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Bodo´s Power Systems®

Electronics in Motion and Conversion

April 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

- Very **easy and fast** measurement
- **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

Suitable for all inductive components from **small SMD inductors** to **very large power reactors in the MVA range**

- **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

ADVENTURES OF OHM
SWIMMING WITH SHARKS
LEGAL
WHAT'S THIS "BABY AS COLLATERAL" CLAUSE?

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

AFRAID OF INRUSH CURRENT?
SELECT EMC FERRITES BY PEAK PULSE

WE meet @ PCIM Europe

Hall 6, Booth 402

REDEXPERT.
Würth Elektronik's online platform for simple component selection and performance simulation:
www.we-online.com/redexpert

- Pulse Designer for EMC PCBFerrites to meet inrush current requirements based on inrush current amplitude and pulse length
- The world's most accurate AC loss model
- Filter settings for over 20 electrical and mechanical parameters
- Inductor simulation and selection for DC/DC converters
- Ability to compare inductance/current and temperature rise/DC current using interactive measurement curves
- Available in seven languages
- Online platform based on measured values
- Order free samples directly
- Direct access to product datasheets
- Comfortable and clear component selection

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A Lifetime in Peace

I was born in 1953, after World War II and have enjoyed a wonderful life in peace. Nevertheless, I remember my mother telling me her stories of how she escaped with my older brother from Silesia, now a Polish region. Looking back at my family, I grew up without a grandpa and uncles. My grandpa died in World War I while my mother was only a child and her brothers died in World War II. Both were told not to serve in the war as they had lost their father and were too young but as the war escalated none of this mattered. I was lucky, my father built diesel engines for submarines which excluded him from serving as a soldier. These stories seemed so far away from me when I was a child. Now it is reality in Europe again. It is a pity that the diplomatic activity could not avoid this. There will only be losers at the end. 'Please stop the war' is the message to all politicians in our world.

These memories and past stories return while watching the news on TV. There are never winners from war and it will be the wider population who suffers the most. My hope is that our children and grandchildren will enjoy peace again soon. I have donated 1.000 € to UNICEF to help the children of Ukraine, this is the same amount that we donated at Christmas instead of sending cards, which we have done for the past two years. I would like to encourage my readers to offer similar help.

Corona is not a topic of conversation anymore and as a lot of people report only mild infections, I hope things will be back to normal soon. We have reserved our hotel for PCIM Europe and my team is ready to travel. As always we will have our booth and are looking forward to meeting you face to face. My podium discussions are now spread over two days, Wednesday and Thursday around lunchtime.

All visitors and conference attendees are welcome to join the podiums at the industry forum for

- SiC on Wednesday, May 11th at 1:10 p.m. CEST,
- GaN on Wednesday, May 11th at 2:15 p.m CEST, and again
- SiC on Thursday, May 12th at 1:45 p.m. CEST

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:

Save energy as much as possible. Reducing room temperature will help. Bundle driving for shopping with multiple items on your shopping list to avoid unnecessary trips.

Best regards

Events

Smart Systems Integration 2020
Grenoble, France April 27 – 28
www.smartsystemsintegration.com

SMTconnect 2022
Nuremberg, Germany May 10 – 12
https://smt.mesago.com

The Smarter E 2022
Munich, Germany May 11 - 13
www.thesmartere.de

electronica China 2022
Shanghai, China May 6 – 8
www.electronica-china.com

PCIM Europe 2022
Nuremberg, Germany May 10 – 12
https://pcim.mesago.com

Battery Tech Expo 2022
Silverstone, UK May 12
www.batterytechexpo.co.uk

CWIEME Berlin 2022
Berlin, Germany May 10 – 12
www.berlin.coilwindingexpo.com

Sensor + Test 2022
Nuremberg, Germany May 10 – 12
www.sensor-test.com

AMPER 2022
Brno, Czech Republic May 17 – 20
www.amper.cz

CDSR Series

Extremely compact, the LEM CDSR leakage current sensor ensures your next EV charger will have the small size and low cost that customers want, while remaining fully compliant with relevant standards.

In addition, it provides highly flexible connectivity, offering both cable IC-CPD (mode 2) and AC wallbox (mode 3).

The CDSR also uses the latest open-loop fluxgate technology, offering high safety for EV users by measuring AC and DC leakage current below 1mA at frequencies up to 2kHz.

- **Single and three phase configuration**
- **32 Arms nominal current per phase**
- **0.5 mA accuracy at 6mA**
- **Test winding and default output signal**
- **Analog and digital communication (SPI)**
- **Complies with application standards IEC 61851, 62955, 62752, UL 2231**

www.lem.com

LEM

Life Energy Motion

Billion Euro Contract with German Automotive Manufacturer

SEMIKRON has secured a billion euro contract with a major German car manufacturer for their power module platform eMPack®. This platform, which is optimised for silicon carbide technology, will be used in he car manufacturer's next generation EV inverters. One of the crucial factors that clinched the deal is SEMIKRON's fully sintered "Direct Pressed Die" (DPD) technology, which allows for extremely compact, scalable and reliable inverters. Series production is scheduled to begin in 2025. The contract is worth in excess of one billion euros. Over the past few years, SEMIKRON has unfalteringly pursued its plan to become an automotive supplier, building upon decades of experience in the development and production of power modules. The strategy SEMIKRON is pursuing here focuses on global megatrends such as zero emission mobility as a means of combatting climate change. In relation to this, the eMobility market will remain one of the fastest growing markets for power semiconductors in the years ahead. According to business intelligence and strategy research company BIS Research, the number of hybrid and electric vehicles will continue to grow by 23% a year until 2029.

And SEMIKRON intends to grow with this market – with the help of its eMPack® power module platform for electric drive systems and full inverter solutions for untility vehicles. SEMIKRON is well equipped to meet this goal and contribute substantially to the shift to zero-emission and sustainable mobility.

www.semikron.com

Investment for Increase in Production of SiC Power Semiconductors

Fuji Electric is pleased to announce that it has made a decision to carry out capital investment in Fuji Electric Tsugaru Semiconductor Co., Ltd. (Goshogawara City, Aomori Prefecture), one of their power semiconductor production bases, for an increase in the production of SiC power semiconductors. Mass production is planned to begin in fiscal 2024. In the Five-Year Medium-Term Management Plan ending in fiscal 2023 (fiscal 2019 - fiscal 2023), FE announced that it will carry out capital investments totaling 120 billion yen toward power semiconductors. Although our capital investments currently focus on front-end process production lines for 8-inch Si (silicon) wafers, our amount of investments in power semiconductors, including this investment in SiC power semiconductors, is expected to expand to 190 billion yen, set against conditions of increased demand for electrified vehicles and renewable energy. SiC power semiconductors are next-generation power semiconductors that use SiC (silicon carbide) materials. Currently, power semiconductors that use Si materials are the most common, but SiC power semiconductors can make it possible to conserve energy and reduce the size and weight of Power Electronics Equipment they are installed in. FE predicts that the power semiconductor market (the market targeted by FE) will account for 2 trillion yen in fiscal 2024, with SiC power semiconductors making up approximately 8% of this. The market growth rate of SiC power semiconductors is expected to be 17% or more from fiscal 2021 to 2024.

www.fujielectric.com

Partnership for GaN IC Power Semiconductor Deployment

Wise-integration and EDOM Technology announced their channel partnership in the field of GaN (gallium nitride) power semiconductors, with the goal of expanding Wise-integration's business in Asian markets. The strategic partnership will leverage Wise-integration's GaN power transistor and digital control capabilities, as well as EDOM's extensive distribution network for semiconductor components and customer-support capability throughout Asia. Gallium nitride (GaN) is a wide-bandgap, next-generation semiconductor technology that has become key in a complete power electronics offering. It operates up to 20x faster than silicon and provides up to 3x the power or 3x the charge in half the size and weight as silicon devices. The company's customers will also benefit from greater access to GaN products and resources globally, especially in Asia, one of the fastest-growing markets for GaN technology. In addition, Wise-integration and EDOM Technology will collaborate on innovative GaN design using Wiseintegration's WiseGan® portfolio and WiseWare® digital control. This will provide customers with more benefits, including reduced bill of materials (BOM), easier, faster-design in, and highest performances due to digital control. "Optimistic about the next-generation materials' market potential of wide-bandgap semiconductors as well asthe small size, high efficiency GaN technology that Wise-integration provides, we are glad to have Wise-integration as EDOM's new partner on expanding

our power solutions, and we will bring more options and advanced solutions to our clients," said Wayne Tseng, Chairman of EDOM Technology. "We are pleased to announce our partnership with EDOM Technology to enable Wiseintegration to accelerate its business opportunities in Asia. By combining our GaN expertise with EDOM's capabilities, I am confident that we will be able to grow our business and help customers realize more benefits from GaN in their power-supply applications," said Thierry Bouchet, CEO of Wise-integration.

www.wise-integration.com

Koshiro Kudo to Become President of Asahi Kasei

Asahi Kasei announced at the end of January 2022 a change in the company’s management. As of April 2022, Koshiro Kudo will assume the role of President & Representative Director. The current President Hideki Kobori will be-come Chairman of Asahi Kasei.

Koshiro Kudo was born on June 5, 1959, on the island of Kyushu in Nobeoka, Miyazaki Prefecture, in southwestern Japan. He graduated from the renowned Keio University in Tokyo in March 1982 and started working for Asahi Kasei the following month. After holding various positions, Kudo be-came head of the ROICA™ business unit, producing premium stretch fibers from elastic polyure-thane filament, in May 2008. He pursued his career in the field of technical textiles and filaments in the following years, becoming President of the Fibers & Textiles Strategic Business Unit (SBU) based in Osaka in 2017.

Two years later, new responsibilities were added as President of the Performance Products SBU, in addition to fibers and textiles, he was in charge of the business with engineering plastics, synthetic rubber, elastomers as well as household and packaging materials. Kudo was also involved in the establishment of a new department for mobility materials, launched in April 2020 to focus on products for the automotive sector.

www.asahi-kasei.com

Investment in Europe Operations to Accelerate Collaborative Innovation

Analog Devices announced it will invest €100 million over the next three years in ADI Catalyst, a 100,000 square foot custom-built facility for innovation and collaboration located at its campus in the Raheen Business Park in Limerick, Ireland. This latest phase of expansion will also see the creation of 250 new jobs in the Irish market by 2025 as a reflection of ADI’s continued commitment to expansion in Europe.

ADI Catalyst is a collaboration accelerator where ecosystems of customers, business partners, and suppliers engage with ADI to rapidly develop solutions. Utilizing technologies in simulated environments and real-world end applications accelerates the development and adoption of these innovative solutions. The newly created jobs at ADI Catalyst will primarily focus on the development of software-enabled solutions and artificial intelligence (AI) innovations

in areas such as Industry 4.0, sustainable energy, automotive electrification, and next generation connectivity.

As an example, one of the current Catalyst projects is focused on supporting healthcare’s exciting migration from a mass market approach to one of customized treatment and therapies. ADI is working closely with its customers and their larger ecosystem to create flexible, next generation modular manufacturing systems that enable the rapid changeover of production lines needed for personalized treatments like CAR T-cell therapies and human implants.

www.analog.com

SENSOR+TEST 2022 in Nuremberg

Almost two months before the opening, preparations for SENSOR+TEST from May 10-12, 2022 in Nuremberg are in full swing. More than 300 exhibitors will present their latest achievements and technologies from sensor and measurement technology on site. Visitors can already discover a whole series of these innovations now.

“We have turned into the home straight and are very pleased to finally be able to return to the Innovation Dialog with exhibitors and participants in Nuremberg and resume it with all its facets. The more than 300 expected exhibitors are looking forward to the presence event, which was sorely missed in the last two years, to present their innovations to the interested public in person again,” says organizer Holger Bödeker enthusiastically.

However, numerous innovations can already be marveled at today. For example, many product highlights are already available for visitors on the SENSOR+TEST website (https://www.sensor-test.com/direct/product-news) - and there are more every day.

“So it’s worth taking a closer look before, during and even after the three days of the event,” recommends Holger Bödeker. This year, the exhibitors will once again show the diversity of their innovative developments not only in text and images, but also in a large number of video presentations.

www.sensor-test.de

Investing in Wide Bandgap Power Semiconductors

Infineon Technologies is adding significant manufacturing capacities in the field of wide bandgap (SiC and GaN) semiconductors. The company is investing more than €2 billion to build a third module at its site in Kulim, Malaysia. Once fully equipped, the new module will generate €2 billion in additional annual revenue with products based on silicon carbide and gallium nitride.

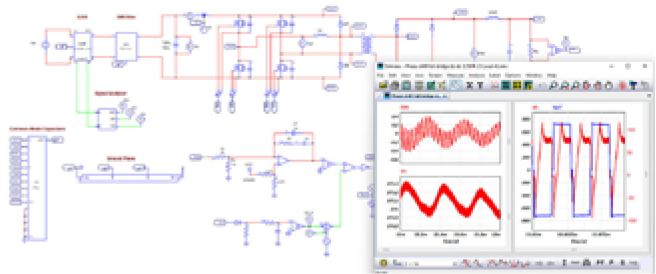
The expansion, following the company's long-term manufacturing strategy, will benefit from the excellent economies of scale already achieved for 200-millimeter manufacturing in Kulim. It will complement Infineon's leading position in silicon, based on 300-millimeter manufacturing in Villach and Dresden. The new investment will greatly reinforce the overall competitive advantage, which is based on the combination of technology leadership, a broad product portfolio and deep application know-how, following Infineon's "Product to System" approach.

"Innovative technologies and the use of green electrical energy are key in reducing carbon emissions. Renewable energies and electro-mobility are major drivers for a strong and sustainable rise in power semiconductor demand," said Jochen Hanebeck, Chief Operations Officer at Infineon. "The expansion of our SiC and GaN capacity is readying Infineon for the acceleration of wide bandgap markets. We are creating a winning combination of our development competence center in Villach and cost-effective production in Kulim for wide bandgap power semiconductors."

www.infineon.com

Expanding Electronic System Design Technology with Acquisition

Altair's acquisition of Powersim expands their electronic system design technology into the domain of power electronics. "Powersim has established a powerful solution that has proven to reduce development costs and time-to-market for thousands of customers around the globe including major companies in the automotive, aerospace, consumer electronics, and industrial applications sectors," said James R. Scapa, founder and chief executive officer, Altair. "The addition of Powersim's technologies and experienced technical team, who has deep domain knowledge in power electronics, rounds out Altair's offerings for electric motor design and many other applications."



This acquisition includes PSIM, Powersim's flagship product for design and simulation of power electronics and motor drives. PSIM delivers simulation speed while producing accurate system-level results, empowers easy implementation including embedded code generation and seamless adoption in any environment, and provides robust system-level design and simulation for various industrial applications.

"We are proud to have created a technology that has become a known brand in the market and leads the way in power electronics and motor drive simulation," said Dr. Hua Jin, president and founder, Powersim. "Joining Altair will allow us to further expand use of our technologies to more organizations looking to accelerate their electronic design."

www.altair.com

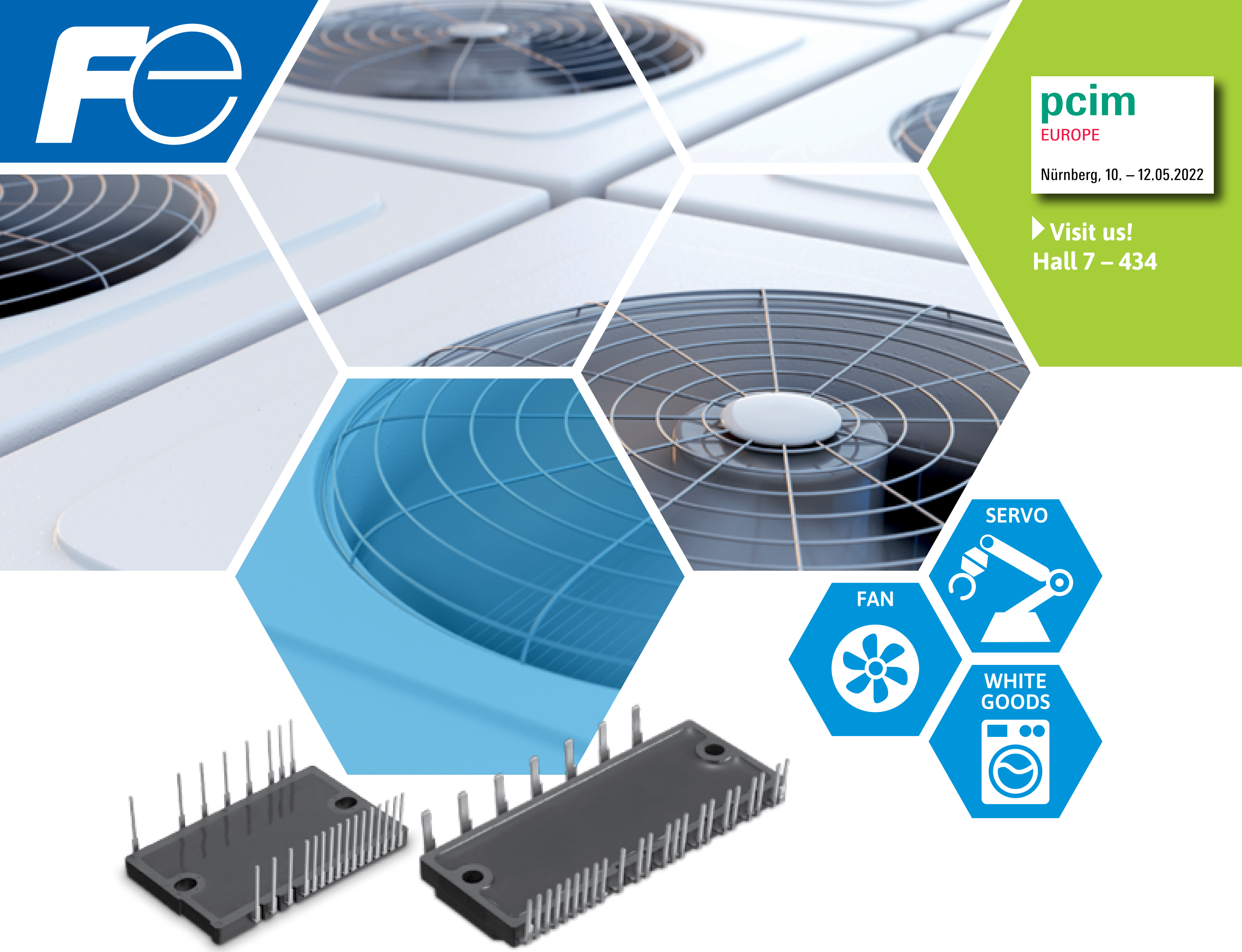
European PhD School on 'Power Electronics, Electrical Machines, Energy Control and Power Systems'

The 22nd edition of the European PhD School on 'Power Electronics, Electrical Machines, Energy Control and Power Systems' is organized by the University of Cassino in cooperation with ECPE European Center for Power Electronics and ANAE for 12 years. It's a unique event in Europe for young power electronics engineers from academia to exchange experience and technical information about their PhD projects.

In 2022, the 22nd edition of the European PhD School on 'Power Electronics, Electrical Machines, Energy Control and Power Systems' will be organized from 23 – 27 May 2022 in Angevin Castle of Gaeta, Italy. It starts with an Industry Day covering keynote presentations from industry experts as well as a dialogue session for detailed face-to-face discussions between PhD students and industry representatives. The 1st day ends with a social dinner including the PhD School Award celebration. The rest of the week is dedicated to high-level lectures from several experts from academia but also from industry, related to the following thematic areas: Power Electronics, Electrical Machines, Energy Control, Power Systems.

In the frame of the PhD School event, ECPE organizes the Industry Day for Recruitment, where HR people from industry can meet PhD students on-site. Established companies in the field of power electronics, electrical drives and systems participate every year. Moreover, a special session with presentations is dedicated to the participating companies.

www.ecpe.org



Small-IPM Series – 2nd Generation

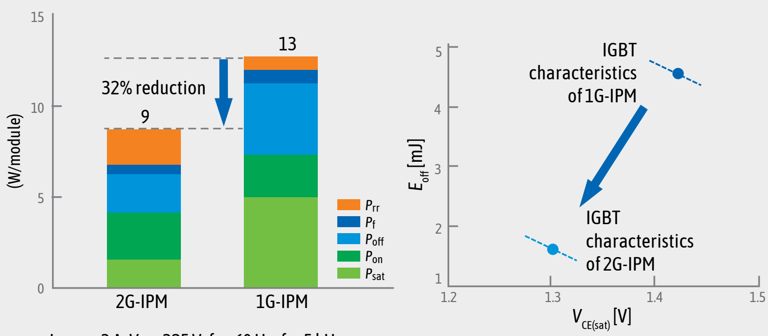
Ideal for Air Conditioners, Inverters and Servo Systems

MAIN FEATURES

- Reduction of losses and improvement of energy efficiency by utilizing 7th generation IGBT technology
- Built-in gate driver IC for optimum switching conditions
- Expansion of permissible operating area by improving the accuracy of overcurrent and overheating protection functions
- Utilizes an ultra-small DIP package with high heat dissipation aluminium insulating substrate

An IPM is a module which include three-phase inverter bridge circuit, control circuit and protection circuits.

Comparison with previous generation



$I_{O\,(RMS)} = 3$ A, $V_{DC} = 325$ V, $f_O = 60$ Hz, $f_c = 5$ kHz, $\lambda = 1.0$, 3 ph-mod, $T_c = 100$ °C

Estimated loss of a 10 hp PAC at intermediate load 650V / 50 A rating

$V_{CE(sat)} - E_{off}$ trade-off

www.fujielectric-europe.com
www.americas.fujielectric.com/semiconductors

Fuji Electric
Innovating Energy Technology

Distribution Deal for Rad Hard Gallium Nitride Power Devices

EPC Space announced that Digi-Key Electronics will be a global distributor for EPC Space's line of radiation hardened (rad hard) GaN-on-silicon transistors and ICs, packaged, tested, and qualified for satellite and high-reliability applications.

Spanning a range of 40 V to 300 V, EPC Space offers a family of rad hard enhancement mode power transistors. These power transistors demonstrate significant performance advantages over competitive silicon-based rad hard power MOSFETs. EPC Space technology produces GaN devices that are smaller, have lower resistance, and have many times superior switching performance compared to silicon solutions.

Digi-Key will also distribute EPC Space's family of rad hard enhancement mode GaN drivers and power stages. Rad hard GaN drivers are optimized to drive rad hard GaN transistors in critical spaceborne systems. Rad hard power stages integrate a high-speed gate drive circuit with power switches to provide a monolithic complete power stage in a tiny footprint for smaller, lower weight systems. "Digi-Key has the fastest global logistics and the most efficient supply chain to service customers from early engineering through volume production. Digi-Key's world-class distribution capabilities will translate into fast and easy service to our global customers who want to access the entire line of EPC's GaN power device products to replace their less-efficient, more costly silicon solutions," said Bel Lazar, EPC Space's CEO.

www.epc.space

Acquiring Tantalum and Polymer Capacitor Business Assets

KYOCERA AVX is set to acquire ROHM Semiconductor's tantalum and polymer capacitor business assets. The two companies recently reached a final agreement, which states that ROHM Semiconductor will transfer its tantalum and polymer capacitor business assets — including all of its tantalum and polymer capacitor manufacturing lines and relevant intellectual property — to KYOCERA AVX. The transfer is scheduled to be executed on August 5, 2022, and ROHM will continue to produce tantalum and polymer capacitor products and supply them to KYOCERA AVX until all relevant production lines have been successfully transferred to the KYOCERA AVX manufacturing site. This will ensure a continuous supply for ROHM customers and immediately increase the already extensive selection of electrolytic capacitor solutions available to KYOCERA AVX customers.

