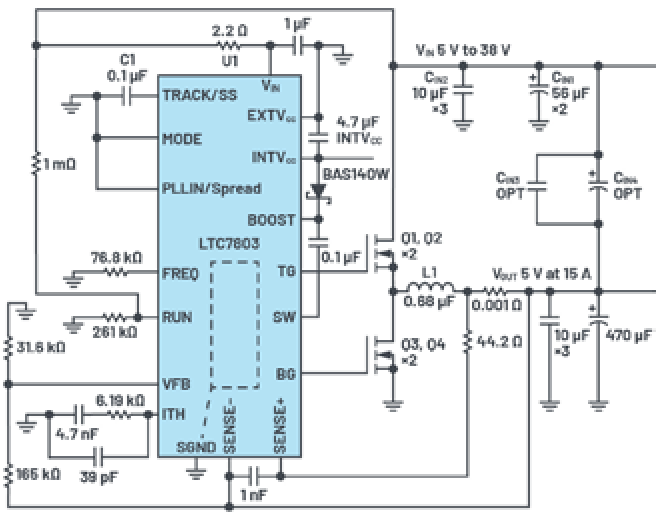

Figure 1: Electrical schematic of a step-down, buck converter with V_{IN} 5 V to 38 V, and V_{OUT} 5 V at 15 A.

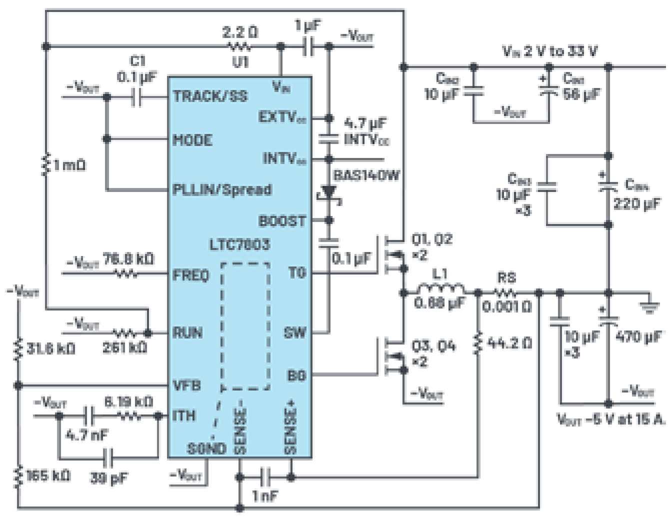

Figure 2: Electrical schematic of an inverting buck-boost converter with V_{IN} 2 V to 33 V, V_{OUT} –5 V at 15 A, and start-up input voltage +5 V.

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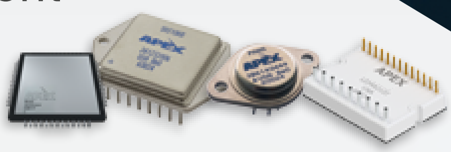

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Unlike in the buck converter, the capacitors CIN3 and CIN4 are not optional in this solution; they function as the input filter. The capacitors CIN1 and CIN2 filter ac between the V_{IN} and $-V_{OUT}$ rails. The following expressions can be used to estimate the stresses on the power train components, assuming CCM operation.

$$D = \frac{|V_{OUT}|}{V_{IN} + |V_{OUT}|} \quad \text{Duty cycle}$$

$$V_{DS} = V_{IN} + |V_{OUT}| \quad \text{Maximum voltage stress on Q1 through Q4}$$

$$I_L = \frac{I_{OUT}}{1 - D + 0.5\Delta I} \quad \text{Inductor L1 peak current, where } \Delta I \text{ is peak-to-peak ripple current.}$$

Converter Functionality and Testing

There's plenty of literature covering the basic and even advanced functionality of these two types of converters.1 In the remainder of this article we'll examine rarely discussed factors.

First, there is a fundamental difference in functionality of the output filters between the buck and buck-boost topologies. In the buck configuration, the inductor is hardwired to the output filter, providing continuous output current in CCM. Unlike the buck, the buck-boost topology does not connect the inductor only to the output. During the Q1/Q2 on-time, the inductor L1 is disconnected from the output filter and the output filter capacitance is the only source of energy to the load. Consequently, it's important to have enough output capacitance to absorb the discontinuous output capacitor current and support the specified output voltage ripple.

There is a drawback in negative buck-boost and, in fact, most inverting topologies. At startup there is a reverse voltage swing at the output filter with amplitude not more than one diode voltage drop, as shown in Figure 3. This brief reverse voltage is due to the flow of the controller's operating current through the forward-biased diode to system ground. The existence of the reverse voltage on polarized capacitors appears unacceptable at first glance. Hence, some designers eliminate polarized capacitors from the output filter, resorting to ceramic-only capacitors. This approach creates

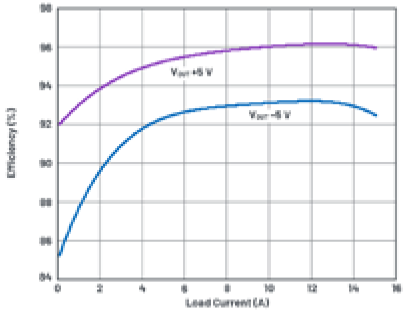


Figure 4: Efficiency of the converters in Figure 1 and Figure 2 (V_{IN} 12 V, natural convection cooling, no air flow).

