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Electronics in Motion and Conversion

December 2017

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Events

Power Electronics Conference 2017
Munich, Germany, December 5
www.power-conference.com

SEMICON Japan 2017
Tokyo, Japan, December 13-15
www.semiconjapan.org

ForumLED Europe 2017
Lyon, France, December 13-14
www.forumled.com

EMC 2018
Düsseldorf, Germany, February 20-22
www.mesago.de/en/EMV/For_visitors/Welcome/index.htm

Respect Life on Earth

We are facing slow moving changes to our planet that inevitably impact our lives. Global warming is one such problem, pollution by radioactive material is another and it is among the worst, as it can create uninhabitable areas forever. Chemical pesticides have caused birth defects and cancer. This is the only world we have and we must be smart enough to keep it well. Our children must have a future for their lives, as for all the generations to come.

Thanksgiving has arrived and Christmas holidays will soon be here. We should be happy to have enough food and to enjoy peace but there is still too much war going on in our world. Our energies should be focused toward education for all the world's children. Education is the key to a better life for upcoming generations, and it's so sad to hear the numbers of kids that receive no education. UNICEF programs support children's education, and they deserve our contribution. That is why my holiday greeting cards are the ones that support UNICEF – it's an easy thing to do – I recommend it!

I recently visited productronica and SEMICON Europa in Munich. It is nice to see progress in semiconductor production and handling, as semiconductors become more and more important in our lives. Power semiconductors especially are key elements that reduce electrical consumption. And not only are new semiconductor materials important, energy storage is a wide field to drive new development. Electrical cars, available for all, will need batteries in large volume and with higher efficiency than those we have today. The associated passive components have to match the performance of Gan and SiC to achieve efficient systems.

In our field, Wide Band Gap semiconductors will make their contribution in system designs with significantly reduced losses. The future is design with SiC and GaN. For all design engineers that desire a more efficient future, I recommend attending the following event in Munich Germany:

Wide Band Gap Conference, December 5th 2017, Munich-Airport
Wide Band Gap semiconductors have become mature over the last decade. The trend is to replace silicon power switches with SiC and GaN. It is important that system design engineers get involved in advanced design work using wide band gap devices for their next project. Experts from semiconductor manufacturers and early users will describe their experience to help ease the transition to the new technology. For conference details see:
http://www.Power-Conference.com

A great group of experts will be presenting and discussing WBG applications. Book your seat now to remain at the frontier of technology for your next design project. I'm looking forward seeing you in Munich during the presentation.

Bodo's Power Systems reaches readers across the globe. If you are using any kind of tablet or smart phone, you will find all of our content on the new website www.eepower.com. If you speak the language, or just want to have a look, don't miss our Chinese version: www.bodospowerchina.com

My Green Power Tip for December:
You may have collected my printed magazine over the years. The ones you do not need can be used to build Christmas Ornaments to decorate your tree. This idea came from people of the Fraunhofer Institute – rest assured it's a good one.

Merry Christmas

Wide Band Gap Conference 5th of Dec 2017 Munich-Airport

Wide Band Gap is no Mystery

Bodo's Power Systems and ICC Media/AspenCore Europe are jointly organizing this Power Electronics Conference with focus on Wide Band Gap Semiconductors.

This 1-Day conference will take place on the 5th of December 2017 and will be held in the Hilton Hotel at Munich Airport Germany.

Parallel with the conference there will be a table-top exhibition which provides a communication platform where conference delegates and the exhibition visitors can talk to leading vendors of Power Electronics technologies.

The areas historically served by silicon devices have in recent years been taken over more often by Wide Band Gap Devices. The Power Electronics Conference is an excellent opportunity to meet experts and share expertise in bringing down barriers and overcoming reluctance to use these new semiconductors. Leading wide band gap companies together with companies from the test and measurement area will join us for a deep insight into designing with GaN and SiC.

www.Power-Conference.com

PCIM Asia 2018 Call for Papers

PCIM Asia, sister event of PCIM Europe in Nuremberg, Germany, offers unique opportunities to one of the fastest growing markets for power electronics. Established in 2002, PCIM Asia is the only specialised exhibition and conference platform in China for power electronics and their applications in the Asian market. From latest developments of power semiconductors, passive components, products for thermal management, new materials, sensors as well as servo-technology and the wide area of power quality and energy-management - PCIM Asia offers a comprehensive, focused and compact presentation of products all under one roof! Benefit from the success of such a well-established international exhibition with conference.

www.mesago.de/en/PCC/home.htm

Wireless-Charging Chip from STMicroelectronics Enables Faster Charging

STMicroelectronics is powering up wireless charging for mobile devices by introducing one of the world's first chips to support the latest industry standard for faster charging.