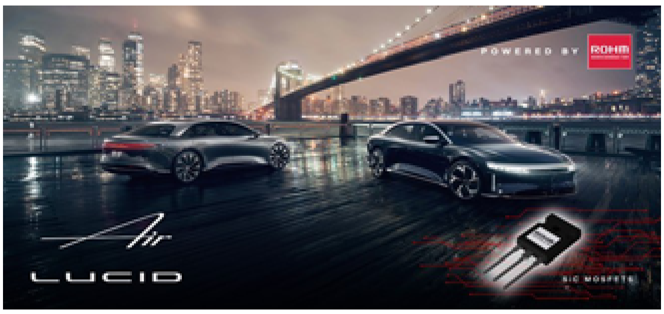
"KYOCERA AVX is excited to announce the acquisition of ROHM Semiconductor's tantalum and polymer capacitor business assets and to further expand our already extensive portfolio of electrolytic capacitor solutions," said Johnny Sarvis, CEO of KYOCERA AVX. "KYOCERA AVX is the leading global supplier of tantalum capacitors, as well as the largest supplier of high-reliability manganese dioxide (MnO2) solid tantalum capacitors for medical, military, and aerospace applications. In addition, we have four global manufacturing plants to ensure we can deliver the flexibility and capacity required by these demanding markets."

www.kyocera-avx.com

SiC MOSFETs Chosen by Lucid for On-board Charging of Luxury EV

ROHM Semiconductor has announced that Lucid is using its silicon carbide metal-oxide-semiconductor field effect transistor (SiC MOSFET) in the Lucid Air. The Wunderbox, the main on-board charging unit in the Lucid Air, integrates a DC-DC converter and the Bi-directional On-Board Charger (OBC), where an advanced power factor correction circuit is capable of operating at high switching frequencies thanks to the performance of the SiC MOSFET. The improved performance at high frequency and high temperature of ROHM's SCT3040K and SCT3080K SiC MOSFETs have helped Lucid to reduce the size of the design, and to reduce power losses, which results in high charging efficiency.

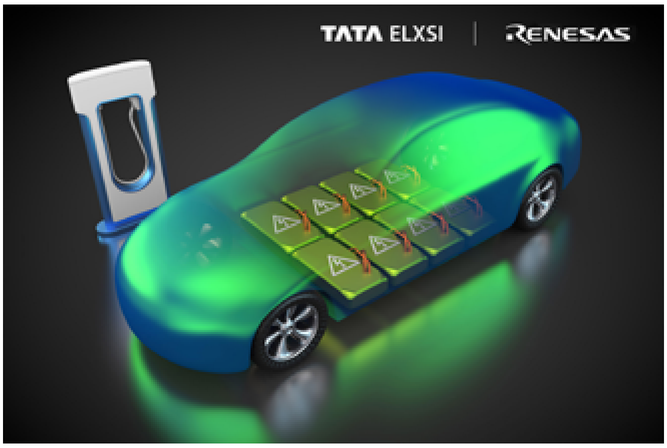
Lucid's mission is to inspire the adoption of sustainable energy by creating the most captivating electric vehicles, centered around the human experience. The company's first car, Lucid Air, is a luxury sedan with a California-inspired design underpinned by race-proven technology. Customer deliveries of Lucid Air, which is produced at Lucid's new factory in Casa Grande, Arizona, are underway. Kazuhide Ino, ROHM's Managing Executive Officer, CSO and Director of Accounting & Finance Headquarters: "We are excited to help Lucid develop systems for electric vehicles that maximize the potential of ROHM's SiC MOSFETs. ROHM will continue to strengthen its SiC device lineup, delivering power solutions - such as the charging systems featured in the Lucid Air - that contribute to technological innovation in next-generation automobiles. New products soon to be added, include gate driver ICs that maximize device performance."



www.rohm.com

Innovation Center Focuses on Electric Vehicle System Development and Market Enablement

Tata Elxsi and Renesas Electronics Corporation announced their collaboration on a design center in Bangalore that will develop targeted solutions for electric vehicles (EV). The Next Generation EV



Innovation Center (NEVIC) was opened in January of this year. Tata Elxsi and Renesas will bring together their deep domain expertise, intellectual property, and assets to the NEVIC and collaborate to create reference designs and solution accelerators for critical EV subsystems like Battery Management Systems and Motor Control Units, among others. With the electric vehicle market, especially the Light EV segment, at an inflection point, the companies aim to provide key enablers for the market, starting with India and expanding globally to optimize development time and effort. "Renesas is pleased to work with Tata Elxsi," said Taizo Hayashi, Vice President of Automotive New Business Creation Division, Renesas. "this collaboration demonstrates our commitment to support the 'Make in India' government initiative and we look forward to generating future business growth in India. The NEVIC Solution Center will be a turning point as OEMs and Tier 1s will now have access to secure system solutions and can leverage Tata Elxsi's Electrification expertise for use case specific customizations."

www.renesas.com

Cooperation Agreement on Battery Technology

BMZ Group and Batemo GmbH are pleased to announce their cooperation, effective immediately. As a developer and manufacturer of accumulators for various industries and applications, BMZ installs more than 300 million round cells annually. Thus, the company has been working for a long time with the tools of the battery cell analysis specialist Batemo, which was founded in 2017. In a next step of the collaboration, the two companies are now entering into a cooperation. As part of this cooperation, Batemo will support BMZ in the distribution of its TerraE round cells. For its part, BMZ will complement its portfolio with comprehensive cell measurement data packages, detailed cell analysis reports and simulation solutions from Batemo. The measurement data, reports and simulation models that Batemo creates and sells are essential for the work of development departments in battery manufacturing. The information and simulations provided by Batemo accelerate the development work, as data is immediately available that would otherwise only be determined in costly and lengthy tests by the battery builders. The measurement data packages (Batemo Cell Data) provide extensive data series on various cell types under a wide range of loads and environmental conditions. For easy evaluation, Batemo provides a free comparison tool with which different cells can be quickly and easily compared with each other in terms

of their electrical-thermal behavior. Furthermore, Batemo offers cell analysis reports (Batemo Cell Report). These are based on tests performed in Batemo's laboratory. Batemo is able to provide customers with information on the internal cell structure, the safety features and the material components of the anode, cathode and separator.

www.bmz-group.com

SEMICON Southeast Asia 2022 Returns to Penang

Semiconductor supply chain sustainability and resilience will come into sharp focus 21-23 June 2022 as SEMICON Southeast Asia returns to the Setia SPICE Convention Centre & Arena in Penang, Malaysia following a two-year hiatus due to the pandemic.

"The rise of the cloud, 5G deployment, connected vehicles, and digitization have created unprecedented demand for high-performance computing," said Linda Tan, president of SEMI Southeast Asia. "As the backbone of the connected world, the semiconductor industry must maintain a sustainable balance of demand and supply to ensure the resiliency and flexibility of its supply chain.

SEMICON Southeast Asia 2022 will commemorate Malaysia's 50th Year of Manufacturing Excellence and celebrate Penang's reputation as the Silicon Valley of the East, built on decades of manufacturing excellence and industrial experience.

www.semiconsea.org

600V 110mOhm and 140mOhm Super Junction MOSFETs

Optimized for Low Profile Server Power, PV Micro Inverter, and Slim Adapters

Alpha and Omega Semiconductor announced the release of 600V 110mOhm and 140mOhm αMOS5™ Super Junction MOSFETs in DFN8x8 Package. αMOS5 is AOS's latest generation of high voltage MOSFET, designed to meet the high efficiency and high-density needs for Quick Charger, Adapter, PC Power, Server, Industrial Power, Telecom, and Hyperscale Datacenter applications.

AONV110A60 and AONV140A60 are two 600V low ohmic MOSFETs packaged in the 8mm x 8mm x 0.9mm DFN8x8 with Kelvin Source. Compared to other packages such as D2PAK, DPAK, or TO-220(F), DFN8x8 is a smaller package offering a well-balanced footprint and thermal dissipation. The 64mm² footprint makes AONV110A60 and AONV140A60 ideal for Active Bridge and high-density PFC/Flyback/LLC applications. In an internal benchmark the Active Bridge solution with AONV110A60 reduced the power loss by almost 50% (3.16W loss with Active Bridge vs. 6.12W loss with Diode Bridge) and increased the efficiency by 1.1%. The two DFN8x8 devices also find great fit in applications with only PFC and LLC stages, given 57% and 80% reduction in footprint and height, respectively, versus D2PAK.

Besides Server applications, AONV110A60 and AONV140A60 also target Solar Micro Inverter and Slim Adapter applications. Micro-Inverter design sees the trend of converting solar energy from two panels via one inverter, which means doubled power rating but not necessarily doubled the system size. DFN8x8 devices could help achieve this goal by paralleling and reducing effective Rdson, and accordingly, power losses. DFN8x8's Kelvin Source would be much favored in a high Fsw inverter design, where switching losses are more significant and need to be minimized. In slim adapter designs, DFN8x8 devices, together with high Fsw controllers and planar transformers, could easily push the system density to 20W+/in3 and efficiency up to 93%+ (with Active Bridges).

"Years ago, we could hardly imagine high voltage DFN8x8 devices widely adopted for server systems above 400W, even limited in low power SMPS, since people are used to through-hole or larger packages such as TO-220(F) or D2PAK. The power design concept has changed tremendously and rapidly with more and more DFN8x8 devices used in Active-Bridge, PFC, Half-Bridge, and Full-Bridge topologies. DFN8x8 devices' value proposition is clear, it is a high voltage SMD package that offers smaller form factor, better switching performance (Low Eon), higher system reliability (Low Gate Ringing), and easier board assembly. AOS will continue to provide our customers with differentiated solutions that best serve the application needs and mission profiles from low power universal charging to high power server, solar, and telecom rectifiers," said Richard Zhang, Director of High Voltage MOSFET Product Line at AOS.

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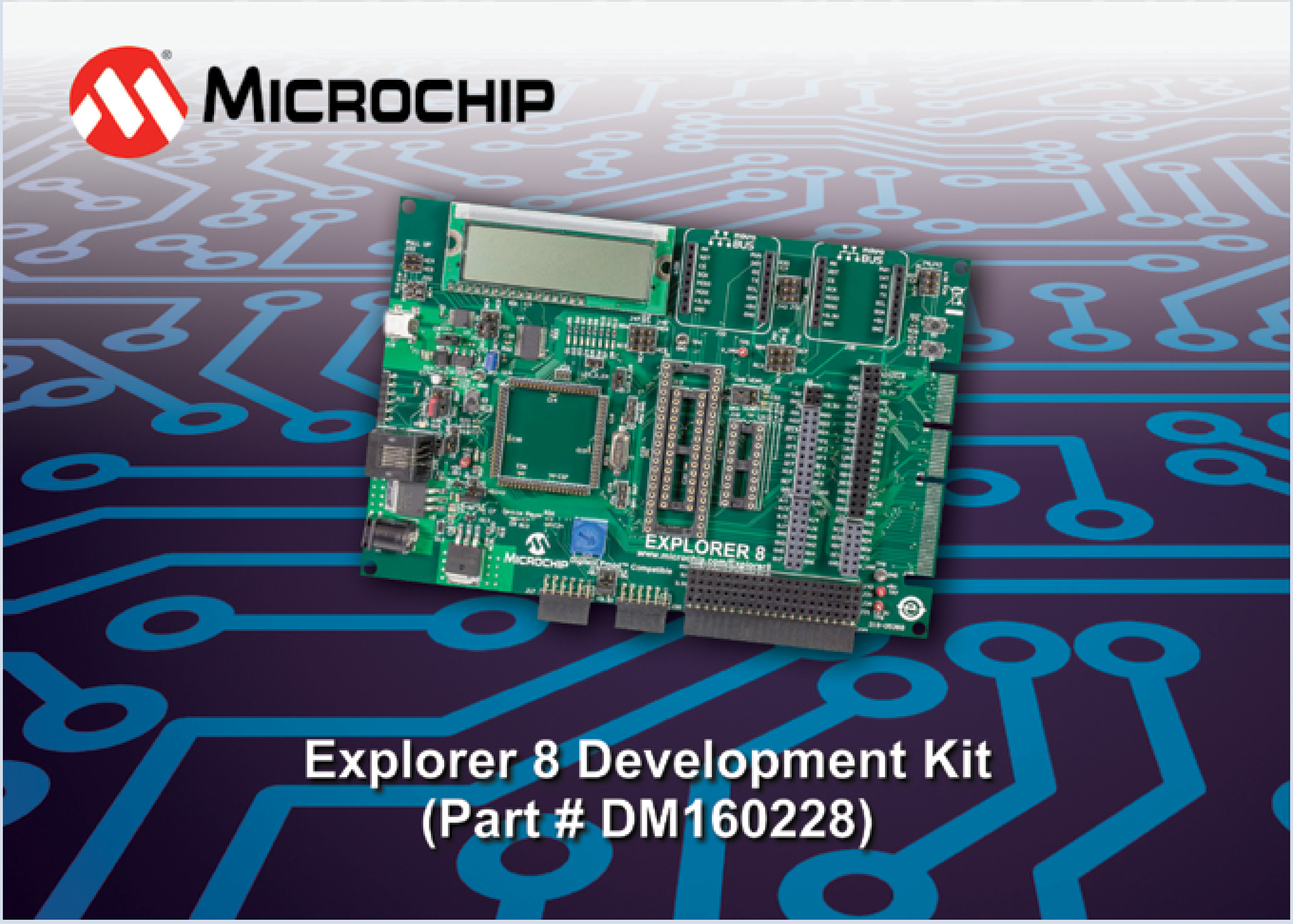

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- Sinter technology in 1700V for harsh wind applications

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GaN ePower Integrated Circuits Applied to Motor Drives

The latest ePower™ integrated circuits based on gallium nitride technology by Efficient Power Conversion are revolutionizing motor drive applications such as industrial drones, e-bikes, scooters, power tools.

By Marco Palma, Director of Motor Drive Systems and Applications at Efficient Power Conversion

Since its introduction, gallium nitride technology has opened a new era in the world of power electronics. The main differences between gallium nitride and silicon technologies are well described in [1] and are summarized in Table 1.

Parameter		Silicon	GaN
Band Gap E_g	eV	1.12	3.39
Critical Field E_{crit}	MV/cm	0.23	3.3
Electron Mobility μ_n	cm²/V·s	1400	1500

Table 1: Material properties of GaN and Si

The three most important parameters in this comparison are the higher bandgap, critical field, and electron mobility. The critical field, measured in volts per centimeter, determines the threshold for avalanche breakdown. The voltage at which a device breaks down is therefore proportional to the width of the drift region. In the case of GaN, the drift region can be 10 times smaller than in silicon for the same breakdown voltage. When these parameters are all combined, if the critical field of the crystal is 10 times higher, it follows that the electrical terminals can be 10 times closer together. This leads to a clear differentiation factor between GaN and silicon: medium voltage gallium nitride devices can be built on a planar technology while this is cost-prohibitive for silicon devices. To be competitive, silicon devices are made on a vertical technology, usually with gate and source on the top and drain on the bottom, making it physically impossible to have two power devices in the same chip. EPC's GaN-on-Si planar technology does not have this limit of having to be built vertically, and a schematic cross section of an integrated circuit that takes advantage of this is shown in Figure 1.

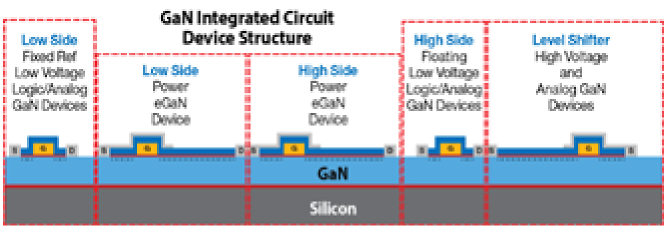

Figure 1: EPC gallium nitride technology enables integration of power devices with gate driver logic

Starting with discrete lateral eGaN® FET devices, EPC quickly moved to higher levels of integration. In 2014, EPC introduced a family of integrated devices comprised of multiple FETs on one chip, which became the starting point for the journey toward a power system-on-a-chip. This trend was expanded with the introduction of the EPC2107 and EPC2108, integrated half bridges with integrated synchronous bootstrap transistors.

In 2018, EPC continued on its integration path with the introduction of GaN ICs combining gate drivers with high-frequency GaN FETs in a single chip for improved efficiency, reduced size, and lower cost. In 2019, the ePower Stage IC family of products redefined power conversion by integrating all requisite power system-on-a-chip functions in a single GaN-on-Si integrated circuit at higher voltages and higher frequency levels - beyond the reach of silicon. Most recently, in 2021 the EPC23101 in combination with the EPC2302 power stage chipset was introduced to the market.

GaN Integrated Circuit Monolithic Power Stage – EPC2152

The first ePower Stage device was introduced in 2019. The EPC2152 is a monolithically integrated single-chip driver plus GaN FET half-bridge power stage IC. Input logic interface, level shifting, bootstrap charging, and gate drive buffer circuits, along with GaN output FETs configured as a half bridge, are integrated within a monolithic chip. This integration resulted in a chip-scale LGA form factor that measures only 3.85 mm x 2.59 mm x 0.63 mm. The two GaN output FETs in half-bridge topology are designed to have the same 8.5 mΩ typical $R_{DS(on)}$.

Integration of GaN FETs with on-chip gate drive buffers practically eliminates the effects of common source inductance and gate drive loop inductance. Power loop inductance is minimized by the LGA pinouts that facilitate the internal vertical layout technique. The block diagram of EPC2152 is shown in Figure 2 and the reference design, EPC9146 BLDC inverter functional block diagram is given in Figure 3.

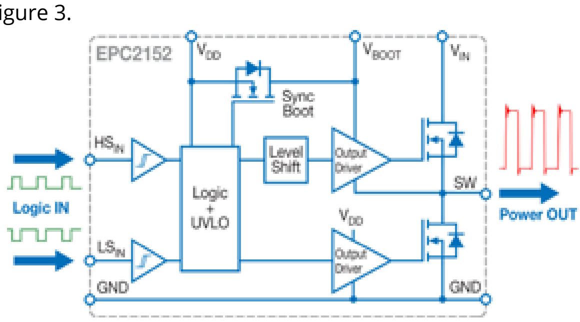

Figure 2: EPC2152 GaN integrated circuit block diagram

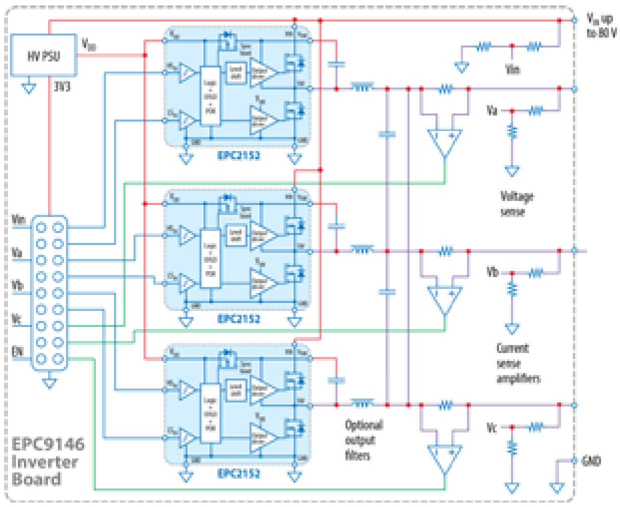

Figure 3: EPC9146 BLDC inverter functional block diagram


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EPC9146 motor drive reference design with EPC2152

To demonstrate the capabilities of the EPC2152 integrated circuit in a motor drive inverter, EPC released the EPC9146 reference design. It is a three-phase brushless (BLDC) motor drive inverter board that contains three EPC2152 monolithic ePower stages, 15 A_{pk} (10.5 A_{RMS}) maximum output current. Besides the monolithic power stage, the board contains all the necessary critical functions to support a complete motor drive inverter, including regulated auxiliary power rails for housekeeping supplies, voltage, and temperature sensing, phase current sensing, and protection functions. The various functional blocks of the EPC9146 are shown in Figure 3. This reference design can be used for all applications where the motor phase current is 10 A_{RMS} continuous with 15 A_{RMS} high current operation for a limited time.

GaN IC Power Stage Chipset – EPC23101 in combination with EPC2302

Following the path toward further integration and increased power density, in 2021 EPC introduced a chipset combining the EPC23101, a high-side GaN with a monolithically integrated Half-bridge gate driver, and the EPC2302 GaN FET, as depicted in Figure 4.

The EPC23101 is a 100 V rated monolithic component that integrates input logic interface, level shifting, bootstrap charging, and gate drive buffer circuits, along with a high-side, 2.6 mΩ typical $R_{DS(on)}$ GaN output FET. The EPC2302 is the 100 V companion low-side, 1.4 mΩ typical $R_{DS(on)}$ GaN FET. Over-voltage spikes can be controlled to less than +10 V above the rail and –10 V below ground during hard switching transitions by choosing the tuning resistors, R_{BOOT} and R_{DRV}.

The EPC23101 IC requires only an external 5 V (V_{DRV}) power supply. Internal low-side and high-side power supplies, V_{DD} and V_{BOOT}, are generated from the external supply via a series-connected switch and a synchronous bootstrap switch. The internal circuits can be disabled to reduce quiescent power consumption by connecting the EN pin to V_{DRV}. The FET gate drive voltages are derived from the internal low side and high side power supplies. Full gate drive voltages are only available after the HS_{IN} and LS_{IN} PWM inputs operate for a few cycles. Compared to the EPC2152, the EPC23101 in combination with the EPC2302 allows designers to make higher current inverters.

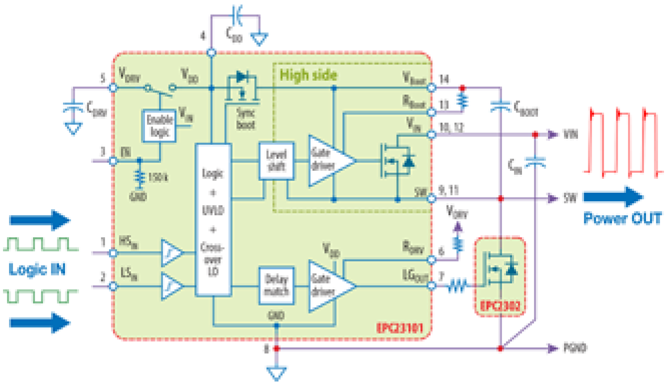

Figure 4: EPC23101 in combination with EPC2302 GaN IC chipset block diagram

EPC9173 motor drive reference design with EPC23101

To demonstrate the capabilities of the EPC23101 IC in a motor drive inverter, EPC released the EPC9173 reference design. On this board, each half bridge of the three-phase inverter comprises two EPC23101 ICs with their PWM signals cross-connected allowing the insertion of a source shunt to read the current, and shown in Figure 5, with a portion of the schematic.

By using the same IC for the low-side switch, it is possible to have a balanced half-bridge inverter and both switches can float with respect to the Power Ground. This makes the insertion of the source shunt easier, avoiding ground bouncing on the input PWM signal nodes. The EPC9173 board includes an over-current detection circuit that can be used either as an over-current or as a current-limit function, depending on the desired algorithm and modulation.