Figure 5: DC2834A converted to inverting buck-boost from the original, off-the-shelf step-down converter.

other problems associated with the size, cost, and dc bias of the ceramic capacitors. Nevertheless, it is possible to use polarized capacitors in inverting buck-boost applications with some limitations. The guidelines vary by vendor—an example of such recommendations can be found in Polymer, Tantalum, and Niobium Oxide Capacitors: Application Guidelines.2

The converters shown in Figure 1 and Figure 2 were thoroughly tested and evaluated. Their efficiency is shown in Figure 4. To simplify the design with a low pin count and wide input voltage range, making it applicable to a wide variety of solutions, the LTC7803 advanced controller was used in both cases. The evaluation board DC2834A was used as a basis (with some modification) to verify both applications. To reduce EMI, the spread spectrum feature of this controller can be employed. Figure 5 shows a photo of the buck DC2834A converted to inverting buck-boost.

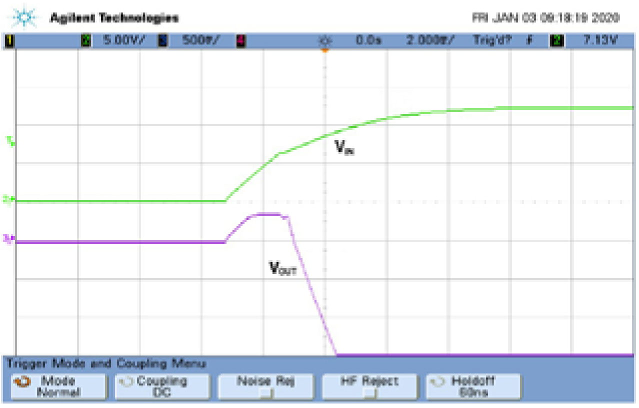


Figure 3: An inverting buck-boost converter with start-up waveforms. Channel 2's V_{IN} is 5 V/div, while Channel 3's V_{OUT} is 0.5 V/div with a 2 ms/div timescale.

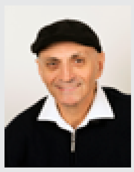
Conclusion

This article presents a way to use the same controller and a number of identical components for positive step-down and negative buck-boost converters. In this way, costs for qualifying components can be reduced. Costs can be further reduced by using a controller that requires a minimal number of power train components and supports synchronous rectification, resulting in efficient, low EMI, wide input voltage range solutions.

References

1 Robert W. Erickson and Dragan Maksimovic. Fundamentals of Power Electronics, 3rd edition. Springer Nature Switzerland AG, 2020.

2 Polymer, Tantalum, and Niobium Oxide Capacitors: Application Guidelines. AVX Corporation.



About the Author

Victor Khasiev was a senior applications engineer at ADI with extensive experience in power electronics both in ac-to-dc and dc-to-dc conversion. He holds two patents and has written multiple articles. These articles are related to using ADI semiconductors in automotive and industrial applications. Topics cover step-up, step-down, SEPIC, positive-to-negative, negative-to-negative, flyback, and forward converters, and bidirectional backup supplies. His patents include efficient power factor correction solutions and advanced gate drivers. Victor enjoys supporting ADI customers by answering questions about ADI products, designing and verifying power supply schematics, laying out printed circuit boards, and troubleshooting and participating in testing final systems.

www.analog.com

Simulation of Magnetization of Permanent Magnetic Objects in a Customized Fashion

In this article, Dr. K.M. Prasad discusses the magnetization of a virgin magnetic material into a permanent magnet in IES's magnetic solver AMPERES. In our previous versions of AMPERES, only the orientation of the different parts of the permanent magnet was customized. Now in the present version of AMPERES, both orientation and the strength of the different parts of the permanent magnet were customized.

By Dr. K.M. Prasad, Senior R & D Engineer, Integrated Engineering Software

In the model, a piece of virgin magnetic material in the desired shape was exposed to highly impressed magnetic fields produced by the magnetic chargers. Different regions were exposed to different impressed magnetic fields simultaneously, to get a customized pattern of magnetic orientation. Images show a semicircular ring magnetized in 6 alternatively reversing magnetization directions oriented along its axis. The angular stretch of each magnetization portion is 300. Accordingly, a magnetic charger having 6 sets of coils with alternatingly changing senses of current flow is modeled.

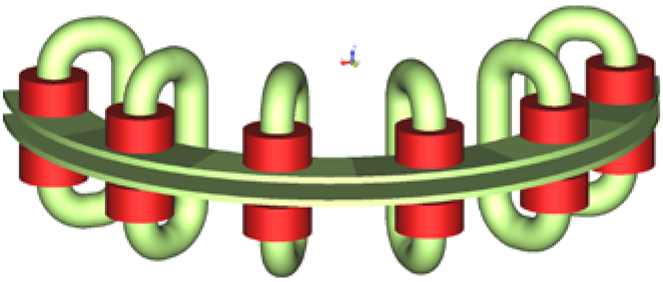


Figure 1: Magnetizing Charger.

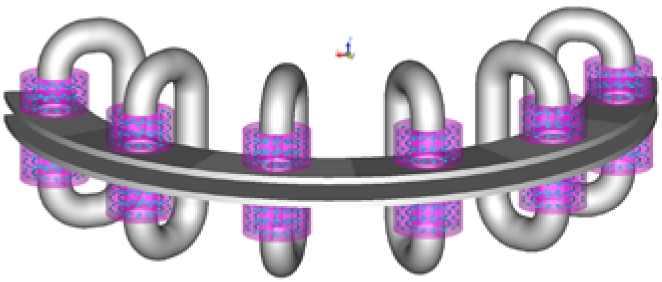


Figure 2: Current sense.