Nowadays, people are using their smartphones and tablets so intensively that many need to top up battery power several times a day. With wireless charging, users don't need to carry the charger or a bulky power bank, and can charge their electronic devices as fast as with a cable. Major mobile manufacturers are committing to wireless charging by joining the industry alliances and launching compatible products.

Users on the move, who put their mobiles down to charge for a few minutes – say, during a break or in a meeting -- need the device to be ready to go again when they are. To enable this, the Wireless Power Consortium (WPC) that manages the Qi specification -- a widely adopted industry standard -- has introduced the Extended Power profile for faster charging. By raising the maximum charging power from 5W to 15W, this new profile enables devices to be charged up to three times more quickly.

One of the market's first wireless-charging controllers to support Qi Extended Power, ST's STWBC-EP combines best-in-class energy efficiency, consuming just 16mW in standby and able to wirelessly transfer more than 80% of the total input power, with unique features created by ST to enhance the user experience. These include a patented solution enhancing active presence detection to wake the system quickly when a compatible object is presented for charging. The patented technology also enhances the performance of Foreign Object Detection (FOD), to cut power and prevent overheating if objects containing metals are brought too close to the charger. Other unique innovations enhance power control and energy transfer to maximize efficiency and ease of use.

"ST's Advanced Wireless-Charging chip enables manufacturers to create new, high-power products that offer superior features and efficiency," said Domenico Arrigo, General Manager, Industrial and Power Conversion Division, STMicroelectronics. "The Qi Extended Power support dramatically shortens charging time and our patented detection and safety innovations greatly improve safety and ease of use."

www.st.com/wbc

Rohm Intensifies Dialog with Customers During its SiC & Power Forum

Following its successful launch in 2015, the semiconductor specialist Rohm has established its SiC & power forum as a lively platform for professional exchange about products and market developments. Round about 90 customers and business partners traveled to Düsseldorf on 24th and 25th of October for a two-day program, to inform themselves about the trends and pitfalls of development, attend lectures and to discuss application scenarios and solutions in personal discussions. The response to the event, which took place at the Lindner Congress Hotel in Düsseldorf, was very positive:

"The energy-saving potentials that can be developed by the power electronics industry are estimated by scientists to account for 20 to 35 percent of the current demand for electrical energy. However, it is not enough to merely optimize the performance of individual semiconductor components in order to achieve optimal energy efficiency in power electronic systems. New system solutions, high-tech materials and innovative component concepts are necessary. That is why we keep close contact to our customers and jointly develop the power products of the future", said Christian André, President of Rohm Semiconductor GmbH. "The SiC & power forum offers us a unique platform to underline our competence in the market and to inform customers from all over Europe about the potential of Silicon Carbide (SiC)", André continues.

www.rohm.com/eu

PowerAmerica Call for Projects

PowerAmerica (the Institute) is part of Manufacturing USA. It is supported by the U.S. Department of Energy's Advanced Manufacturing Office (AMO) and investments from industry, state, university, and other partners. The Institute is a public-private partnership committed to increasing technical capabilities, domestic production, supporting manufacturing, and creating jobs across the U.S. wide bandgap (WBG) semiconductor industry. The purpose of the Institute is to accelerate the commercialization of WBG semiconductor power electronics. PowerAmerica is led by North Carolina State University in Raleigh, NC. This Call for Projects is focused on enabling U.S. industry to develop advanced wide bandgap power semiconductor devices, power electronics architectures and assemblies, and packaging and manufacturing processes with the potential to improve performance and lower cost. Demonstration of WBG devices in high volume, commercially viable, power electronic applications is also desired. The competition for wide bandgap semiconductors is essentially silicon power electronics. WBG proposals need to show not just clear technical advantages, but also the economic, operational, and system level cost benefits over silicon, in a given application.

PowerAmerica

The focus of the Institute is on projects that have a manufacturing strategy and additionally, help support the U.S. WBG supply chain.
Large-scale adoption of WBG power electronics is sensitive to pricing, perceptions of reliability, the availability of devices and modules, and the knowledge base of how best to design devices, modules, and systems that can exploit the superior physical characteristics of wide bandgap semiconductors. Furthermore, workforce development and education activities are critical for maximizing U.S. competitiveness as well as creating a pipeline of trained professionals to support this growing industry.

www.poweramericainstitute.org/2017-call-for-projects

Alpha Introduces TrueHeight® Preforms

Alpha Assembly Solutions is introducing ALPHA® TrueHeight® Preforms, a solder preform engineered with embedded spacer technology that can address all major applications requiring 75µm bondline and above. ALPHA® TrueHeight® Preforms are engineered with simplicity in mind to allow ease of implementation and maximum soldering performance. The architecture of the design not only addresses the bondline thickness requirement, but also reduces the opportunity for voiding. The design minimizes areas where gases can be trapped, compared to other technologies, during the reflow process.