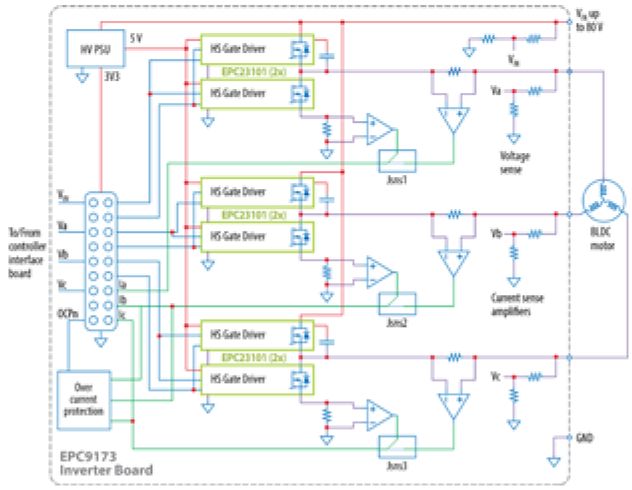

Figure 5: EPC9173 BLDC inverter functional block diagram

Applications

PWM frequency increase and dead time reduction

GaN integrated circuits and FETs bring several advantages in motor drive applications. The easiest advantage to understand is the reduction of inverter size, which is due to an intrinsic smaller dimension of a GaN FET and ICs versus the equivalent MOSFET. However, to get the most out of the new technology, it is better to operate a motor at a higher PWM frequency and to consequently reduce the dead time [2].

Conventional silicon MOSFET inverters are constrained by high switching losses and by the commutation behavior, and usually are not operated above 40 kHz PWM frequency and with dead time lower than 200 ns. GaN-based inverters are not limited in this sense and can increase the efficiency of the motor because of lower ohmic dissipation due to reduced current ripple (Figure 6, [4]) and fewer torque harmonics that are responsible for motor vibrations [2].

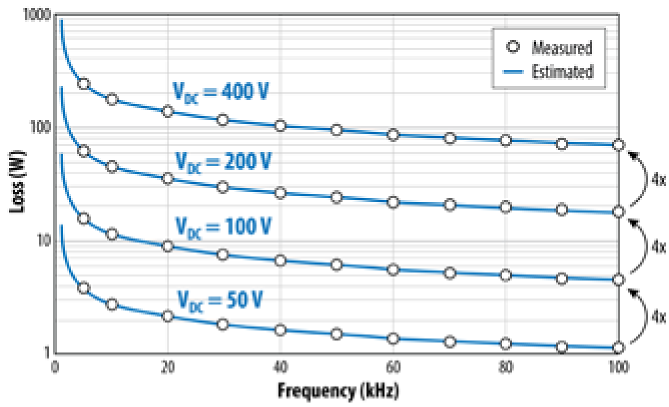

Figure 6: Comparison between measured and estimated PWM-induced losses in a motor with 50% duty cycle square wave voltage excitation [4]

Moreover, increasing switching frequency helps to reduce the input filter and to remove the need for electrolytic capacitors. A comparison between two inverters, one running at 20 kHz, 500 ns dead time, and the other, based on GaN, running at 100 kHz, 14 ns dead time is shown in Table 2. The GaN inverter has no input inductor and uses only two ceramic capacitors. Both inverters were operating in the same setup in the same conditions, and the motor is more efficient because many energy wasting harmonics were removed in the GaN inverter case.

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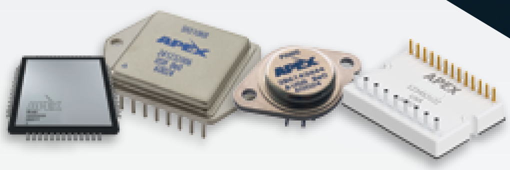

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Applications with low L/R time constant in the motor

All applications that require high electrical frequency and fast dynamics, such as drone propellers and e-bike in-pedal motors, use very low inductance (single-digit ΩH range) motors. With the advent of more efficient magnetic circuit designs realized by better materials and higher strength permanent magnets, the number of turns on an electromagnetic phase can be reduced and still produce the same back-emf.

Setup	Inverter 20 kHz, 500 ns dead time 400 RPM, 5 A_{RMS}	GaN inverter 100 kHz, 14 ns dead time 400 RPM, 5 A_{RMS}
Input inductance	2.7 µH	None
Input capacitor	660 µF electrolytic	44 µF ceramic
Pin	121.3 W	113.3 W
Pout	119.6 W	111.3 W
$\eta_{inverter}$	98.50%	98.20%
Speed	42.25 rad/s	41.94 rad/s
Torque	1.876 Nm	1.940 Nm
Pmech	79.3 W	**81.36 W**
η_{motor}	66.30%	73.10%
η total efficiency	65.30%	**71.80%**

Table 2: Comparison between 20 kHz, 500 ns inverter and 100 kHz, 14 ns GaN inverter with reduced input filter [2]

Permanent magnet brushless motors generate back-emf voltage, e, proportional to speed, ω $(e = K_e \cdot \omega)$, and the maximum speed a given motor can run is directly related to the DC bus voltage and the voltage constant, Ke. To increase the speed, it is necessary to lower K_e, by reducing the phase coil turns count, which reduces the inductance by the square of the difference. Limiting the current ripple to less than 10% of the phase current is a good design practice and can be only achieved by increasing the PWM frequency.

The current rise with time is related to the ratio of voltage to inductance, and as inductance decreases, the current rises quicker, as does the PWM induced current ripple. The decreased current rise time and larger ripple increases the amount of heat generated and creates additional EMI noise, which is not desirable. In general, these motors have a small time-constant, $\tau = \frac{L}{R}$, that can benefit from a 100 kHz PWM frequency.

Input current and voltage ripple

The input voltage ripple Δv_{in} in an inverter is proportional to the output phase current and inversely proportional to the PWM frequency and input capacitance, as per eq. (1)

$$\Delta v_{in} \propto \frac{1}{f_{PWM}} \frac{I_{phase}}{C_{in}} \quad (1)$$

The desired ripple depends on the EMI constraint given by the emissions generated by the cables from the dc source to the inverter. If the PWM frequency is in the range of 20 kHz, the required input capacitance Cin can only be practically obtained by using electrolytic capacitors that are bulky and less reliable than ceramic capacitors. Moreover, the electrolytic capacitors are limited by the RMS current that can flow through them, thus requiring more capacitors in parallel and resulting in a total input capacitance that is higher by more than one order of magnitude than needed for a design. When the frequency is increased to 100 kHz, designers can use ceramic capacitors such as X7R, keeping in mind, as a design rule, the effective capacitance drops to half of the specified value when the applied voltage is half of the rated voltage. The EPC9173 reference design provides for both electrolytic and ceramic capacitors, giving chance for designers to select their preferred switching frequency and to add or remove the capacitors as preferred.

Power tools with trapezoidal modulation

Many power tools applications are still using trapezoidal modulation schemes and related inverter schematics. Usually, these applications are based on three hall sensors to detect the rotor position with a resolution of 60 electrical degrees, and they have a single shunt to measure the current in the DC bus return. The six-step operation has many advantages for BLDC drives, such as maximum power utilization and widened flux-weakening region. However, due to the maximum utilization of inverter output, a saturation of the current regulator makes it difficult to maintain instantaneous current control capability. In most conventional systems it is implemented by voltage angle control with cycle-by-cycle current limit, with unsatisfactory dynamic performance. If the current limit is reached during the PWM cycle, the energizing device (depending on the current direction) is switched off until the next PWM cycle.

The principle of the BLDC motor is to energize the phase pair, which can produce the highest torque. To optimize this effect the back-emf shape is designed to be trapezoidal, but, in reality, it is sinusoidal with some higher harmonics. The combination of a DC current with a trapezoidal back-emf makes it theoretically possible to produce a constant torque. In practice, the current cannot be established instantaneously in a motor phase. As a consequence, the torque ripple is present at each 60-degree phase commutation.

With the current-limiting cycle-by-cycle scheme and low inductance motors, the lower the PWM frequency, the higher the current ripple. This in turn generates heat and unnecessary power dissipation. Using a GaN inverter, with the same trapezoidal scheme, makes it possible to increase the PWM frequency and then reduce the current ripple, obtaining higher efficiency, less heat, and fewer vibrations.

The GaN motor drive reference designs EPC9173 and EPC9167 are equipped with a current comparator circuit whose output can be used by the microcontroller as a signal for cycle-by-cycle current limiting to follow a trapezoidal modulation. With this system, power tools designers can test the reference designs to assess the GaN advantage in their application.

Conclusions

When dealing with motor applications, GaN inverters can increase the efficiency of the system if PWM frequency is increased, the dead time is drastically reduced, and the input capacitance is converted from electrolytic capacitors to ceramic capacitors. Using EPC's new GaN integrated circuits, such as the EPC2152 and EPC23101, results in increased power density and system efficiency, while saving much system design effort.

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Simple Approach to Increase Output Power for Renewables and Motor Drives

The SEMITRANS 20 meets the increasing power demands of converters for renewable and high power motor drive applications, requiring higher power density and scalability.

The output power for converters has steadily increased with time, with the newest wind turbines now capable of producing up to 15MW. Such increases in power present new challenges for developers focused on renewables and drives, achieved by increasing voltage, current or both.

By Bernhard Eichler, Emiliano Meza, SEMIKRON Elektronik GmbH & Co. KG

The SEMITRANS 20 enables a higher current capability than previous generation power modules with the latest packaging and chip technology. It is also optimized for parallel operation in order to further increase the converter current capability. Additionally, the SEMITRANS 20 enables simple implementation of 3-level topologies, which is a key to increasing the operation voltage.

Increase Current at Module Level

For high power applications, power modules connect multiple IGBT and diode chips in parallel to increase overall current rating. In doing so, however, the power module design must ensure even current sharing among the chips in parallel. An unequal current distribution would lead to some chips heating more than others, ultimately reducing lifetime. The SEMITRANS 20 package eliminates this concern by enforcing even current sharing through its symmetric Direct Bonded Copper (DBC) layout.

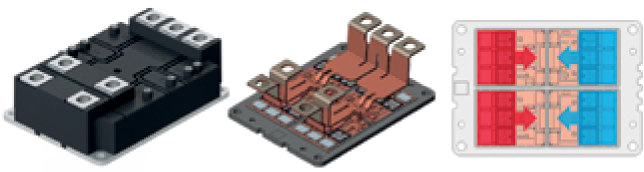


Figure 1: Symmetric chip layout of SEMITRANS 20 Power Module

As shown on the right in Figure 1, each IGBT and diode in the SEMITRANS 20 is connected to the DBC with symmetric paths to the terminals. This symmetric layout ensures even current sharing among the chips for each switch, which becomes especially important at increased switching speeds. Its homogenous stray inductance makes the SEMITRANS 20 an ideal candidate for Silicon Carbide in the future.

For switching frequencies below the 10kHz range, the new M7 IGBTs maximize space utilisation by increasing the current in a given chip area. The SEMITRANS 20 further optimises its footprint on the heatsink by utilizing over 70% of its baseplate for active chip area, while previous power module designs only used about 55%. This increases current and thus power density, but thermal resistance must then be carefully considered in order to keep the chips cool, enabling safe operation and increased life.

The higher current per square millimetre creates a new challenge: cooling the chips in a limited area, which requires a reduction in thermal resistance. To resolve this, SEMIKRON offers the new High Performance Phase Change Material (HP-PCM), which is a thermal interface material that achieves a thermal resistance similar to that of our benchmark thermal paste High Performance Thermal Paste (HPTP). Phase change material eases manufacturing, since it is solid at room temperature and less sensitive to debris, which can be easily brushed away. Since phase change material is challenging to apply, SEMIKRON also offers power modules with pre-applied HP-PCM. The phase change material is applied in a controlled, dust free environment with optimal printing patterns for each housing. This in combination with a 4-screw mounting approach reduces overall assembly cost and effort.

Increased Converter Current at System Level

Once a target output power is higher than a single module can handle, paralleling is required. While driving each power module with individual drivers is possible, this increases cost and decreases the calculated Mean Time Between Failure rate (MTBF). That is as numerous driver components are incorporated and the MTBF decreases with each component added to the system. Therefore, a single driver for multiple modules in parallel reduces cost and increases reliability. Driving multiple power modules with only one gate driver comes with certain requirements: not only does the gate driver need sufficient output power; sharing the driving power evenly between the power modules is also important.

With its symmetric layout and low stray inductance of only 10nH, the SEMITRANS 20 allows even current sharing among the modules with a single driver, as shown for a short circuit event in figure 2. In combination with the SKYPER 42 LJ PV, the SEMITRANS 20 offers scalability for high power applications up to 1500V_{DC}. With its increased output current, a single SKYPER 42 LJ PV provides sufficient power to drive up to five SEMITRANS 20 modules in parallel switching at 2.5 kHz. This allows for water-cooled power blocks of up to 3.5MW output power. The driver core design provides flexibility to adjust the number of power modules in parallel while maintaining high reliability as a qualified SEMIKRON product. For 3-level topologies, it also offer users the capability to customize the turn-off sequence in order to implement a safe shutdown in case of a short circuit condition.

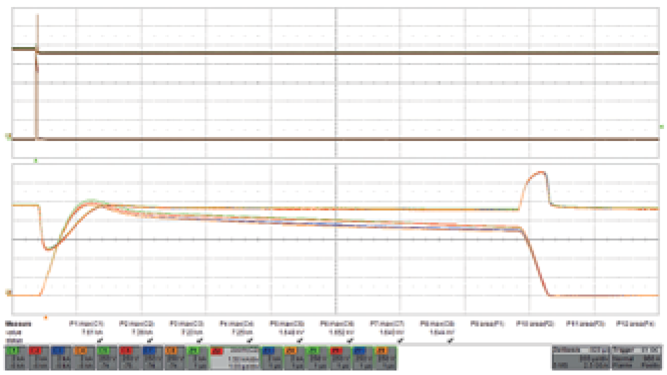


Figure 2: Short circuit of four paralleled SEMITRANS 20 modules with max current of 10 000A

3-Level Topology for Increased Voltage and Power

Since increasing the system current requires more costly cables with higher cross-sections, increasing the voltage should also be considered. Presently, the low voltage directive for renewables allows operation up to $1500V_{DC}$. Implementing a 3-level topology enables converters to achieve these high voltages while still using standard 1200V devices. Additionally, filter effort is reduced thanks to a doubling in the effective switching frequency at the inverter output for 3-level designs.

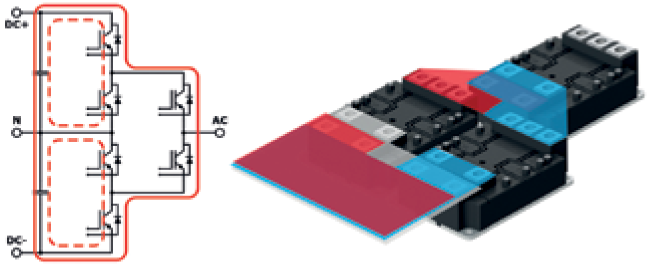


Figure 3: Compact, low inductance layout for ANPC topology

For bi-directional power flow, the Active Neutral Point Clamp (ANPC) topology has gained popularity as it provides consistent losses throughout the power factor range. This allows energy storage to push and pull the same amount of power to and from the grid. For high power systems, this ANPC configuration can be made using standard half-bridge modules.

In the High Frequency / Low Frequency (HF/LF) configuration the DC input side is switched at the PWM switching frequency (e.g. 3kHz) while the AC output side is switched at the grid frequency, typically 50/60Hz. In this configuration, the commutation loop for the fast switching input side is kept short within a single power module, shown with dotted lines in Figure 3. The connection between input and output stages switches at the grid frequency, allowing slow switching for the longer commutation loop (solid line in Figure 3).

Thanks to its terminal locations, the SEMITRANS 20 offers a simple solution for any ANPC power electronic stack, as shown in Figure 3 (right). This enables a simple three-layer DC link design and smooth connections among all three modules per phase. Additionally, all driver connection locations are accessible, even after connecting the DC link and busbars.

Sintering for Increased Reliability for Harsh Applications

In addition to ever-increasing power, the rotor side of wind converters often operates at a low fundamental frequency, especially for Doubly Fed Induction Generators (DFIG) or in generators without gearboxes, such as Direct Drive (DD) wind turbines. This lower frequency can stress power modules by subjecting them to very high load cycles. For the highest reliability in wind, the chips in 1700V SEMITRANS 20 power modules are attached to the substrate via sintering, shown in Figure 4.

Introduced by SEMIKRON in 2007, silver sintering offers a substantially higher melting temperature compared to a conventional solder connection between chip and substrate: 962°C for sintering and around 250°C for solder. The sinter connection is created under high pressure and temperature, resulting in a strong, non-porous connection. With an maximum chip operation temperature of 175°C the sinter connection offers a higher margin to the melting temperature. This enables the SEMITRANS 20 to extend power-cycling capability by a factor of three compared to standard soldered modules.

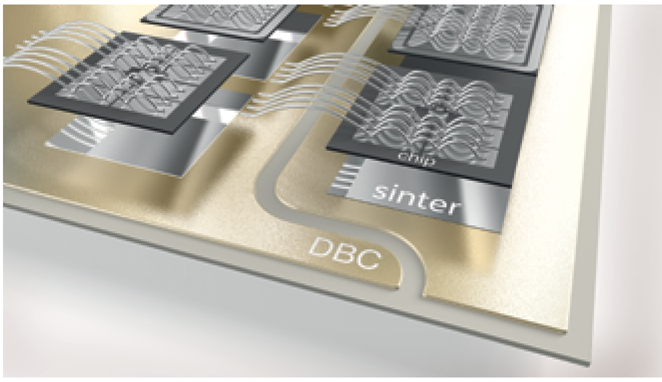


Figure 4: Sinter Technology for chip die attach

Conclusion

With its high current capability and scalability, the SEMITRANS 20 enables increased power for renewables and high power drives. The symmetric package design in combination with the latest IGBTs enable higher current density. To cool such a power dense package, the new High Performance Phase Change Material offers reduced thermal resistance from power module to heatsink. The SEMITRANS 20 is also simple to implement into an HF/LF ANPC configuration, great for bi-directional, $1500V_{DC}$ applications such as wind and energy storage. For wind application using 1700V devices, sinter technology increases the SEMITRANS 20 power cycling threefold compared to standard solder technology to increase lifetime. This makes the SEMITRANS 20 the perfect package for the next generation of high power renewables and motor drives.

www.semikron.com

Are Hybrid Transducers the Future for Power Converters with SiC MOSFETs?

Markets are expected to open up for sensors capable of delivering response times as low as 100ns and unprecedented cut-off frequencies above 1MHz

Much of what many operators in the industrial world are looking to achieve in terms of sustainability and productivity gains revolves around having the most efficient power converters. Suitable for working in the harshest of environments, including in a wide range of temperatures, the power converter of the future will need to be high-power yet lightweight, quiet and capable of high-frequency operation. Low power consumption will be essential.

By Bastien Musy - VP of Global Product Management, LEM

The high-frequency requirement and the need to be as compact as possible mean that power converters must incorporate smaller passive components if benefits of reduced size and weight are to be realised. The trend to move away from pure silicon and increasingly make use of high-frequency silicon carbide (SiC) MOSFETs in high-voltage pulsed-power circuits has made it possible to cut space requirements, reduce costs, boost efficiency and enhance performance.

Because of their faster switching capabilities, SiC-based devices are able to operate at bandwidth frequencies that are greater than 100kHz. This has led to them being used in such applications as uninterruptible power supplies (UPSs), solar inverters, AC variable speed and servo motor drives, power factor correction (PFC) and computer-controlled welding machines.

However, there has always been a trade-off between performance and response time and users in these various market sectors have been struggling for a solution that can satisfy their increasingly demanding requirements. While classic open loop transducers and closed loop versions are capable of frequency responses as high as 300kHz, in today's market these are still not sufficient for the high bandwidth sensing needs that have been driven by the adoption of SiC insulated-gate bipolar transistors (IGBTs).

Bandwidth above 1MHz

LEM, the market leader in providing innovative and high quality solutions for measuring electrical parameters, was approached by a customer in the welding sector, for whom existing response times and frequency responses on their power converters were proving to be inadequate. It was against this backdrop that LEM developed a hybrid transducer that more than trebled the performance levels of anything else on the market.

The hybrid is a mix of ASIC (application specific integrated circuit) and DC-based transducer with a pure inductive coil to speed up the signal. Thanks to the pick-up coil on LEM's ASIC, the transducer is capable of reacting like a current transformer. While existing AC transducers based on a pure coil can achieve higher levels, there is no DC transducer featuring open loop technology and a pick-up coil that can perform at bandwidths above 1MHz – until now.

The LEM solution – the HOB family of around 20 low power consuming multi-range current sensors capable of measuring DC, AC or pulsed current up to 250A – was developed to meet high bandwidth sensing targets when using fast-switching SiC MOSFETs in high-voltage pulsed-power circuits where rapid and flexible high-voltage pulses are essential. The customer specifically wanted a top performance solution that delivered rapid response reaction times and expanded bandwidth, all in a smaller footprint.

Totally different semiconductor technology

While a closed loop sensor would ordinarily represent a high-cost option for any sector wanting to achieve these goals, LEM expects its hybrid transducer to become rapidly attractive to a range of markets that are looking to adopt any kind of switch-mode converters based on SiC and GaN (Gallium Nitride) wide band gap (WBG) power modules. The growing trend to switch-mode converters is being driven by the need for devices and equipment to be as small as possible and to achieve superior power/weight ratios.

Thanks to what LEM calls “a totally different semiconductor technology”, SiC or GaN very high-speed transistors not only ensure faster switching times but also offer higher frequency capabilities and higher voltage withstanding. The company expects that this transistor technology will become the norm in just five years.

Far more important than bandwidth frequency in the HOB family, however, is response time – the time between the primary current and the output on the transducer. This was a key factor for LEM’s customer who was aware that transistors that are switching faster and faster must have a current transducer able to follow the di/dt (the rate of change of current) as closely as possible.

Response rate as little as 100ns

Traditionally, while the di/dt could be as high as 500A per microsecond (possibly even 1kA/us) with this technology, the response time on other transducers was around 1.5 microseconds. For its customer, LEM was committed to providing a guaranteed response rate as fast as 200 nanoseconds. Not only was this target met but it was exceeded, with the new HOB and its pick-up coil offering 150ns response time (10 times faster than anything else on the market). In some instances, the response rate was as little as 100ns.

The models within the HOB family offer nominal currents of 50A, 75A, 100A and 130A, with currents at maximum power (Ipm) of 2.5 times those figures. The special (SP) models in the range are custom-designed to meet individual user specifications but all of them have a cut-off frequency (at -3dB) of above 1MHz. The standard HOB family of transducers has a 5V power supply (with voltage reference of 2.5) but other models have power supplies of 3.3V, 3.4V and 3.5V. All are capable of operating in temperatures from -40°C to +105°C.

Among the other features that put the HOB sensor ahead of its competitors include galvanic separation between the primary and secondary circuit, an integrated busbar and an innovative design that enables space-saving THT (through hole technology) PCB mounting.

The future for hybrid technology

With a footprint the same as previous transducers on the market, the hybrid transducer is based on technology that LEM has provided successfully in the past for the automotive sector. However, thanks to its improved compactness and superior performance levels, LEM expects the technology to spread out into other domains as transistor production costs come down, automation increases and volumes rise.

The future for this new hybrid technology is expected to be assured when the market grows for very low cost, excellent performance, high response time applications. Some of the extremely demanding applications that are perfect for LEM’s new HOB unit include hand-held plasma cutters, welders and DC-DC converters, as well as the previously mentioned UPS market, switched mode power supplies, AC variable speed and servo motor drives, and static converters for DC motor drives.