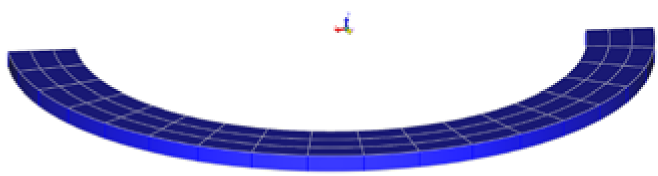


Figure 3: Semicircular ring to be magnetized.

The virgin piece of the semicircular magnetic ring was sandwiched between the charger plates, and appropriate material was assigned to the model. This model was discretized and solved by selecting the command "Magnetize" in AMPERES. Once magnetization was done, the geometry related to the magnetic charger was deleted and the appropriate permanent magnetic material property was assigned to the semicircular disk. This model was solved by hitting "Run Solver" in AMPERES to determine the magnetic fields produced by the magnetized ring.

This simulation involved two important actions. First, the material to be magnetized was divided into many smaller volumes because the higher the number of divisions, the better was the accuracy. However, the number should not be more than a required number. In this example, the semicircular ring was divided into 6 equal angular portions and each angular portion was subdivided into 9 smaller volumes. In total, the semicircular ring was divided into 54 (=6X9) smaller volumes. The reason for dividing the magnetizing piece into smaller volumes was that AMPERES calculated the magnetic flux density vector (B) at the geometric center of each smaller volume and magnetized it in the direction of B vector. The program will also assign an appropriate new permanent magnetic material to each smaller volume.

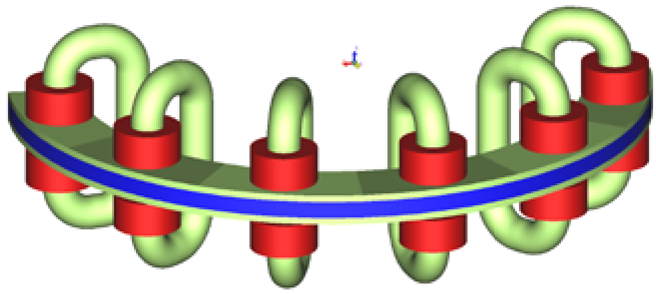


Figure 4: Semicircular ring sandwiched between the plates the magnetizing charger.

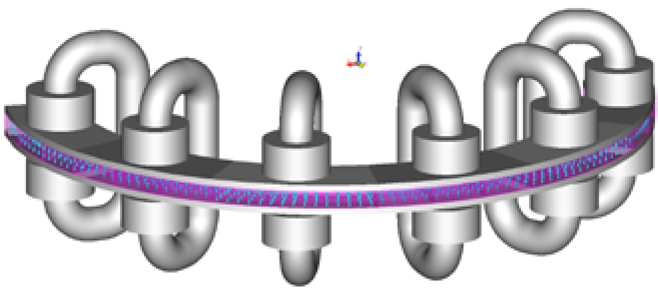


Figure 5: Permanent magnet directions of discretized volumes of the semicircular ring after magnetized.

The demagnetization curve of this new material which would be a scaled down version of the demagnetization curve of the permanent magnetic material that was assigned to the virgin material. The scaling factor is the ratio of the B field value at the geometric center of the smaller volume and the user specified minimum B field required to magnetize the virgin material to the fullest strength. Fullest strength we mean, the permanent magnet will have the vendor specified demagnetization curve after the magnetization.

It is important to note that the magnetic material property of the virgin piece is the same as that of the permanently magnetized piece. For the virgin piece, the magnetic material can be a linear material with a constant relative permeability, or a nonlinear material specified by a nonlinear B-H curve confined to the second quadrant only.

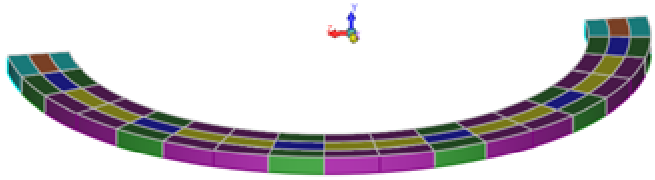


Figure 6: Minor permanent magnetic materials assigned to discretized volumes after magnetized.

After the magnetization is done in AMPERES, program assigns different minor permanent magnetic materials which are the scaled down versions of the permanent magnetic material initially assigned. The B-field results shown in Figures 7 and 8 are with the minor permanent magnet materials, whereas the same shown in Figures 9 and 10 are with the permanent magnet material initially assigned. From these results, you can see the effect of using minor magnetic materials which were calculated by AMPERES.

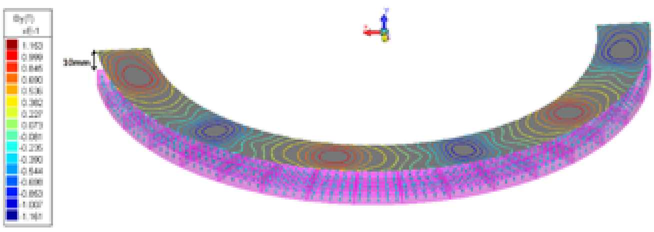


Figure 7: Magnetic charger deleted. Contours of the Y component of magnetic flux density vector B on a surface 10mm above the magnetized semicircular ring.

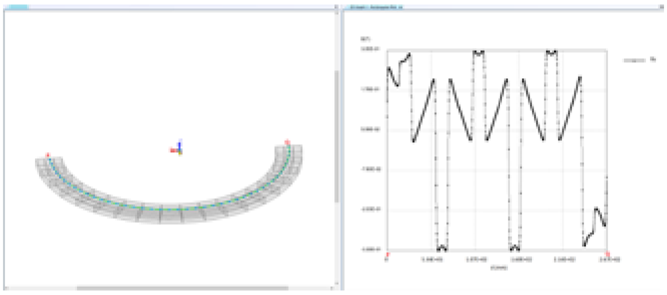


Figure 8: Variation the Y component of magnetic flux density B along a semicircular arc 1mm above the magnetized ring.