"Engineers can be confident of achieving their design goals during manufacturing when using ALPHA® TrueHeight® Preforms", said Eric Poh, Regional Product Manager for Solder Preforms at Alpha Assembly Solutions, a part of the MacDermid Performance Solutions Group of Businesses. "TrueHeight® Preforms have the advantage of flexible spacer positioning, so strategic locations can be chosen to ensure consistent bondline thickness".
ALPHA® TrueHeight® Preforms can be flux coated as well from a wide selection of fluxes.

www.alphaassembly.com/Products/Preforms

Power Integrations Expands Asian Presence

Innovative power-IC company opens facility in 'Silicon Valley of the East'

Power Integrations announced the opening of a new location in Penang, Malaysia. The facility will serve as a production-support and R&D center as well as an operations hub from which the company will manage its Asian supply chain. The Penang office further expands Power Integrations' global footprint, which includes R&D centers in Silicon Valley (where it is also headquartered), Canada, Switzerland, and the UK, as well as design-support centers in the Philippines and Germany, and 19 field labs worldwide. The company officially opened the facility earlier this month with a ceremony officiated by the Rt. Hon. Mr. Lim Guan Eng, Chief Minister of Penang. Speaking at the opening, Balu Balakrishnan, Power Integrations' president and CEO, explained the company's decision to locate the new facility in Penang: "Although we are a Silicon Valley company, we are also becoming more Asian in our culture and focus. This reflects the fact that Asian customers account for a large percentage of our sales, and that our supply chain - foundry, assembly and test – is based predominately in Asia. Penang offers a strong pool of engineering talent and a supportive business climate, particularly for technology companies such as Power Integrations. Where better, then, to set up shop than the 'Silicon Valley of the East'?"

www.power.com

Semikron Innovation Award & Semikron Young Engineer Award

The Semikron Innovation Award and the Semikron Young Engineer Award is given for outstanding innovations in projects, prototypes, services or novel concepts in the field of power electronics in Europe, combined with notable societal benefits in form of supporting environmental protection and sustainability by improving energy efficiency and conservation of resources. Both prizes have been initiated and are donated by the Semikron Foundation which is awarding the prizes in cooperation with the European ECPE Network. With the award the Semikron Foundation wants to motivate people of all ages and organisations of any legal status to deal with innovations in power electronics, a key technology of the 21th century, in order to improve environmental protection and sustainability by energy efficiency and conservation of resources. The Semikron Innovation and Young Engineer Prizes 2018 will be awarded in the frame of the ECPE Annual Event in March 2018 in Stuttgart. A single person or a team of researchers can be awarded.

www.ecpe.org

www.semikron.com

BMZ Central Service Offers Battery Recycling

The BMZ Group offers a unique return and recycling service for lithium ion batteries in any EU member state. "For customers of the BMZ Group worldwide, the advantage is that they can receive all of the services their business needs from a single source," explains Sven Bauer, CEO & Founder of the BMZ Group in Karlstein a.M. From development to construction, hardware and software, cell sourcing and battery returns, the customer can obtain all services throughout the entire supply chain from BMZ. "In our after sales service, BMZ offers long warranty periods, long replacement part availability, loaner batteries, and battery recycling. The BMZ Central Service offers customers access to battery disposal and recycling experts by telephone and by mail," Bauer explains.

BMZ GmbH has been working with the European Recycling Platform for many years to secure valuable materials for the future. Each battery has a limited life span, which means they become unusable after a certain time period and must be disposed of. Most types of batteries contain poisonous heavy metals such as nickel, cadmium, or mercury. All of these heavy metals can be reclaimed and reused. Recycling means saving valuable raw materials and energy, saving limited space, securing a healthy environment and a better quality of living, and reducing health hazards for ourselves and for future generations.

www.bmz-group.com


One Hitachi.
Endless Possibilities.
HITACHI
Inspire the Next
High Voltage IGBT Robust. Reliable. Reputable.
Hitachi Europe Limited, Power Device Division email pdd@hitachi-eu.com