Already, LEM is receiving requests from customers for a PCB-mounted transducer offering nominal currents of 300A, 600A and more. While it is difficult to work out exactly how quickly demand will move, LEM has put itself in a position where it is now ready to provide a large number of markets with an open loop multi-range current sensor that combines unprecedented response times and frequency bandwidth with reliability, low power consumption, low noise and enhanced immunity to the dv/dt (acceleration) issues that SiC power modules can be prone to.

www.lem.com

Future-Proof Power Module Package for High-Power Applications

While the XHP 2 power module package from Infineon Technologies AG is designed for use in today's applications, it also meets the requirements of future-oriented applications. The package supports the outstanding performance of the 1.7 kV IGBT5 with its .XT joining technology, which is suitable for a continuous operating temperature of 175°C and for the demanding module characteristics of future generations of SiC MOSFETs.

By Wilhelm Rusche, Waleri Brekel, Alexander Höhn, and Wolfgang Bücker, Infineon Technologies

Multiple requirements shaped the XHP 2 design

Different applications require different module requirements. In line with this, Infineon's XHP 2 module package addresses voltage classes from 1.7 kV to 3.3 kV for different platforms [1]. For some applications, however, there are certain design challenges that need to be addressed. These include the large creepage distances for high-voltage classes, and the closely spaced DC terminals for fast-switching SiC MOSFETs required to obtain a symmetrical and low-parasitic commutation inductance.

In figure 1a, the arrangement of the DC(+) and DC(-) terminals are depicted. The DC terminals are arranged in two rows to build a strip line bus bar with a resulting low module inductance of Ls<10 nH. This low module inductance enables a very low inductive commutation loop for the design of the application. Without compromising this design, the terminal has been designed to provide the required creepage distance for the 3.3 kV voltage class. With respect to clean switching behavior [2], the switching technologies in all voltage classes will benefit from the low-inductive design, and also simplify the hardware designer's job.

For the control board, the auxiliary connections are spaced at a suitable distance from the sides at the center of the module to allow the proper creepage distances on the printed circuit board (PCB). Furthermore, if the modules are connected in parallel per phase and mounted side by side, the aux terminals for the top and bottom system are aligned in corresponding row that equivalent control terminals can be simplified connected from one module to the next.

As depicted in figure 1b, the height of the control terminals enables a double-sided PCB to be mounted on top of the module, offering an additional degree of freedom for the PCB designer.

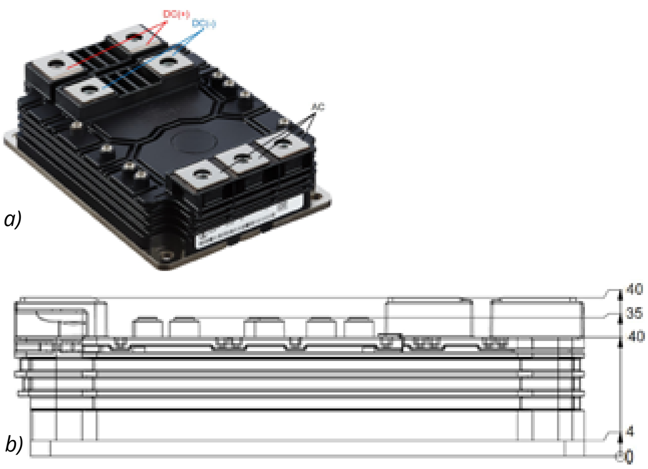


Figure 1:
a) Typical appearance of XHP 2
b) Aux terminal height

Thermal aspects of module's main terminals

For power modules with the IGBT5/.XT generation of silicon (Si) chips, the targeted current capability is at least I_{nom}=1800 A. In conjunction with the high current capability, the package have to be able to withstand the established operation temperature of this IGBT5/.XT, which is $T_{vj,max}$=175°C. This temperature target should also be considered for extreme situations with low-voltage applications, when the package must transfer high currents, such as in low-voltage ride-through (LVRT) grid faults of a wind turbine at the same time. Due to these challenges, the temperature and the current capability of the terminals are key.

As the ohmic loss is proportional to the square of the current, heat dissipation is an important issue for both the module and the laminated DC busbar in the application assembly. The design of Infineon's XHP 2 power terminal respects this application-relevant interface. In addition to the DC terminals, the RMS current in the AC terminals also needs to be considered. Which, in relation to the DC current, is higher by a factor of √2. Because of this relation three single AC terminals combined with a superior thickness for high-current capability are provided.

With an expectation of increasing phase-leg current with new chip generations, the Pout,terminal behaves disproportionately. Thus, for higher output current densities, it is essential to dissipate terminal-generated losses to the environment at the system level.

DC terminal IR measurements

Besides the simulations carried out in the development phase when creating the mechanical design, the terminal temperature under load was measured and verified by infrared (IR) tests on the hardware. The DC connections, which are typically contacted with sealed laminated busbars, offer few opportunities to dissipate the power loss by natural convection. For this investigation, an open,

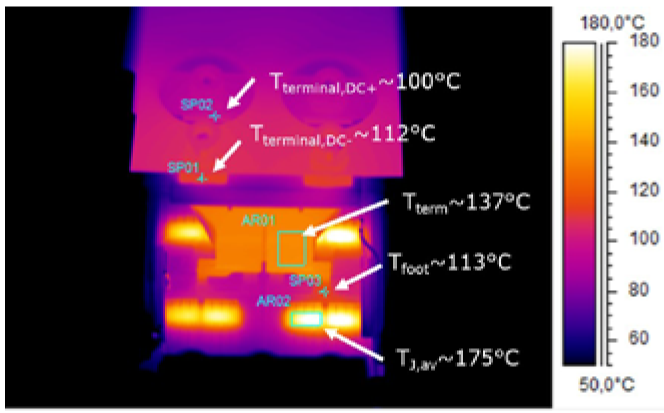
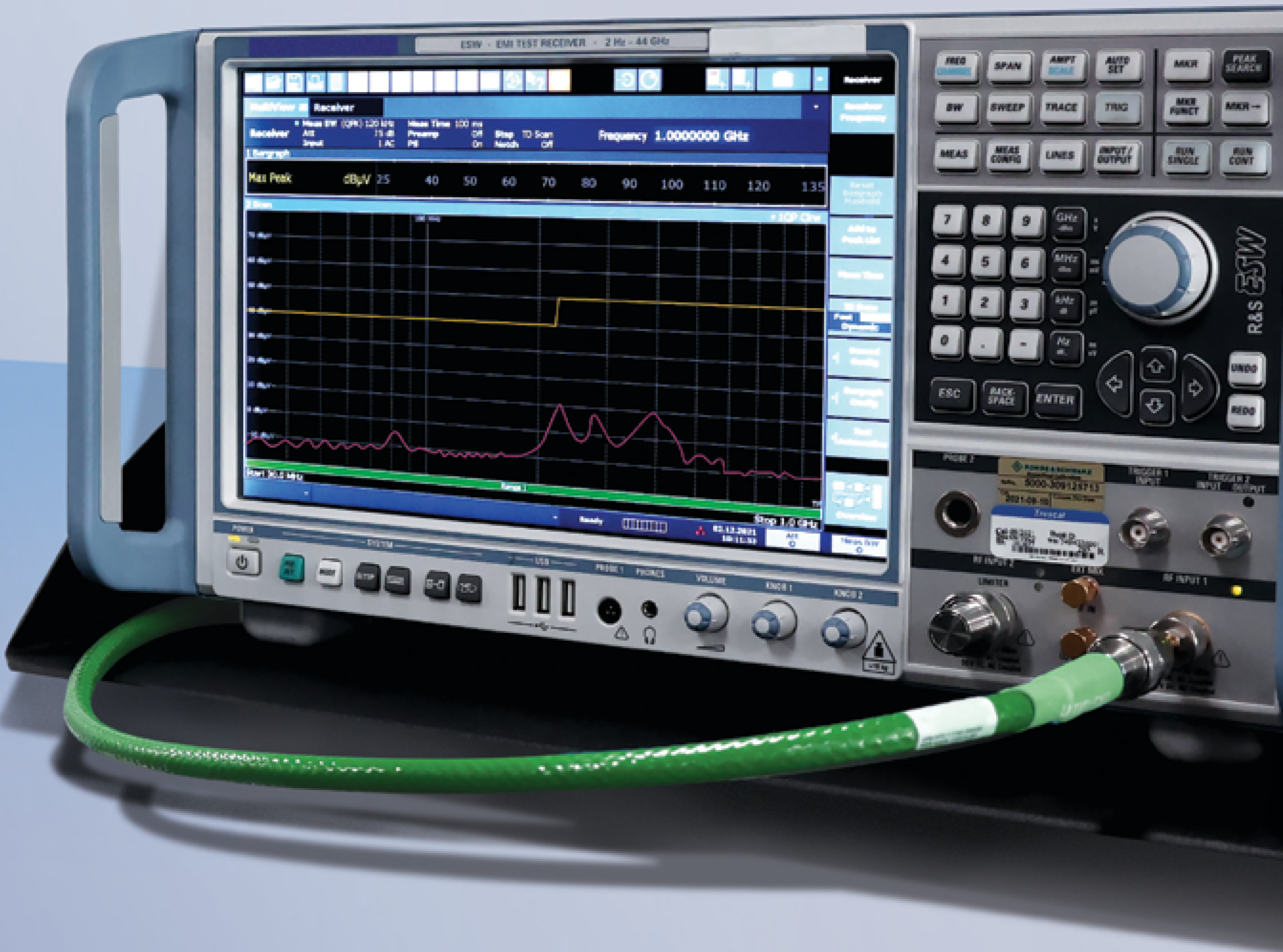


Figure 2: Infrared measurement and temperature of an open, black-coated module; DC terminals under DC-load condition I_{DC}=876 A show a temperature at screw position of $T_{terminal,DC(+/-)}$~110°C

EMI. Simplified.



EMI mitigation can be one of the trickiest tasks in power supply design. With their high level of integration and an internally-optimized layout, DC/DC power modules from Texas Instruments can help streamline the emissions compliance process and help get you to market faster, with fewer headaches.

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black-coated XHP 2 module, with a mounted DC-link busbar on the DC terminals, was tested under high continuous load conditions.

Figure 2 depicts the infrared test results of the DC terminals. A high DC current of IDC=876 A, ~50 percent of I_{nom} is equivalent to a phase-leg current of around Iphase,leg=1238 A. The current flows from the DC(-) terminal to the low side diode then to the high side diode and back through the DC(+) terminal. This current is heating up all diodes in the module to 175°C. The module is mounted on a liquid-cooling plate, and the resulting case temperature is measured at T_C~120°C. The temperature under such harsh conditions in the connection area (at the screws) between the module DC terminal and the DC busbar is below 125°C. Based on these results, no critical values could be detected on the DC terminals of the power module, which confirms the high-current and high-temperature capability of Infineon's XHP 2 design.

Dynamic switching characteristics

The module circuit for a single module is made in a half-bridge configuration. In figure 3, the circuit diagram and the top view of the module with electrical connections are depicted. Besides the required gate-emitter control terminals, additional aux-main-emitters, connectors 8 and 12 marked in red are provided. These additional terminals enable the option for the usage of the voltage drop of the leakage inductance, if a more sophisticated gate-control design is required [3].

Figure 4 illustrates the IGBT turn-on, turn-off and diode recovery at T_{vj}=175°C and 25°C of an FF1800XTR17T2P5 power module with IGBT5/.XT under the nominal conditions of U_{DC}=900 V, $I_{C\ nom}$=1800 A from a double-pulse test.

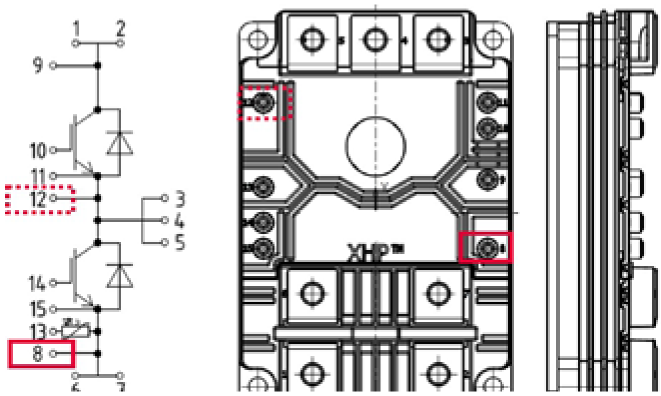

Figure 3: Circuit diagram of the XHP 2 power module

In figure 4a, examples from the turn-off tests show, with a total stray inductance of LS~30 nH for the setup, the overvoltage shoot at ΔUCE~300 V is low, which demonstrates another advantage of the low-inductive mechanical design. All other switching events shown in the turn-on in figure 4b, and the diode commutation behavior in figure 4c show smooth waveforms and characteristics without snap-off or oscillation effects.

The mechanical design of the power terminals DC(+) and DC(-), as shown in figure 1, is optimized for the paralleling of modules. As shown in the example in figure 5, the IGBT turn-on switching behavior of two hard, parallel-connected modules is presented. The current sharing of the devices is very similar. There is no current mismatch affected by the DC busbar design described in [4], [5].

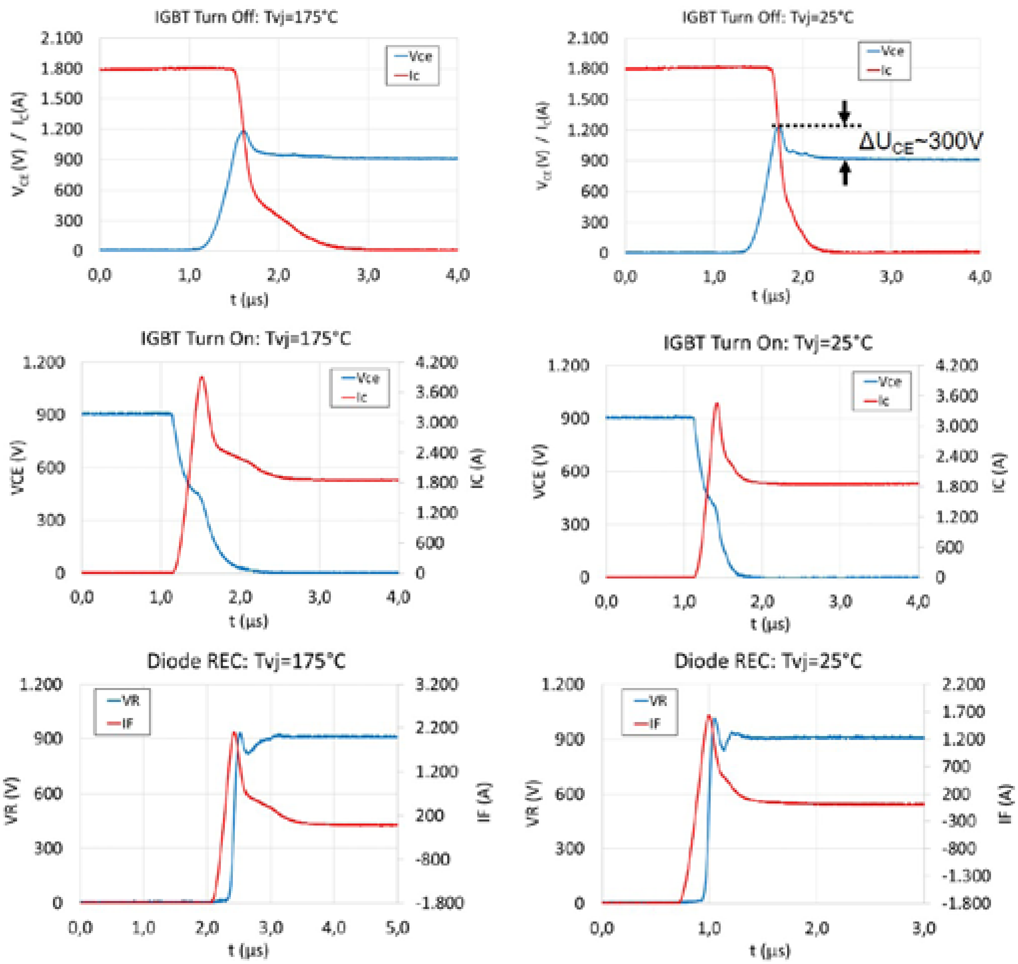

Figure 4: IGBT a) turn-on, b) turn-off and c) diode recovery at nominal conditions of an FF1800XTR17T2P5 at T_{vj}=175°C and 25°C power module

Summary of application-oriented module design
Infineon's XHP 2 power module design strictly adheres to the requirements of a low-inductance and symmetrical design and has served as a template for this housing class. The module equipped with the 1.7 kV IGBT5/.XT will be serving light rail applications, on and off-shore wind turbine applications, and any other demanding application where reliability and robustness are system relevant.

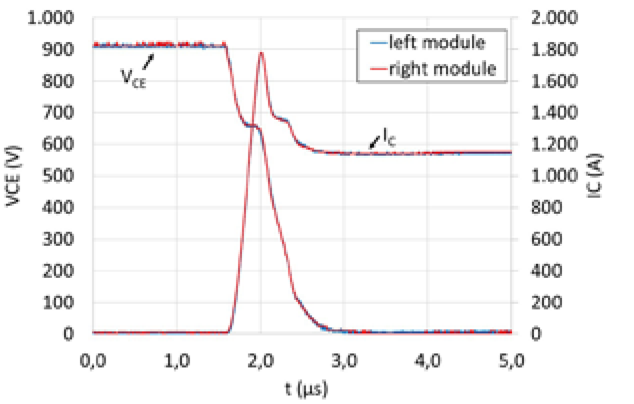

Figure 5: IGBT turn-on of two modules in parallel. Blue represents the left module, and red the right module.

According to the principle "form follows function," the creepage distances of the housing correspond to the 3.3 kV voltage classes. These distances have been implemented without compromising the low-inductance and symmetrical design, which enables the use of advanced SiC MOSFET components on the same platform.

The power loss of the terminal is a key application-design issue and the design of the module has thus optimized terminal losses accordingly.

Based on these features, the Infineon XHP 2 can indeed be called an application-oriented, multi-package housing designed for the next generation of high-power applications.

With Infineon´s XHP 2, the journey into the future can start now!

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3 Benefits of Using a Low-Iq Buck/Boost Converter to Extend Battery Life in Flow Meters

Lithium thionyl chloride (LiSOCl2) batteries are popular in smart flow meters because they provide higher energy density and a better cost-per-wattage ratio than battery chemistries such as lithium manganese dioxide (LiMnO2). One disadvantage of LiSOCl2 batteries is poor response to peak loads, which can result in a decrease of the usable battery capacity.

By By Wenhao Wu, Applications engineer, boost converter and controller solutions, Texas Instruments

So in this article, we'll describe an effective method to decouple peak loads from the battery, in the range of a few hundred milliamperes, that can help increase battery life.

Maximizing the usable battery capacity is important because it enables the system design to support:

- More meter readings and data transmissions from the same battery.
- A longer lifetime from the same battery.
- A smaller battery for the same operating lifetime.

The overall effect minimizes battery and maintenance costs, as well as development costs, by enabling more reuse of a single flow meter design across more kinds of flow meters

The design challenge: extend the battery life

A successful meter design needs to sustain a long operational time (>15 years) while enabling functionalities such as valve control, data recording and data transmission. Extending battery life is an effective way to increase meter operational time. If you connect the battery to the load directly without any power buffer in between, however, the meter's complex load profile may deteriorate the battery's lifetime performance.

Based on the current level, you can divide the load consumption profile of a standard meter into standby mode, middle-stage mode and active mode. Each mode influences battery life differently:

- Standby mode consumes 5 µA to 100 µA. It is mainly quiescent current (IQ) from metrology, microcontroller and protection circuitry. Although the absolute value is very small, it is typically the main contributor to meter lifetimes. In standby mode, the IQ of any connected DC/DC converter should be in the nanoampere range, with the leakage of any power buffer small in order to improve efficiency.
- Middle-stage mode consumes 2 mA to 10 mA. The analog front end in RX stage usually contributes to this load. The power buffer's efficiency is important to minimize energy loss in this mode.
- Active mode consumes the highest current. In active mode, the load usually comes from the driving valve and analog front end in TX stage, which needs 20 mA to several hundred milliamperes. Directly drawing this current from a LiSOCl2 battery causes severe capacity derating.

Table 1 demonstrates the Saft LS33600 battery's capacity derating vs. nominal capacity of 17 Ah at different load and temperature conditions. At an operating temperature of +20°C, a 200-mA load current leads to a 42% capacity degradation. Therefore, the battery should never directly supply the load. Only by employing a low-leakage power buffer can you limit the peak current to less than 10 mA.

Capacity (Ah)	**–40°C**	**–20°C**	**+20°C**
10 mA	–41.2%	–17.6%	No derating
100 mA	–82.35%	–58.8%	–23.5%
200 mA	N/A	N/A	–42.0%

Table 1: Characteristics of capacity vs. current for the LS33600 from Saft Batteries

TI's 60-nA IQ buck/boost converter, the TPS61094, helps extend battery life while maintaining excellent efficiency over standby, middle-stage and active modes. The TPS61094 has three main benefits:

- **Ultra-high efficiency in a wide load range.** The TPS61094 has >90% average efficiency for loads from 5 µA to 250 mA under conditions of VOUT = 3.3 V and VIN >1.5 V. This enables an efficient power supply in most flow-meter use cases.

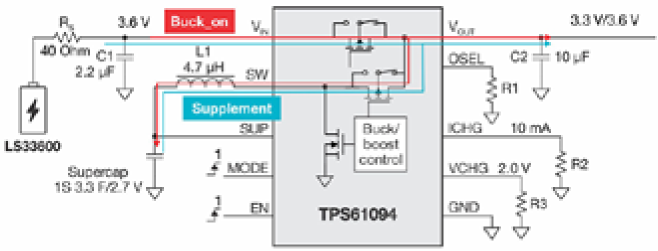

Figure 1: Configuration of the TPS61094

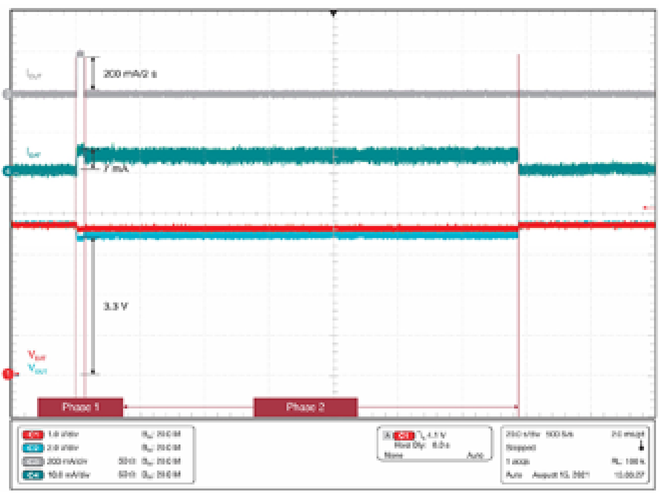

Figure 2: Oscilloscope result of battery peak current at heavy load

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Hitachi Energy

- **Limits the peak current drawn from the battery.** The TPS61094 can limit its peak input current when it is working in Buck_on mode when charging the supercapacitor, and also in supplement mode when it is supplying a heavy load on VOUT with the battery. Figure 1 illustrates the configuration of the TPS61094, while Figure 2 shows the battery's peak current when there is a 200-mA and 2-s load pulse on VOUT. In phase 1, where the load is heavy, the peak current is limited to 7 mA. After the load is released in phase 2, the device is charging the supercapacitor with a 10-mA constant current. When the supercapacitor voltage charges back to 2.0 V, the device stops charging but still stays in Buck_on mode.
- **Unchanged available energy from the supercapacitor over the temperature range.** Typically, using hybrid-layer capacitors (HLCs) or electric double-layer capacitors (EDLCs) as power buffers will improve pulse-load capability. The energy stored in these passive components depends on the battery voltage, however. When the temperature decreases, the battery voltage also goes down, which deteriorates the HLC or EDLC's pulse-load capability and increases the battery's supply current. The TPS61094 eliminates this issue by keeping the voltage on the supercapacitor stable, regardless of temperature.