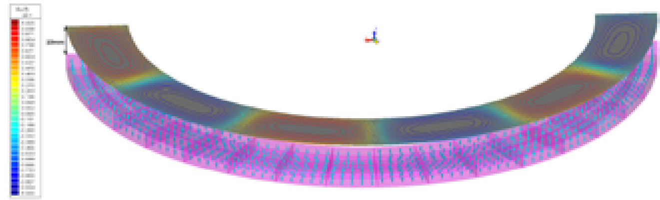


Fig.9: To all small volumes initial permanent magnet material is assigned. Contours of the Y component of magnetic flux density vector B on a surface 10mm above the magnetized semicircular ring.

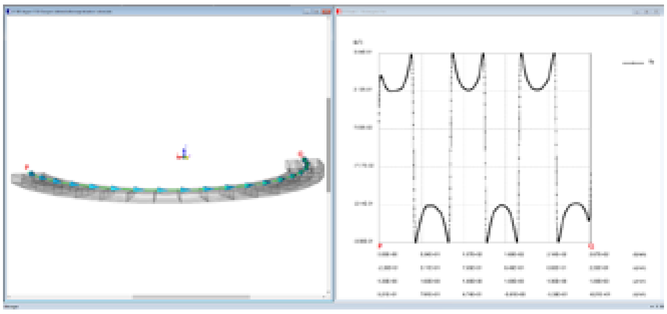
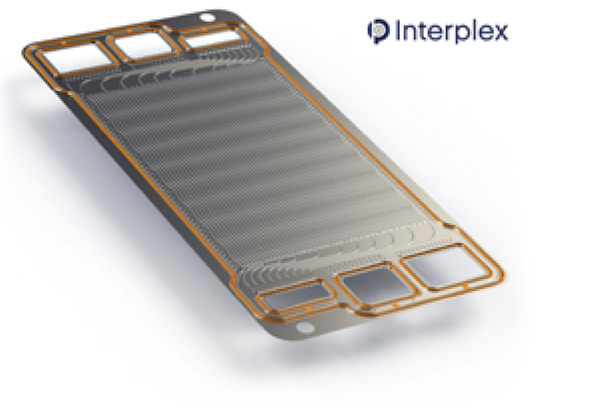


Figure 10: To all small volumes initial permanent magnet material is assigned. Variation the Y component of magnetic flux density B along a semicircular arc 1mm above the magnetized ring.

www.integratedsoft.com

Low Contact Resistance Coating For Heightened Fuel Cell Efficiency

Fabricated from corrosion-resistant SUS316L stainless steel, the Interplex bipolar plate (BPP) solutions for hydrogen fuel cells support an extensive operational lifespan of over 8,000 hours. They have thicknesses down to 0.8mm. Their low contact resistance (< 2mΩ·cm² at 1Ma pressure levels) helps to significantly boost the efficiency levels of the fuel cell stacks they are used in and enables power densities to be raised. Thanks to the precision stamping techniques employed, Interplex BPPs exhibit only ≤8% variation in the evenness with tight tolerances of flow channel thickness (across their active area), as well as offering enhanced plate flatness. These BPPs thereby deliver assured leak-tight operation and even power distribution across the entire surface of their plates. Likewise, advanced laser welding results in exceptional weld quality.

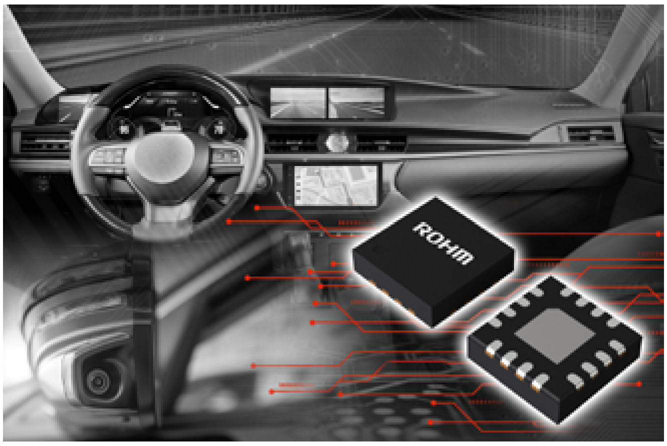


The high-speed stamping and coating procedures that Interplex has developed are key factors too. Via these, the company is able to reach high productivity figures – with physical vapor deposition (PVD) coating of plates being done in a fifth of the time compared to other suppliers. In addition, proprietary over-molding technology for attaching the silicone rubber gaskets to the BPP is done to elevated degrees of accuracy. It allows assembly problems to be minimized when stacking the BPP with a membrane electrode assembly (MEA).

www.interplex.com

DC/DC Converter IC for Advanced Driver Assistance Systems

ROHM developed the buck DC/DC converter IC with built-in MOSFET (Switching regulator), BD9S402MUF-C, for automotive applications such as infotainment and ADAS (Advanced Driver Assistance Systems) incorporating onboard sensors and cameras that are becoming more advanced. The BD9S402MUF-C supports output voltages down to 0.6V and 4A output current at switching frequencies higher than 2MHz in a compact size demanded by increasingly sophisticated secondary power supply applications for high performance MCUs and SoCs. What's more, it is incorporating proprietary QuiCur™ high-speed load response technology and enables stable operation at an industry-leading 30mV (measurement conditions: 5V input voltage, 1.2V output voltage, 44µF output capacitance, load current variation 0 to 2A/2µs). This translates to a 25% reduction in output voltage fluctuation over class-leading standard products with equivalent functionality, making it ideal for use in the latest ADAS with severe power supply conditions requiring stable operation within 5% even with low voltage output. The BD9S402MUF-C is also equipped with a load response performance selection function that allows users to easily switch priority between 'voltage fluctuation' (for stable operation), and 'capacitance reduction' (to ensure stable operation at 22µF) via terminal setting. The result is that users can reduce the resources required for power circuit design, as stable operation can be achieved not only at the initial design, but also during specification or model changes.



www.rohm.com

Power Chip Cooler with a Thermal Resistance of Merely 1.4 K/W

SEPA EUROPE introduces the HZB50B, a chip which, cooler with its low thermal resistance of only 1.4 K/W, is suitable for both, powerful processors and FPGAs. It is noticeable at first glance that the HZB50B has a very light and compact construction. It measures merely 50 x 50 x 11.5 mm and weighs only 39 g which renders it suitable for low installation heights. The heat sink was produced from pure aluminum by modern impact extrusion which means that large quantities can be manufactured cost-effectively. Thanks to its robust ball bearing system, it has a service life of 350.000 h (at 40°C) and is thus particularly suitable for failsafe cooling. The brass push pins ensure easy attachment. The PCB only requires preparing with the corresponding holes and reinforcements. The compression springs provide an ideal thermal transfer from the semiconductor to the heat sink. The chip cooler HZB50B is available with 5 and 12 V and can also be supplied on request with preassembled adhesive pads.

www.sepa-europe.com

Automotive-Grade Low-Dropout Linear Regulators

Taiwan Semiconductor announces the availability of the TQL8xx Family of automotive-grade, low-dropout (LDO) regulators. These AEC-Q101 qualified LDOs offer manufacturers a reliable alternative source for the critically important linear regulators utilized in numerous battery-driven automotive functions, including dashboard, cluster, climate control, fuel pump and advanced driver-assistance systems (ADAS). They are also well suited for secondary supply applications where a regulated output is essential during very low-cranking voltage conditions. Designed for stability in automotive battery-connect applications, TQL8xx LDOs maintain 2% accuracy over a wide range of input voltages and a full operating temperature range of -40 to +125C. They are offered in models with fixed outputs of 3.3V or 5.V and feature typical dropout voltages of 70-80 mV @ IO=100 mA.

www.taiwansemi.com

Offline AC-DC Primary-Side PWM Controllers for Flyback Converters

Elevation Semiconductor announced the release of its two power ICs with smaller footprints for fast-charging solutions. The HL9510 and HL9512 are flyback PWM controller ICs that operate in a quasi-resonant (QR) mode to enhance the system efficiency and power density. Both ICs offer constant output voltage regulation through the optocoupler feedback controller or shunt regulator and integrate high-voltage startup.

The HL9510 and HL9512 protection include VDD over-voltage protection (VDD-OVP), Brown-out protection, DMAG over-voltage protection (DMAG-OVP), DMAG under-voltage protection (DMAG-UVP), IC internal over-temperature protection (OTP), and IC external thermal shut-down (SD).

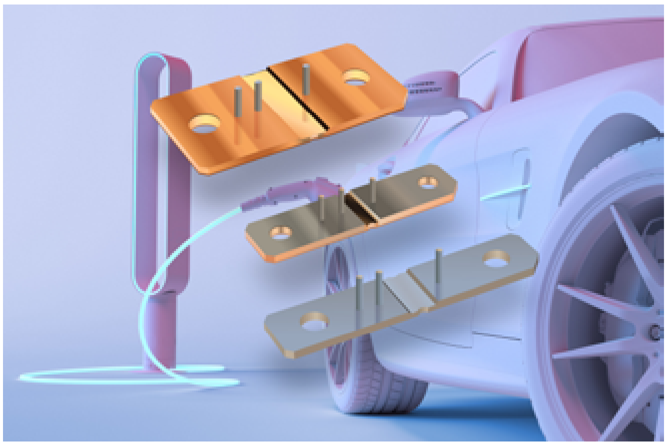
The brown-in voltage is programmed by an external DMAG pin resistor and has a wide VDD operating range to cover variable output mode applications, such as USB-PD/PPS or conventional DP/DN protocol communication. Its protection is also implemented with auto-restart mode. The VDD-OVP, DMAG-OVP, and external SD protection can be configured with auto-restart or latch mode, and the DMAG-UVP can be configured with auto-restart or long auto-restart mode. The HL9510 is designed to integrate an internal HV startup circuit, whereas the HL9512 can be done by the external MOS combined IC's AUX and ST pins. The HL9510 is available in a

10-lead SOIC package ideal for USB PD/QC portable device battery chargers, high-efficiency AC-DC power adapters, and a power supply with fixed or variable output voltage. The HL9512 also comes in the same package and is ideal for smartphones, tablet PC battery chargers, portable device adapters, and flyback power suppliers with low and/or variable output voltage.

www.elevation-semi.com

High Power Shunt Resistors with Metal Sensing Pins

Bourns announced an extension to its Model CSM2F Series power shunt resistor portfolio with 12 series. These series feature riveted through-hole metal sensing pins meeting the growing need for accurate positioning of voltage sense points in high current applications.