The usable energy in the supercapacitor is defined by the capacity of the supercapacitor, the set maximum voltage across the supercapacitor and the undervoltage lockout of the TPS61094. The more usable energy that a supercapacitor has, the longer the operating time with a continuous, heavy load.

Figure 3 shows a power-buffer solution using the TPS61094 or only supercapacitors, respectively. For the TPS61094 solution, the supercapacitor voltage is set to 2 V. By supplying a continuous load, the TPS61094 can draw power from the supercapacitor until 0.6 V. Therefore, it is possible to calculate the available energy on the supercapacitor with Equation 1:

$$E = \left(\frac{1}{2}CV_1^2 - \frac{1}{2}CV_2^2\right) \times \eta$$

where η is average efficiency of the converter.

In the worst case of –40°C, the TPS61094 has an average efficiency of 92% at 150 mA for an input voltage from 2 V to 0.6 V. Equation 2 shows the calculated result:

$$E = \left(\frac{1}{2} \times 3.3 \times 2^2 - \frac{1}{2} \times 3.3 \times 0.6^2\right) \times 0.9232 = 5.5447\,\mathrm{J}$$

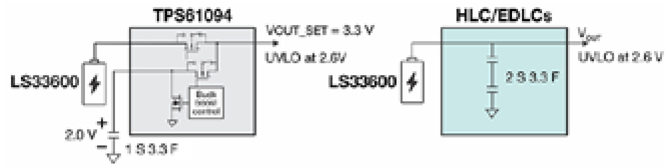

Figure 3: TPS61094 vs. HLC/EDLC configuration

For HLC or EDLC solutions, the available energy changes following the battery voltage. For a 10-mA current at –40°C, the LS33600 voltage reduces to 3 V. Equation 3 calculates the available energy:

$$E = \frac{1}{2} \times 1.65 \times 3^2 - \frac{1}{2} \times 1.65 \times 2.6^2 = 1.848\,\mathrm{J}$$

Comparing results between Equations 2 and 3, the TPS61094 solution has double the available energy of the HLC and EDLC solutions. This means more energy can be delivered to loads, and lowers the peak current drawn from the battery under extreme conditions. For example, if there is a 200-mA load at 3.3 V to drive a valve, an HLC or EDLC solution can only support the load for 2.8 s. The TPS61094 buck/boost converter with an integrated supercapacitor can support the load for as long as 7.8 s, assuming that the power buffer supplies all of the load.

Conclusion

The complex load-consumption profile of flow meters requires a power buffer to help extend LiSOCl2 battery life. With excellent efficiency over wide operating conditions, the TPS61094 is a good choice to remove lifetime extension challenges. By limiting the peak current drawn from the battery, this buck/boost converter maximizes its capacity and raises the supercapacitor's available energy, enabling the system to operate longer in low-temperature conditions than an HLC or EDLC solution.

Additional resources

- Check out the TPS61094 data sheet.
- Read the application note, "The Long-lifetime, cost-competitive solution in smart meters based on TPS61094."
- Read the Analog Design Journal article, "IQ: What It Is, What It Isn't, and How to Use It."
- Read the article, "5 best practices to extend battery life in flow meters"

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GaN - Assuring Price, Volume and Security of Supply

(Performance and Reliability are Expected)

Gallium nitride is still regarded as a new technology by many. Although GaN is now widely used in chargers and adapters for mobile phones delivering efficiency and power density benefits, other sectors, such as automotive, LED drivers, renewable energy, consumer audio and phone handsets, are only just realising that GaN's superior switching performance is suitable for their applications too.

By Denis Marcon, General Manager Sales and Marketing Europe and USA, Innoscience

Of course there are early adopters, but before the market switches en-masse, they need to be confident that commercial factors as well as engineering concerns have been considered too. Innoscience, the largest 8-inch GaN-on-Si device manufacturer, is addressing these concerns with proven technology, rugged, qualified processes and massive capacity.

Innoscience was founded in December 2015 with the aim of creating the world's largest manufacturing company fully focused on 8in GaN-on-Si technology. From the very beginning, Innoscience executives understood that for GaN technology to become ubiquitous in many markets, performance and reliability - although vital - were only the starting point. Before GaN could become widely adopted, customers would have three additional key demands. First, GaN technology devices must be affordable, as the industry is not willing to pay a big premium. Second, a large manufacturing capacity is necessary in order to deliver large volumes and absorb fluctuations in demand. Thirdly, customers require security of supply, allowing them develop their products and systems using the new GaN devices without worrying about possible production discontinuations and shortages.

Remember that the emergence of GaN has coincided with one of the most brutal periods of global chip shortages ever experienced by the electronics industry.

Therefore, Innoscience understood that only by focusing on 8in GaN-on-Si technology, dramatically scaling-up GaN-on-Si device manufacturing and controlling its own production fabs, would it be possible to meet the requirements of the electronic industry (price, volume and security of supply).

Innovative technology

But just as performance and reliability must always be proven before any other concerns, let's first look at the technology, which Innoscience has developed together with its trusted international partners.

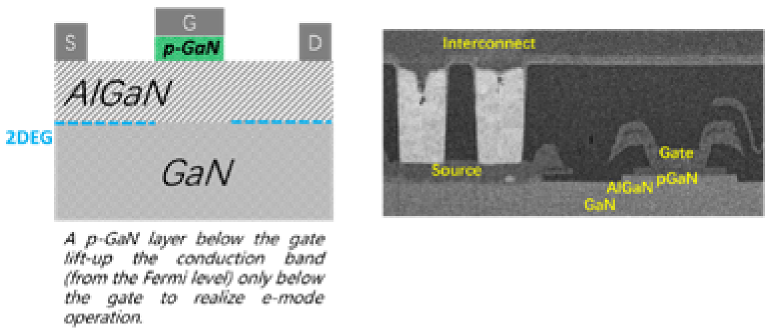

Figure 1: A p-GaN layer, grown on top of the AlGaN barrier, forms a Schottky contact with the p-GaN layer resulting in normally-off/e-mode operation.

Power semiconductor engineers demand devices that show a normally-off operation - i.e. no current conduction when the transistor's gate is set at 0V. Since the natural form of GaN HEMTs (High Electron Mobility Transistors) is normally-on (so-called depletion mode), special drivers must be placed in a cascode package solutions to realize normally-off operation. However, Innoscience's GaN HEMTs are intrinsically normally-off (enhancement mode) devices. Normally-off operation is realized by growing a p-GaN layer on top of the AlGaN barrier, forming a Schottky contact with the p-GaN layer (Figure 1). This increases the potential in the channel at the equilibrium, resulting in normally-off/e-mode operation.

Low specific $R_{DS(on)}$

A key parameter for defining device performance is the specific $R_{DS(on)}$, the on-resistance per unit area. The lower the specific $R_{DS(on)}$, the smaller a device can be made, enabling more devices per wafer and lower device cost.

Innoscience has developed a proprietary strain enhancement layer technology, which consists of the deposition of a specific layer after the gate stack definition. The stress modulation created by the strain enhancement layer induces additional piezoelectric polarizations which causes the 2DEG density to increase reducing the sheet resistance by 66%. Since the strain enhancement layer is deposited after the gate formation, it only affects the resistance in the access region and it does not impact other device parameters such as threshold and leakage etc.

Therefore, Innoscience's GaN-on-Si e-mode HEMTs show very low specific on-resistance. Because Innoscience has optimized both epitaxy as well as device process technology, the (dynamic) $R_{DS(on)}$ does not increase over the full temperature and voltage range, suiting it for power switching applications.

High throughput, high yield

Silicon technology has been in mass production for 50 years. Silicon device manufactures supported by the tool makers, have optimized their process in terms of throughput and quality in order to utilize every available mm silicon wafer area, and to produce as many wafers as possible. Innoscience is leveraging all this experience and expertise. The company is committed to 8in wafer processing, and its two fabs are equipped with the latest equipment, including ASML scanners. Process flows are similarly optimised. Because Innoscience is a fully-integrated company, controlling all manufacturing stages from device design, through EPI and wafer processing to failure & reliability analysis - i.e. full GaN-on-Si production - the company achieves both high wafer and device yield. It also means that new products can be designed and in test within 3 -6 months and be ready for mass production within just 6 months.

Today, Innoscience produces more than 10,000 8in GaN-on-Si wafers every month; this will increase to 70,000 wafers per month by 2025. The first Innoscience fab is already qualified to ISO9001 and the IATF 16949:2016 certification for automotive use, and the GaN HEMTs are qualified to the JEDEC standard as well as Innoscience performs more advance reliability tests to test their devices

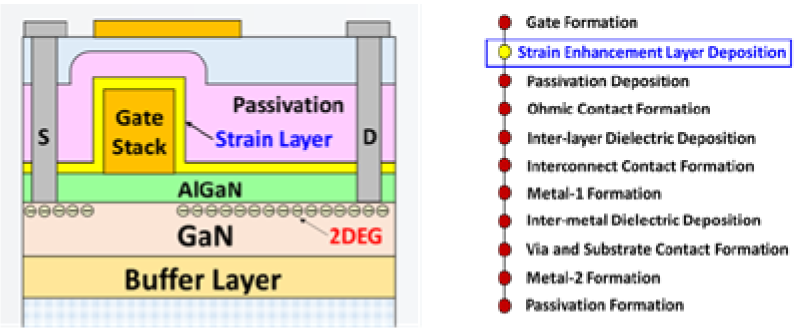

Figure 2: Innoscience has developed a strain enhancement layer technology resulting in low $R_{DS(on)}$.

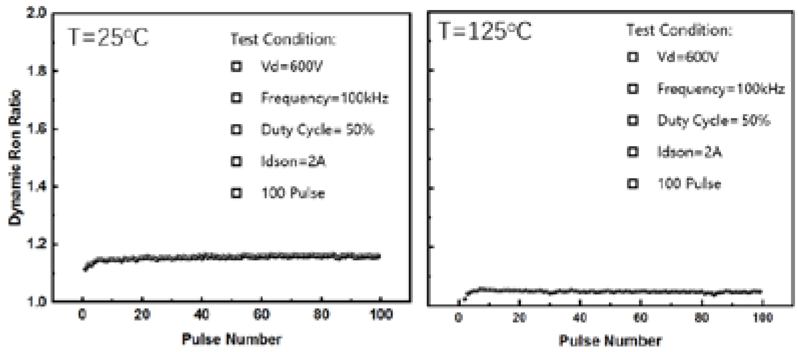

Figure 3: Innoscience's GaN devices show no appreciable drift in $R_{DS(on)}$ over the full temperature and voltage range.

Product mix

Uniquely for a GaN company, Innoscience offers devices that cover low (30-150V) and high voltage (650V) range. Innoscience's GaN HEMTs (InnoGaN) are available from 30-150V in chip scale packages (csp) measuring 2x2mm to 2.2x3.2mm with $R_{DS(on)}$ down as low as 5.5mΩ (typ). 650V parts in DFN and wafer scale feature $R_{DS(on)}$ levels as low as 106mΩ (typ). Innoscience GaN HEMTs are being used in USB-PD chargers up to 120W, and in LLC converters. They are to be found inside data centre power supply racks. In the near future, they will be found inside automotive applications including LiDAR systems, on-board chargers (OBC), 48-12V DC/DC step down converters and high voltage 650/900V DC/DC converters. Innoscience InnoGaN parts outperform traditional silicon FETs in LED lighting. Astonishingly, Innoscience's 40V bidirectional part is the first time in the world that GaN HEMTs can be used inside a smartphone, reducing the size of the over-voltage protection (OVP) unit inside the battery management system (BMS) by at least 50%.

Conclusion

By combining world-class technology, state-of-the-art processing technology and the world's largest 8in GaN-on-Si capacity, Innoscience is answering both engineering and commercial challenges, enabling designers working in all market sectors to benefit for the proven performance benefits with no cost penalty.

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Floating Measurements with Fast Common Modes and Isolated Probes

Current modern power electronics systems rely on stacked topologies which inevitably leads to the need to measure signals that ride on fast common mode transients. Fiber Isolated probes allow the measurement of such signals but still some pitfalls do exist.

By Enrique Ojeda, Founder, Saker Medium Voltage

Introduction

Traditionally engineers have faced the need to measure ground referenced signals. The principles to increase signal integrity are well known, such as keeping connections short and avoiding areas in between conductors in which magnetic flux can create distortion.

However the real challenge comes when common modes are present and actually the measurement becomes more difficult as the common mode transient is faster. Probes meant to be floated have a finite CMRR and the common mode voltage will always show up at the output interfering with the differential measurement. Fiber isolated probes currently offer the best CMRR but still not everything depends on the probe and the measurement setup makes a great difference. All measurements seen in this article are taken with the ISOVP fiber isolated probe from Saker.

Fast pulse with no common mode

First a square step with a rise-time of 4.5ns and no common mode present is measured with wires 4cm in length before connecting the coaxial cable that connects to the ISOVP probe. The measurement is done at the 50Ohm termination. Figure 1 shows the setup and the measured signal. Even though the measurement setup is less than perfect in that we are using 4cm wires to measure this fast signal the measure is still faithful enough and distortion is not huge a problem.

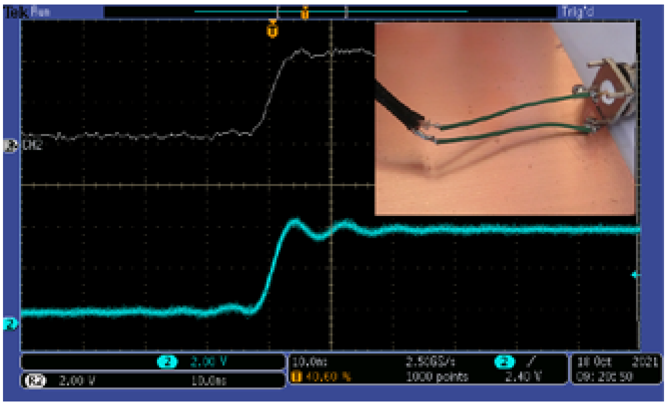

Figure 1: Pulse measured with wires 4cm in length, no common mode. Some ringing in CH2 is seen compared to the original undistorted pulse (upper trace).

Measurements of signals in fast common modes

In this case we use a small battery oscillator (based on a LTC6907) that is connected to the drain of a Mosfet which provides the common mode voltage change necessary for the measurements. This oscillator board has an SMB output but we will solder the cables directly to the this board for this test. The differential measurement is the output of the oscillator, a 2V level signal which is not in sync with the switching of the Mosfet. First we measure this signal using the same 4cm long wires are before. Figure 2 shows the schematic and the falling drain voltage (200V in 7ns) together with the oscillator output. The scope is set in persistence mode so that multiple sweeps can be observed. There is a huge distortion seen at the CH2 at the moment of switching in CH1, so what is happening? The fiber isolated probe is supposed to eliminate the contribution of the common mode voltage isn't it?

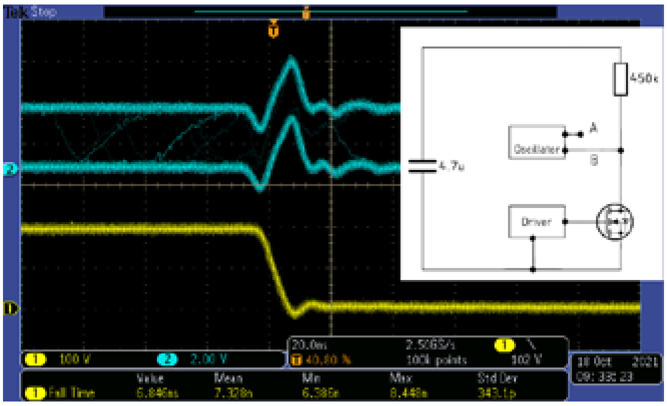

Figure 2: Oscillator riding on top of mosfet drain. CH1 is the 200V 7ns common mode and CH2 is the measured oscillator output with 4cm long cables.

The same measurement with wires 1cm in length instead of 4cm brings some improvement but still the distortion is too large. So finally we can make use of the output SMB connector in the oscillator and make a direct connection from oscillator to probe. This gives the lowest distortion possible as seen in Figure 3. Again the scope is set to persistence mode so that multiple switchings can be observed. This result closely matches the CMRR of the optical probe: a 200V 7ns has a fundamental frequency at 50MHz and the CMRR at this frequency is around 67dB. 200V with a 67dB attenuation results in 90mV.

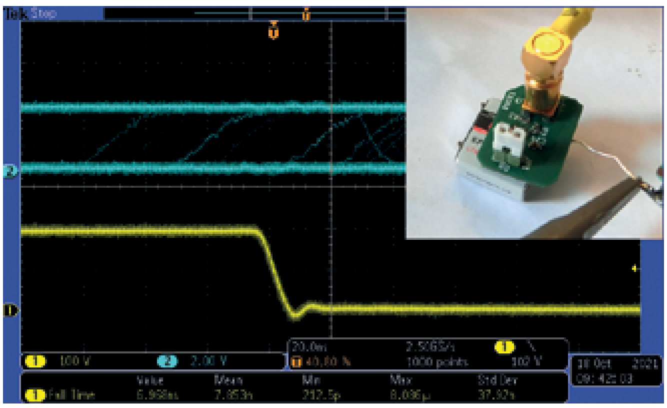

Figure 3: Oscillator connected to probe with SMB connector. CH2 shows negligible to no distortion.

Practical example

A fast measurement is made with a Infineon GaN evaluation board on the high side driver (model EVAL_1EDF_G1B_HB_GAN). The board uses a pair of EiceDRIVER (1EDF5673K) gate drivers for the GaN transistors (IGOT60R070D1). A resistive load is used to increase switching speed of the common mode on purpose. The measurement result follows what should be expected. The spikes at the switching transitions are not due to CMRR limitation of the probe, but due to the divider created by Crss and Ciss in the high side transistor. Note that a coaxial connection is what makes this fast measurement free from ringing and more accurate.

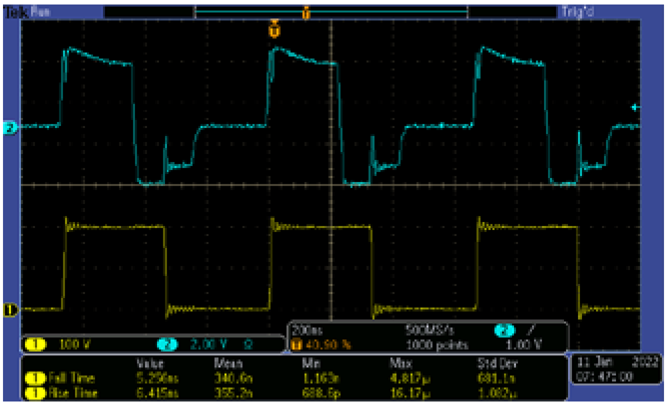

Figure 4: High side gate measurement of a GaN driver switching at 1.5MHz. Oscilloscope set to averaging mode to reduce noise.

Simulation

So what is happening? Clearly the introduction of common modes influences the distortion in a much greater way than differential signal transition speed. Simulation brings some light into the problem. The critical parameters are the source impedance, the parasitic capacitance to ground of the center conductor and the length of this conductor as it increases its series inductance. The source resistance together with the cable self-inductance and parasitic capacitances form a resonant circuit that is fed with the common mode voltage swing. The higher the values of any of them the worst will be the distortion of the measurement. The source resistance is normally given by the device under test (DUT) in question and the cable inductance is dependent on the length of the cable used which can only be so short. So in practice the best way to reduce the output distortion is to eliminate the parasitic capacitance present by using a coaxial cable all the way into the DUT.

Figure 5: ISOVP connected to the Infineon GaN eval board. Note the direct coaxial connection.

Conclusion

Fiber isolated probes allow the accurate measurement of signals riding in fast common modes due to their improved CMRR compared to differential probes. However some additional precautions need to be taken in the measurement setup, otherwise the CMRR will be ruined. The center conductor in the coaxial input of the probe needs to be protected from external electric fields, and thus it is important to minimize the length of the center conductor in a coaxial cable exposed without shielding.

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SiC Devices Used in PFC for EV Charger Applications

This article analyzes the technological trends of the DC electric vehicle (EV) charger. It introduces the current status of silicon carbide (SiC) devices and their advantages, as well as the SiC technology development at Infineon. A three-phase, Vienna rectifier solution for unidirectional chargers, a two-level, three phase, active front-end topology, and a full-SiC device solution for bi-directional chargers are introduced.

By By Ming Zhou and Andrea Piccioni, Infineon Technologies

DC EV charger development

With continuing pressure on governments to reduce carbon emissions, electric vehicles are receiving more and more attention. However, when deciding which vehicle to select, consumers have to consider such factors as lack of infrastructure and long recharging times.

AC charging piles are suitable for recharging EVs at home or at the working place, as the power rating of current on-board chargers usually ranges up to 11 kW, which takes 8~10 hours to recharge to full battery status. However, for longer trips, such as vacations, consumers expect faster recharging during breaks.

Direct current (DC) EV chargers, with the conversion from AC to DC, and isolated DC to DC, have a higher power rating than AC charging piles. The power rating of DC EV charger sub-units using discrete devices is currently 11 kW-22 kW, but will increase in the near future to the 30 to 50 kW range.

Several DC EV charger sub-units in parallel could boost the power rating of DC charging piles from 120 kW up to 360 kW. With this kind of DC charging pile, consumers can recharge batteries to 80 percent of the battery capacity in less than half an hour. Owing to the benefits of quick recharging and the rapid development of EVs, the DC EV charger market has experienced an extraordinary growth in recent years. In the meantime, this market is meeting technical challenges in terms of reliability, efficiency, and power density. The next generation of power semiconductor SiC devices will be beneficial in meeting these challenges and development targets. In this paper, we introduce the SiC devices used in PFC for DC EV charger applications.

SiC at Infineon

Wide-bandgap materials and devices have been developed rapidly in recent years. With low switching losses, SiC devices, enable customers to increase the switching frequency. Thus, SiC products are widely used in DC EV chargers, solar inverters, uninterrupted power supply (UPS) and switched mode power supply (SMPS) applications.

Infineon has over 20 years of field experience with silicon carbide, using a trench structure, shown in figure 1, which facilitates performance without violating the gate oxide in on-state and off-state conditions. To demonstrate the gate-oxide reliability of trench structures, Infineon has done reliability evaluations for gate-oxide, resulting in the findings illustrated in figure 2. Besides the above-mentioned advantages, Infineon CoolSiC™ MOSFETs also have a higher threshold voltage, short-circuit capability, and wide controllable dV/dt. Infineon has expertise in the area of drift of gate threshold voltage ($V_{GS(th)}$) for SiC MOSFETs under long-term operation. It provides design guidelines to limit the related increase of on-state resistance ($R_{DS(on)}$) as the major impact for the user in the application. These advantages make Infineon CoolSiC MOSFETs easy to use [1][2][3][4][5][6].