These latest additions to the Bourns® Model CSM2F Series shunt resistor family are engineered using the Company's electron beam-welded resistive technology that supports high power designs up to 50 watts with continuous current up to 1414 amps. In addition, these new series are constructed with a metal alloy resistive element that delivers a thermal EMF as low as 0.25 µV/K.

Available in two or three tin-plated copper pin options, the Model CSM2F Series with additional sensing pins offers a third pin option that is connected to the ground side of the circuit. The three-pin design helps reduce sensing errors by carrying the ground current on a separate path from the sensing circuit for higher measurement accuracy. The Bourns® Model CSM2F Series shunt resistor family extension also features a wide resistance range from 25 µΩ up to 200 µΩ, and a low ±50 PPM/°C TCR in the 20 °C to 60 °C temperature range. Giving designers additional flexibility, the series are offered in three different surface finishes to match various customer environmental and soldering needs, and are available in four package sizes: 6918, 8518, 7036 and 8536 (metric).

www.bourns.com

ASIL C Certified Battery Management System for High Voltage Applications

Sensata Technologies announced a Battery Management System (BMS), the Lithium Balance n3-BMS, for high voltage applications. It is ideal for applications with power up to 1000 volts/2000 amps, especially for battery makers and manufacturers of electric trucks, buses, and other heavy commercial vehicles. The demand for ISO 26262 certified components is on the rise as battery packers and

electric commercial vehicle OEMs prioritize functional safety in their platforms while striving for faster time-to-market. However, the ISO 26262 certification process is complex, costly and can take years to complete. An off-the-shelf, Automotive Safety Integrity Level (ASIL C) certified solution like the Lithium Balance n3-BMS can reduce the development time and associated costs.

The layered software structure of the n3-BMS provides customers with the option to customize the battery management system with their own code and algorithms without impacting the ASIL C certification. The BMS software architecture consists of a "Base Software Layer" (BSW) and an "External Software Layer" (ESW) which are connected by an open API link layer. Since all the safety-critical functionalities of the BMS are in the BSW layer of the software, developers are free to implement their own software code and algorithms in the ESW without any risk to the ISO 26262 certification of the system.

www.sensata.com

Reliable DC-link Film Capacitors in PV Inverters

The inverter is one of the core components of the PV system in a solar power generator set, which needs to meet different functional requirements, not only to ensure DC/AC conversion but also to guarantee the quality of the output power. Because modules are typically used in outdoor and require long-term operation with reduced maintenance, end users and designers have extremely demanding quality and reliability requirements for the components used in these equipment.

As the carrier and support in the energy conversion process, film capacitors play a vital role in in every link of PV inverters, and improper selection will have a fatal impact on the stability and operating life of the equipment.

Wuxi CRE New Energy Technology Co., Ltd. has been focusing on the application of film capacitors in power electronics. According to the harsh application conditions of photovoltaic inverters, the company has designed and developed a series of film capacitors with high temperature and humidity resistance, low ESR(reduce heat), high reliability and long life.

Among them, the performance characteristics of DMJ-PS DC bus capacitor are as follows:

- Max. operating temperature: 105 °C (housing)
- Climate category (IEC 60068-1:2013): 40/105/56
- Dielectric: polypropylene (MKP)
- Plastic housing (UL 94 V-0)

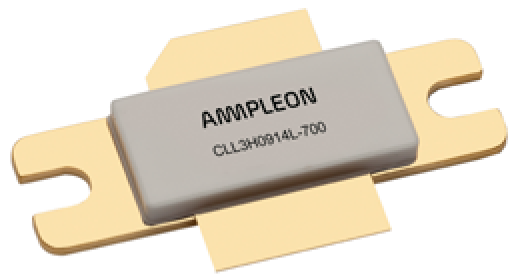
- Epoxy sealed (UL 94 V-0)
- Max. Capacitance: 200 µF
- Voltage range 300 V ~ 2000 VDC
- RoHS compliant
- 2-Pin/4-pin parallel leads, lead-free tinned
- Good self-healing properties, overvoltage resistance, high current resistance and low losses
- Resistant to hot and humid environment (85°C/85%RH 1000h)
- High reliability, long service life

www.cre-elec.com

GaN-SiC HEMT Transistor for Long Pulse Radar Applications

Ampleon introduces the CLL3H0914L-700 GaN-SiC HEMT for wireless infrastructure, avionics/defence, non-cellular communication, cooking/ defrosting, and ISM-related applications. This rugged GaN transistor is optimised for radar implementations where long pulse width and high-duty cycles are required. The transistor was engineered to achieve over 700W of peak output power from a single transistor while operating at a voltage of 50V with efficiency of over 70% as well as designed thermally for long pulse applications, such as pulse widths (~2 milliseconds) and 20% duty cycles.

This high-power density and low-thermal resistance HEMT is now in full volume production. Units are available directly from Ampleon or authorised distribution partners, RFMW and Digi-Key. Large signal models in ADS and MWO can be sourced via the Ampleon website.



www.ampleon.com

Higher Voltage Biasing High Voltage Power Supplies

Dean Technology announced the introduction of a series of high voltage power supplies designed specifically for higher voltage applications needing a biasing module. The UMR-A-10000 series, which is another extension of the existing UMR Collection of power supplies, offers output voltages up to 10kV, input voltages at 12 or 24V, and power at up to 30W. In addition, this line of power supplies offers a high voltage flying lead.

UMR-A-10000 modules, like the UMR-A and UMR-AA before them, offer low ripple and highly stable outputs. All models come standard with voltage and current monitoring; the ability to upgrade each unit to include buffered monitors and current regulation will be available in the coming months.

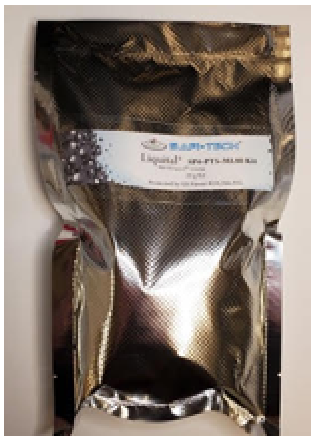
"This UMR-A-10000 series finally gets our UMR-A family above the 6kV threshold, which has been a consistent demand from our customers since the UMR's inception," said Scott Wilson, Sales and Product Development Manager for Dean Technology. "As always, we are a customer driven organization, and as such will continue to evolve our UMR product line to offer more options for our customer's high voltage applications. We look forward to releasing even higher voltages in the future."

The UMR Collection of power supplies are form-fit-function replacements for industry standard units and is comprised of six product lines – the UMR-A, UMR-AA, UMR-C, UMR-HPC, UMR-BPC, and the new UMR-A-10000.

www.deantechnology.com

Supercooled BiSn Solder Paste

Indium Corporation® and SAFI-Tech, an Iowa-based startup that is creating no-heat and low-heat solder and metallic joining products, have announced the launch of a supercooled BiSn solder paste using SAFI-Tech's innovative solder platform. Using SAFI-Tech's platform, liquid metal is encapsulated in a proprietary soft shell, keeping the solder alloy in a sub-cooled (liquid) state far below its normal melting/freezing point. The shell of these powder-like microcapsules can be removed using a traditional flux and reflow process, or burst by compression. SAFI-Tech's supercooled BiSn solder paste can be fluxed and reflowed at 135°C, a temperature that is currently impossible to reach using conventional BiSn solder alloys. Target applications include flexible hybrid electronics and heat-sensitive applications currently using conductive epoxies.



www.indium.com

800 V and 950 V AC-DC Integrated Power Stages

Optimized performance, efficiency, and reliability in high-voltage power supplies need to be combined with reduced bill-of-material (BOM) count and cost, as well as lower design efforts. With its 5 th generation fixed-frequency (FF) CoolSET™ portfolio, Infineon Technologies offers the right components to meet these needs and effectively manage the critical design trade-offs. The 800 V and 950 V AC-DC integrated power stages (IPS) are housed in a DIP-7 package and address applications such as auxiliary power supplies for home appliances, AC-DC converters, battery chargers, solar energy systems, and motor control and drives.

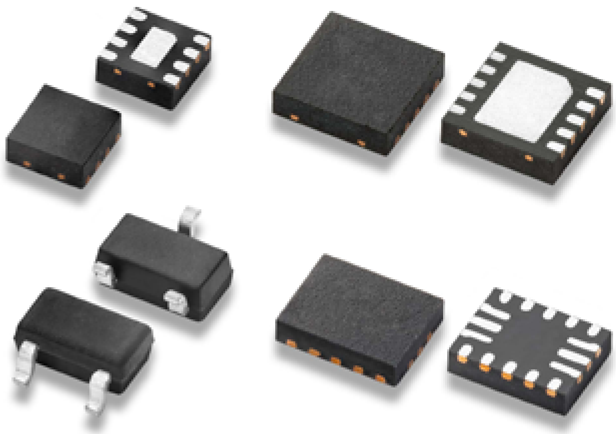
The FF CoolSET solution combines a PWM controller IC with the latest high voltage CoolMOS™ P7 superjunction (SJ) MOSFETs in a single package. The extended portfolio now includes the first device on the market that uses an avalanche-rugged SJ MOSFET with a breakdown voltage of 950 V to allow for a wider input voltage. The new devices enable both isolated and non-isolated topologies such as flyback or buck and operate at switching frequencies of 100 kHz as well as 65 kHz. Accommodating both the cost-efficient buck topology and flyback in one single device simplifies the supply chain for customers. An integrated error amplifier supports direct feedback from the primary output, which is typical for non-isolated topologies. Moreover, this further minimizes the number of components and design complexity.

www.infineon.com

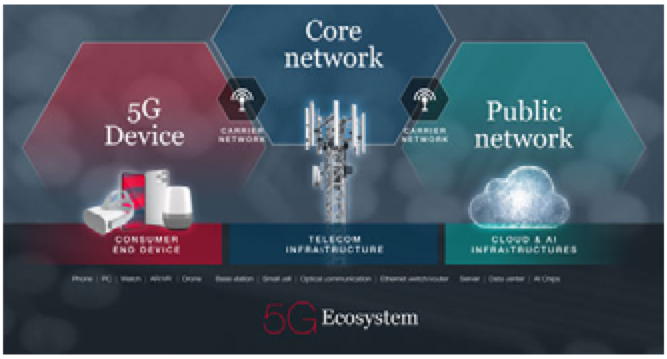
Protection ICs Series provide Protection, Sensing, and Control Features in a Single Chip

Littelfuse announced the eFuse Protection ICs product line, a series of four versatile circuit protection devices. The eFuse Protection ICs utilize an innovative design that provides a wide range of power input (3.3V to 28V) and integrated protection. In addition to overvoltage protection, these electronic fuses protect against overcurrent, short circuit, inrush current, reverse current, and overtemperature events with real-time diagnostics—all in one chip. "The eFuse Protection ICs provide today's electronics designers with significant flexibility by integrating robust circuit protection, sensing, and control in a single chip," said Bernie Hsieh, Assistant Product Manager of the Protection Semiconductor Business team at Littelfuse. "Providing a low power consumption, high accuracy current limiting circuit with quick response time makes them a win-win-win for many portable electronics and datacom applications." The eFuse Protection ICs are available in tape and reel format in quantities of 3,000 (LS0504EVT23, LS0505EVD22) or 5,000 (LS1205ExD33, LS2406ERQ23).