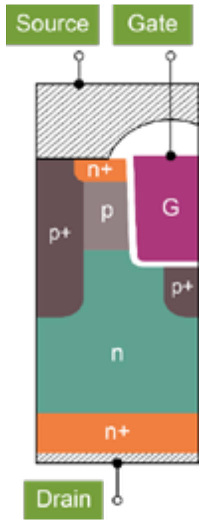

Figure 1: Sketch of the Infineon CoolSiC MOSFET cell structure

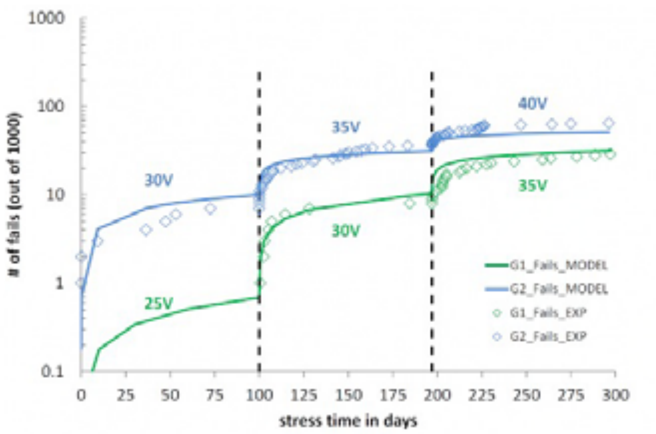

Figure 2: V_{GS} overstress test

PFC for DC EV charger applications

Unidirectional DC EV chargers usually use a Vienna PFC topology and DC-DC part with LLC resonant converter and a full-bridge rectifier topology, which is shown in figure 3. There is another common DC-DC topology, the phase-shift full bridge (PSFB), which has a different topology and control method. The PFC part in the DC EV charger can use Infineon products, such as 1200 V Si or SiC diodes for D1~D6, CoolMOS™ MOSFET and TRENCHSTOP™ IGBT5 for SW1~SW6. The LLC DC-DC primary side can use the CFD series CoolMOS MOSFET, and the secondary side can use 650 V Rapid Si diodes or 650 V Infineon CoolSiC diodes. Due to the wide output DC voltage range, usually from 200~1000 VDC, relays are used to connect full-bridge rectifiers either in series or parallel.

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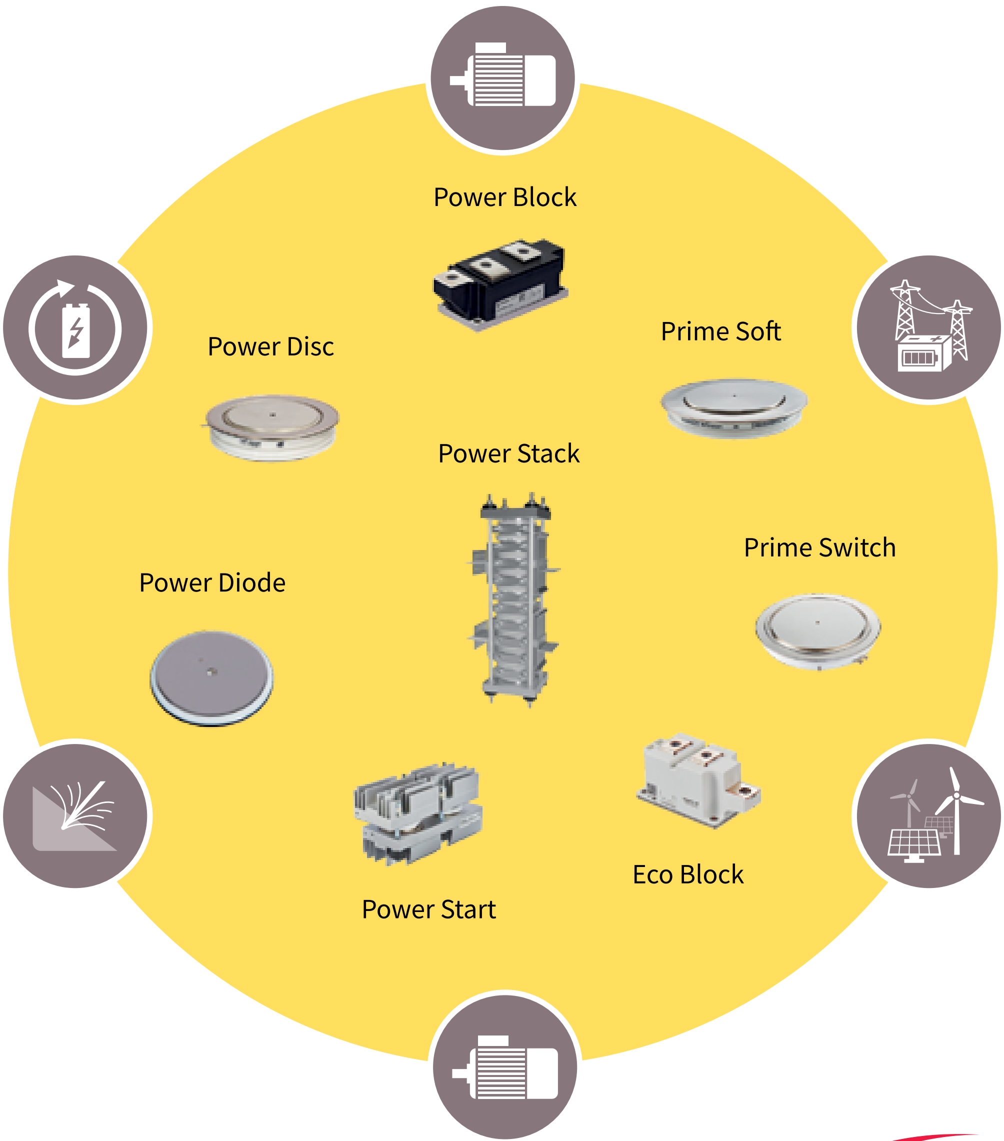

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In this paper, we focus on PFC for DC EV charger applications. The Vienna PFC topology is widely used in unidirectional DC EV charger applications, as shown in figure 4. Because the reverse-recovery current of SiC diodes is lower than that of Si diodes, this kind of current will flow through SW1~SW6, when they are turned on. Therefore, if there is less reverse-recovery current, the turn-on switching loss for SW1~SW6 can be reduced. For this reason, 1200 V SiC diodes are widely used in unidirectional DC EV charger applications to achieve lower power losses and higher efficiency. Lower power loss means a lower junction temperature for the power device, which can improve reliability or increase power density.

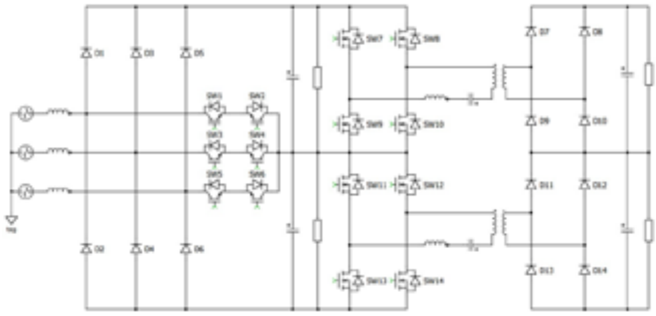

Figure 3: DC EV charger topology

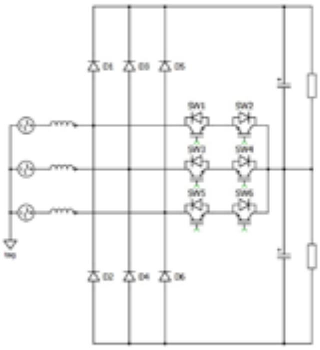

Figure 4: Vienna PFC topology

A three-phase, full-bridge topology (B6) is also widely used in DC EV charger applications, as shown in figure 5. As we know, this kind of B6 topology can also work as an inverter, therefore can be used for bi-directional applications. If the PFC diodes and rectifier diodes (D1~D14) in figure 3 change to switch devices, the topology changes to neutral point clamped 2 (NPC2, as shown in figure 6) and bi-directional DC-DC (CLLC, or dual active bridge) topology, which is a bi-directional charger topology, as shown in figure 7.

A bi-directional function in the DC EV charger usually means discharging the battery in EVs to the grid, electric equipment or other EVs, when the battery state of the charge is high, or under certain conditions, such as during a power cut or outdoor camping. Discharging to the grid is also known as vehicle-to-grid (V2G) technology, which includes benefits such as reducing the total cost of EV ownership and optimizing grid stability. This kind of technology will certainly be used in future chargers, and the bi-directional charger should become a trend among DC EV chargers.

As shown in figure 8, using 1200 V CoolSiC MOSFETs to replace 600 V/650 V CoolMOS in DC-DC, and using B6 to replace NPC2 as shown in figure 9, can reduce the number of power devices in the system and make it easier to control. These advantages also help bi-directional DC EV charger systems to achieve higher efficiency, higher power density and lower unit weight.

Introduction to 15 kW PFC with different devices and topologies
As seen in the introduction, there are several different solutions for unidirectional and bidirectional DC EV charger applications. The study has focused on PFC parts in order to compare efficiency and cost, and to make recommendations for both unidirectional and

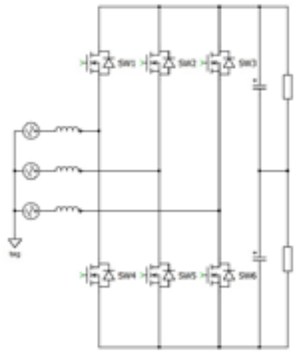

Figure 5: Three-phase, full-bridge topology (B6)

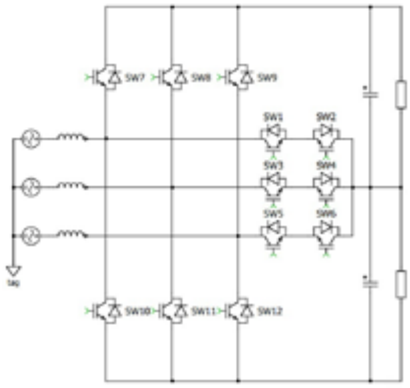

Figure 6: NPC2 topology

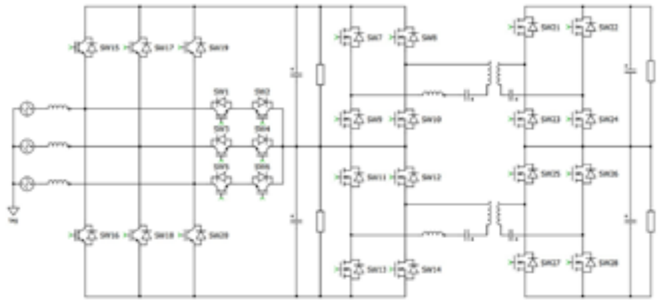

Figure 7: Bi-directional DC EV charger topology A

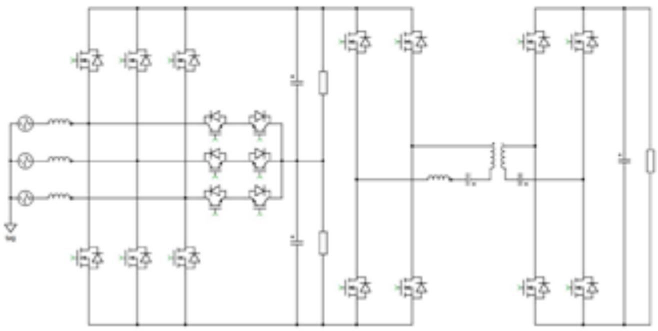

Figure 8: Bi-directional DC EV charger topology B

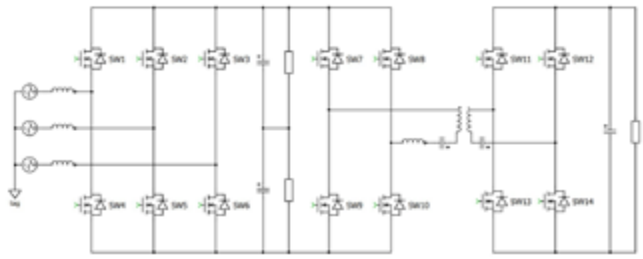

Figure 9: Bi-directional DC EV charger topology C


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bidirectional applications. Three 15 kW, three-phase PFC solutions for both unidirectional and bidirectional PFC are shown in Tables 1 and 2. The solution using both Si devices and SiC devices is called a hybrid solution.

Unidirectional PFC solution		
	D1~D6	SW1~SW6
Si Vienna PFC	Si Vienna PFC	650 V IGBT
Hybrid Vienna PFC	1200 V SiC Diode	650 V IGBT
SiC MOS B6	NA	1200 V SiC MOSFET

Table 1: Unidirectional PFC solution

Bi-directional PFC/Inverter solution		
	SW1~SW6	SW7~SW12
Si NPC2	650 V IGBT	1200 V IGBT
Hybrid NP C2	650 V Hybrid IGBT	1200 V IGBT
SiC MOS B6	1200 V SiC MOSFET	NA

Table 2: Bi-directional PFC/Inverter solution

After simulation under the conditions shown in table 1 and table 2, the resulting curves for power loss versus switching frequency are displayed in figure 10 and figure 11. From the curve for unidirectional PFC solutions in figure 10, the Vienna PFC hybrid solution with 1200 V CoolSiC diode has almost the same power loss as the CoolSiC MOSFET B6 solution, and better cost performance than the B6 solution. From the curve for bi-directional PFC solutions in figure 11, the Si NPC2 solution has the highest power loss, the hybrid NPC2 has a lower power loss than the Si NPC2 solution, and the B6 with a CoolSiC MOSFET solution has the lowest power loss and the highest switching frequency. Owing to this high switching frequency, we can also use low inductance, small heat sinks and small PCB dimensions, which help to reduce the system cost.

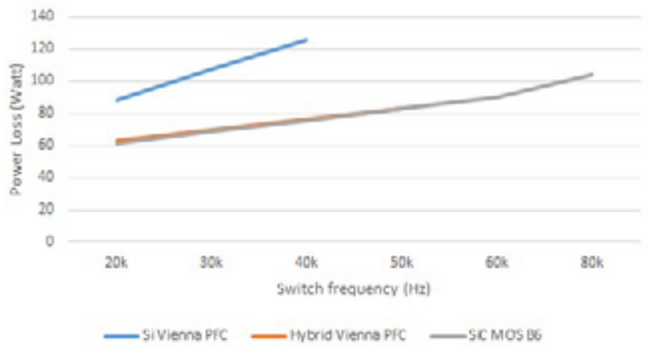

Figure 10: Unidirectional PFC power loss curve

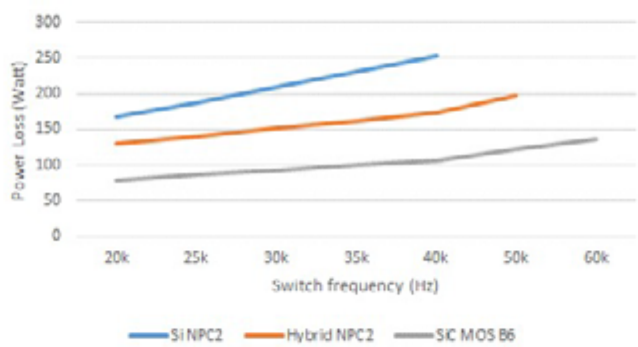

Figure 11: Bi-directional PFC/INV power loss curve

Conclusion

In this article, we introduce the unidirectional and bi-directional DC EV charger topology, in particular for PFC parts and SiC devices, including 1200 V SiC diodes and MOSFETs used in a hybrid Vienna PFC and B6 topology. From the power loss and switching frequency curves, we can recommend using 1200 V SiC diodes in the hybrid Vienna PFC for unidirectional DC EV charger PFC parts, which result in the best efficiency and cost performance. Using bi-directional DC EV charger PFC parts with 1200 V SiC MOSFET in a B6 topology results in the best efficiency and performance, with cost benefits for the whole system.

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Voltage Converters for Railway Technology – Costs at First and Second Glance

Price pressure rises, also in railway industry, and will hence have an essential impact on the initial acquisition costs for electronics applications. As vehicles and the related infrastructure for railway projects are supposed to operate for decades, a reliable long-term planning is highly recommended: In many cases, costs will not emerge directly at the moment of purchasing, but will manifest only after some years of use. This article will analyze the key factors of decision when optimizing long-term costs and the comparative values this decision can be based on.

By Willi Spiesz and Kristina Schmidt, Grau Elektronik GmbH, Karlsbad

Introduction

Voltage supply is the core part for a wide range of electrotechnical devices and applications. Devices and plants in various fields of application will be stressed in very different ways. As far as railway technology is concerned, very long operating times and functionality under harsh environment conditions (ambient temperature, temperature fluctuations, temperature change rates, vibration, humidity, pollution, EMC immunity) are required. It soon becomes clear that standard components for railway applications, as DC/DC converters for example, will not offer a satisfying solution.

Lifetime as a benchmark

Wearing parts as rail wheels, couplings, brake pads, compressors, valves, batteries or displays have to be maintained on a regular basis and, depending on their stress conditions, replaced at certain intervals. This will cause costs and downtimes for the vehicles. On the other hand, when it comes to electronic parts and system components, mechanical wear only plays a subordinate role. Of course, connections – as between component and circuit board, plugs and line junctions – are stressed mechanically as well. These stresses have to be qualified according to sweep cycle/frequency aging approval tests, so that usage times from 20 up to 25 years can be modelled, implemented and verified.

Life cycle costs are often underestimated. These also include costs – as the requalification for second source components, for example – that will occur in case the initial supplier fails for whatever reason. In order to keep these costs as low as possible, the vehicles' components are subject to very high requirements. The EN50155 standard (railway applications – rolling stock – electronic equipment) is the relevant set of rules for this purpose that describes the entire requirements. Speaking of voltage converters, a lifetime up to minimum 20 years (according to life class L4) is expected for a device running from 350 up to 360 days a year and from 16 up to 24 hours a day. Depending on agreement, even longer operating times can be aimed at (according to life class Lx). Nevertheless, each failure and each replacement will cause system costs.

Can we rely on the initial type testing?

Let us draw attention to an interesting fact that often goes unrecognized: The proper behavior of an electrotechnical component can change for the worse during lifetime, by drying out of electrolytes used in electrolyte capacitors, for example. Semiconductors' technical properties are also expected to alter, for example, regarding CTR (current transfer ratio) in optocouplers. Isolation material, circuit boards, plugs including their contacts, are subject to changes in their specified initial values as well, depending on the quality of material and processing (concerning contact resistance, for example). Looking at the topic of EMC leads to the following observation: Interference immunity will decrease over years whereas interference emission will rise on the other hand (see figure 1) and the corresponding specific limit will be exceeded from a certain time on. As a result, significant dysfunction may occur.

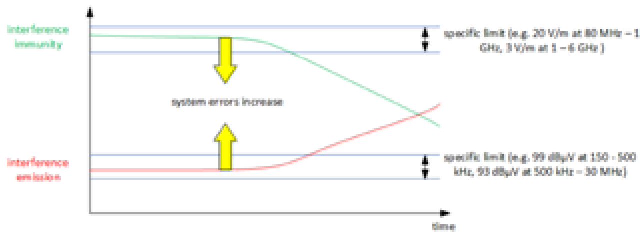

Figure 1: Development of interference immunity and interference emission over time

Hence, depending on the application, the second glance really matters when it comes to choosing and purchasing devices. Unlike applications in the automotive field that are subject to technical inspections on a regular basis, limit checks concerning electrical devices for railway technology are only required once – as initial type testing. The issue of long-term functionality and compliance with specific limit values becomes thus a matter of trust. With this in mind, not only the instantaneous procurement costs are a decision-making criterion: In view of increasing service life, maintenance and repair costs also come into focus. A purchase that initially appears to be a good deal can easily turn out to be a kind of boomerang, causing significant problems and considerable costs over time.

Failure and repair costs: MTBF as decisive factor

For illustrative purposes, we can refer to an example based on real operation: 17,901 units of the same device (here: one of our 100 W DC/DC converters, specified for an input voltage of 42.2V up to 154V and an output voltage of +/- 15V) have been evaluated since 2002. According to the data sheet, the MTBF is 500,000 hours at an ambient temperature of 40 °C (Note: our calculation is carried out according to the guideline SN 29500, which is generally used for MTBF considerations). In total this results in 1,176,000 operating hours related to an average operating time: In this case, we assume 350 days per year at 16h per day. Consequently, the number of expected failures will be 1,807 projected on 5,600 hours per year. However, what we observed in reality: Our devices' actual MTBF does even remain below the target values we have just considered, proofing that only 140 converters failed or have been complained by costumers until the reference date January 31, 2022. This corresponds to a failure rate of only 0.78 percent.

As an example for a small converter, modeling a failure by calculating with € 75.00 costs for the user and additional € 75.00 for the manufacturer caused by a repair, this results in € 21,000.00 of additional costs related to 140 failed converters, which corresponds to € 1.16 per device considering the total number. Evaluating the benefit in terms of additional costs, let us draw a comparison with a fictitious competitor, whose acquisition costs may be possibly lower, but whose MTBF value may be only half as high. 3,382 failed converters would result in additional total costs of € 597,300.00 for an MTBF of 250,000 hours and thus € 28.34 additional costs per device - provided that the device in question is still able to be repaired. In case a replacement is due, costs will be even higher. Besides, indirect additional costs have not yet been taken into account. Moreover, when transferring the calculation to larger modules with a more complex structure, the maintenance and repair costs will also increase in function of the purchase price.

Figure 2: Our sample device 105 SBB 110 D15

Expert knowledge pays off

Requalifying a yet licensed component in a railway vehicle will produce immense effort and costs because type testing including the related certificates (EN50121-3-2 for EMC, EN 61373 for vibration and shock, EN 45545-2 for fire load) has to be performed in the corresponding system environment. Modifying the bill of materials and possibly searching for new suppliers will demand additional resources and staff. Thus, five-digit amounts of additional costs can quickly arise.

Near-term support, advice and qualified assistance when treating technical questions are further decision-making factors. That is where the second glance matters – above all, it pays off at long term. Later during operating time, the different applications' interaction with other system components will often raise questions that require special knowledge: Years of experience in development prove to be a strategic advantage.

Summary and Outlook

As the relevant standards for railway applications set especially high expectations in terms of service life, this article first highlighted the central role of life cycle costs. Based on the initial type testing, we discussed possible changes in electrical components' properties and emphasized the importance of high quality components when purchasing. We introduced the MTBF as a benchmark, illustrated by a practical example emerging of our range of applications. Hence, we underlined the risk of escalating costs in the event of high failure rates and demonstrated how expert knowledge already gains momentum during development phase.

These findings may also help when it comes to a question that many vehicle manufacturers may ask themselves eventually: Rather develop and product converters in-house or rather purchase externally? Time and cost savings, resulting from years of practice in development and manufacture of high-availability voltage and power supply systems, should not be underestimated. If someone has already invested many years in acquiring specialized knowledge in the field of converter topology, in optimizing the design of corresponding devices, and in setting up specialized production sites, his leading edge can only be caught up with immense effort. In many cases, this additional effort ultimately will not pay off for an in-house project - so it is worth consulting the specialist.

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SCR Based Pulse Generator for Power Choke Measurements up to 10kA

A SCR based pulse generator has been developed and tested on various inductive power components by Bs&T Frankfut am Main GmbH. The pulse generator has some unique properties which benefits from the high pulsed current handling capabilities of SCR's and offers some major advantages compared to IGBT based systems.

By Dr. Christian Teske, CEO of Consolidated Electrodynamics Limited and JC Sun, Bs&T Frankfurt am Main GmbH

Introduction

One of the problems of power electronics is the determination of the properties of inductors during their desaturation-saturation-transition. This becomes especially true for high power applications where the saturation of inductors can have fatal consequences. The calculation of inductor properties is difficult due to the non-linear properties of core materials and often not consistent due to manufacturing tolerances, imprecise data sheet specifications, variations in material properties, etc. Hence, there is a requirement for measuring the saturation properties of power chokes and inductors in general L(I) and dL/dI, to determine their electrical properties under worst case scenarios.

In order to avoid heavy equipment for testing and large power loads, one of the solutions to this problem is to apply high power pulses to a test specimen for a short duration of time i.e. several ms to 100ms. The resulting current and voltage waveform can be used to determine the relevant properties of the DUT (Device Under Test). For this high power SCR's can be used in order to drive very high pulsed currents through inductors and create desaturation-saturation-transitions, enabling high load measurements and worst case scenario documentation of the test specimens. Due to the higher pulsed current handling capabilities SCR's are general more suitable for this purpose than IGBT's. Bs&T has developed several pulse generators based on this technology for various applications.

Figure 1: Bs&T pulse generator during a test.

Basic Principle of Bs&T pulse generators

For measuring power chokes or any other kind of inductor the basic principle of operation is to apply a certain amount of energy for a short period of time to the DUT in order to drive it through a double saturation-desaturation-process and extract the relevant electrical properties out of this transition. This is achieved by charging a capacitor bank up to a certain voltage/energy level. Via an SCR switch this voltage pulse is applied to the DUT and creates in union with an internal inductor a resonance circuit. Dependent on the DUT characteristics this voltage pulse will lead to a rising current, from which the current dependent inductance L(I) and the power dissipation losses Pdiss can be extracted via current measurements using a pearson type contactless current probe. Due to the superior pulsed current handling capabilities of SCR's the test specimen can be driven with several kA or even >10kA if required. A Diode anti parallel to the SCR guarantees a double saturation-desaturation-transition of the test specimen. This is a unique property of the Bs&T pulse generators which can't be met by any other choke testing equipment.

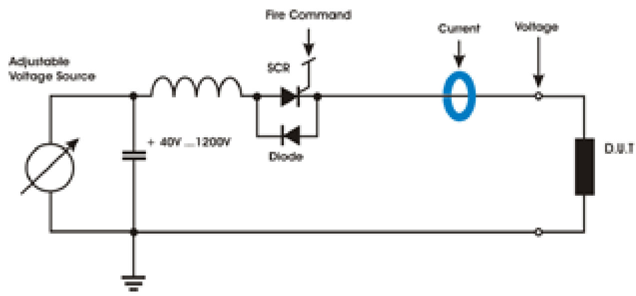

Figure 2: Basic operation principle of the Bs&T pulse generator.

Currently there are several Bs&T pulse generators available which cover a wide range of pulse energies and charging voltages. Pulsed currents can go up to 10kA and beyond. All pulse generators are short circuit safe which means that if the output for any reason is shorted out the capacitor bank will safely discharge without any damage to the internal components.

	Bs&T Pulse	Bs&T Pulse+	Bs&T Ultra
Pulse current range	3kA	3kA	10kA
Voltage range	40-1000V	40-1200V	40-1200V
Short circuit ringing frequency	2.5kHz	10kHz	1kHz
Pulse energy	250J	125J	1kJ
Pulse length*	100ms	100ms	200ms
Dimensions (WxLxH)	470x370x-136mm	470x370x-136mm	470x370x-190mm
Weight	8kg	8kg	16kg

Table 1: Performance data of the current versions of Bs&T Pulse.

**For an SCR pulse generator the pulse length is defined as the length of measurement data recording per pulse.*

Difference to other measuring methods

Recently there have been some publications which elaborated on the difference between the IGBT pulse generators and SCR based systems, claiming that the turn off capability makes IGBT based systems far superior. Regarding the fundamental physics of the pulse generation and the saturation of the DUT, there is actually little difference. To see that just replace the SCR-Diode combination in figure 2 with an IGBT, they are basically the same. Both systems store electrical energy in a capacitor bank and connect the DUT to the electrical energy storage system via some kind of switch (IGBT or SCR). Hence, in both systems a temporary resonant circuit with a nonlinear inductor is created. However, the IGBT based systems

usually switch off before complete saturation of the inductor is reached in order to save the IGBT from destruction by large surge currents. That's why with IGBT based pulse generators a pulse width needs to be specified. Figure 3 is a measurement made with a Bs&T pulse SCR based system. Following the current waveform until short of inductor saturation, both systems the IGBT based as well as the SCR based would have approx. the same results. The IGBT based system would then switch off after a defined pulse width, preferably shortly before saturation, whereas the SCR based system simply remains on.

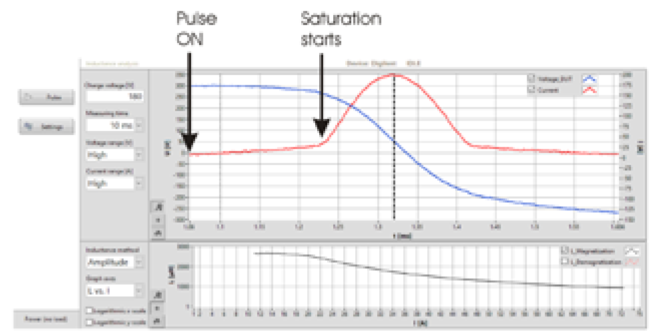

Figure 3: Typical voltage current waveform for a power choke tested with an SCR based pulse generator. Note the second saturation-desaturation-transition when the voltage reverses.

With respect to the measured voltage and current waveform at the point where saturation occurs there is no major difference. However, with the IGBT based system the operator needs to define some pulse width in advance in order to prevent the destruction of the IGBT from surge currents. This problem does not occur with the SCR based system simply because an SCR has a much higher surge current handling capability than an IGBT. Hence for the rest of the time – which is not necessarily relevant for the actual inductance measurement – the capacitor will be discharged through the DUT in order to create several saturation-desaturation-transitions, which help to determine the properties of the inductor under extreme or failure conditions. Further, the losses of the DUT can be determined by the damping curve, which is something no other pulsed system can achieve. As a consequence of this one single measurement with the SCR based system achieves much more information than with an IGBT based pulse generator. The following table 2 shows a comparison.

	IGBT based pulse generator	SCR based pulse generator
Initial desaturation to saturation transition	YES	YES
Worst case study of properties during saturation of DUT	NO	YES
Measurement of Losses	NO	YES
Voltage reversal	NO	YES

Table 2: IGBT based pulse generator vs SCR based pulse generator.

In general, the problem of the IGBT based systems simply boils down to the low surge current capability of IGBT's, which necessitates the definition of a pulse width at the beginning of a measurement. With the SCR based system this is not necessary. One simply defines the discharge voltage/energy. The transition period from desaturation to saturation can be seen in the measured waveform (see figure 3). Hence, there is no need to define a pulse width when the maximum pulse width, which can be applied to a test specimen before it saturates, can actually be measured under worst case conditions.

Summary

Regarding the measurements of inductive component properties with the Bs&T SCR based pulse generator the advantages can be summarized as follows:

- High current range from 1A to 10kA or more.
- Adjustable voltage applied to the DUT from 40V to 1200V or more.
- Bipolar (positive and negative) current drive of the DUT.
- Documentation of the inductor properties when saturated (worst case study).
- Pulse energy adjustable from mJ to kJ or more.
- Voltage reversal across DUT during measurement.
- No need to define any pulse width prior to measurement.
- Reliable measurement of power losses without thermal stress.
- Measurement of AC resistance.
- Compact apparatus for providing high pulsed power up to several MVA to a DUT.
- Short circuit safe.

Conclusion

The Bs&T pulse generator design has proven, that a powerful SCR based pulse generator can be designed for testing the saturation properties of inductors as well as the power losses. Further, the bipolar current drive provides a double saturation to desaturation transition, which provides a more realistic AC environment and which can't be accomplished by any other method. Hence, the Bs&T pulse generator is a unique tool for a wide range of applications in the power electronics industry.

About the Authors:

Dr. Christian Teske is the founder of Consolidated Electrodynamics Limited. He holds a PhD in applied physics from the Goethe University in Frankfurt am Main and has written several publications on pulsed power applications. Dr. Teske designed the main components of the Bs&T pulse generator and also holds several patents.

JC Sun is founder of Bs&T Frankfurt am Main GmbH, specialized in field of testing and validation of soft magnetic materials, shaped cores and wire wound components, conform IEC/IEEE standard, is active member of national committee of TC 51

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The Interleaved Inverting Charge Pump - Part 2: Implementation and Results

In Part 1 of this series, we introduced a unique method of generating a low noise negative rail from a positive supply, and we presented a derivation of the equations governing its operation. Part 2 dives into a practical example of this interleaved inverting charge pump (IICP) implementation with Analog Devices' ADP5600.

By Jon Kraft, Senior Staff Field Applications Engineer and Alex Ilustrisimo, Applications Engineer, Analog Devices

We compare the voltage ripple and radiated emissions of the ADP5600 to a standard inverting charge pump to show how interleaving improves low noise performance. We also use the equations from Part 1 to optimize performance of this solution in the context of applying it in a low noise phased array beamforming circuit.

Commercially Available Interleaved Inverting Charge Pump

As stated in Part 1, IICPs are used within integrated circuits to generate small negative bias rails. The ADP5600 uniquely combines a low noise IICP with other low noise features and advanced fault protection. The ADP5600 is an interleaved charge pump inverter with an integrated low dropout (LDO) linear regulator. Its unique charge pump stage exhibits reduced output voltage ripple and reflected input current noise when compared to conventional inductive or capacitive based solutions. Interleaving is clever as a low noise concept, but interleaving channels is not a cure-all for noise problems. Achieving true low noise requires an IC specifically designed to realize the low noise advantages of an IICP, while keeping the solution size small and efficient.

Fixed and Programmable Switching Frequency

Many inverting charge pumps operate to a few hundred kHz. This relatively low frequency limit necessitates relatively large capacitors and limits where the frequency spurs can be placed. The ADP5600 can operate at a switching frequency from 100 kHz to 1.1 MHz, allowing it to be used effectively in modern systems. Furthermore, this frequency is always fixed—there is no frequency variation vs. output load. Switching frequency variation (spread spectrum frequency modulation) is commonly implemented to improve the charge pump's efficiency, but it may create problems in noise sensitive systems.

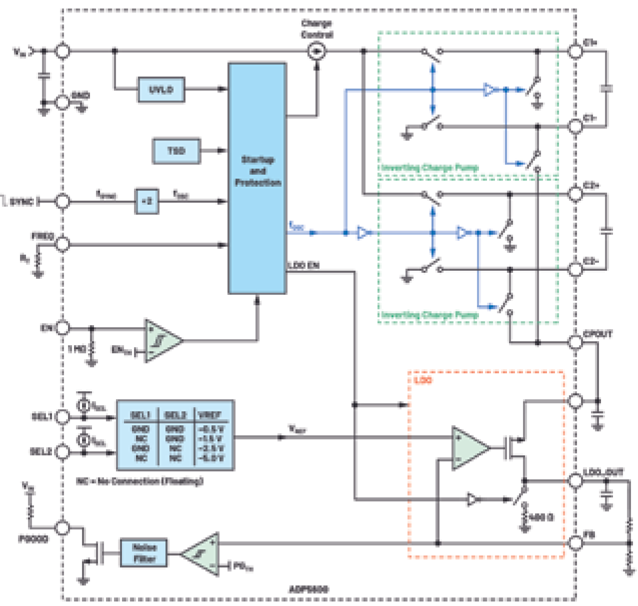

Figure 1: ADP5600 interleaved inverting charge pump simplified block diagram.

External Frequency Synchronization

Many low noise systems need to place high amplitude switching noise into defined frequency bands where the generated noise minimally impacts the system. With this in mind, converters' operating frequencies are synchronized in noise sensitive systems, but synchronization is a rare feature in charge pump inverters. In contrast, the ADP5600 can be synchronized to an external clock up to 2.2 MHz.

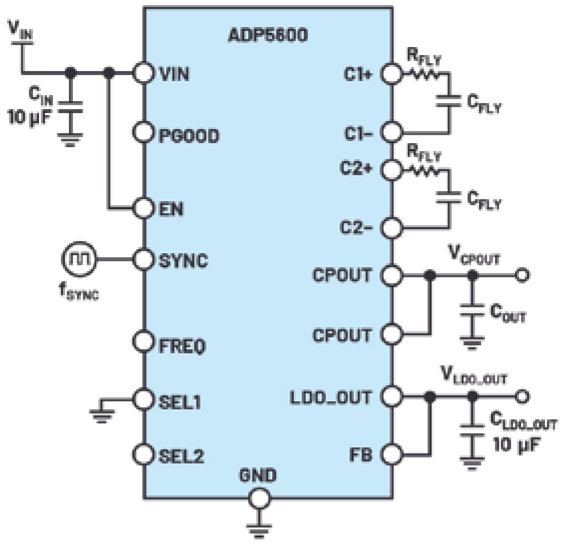

Figure 2: ADP5600 interleaved inverting charge pump test setup.

Low Dropout Voltage Regulator

Because the ADP5600 covers a wide input voltage range, its charge pump output voltage may be too high to power lower voltage circuitry. Therefore, the ADP5600 includes an LDO postregulator. It also features a positive voltage referenced power-good pin for easy power sequencing when the LDO output is in regulation.

Fault Protection

Finally, the ADP5600 includes a comprehensive set of fault protection features for robust applications. This includes overload protection, shorted flying capacitor protection, undervoltage lockout (UVLO), precision enable, and thermal shutdown. An additional novel feature, flying capacitor current limiting, also reduces the peak current spikes when charging the flying caps.

Test Data from the ADP5600

Part 1 presented theoretical proof that IICP architecture significantly improves ripple when compared to noninterleaved solutions. For the sake of brevity, the derivations shown in Part 1 were ideal—they overlooked parasitics, layout dependencies (IC and PCB), timing mismatches (that is, an imperfect 50% oscillator), and R_{DS} mismatches. These factors result in some deviation from the calculated and measured voltage ripples. As always, it is best to put the ADP5600 into action, observe its performance, and use the derived equations to guide the optimization of the circuit for the best performance.

A standard ADP5600 evaluation board was used here, but with the insertion of RFLY, and modifications to the values of C_{FLY} and C_{OUT}. Furthermore, we use the ADP5600's SYNC feature to vary the switching frequency. The block diagram in Figure 1 shows that the individual charge pumps switch at one half of this SYNC frequency; that is, $f_{OSC} = ½ f_{SYNC}$.

Figure 3 and Figure 4 show the output voltage ripple for the interleaved and noninterleaved inverting charge pump, respectively, when operated under the same conditions.

With these conditions, the input and output voltage ripples of the ADP5600 are nearly 14 times lower than a traditional inverting charge pump. We can also determine if this voltage ripple matches the equations derived in Part 1 of this series. Recall from Part 1 that the output (or input) voltage ripple of an IICP was given by:

$$\Delta V_{OUT} = \frac{I_{LOAD}}{4 \times f_{OSC} \times C_{OUT}} - I_{LOAD} \times (R_{OUT} - 2 \times R_{ON}) \times \frac{C_{FLY}}{C_{OUT}} \times \frac{\beta - 1}{\sqrt{\beta}} \text{ where } \beta + e = e^{1/8fRC} \quad (1)$$

where f is f_{OSC}, R is R_{ON}, and C is C_{FLY}

Using Equation 1, and substituting in real values for ROUT and RON, it is possible to compare the calculated and measured output voltage ripple. Table 1 gives these results for a variety of tested configurations and notes the improvement over a noninterleaved charge pump implementation.

Table 1 shows that the interleaved voltage ripple closely matches the prediction from Equation 1. The improvement over the standard, noninterleaved, inverting charge pump is also shown. Some setups within this table also include an additional external resistance, R_{FLY}, connected in series with C_{FLY}. Those results demonstrate that R_{FLY} further reduces the voltage ripple, but at the expense of charge pump output resistance. This was also predicted by Equation 1 and the analysis from Part 1 of this series.

In addition to the output voltage ripple, the radiated emissions from the IICP also show improvement over a standard charge pump. To measure this, a 25 mm antenna was placed over the evaluation board (Figure 5) and various configurations were tested. Figure 6 shows a comparison of one such configuration vs. a standard noninterleaved charge pump inverter. The IICP topology results in a 12 dB to 15 dB reduction in noise for the first and third switching harmonics.

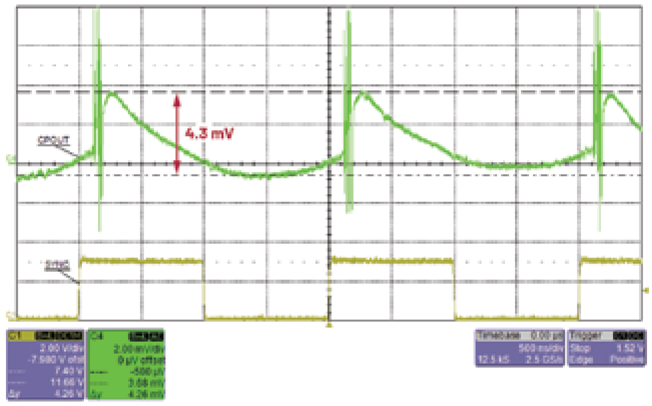

Figure 3: ADP5600 IICP output voltage with V_{IN} = 6 V, $C_{OUT} = C_{FLY}$ = 2.2 µF, f_{OSC} = 250 kHz, I_{LOAD} = 50 mA.

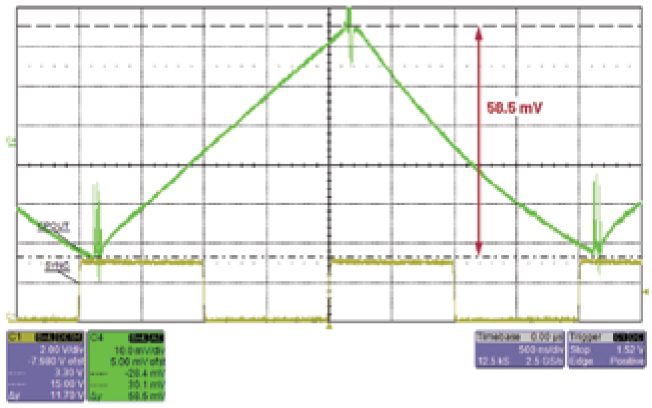

Figure 4: Standard inverting charge pump output voltage with V_{IN} = 6 V, $C_{OUT} = C_{FLY}$ = 2.2 µF, f_{OSC} = 250 kHz, I_{LOAD} = 50 mA.

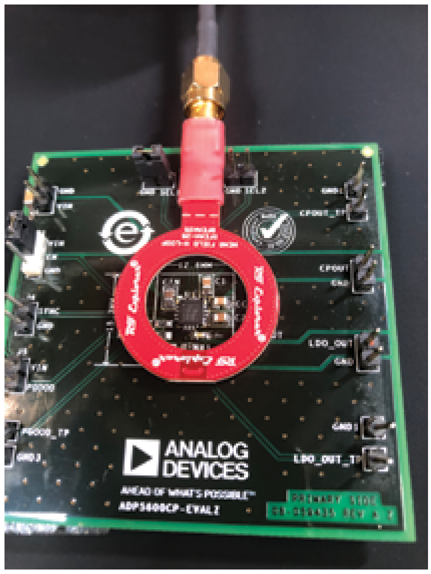

Figure 5: Radiated emissions test setup with the ADP5600 evaluation board.

Table 1: V_{OUT} Ripple for Various Use Cases; V_{IN} = 12 V, I_{LOAD} = 50 mA, R_{ON} = 2.35 Ω. The actual capacitances of C_{OUT} and C_{FLY} (with their capacitive derating at voltage) were used, not their nominal values.

fOSC (kHz)	COUT (µF)	CFLY (µF)	RFLY (Ω)	Measured V_{OUT} (V)	Measured R_{OUT} (Ω)	V_{OUT} Ripple (mV)		Improvement over Noninterleaved
						Meas	Calc	
250	1.6	1.6	0	11.48	10	5.3	6.0	12×
250	1.8	1.8	25	8.86	63	3.4	3.2	18×
250	4.6	1.6	0	11.48	10	1.9	2.4	12×
500	2.8	1.6	0	11.45	11	2.5	2.9	7.5×
500	1.8	1.8	25	8.74	65	3.1	2.7	10×
1000	1.6	1.6	0	11.40	12	4.3	4.2	3.7×
1000	1.8	1.8	25	8.438	71	2.8	2.8	5.6×

Application Example of the IICP

Low noise power is required for data converters, RF amplifiers, and RF switches. The main challenges facing power supply designs in these systems are:

- Power dissipation and high temperature operation
- EMI immunity and low EMI contribution
- Large input voltage ranges
- Minimizing solution size and footprint

To illustrate the complete design and advantages of the IICP, let us consider an application that powers RF amplifiers, RF switches, and phased array beamformers. The application is included in the ADTR1107 data sheet and replicated in Figure 7.

In this example, several high power positive voltage rails are required—which are left here as a job for inductive buck converters. Two negative rails are also needed: AVDD1 and VSS_SW. AVDD1 is used by the ADAR1000 to generate low noise bias rails for VGG_PA and LNA_BIAS. AVDD1 is –5 V at 50 mA, and VSS_SW is the –3.3 V at <100 µA rail to the RF switch within the ADTR1107. Four ADTR1107s are used per ADAR1000, so the –3.3 V rail draws a max of 1 mA. Typically, the supply rail into these systems is 12 V.

The ADP5600 is a good choice to produce –5 V at 50 mA and –3.3 V at 1 mA rails from 12 V, as it achieves low input and output voltage ripple, and low radiated emissions. Furthermore, the ability to synchronize the switching frequency over a wide range allows the switching noise to be placed where it will have the least impact on the system. Figure 8 shows the final design.

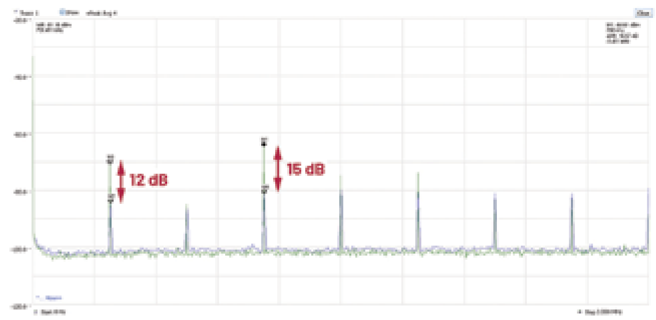

Figure 6: Radiated emissions, V_{IN} = 12 V, I_{LOAD} = 50 mA, C_{FLY} = C_{OUT} = 2.2 µF, f_{SYNC} = 500 kHz. Green = standard, blue = IICP.

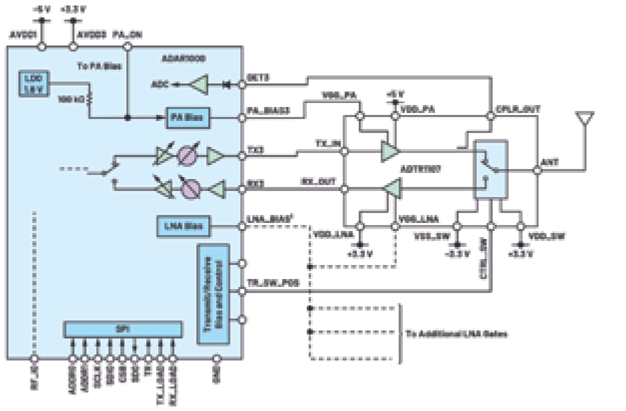

Figure 7: ADAR1000 plus four ADTR1107 power rails.