www.littelfuse.com



Silicone Solutions for 5G Networks



Dow announced that it has launched 5G.dow.com, an engaging, guided selection tool that allows customers to find the application-specific silicone solutions they need for their 5G-enabled technology.
5G, or fifth-generation technology, is an exciting evolution in telecommunications, enabling unprecedented levels of intelligent connectivity with significant improvements in the quality of service, time delay, throughput speed, energy efficiency and system performance.
With product innovations and proven materials, the Dow 5G Ecosystem helps to advance this technology with Dow's robust portfolio of product options in thermal management, electromagnetic interference (EMI) shielding, adhesion, sealing and encapsulation, and component molding. Dow's high-performance silicone solutions help advance both innovation and sustainability goals by offering materials with thermal protective properties, low volatile emissions, solvent-free formulations and room-temperature curing to conserve energy.
"5G.dow.com is one of many such tools being implemented across Dow globally to help provide a more customized, step-by-step journey for our customers and make it easier for them to find the most relevant information on Dow.com," said Cathy Chu, strategic marketing director, Dow Consumer Solutions. "This platform can play a significant role in enabling next-generation technologies and the future of faster, smarter, simpler connectivity. We are excited to now make this incredible resource available."

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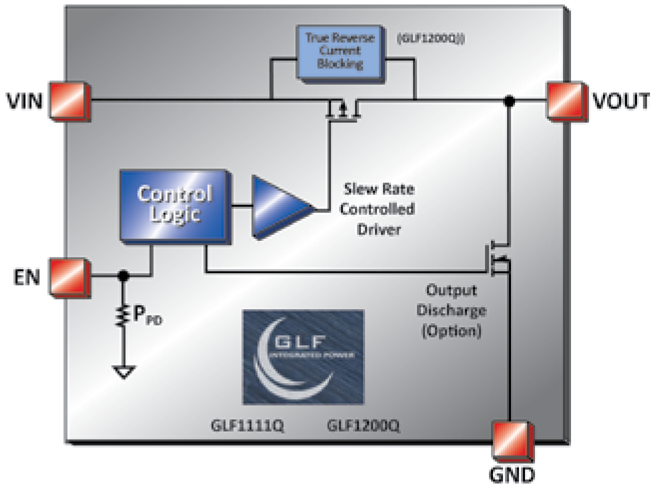
AEC-Q100 Qualified IC Load Switches for Automotive



GLF Integrated Power is pleased to introduce two Automotive grade AEC-Q100 IQSmart™ load switch ICs. The AEC-Q100 qualified GLF1111Q and GLF1200Q are rated for a wide temperature range (Grade 1 -40°C to +125°C). The GLF1200Q features a true reverse-current blocking, which prevents a backup power source from being discharged when an input node is shorted. The GLF1200Q works all of the time regardless of on or off state.
Applications for the GLF1111Q and GLF1200Q include infotainment and cluster display systems, diagnostic systems, passive entry/start systems (PEPS), customer premise equipment (CPE), face recognition systems and intelligent cockpit and autonomous driving applications.
Both the GLF1111Q and GLF1200Q IQSmart™ devices, packaged in a SOT-23-5L, offer easy visual inspection of solder joints. Both feature integrated slew-rate control that limit inrush upon turn on, therefore minimizing the effects of voltage droop.
Each load switch IC supports a wide-input voltage range (1.5V to 5.5V), meaning a single device can be used in a variety of voltage rail applications, which helps to simplify inventory management. And both are offered with an optional output discharge switch.
"We have added two new devices to our IQSmart™ family to offer high performance in more applications," said Eileen Sun, President, and CEO at GLF Integrated Power. "The GLF1111Q and GLF1200Q address the ever-expanding, evolving range of automotive electronic systems that require a high-performance load switch with a wide-ambient operating temperature range to assure reliable, long-term operations."

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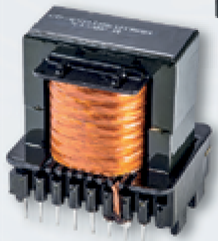

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- Matching / customized products for big and small projects
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- **Power supplies & converters**
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- **DC/DC converter and „Point-of-Load“**
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  - Input voltages from 3.3 - 800 V
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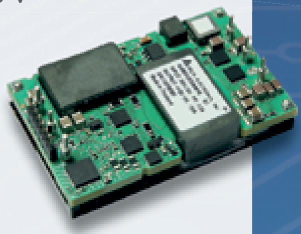

Your advantages
- Wide portfolio of power supplies for different conditions
- High reliability and lifetime

Power semiconductors
suitable for your applications

- **GaN transistors (15-650V)**
- **Low voltage MOSFETs (20-250V)**
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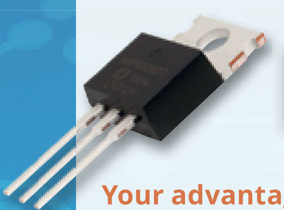
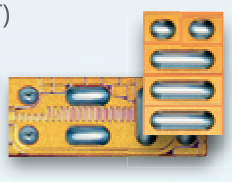
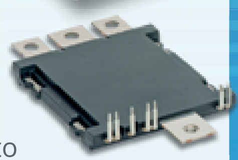
- **High performance semiconductors:**
  - IGBT and diode modules
  - Bipolar Snubber and Welding diodes
  - Thyristors
  - Automotive modules (SiC + IGBT)







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