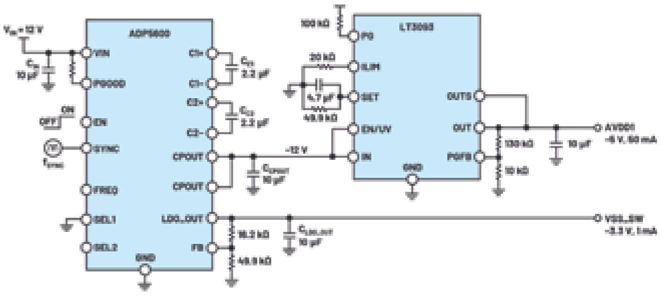

Figure 8: ADP5600 and LT3093 are used to power AVDD1 and VSS_SW.

The LT3093 is a very low noise LDO linear regulator, which is capable of high voltage that allows the ADP5600 charge pump output (CPOUT) to be connected directly to its input. Its –5 V output is set by the resistor on the SET pin, and a programmable power-good pin can notify other systems when the AVDD1 rails are in compliance. The ADP5600's LDO regulates the much lower current VSS_SW rail. While not as low noise, or as high of a power supply rejection ration (PSRR) as the LT3093, it is capable of providing a stable rail for VSS_SW. The output voltage ripple of all three rails (charge pump, AVDD1, and VSS_SW) is shown in Figure 9.

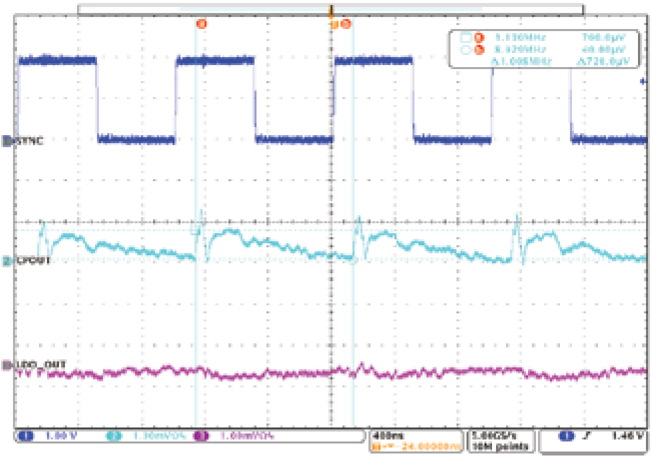

Figure 9: Charge pump output voltage ripple for V_{IN} = 12 V, C_{OUT} = 10 µF (nominal), C_{FLY} = 2.2 µF (nominal), f_{SYNC} = 1 MHz (f_{OSC} = 500 kHz), I_{LOAD} = 50 mA.

Conclusion

This 2-part series presented a new method to generate low noise negative rails from a positive supply. Part 1 covered the concepts behind interleaved inverting charge pump operation. Part 2 put these ideas into practice with a complete solution built and tested using Analog Devices' new ADP5600. This solution was optimized with the mathematical model derived in Part 1. The conducted and radiated emissions were compared to a standard inverting charge pump. Under some conditions, an 18-fold improvement was realized over standard charge pump inverters, which is important for meeting the low noise requirements of modern precision and RF systems.

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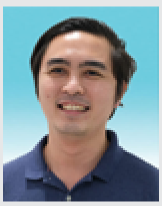
About the Authors

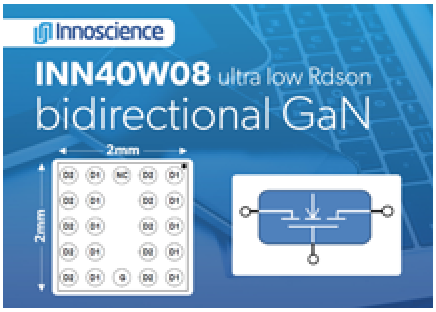
Jon Kraft is a senior staff FAE in Colorado and has been with ADI for 13 years. His focus is software-defined radio and aerospace phased array radar. He received his B.S.E.E. from Rose-Hulman and his M.S.E.E. from Arizona State University. He has nine patents issued (six with ADI), and one currently pending.



Alexander Illustrisimo graduated from Central Philippine University with a bachelor's degree in electronics engineering. He joined ADI in 2014 and has worked as an applications engineer for power management products for more than six years, with a focus on LDO regulators and switching regulators.

40V Bi-Directional GaN HEMT for Smart Mobile Devices, Chargers and Adapters

Innoscience Technology announced the INN40W08, a 40V bi-directional GaN-on-Si enhancement mode high-electron-mobility-transistor (HEMT) for mobile devices, including laptops and cellular phones. The INN40W08 HEMT has been developed using the company's advanced InnoGaN technology which features ultra-low on resistance. Featuring a bi-directional blocking capability, the INN40W08 GaN HEMTs have a ultra-low on resistance of just 7.8 mΩ. This is achieved by the company's InnoGaN patented strain enhancement layer technology which reduces sheet resistance by 66%. Gate charge (QG) is typically 12.7nC. The 5x5 grid wafer level chip scale package (WLCSP) measures just 2x2 mm. This small footprint enables INN40W08 GaN HEMTs to be integrated inside mobile phones. Applications include high side load switching, over-voltage protection in a smart phone's USB port and multiple power supplies including chargers and adapters. Innoscience's GaN technology enables efficient and more compact over-voltage-protection (OVP) systems by replacing 2 Silicon MOSFETs with 1 InnoGaN (or BiGaN) transistor. This saves on the overall OVP costs and makes the OVP unit smaller, which is very important considering the space constraints on a mobile phone's circuit board.

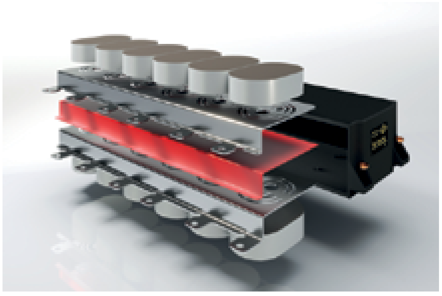


www.innoscience.com

DC-LINK LI Capacitors for SIC Power Semiconductors

WIMA low-inductance (LI) DC-Link capacitors are characterized by a flat, space-saving design with particularly low self-inductance. In addition to general applications, they are particularly suitable for applications in combination with silicon-based SiC power semiconductors.

In addition to a low leakage inductance of < 10 nH in almost any capacitor configuration, they also feature a significant resonance point shift in high frequency ranges compared to conventional designs. Optionally, an ESR-optimized design and an application temperature of up to +125°C is possible.



The LI configuration with flat, space-saving design is available for all types and contact configurations. Existing capacitor designs can easily be replaced with LI capacitors that have a higher maximum energy density per volume compared to previous DC-Link configurations. Single Side Cooling (SSC) provides ideal heat dissipation with one-sided (water) cooling systems. The LI design is available in 2- and 3-voltage level configurations.

www.wima.de

Compact Power Electronics Capacitor Boosts Miniaturization of AEDs

Recently, Wuxi CRE New Energy Technology launched its compact and miniaturized product DEMJ-PC series (1500VDC~5000VDC,32~500μF), which is suitable for the application of automatic external defibrillator (AED) for energy storage pulses in the medical field. The energy density is greatly improved. The volume and weight are reduced by 50% compared with similar products, creating conditions for further miniaturization of AED into home users.

AED is an emergency device that automatically identifies abnormal heart rhythms and delivers electric shocks to defibrillate them. It acts on the heart with pulsed electric current to administer electric shock therapy to eliminate heart rate abnormalities and restore the heart to sinus rhythm. The energy storage capacitor can be considered the core component that provides its discharge energy. Because of the simple operation for non-professional use, AED is also known as a "life-saving device". In recent years, it has become one of the standards for first aid facilities and equipment in public places, reflecting the enhancement of public awareness of first aid and the improving the social first-aid system.

Customers have proved CRE's compact energy storage pulse capacitors. The success of the product development and rapid market introduction is due to CRE's continuous research on capacitor technology and focus on the power electronics market.

www.cre-elec.com

Automotive Grade High Current Shielded Power Inductor

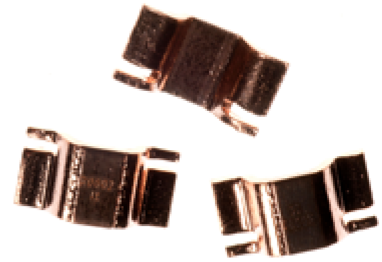
Bourns announced two automotive grade high current shielded power inductor series that offer enhanced mechanical strength for harsh vibration application environments. Bourns® Model SRP1038WA and SRP1265WA shielded power inductor series are designed with a wider side terminal leadframe capable of withstanding 15 G typical or 30 G peak vibrations. Vibration testing was conducted according to MIL-STD-202 Method 204. The two series also feature a compact package, high saturation current, low DC resistance, low buzz noise and excellent temperature stability over a wide temperature range of –55 to +165 °C. Such features make these automotive grade, AEC-Q200 compliant power inductors ideal for power management and EMI filtering in a wide range of consumer, vehicle, industrial and telecom electronics applications.

The two series add advanced capabilities to Bourns' industry-leading shielded power inductor portfolio by increasing the width of the side terminal frame by more than 50 percent compared to existing Bourns® models without increasing the package size or required printed circuit board area. Bourns employs a uniquely-formulated metal alloy powder core and bonding agent and uses a molded construction manufacturing process where the magnetic shielded design allows for low radiation while the metal alloy powder core provides high saturation current. The high temperature-grade materials used enable a wide operating temperature range suitable for many types of harsh environment applications. The maximum operating temperature of +165 °C for these models is 10 percent higher than standard Bourns® Model SRP-A power inductors and they provide more headroom to maintain the rated operating current even under challenging environmental conditions.

www.bourns.com

SMT Kelvin Shunt Resistors

TT Electronics announced its LRMAP4026 series low resistance metal alloy power resistors designed for power supply, motor drive, and battery monitoring applications. This resistor series provides four-terminal Kelvin precision and high current capacity to all industrial applications, including automotive. Because four-terminal Kelvin connections improve precision, only a small portion of a design's error budget is consumed, enabling greater design freedom elsewhere in the circuit. The gullwing design provides spacing from the PCB which minimises the board temperature rise and enhances reliability of the assembly. "The electron-beam welded SMT shunt LRMAP4026 is the latest addition to TT's growing portfolio of SMT current sense resistors with AEC-Q200 qualification," said Brian Stephenson, Director of Engineering, TT Electronics. "This new series helps our customers achieve accurate and stable current measurement, providing resiliency to surges whilst controlling the amount of heat entering the PCB tracks." LRMAP4026 offers up to 5W in a 4026 footprint. Available in seven values from 0.2 to 3mΩ, LRMAP4026 gives designers a high degree of flexibility in a rugged component, featuring a wide temperature range of -65 to +170°C suitable for demanding applications. The four-terminal design allows complete separation of current path and voltage sense – reducing the difference between unmounted and mounted resistance and TCR values, a common problem with two-terminal types.



www.ttelectronics.com

Power Analysis Solution for SiC and GaN Applications

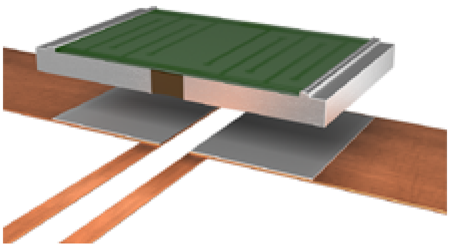
HIOKI launched its Power Analyzer PW8001 ideal for high power measurements at high frequencies. The high bandwidth and high-accuracy current sensors allow for unrivalled accuracy for example when developing state-of-the-art SiC and GaN applications. At the same time, best protection against external noise is guaranteed because of the highest Common Mode Rejection Ratio in the industry for both power analyzer and current sensors - also designed by HIOKI. The 15 MHz sampling rate and 18-bit A/D conversion result in extremely accurate measurements and waveform reproducibility.

A unique feature of the PW8001 is the automatic phase shift correction function (APSC). It allows to compensate for phase delay and enables accurate reactor or transformer loss measurements at high switching frequencies. Optional four motor inputs enable the complete analysis of multiple motor systems like drones, robotics or in-wheel motor drive systems of electric vehicles.

www.hioki.com

Low-ohmic Snubber Shunt for High Pulse Loads

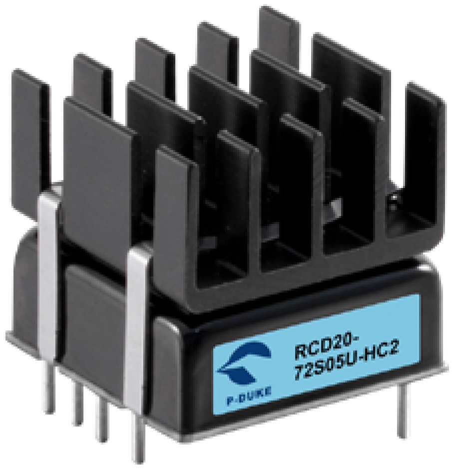
In the case of fast switching operations in power electronics, such as in the automotive sector, voltage peaks can cause inductances, which can damage or destroy sensitive downstream components in the circuit. To dampen these voltage peaks, a so-called RC snubber shunt can be used, which dissipates the excess energy outwards. Isabellenhütte has developed a powerful low-ohmic snubber shunt, SMT-V, which has a particularly high pulse power rating. The SMT-V developed by Isabellenhütte has a low resistance value at 17.5 mOhm and a very small compact design. It is based on the existing current measuring resistor SMT, which due to a very large Cu legs allows for a very good heat dissipation from the respective component and already has a high pulse power rating and long-term stability. The design and material of the new SMT-V, however, were adapted so that they can better withstand this particular pulse load. The development arose from a customer request, since no adequate standard component with this resistance value was available on the market. The special feature of this snubber shunt compared to other shunt series from Isabellenhütte is that it is not used for current measurement, but rather is intended to specifically absorb high pulse loads.



www.isabellenhuette.de

20W Railway approved DC/DC Converter with patented Hold-up Function

RCD20U is a DC/DC converter series that provides high performance and high reliability for railway and industrial applications. It comes in a compact 1"x1" industrial standard package and delivers up to 20W output power. These converters feature 8:1 and 12:1 ultra-wide input voltage ranges of 9-75VDC and 14-160VDC which simplify the design of the power stage of a system. Using just one DC/DC model converter for different supply voltages (24, 28, 36, 48, 72, 96, 110VDC) in different regions avoids multiple input voltage models in the warehouse.



The patented enhanced Hold-Up Function is designed to simplify the design of supply interruption and changeover as per EN 50155. Generally, to keep the device functioning during the supply voltage interruption or changeover, capacitors are required to be installed at the input terminals. The capacitance and rated voltage of the capacitors vary according to the supply voltage in use. The BUS pin of RCD20U provides a stable and fixed charging voltage which allows the usage of just one Hold-Up capacitor for any input voltages and in addition, reduces the in-rush current at the start-up phase.

This series includes single output and dual output models with 5, 5.1, 12, 15, 24, ±12, ±15VDC. It has various self-protection functions such as: over-current protection, output short-circuit protection, output over-voltage protection, adjustable input under-voltage lockout and over-temperature protection. By installing a heat-sink on the module these converters achieve the operating temperature class OT4 and the extended operating temperature ST1, as per EN 50155 standards.

www.pduke.com

eBook Untangles the Complexities of Electromagnetic Compatibility Design

Mouser Electronics announces an eBook in collaboration with Würth Elektronik, exploring the ways in which new electronic designs incorporate high-speed data transfer, connectivity, wireless power, battery management and near-field communication into a single device. In "Behind the Mystery of Electromagnetic Compatibility Design", subject matter experts from Würth Elektronik and Mouser offer rich analyses of some of the most important breakthrough technologies in electronic component design, and how those solutions can improve electromagnetic behavior.

While modern electronic designs have evolved to incorporate an increasing number of components and applications, they must still contend with the same electromagnetic environment that carries a huge risk of interference. The "Behind the Mystery of Electromagnetic Compatibility Design" eBook features four detailed articles plus product information for more than a dozen Würth Elektronik solutions, allowing readers to quickly find and learn more about the components needed for advanced electromagnetic compatibility design.

www.mouser.com

Fuse Provides 1000Vdc Automotive Grade Protection

Littelfuse announced the EV1K Series Fuses, an Automotive Grade fuse with a rating of 1000 Vdc. They are designed and tested to meet the overcurrent circuit protection needs of the eMoblilty market, specifically Electric Vehicle (EV) applications. There is a clear need for more robust safety solutions as the eMobility market transitions from 500 Vdc to 800 Vdc pack voltages," said Juergen Scheele, Vice President, Business Development xEV/AEB at Littelfuse. "The EV1K series fuses are designed to withstand severe automotive environments, providing 1,000 Vdc rated Automotive Grade solutions with amperages from 60 A to 125 A. Fuses up to 600 A are also under development." The EV1K series fuse is provided in bulk package of 60pcs per box.

www.littelfuse.com

Hot Swappable Power Supplies Simplify Installation of LED Horticultural and Commercial Lighting

Advanced Energy announced the introduction of the LCM4000HV series of configurable power supplies. The power system features hot swap functionality and simplifies installation, maintenance and scalability of high-volume LED lighting projects such as horticultural and commercial lighting.

Rated for up to 4000 W and operating with efficiencies of up to 95%, the LCM4000HV single-phase AC-DC high voltage power modules combined with the LCM12K 19" 1U rack mount shelf creates a centralized current source for medium- to large-scale LED lighting installations.

"Indoor growers seeking to reduce costs and maximize their farm productivity are turning to centralized power systems that distribute DC rather than AC power directly to individual LED lamps. This approach can save up to 50 percent of their power conversion expenses," said Joe Voyles, Vice President of Industrial Power Conversion at Advanced Energy. "In addition to delivering energy savings, the LCM4000HV family accelerates the installation of the power conversion subsystem, provides hot swap functionality, simplifies maintenance and enables rapid scalability."

The LCM4000HV modules are fully compliant with DesignLights Consortium (DLC) Technical Requirements for Horticultural Lighting (Version 2.1) and can be used with Advanced Energy's LCM12K 19" 1U rack mount shelf to deliver power up to 12 kW with hot plug replacement.

www.advancedenergy.com

CAD Mechanical Models, Schematic Symbols and PCB Footprints

Taiwan Semiconductor and SnapEDA are announcing the availability of a comprehensive library of CAD models for all TSC components. The library includes 3D mechanical models, schematic symbols, and PCB footprints. By creating a one-stop, comprehensive library of CAD models for the entire catalog of Taiwan Semiconductor components, printed circuit board designers will be able to complete projects faster and more reliably.

"Engineers are looking for ways to design electronic products faster and better using information they can access in real time, globally," said Vice President, TSC Products, Sam Wang. "By making our entire product line's footprint, symbols and 3D models available through an array of channels, we're doing our part to simplify the electronic designer's job and promote design-ins with TSC products."

The library, created and maintained by SnapEDA in collaboration with TSC, is accessible on the SnapEDA and TSC websites and automatically syndicated to TSC-authorized distribution channels, including Digi-Key and. Mouser.

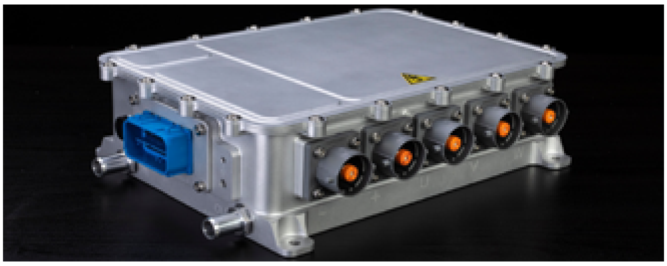
"Today's engineers want technical resources and documentation at their fingertips 24/7. This is driving them towards digital self-

serve product selection experiences," said Natasha Baker, CEO & Founder, SnapEDA. "We're thrilled to partner with Taiwan Semiconductor – a leader in automotive grade power electronics devices – to bring a seamless design experience to their website, as well as over 30 partner platforms via the SnapEDA ecosystem. By making Taiwan Semiconductor technical resources ubiquitous, we›ll help engineers design faster with their devices.

www.snapeda.com

800V Silicon Carbide Inverter

McLaren Applied's IPG5 is an 800V Silicon Carbide (SiC) inverter that supports ultra-fast charging and delivers high powertrain efficiency. It can power electric motors to over 350 kW peak, 250 kW continuous, at a weight and volume of 5.5kg and 3.79L respectively. It has been designed for automotive applications, including direct drive, that are capable of operating high-speed motors efficiently and adhere to ISO 26262 ASIL-D standards. For systems integrators, at 3.79L, IPG5 packages easily due to cutting-edge volumetric power density – a cost effective contrast to conventional inverters. The inverter can be offered without a case, which offers huge flexibility when packaging an off-the-shelf component into a custom system.



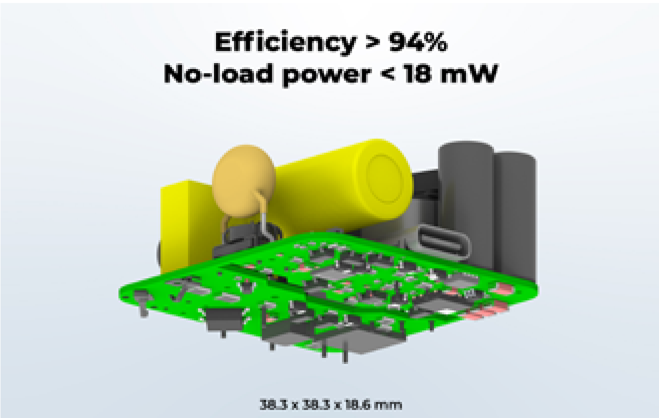
McLaren Applied is currently delivering prototype units to customers ahead of volume production from 2024.

Nick Fry, Non-Executive Chairman at McLaren Applied comments, "The launch of the IPG5 inverter is a huge milestone for McLaren Applied. We're delighted to advance to the next stage of development and to begin delivering prototypes to customers. Across the industry, we're seeing rapid progression of technology – if OEMs want to remain competitive and deliver vehicles with greater ranges, faster charging times and better acceleration, they must make the transition to an 800V Silicon Carbide architecture."

www.mclaren.com

Board with Silicon or GaN FETs and Proprietary Conversion Architecture

Eggtronic has announced an AC/DC demo and development board to speed the design, prototyping and implementation of power converters, power adapters and device chargers. The 35 W AC/DC development board is built using Eggtronic's EcoVoltas® QuarEgg+™ technology. Suitable for both USB-PD and fixed power output applications, the board is available with a gallium nitride (GaN) FET (for maximum performance) or a silicon FET (for cost-effective high-performance solutions).



Eggtronic developed the EcoVoltas proprietary, patented power conversion architecture to help engineers meet long-term goals on cost, size, weight and sustainability. The architecture boosts the performance of FET switching devices, whether they are based on legacy silicon or GaN and silicon carbide (SiC) wide bandgap (WBG) materials. EcoVoltas QuarEgg+ micro-sized, ultra-efficient power converters offer up to five times lower losses and are twice as small as traditional silicon converters and have up to two times lower losses and are 30% smaller than previous GaN converters.

The AC/DC development board combines the FETs with all of the components needed to deliver a working USB-PD or fixed-output converter. Peak efficiency is in excess of 94%, while a very flat efficiency curve ensures maximum efficiency and minimum power losses across the widest possible range of loads. By using the development board designers can also minimize so-called 'vampire power' thanks to a no-load power consumption that is below 18 mW.

www.eggtronic.com

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