Special Session on Digital System Design and Integration

The Integrated Power System (IPS) on electrical platforms are comprised of complex power architectures. As the system architectures grow in their complexity, current design and integration approaches tend to be limited in their scope as to how the system will operate dynamically under various operating conditions. To study these inter-operational dynamics a multi-tiered digital twin simulation strategy must be employed. The digital replica of the host platform would be able to track the design, integration and operation of the platform from its conception right through its entire lifecycle.
In recent years set-based design and total system simulation/emulation have proven to be critical in understanding the total system dynamic, which has resulted in reducing costly expenses sustained in post-integration system testing and commissioning. As part of this effort the concept of total digital system design (also known as Digital Twin or Digital Thread) has allowed the developers and integrators to address some of the most complex and challenging engineering issues.
This panel discusses the opportunities, examples and challenges associated with the introduction of a multi-faceted digital system design for highly integrated systems.
TOPICS OF THE SPECIAL SESSION

- Digital Twin (total digital system design)
- Digital Integrated Power System Development,
- Communications/command/ control /data / security (C4DS) Network simulation,
- Simulation methodologies in network and system synthesis,
- Simulation of system network and associated viabilities.
- The inter-operability of the power architecture and computer network system.

Submission of provisional full papers: 20th November 2017 Notification of acceptance: 20th February 2018 Submission of final full paper: 30th April 2018

www.speedam.org/?page_id=957

International Symposium on 3D Power Electronics Call for Papers

The Power Sources Manufacturers Association (PSMA) is pleased to announce that the Second International Symposium on 3D Power Electronics Integration and Manufacturing will be held June 25-27, 2018, in College Park, Maryland. Engineers and researchers interested in being Lecture and Dialog Session presenters are invited to submit abstracts for review through the Call for Papers section on the symposium's website (www.3d-peim.org/call-for-papers).
Design and manufacturing professionals from the world's leading packaging and manufacturing societies and associations will come together at 3D-PEIM to address the future of integrated power electronics design and to advance the 3D power electronics systems of the future. Members of the worldwide electronics community interested in presenting should submit their abstracts by December 15, 2017.
The 3D-PEIM symposium is underwritten by the PSMA as part of their ongoing commitment to educate and inform the power electronics industry. Other supporting organizations include the IEEE Electronics Packaging Society (IEEE/EPS), North Carolina State University, the University of Maryland and Virginia Tech. "This symposium is all

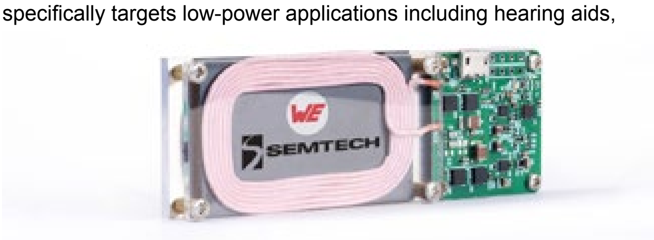
3D-PEIM
INTERNATIONAL SYMPOSIUM ON 3D POWER ELECTRONICS INTEGRATION AND MANUFACTURING

about developing new approaches and technologies for designing and manufacturing power sources," said General Chair of 3D-PEIM Patrick McCluskey, PhD., Professor of Mechanical Engineering and Leader of the Electronic Products and Systems Division at University of Maryland, College Park. "Tutorials and technical sessions will cover the latest developments in electro-thermo-mechanical co-design, additive manufacturing, embedded circuits, materials, and system integration."

www.3d-peim.org

Würth Elektronik eiSos Supplies Wireless Power Coil for Semtech's LinkCharge®

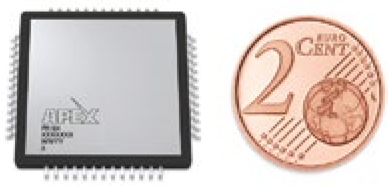
Würth Elektronik eiSos announced its collaboration with Semtech Corporation by integrating its transmission coil, WE-WPCC, with Semtech's LinkCharge® LP (low power) platform, an innovative wireless charging solution that concurrently charges multiple, low-power devices using a single transmitter. The WE-WPCC series transmission coil excels with its NiZn ferrite shielding to protect sensitive electronics and concentrate the magnetic field. The coil is specially designed for resonant inductive coupling and allows several receivers to be used at the same time. Semtech's LinkCharge LP (TSWITX-5V-2RX-EVM), featuring Würth's transmission coil, provides positioning and spatial freedom that allows for charging of multiple devices. The platform delivers one-watt of output power to charging devices and specifically targets low-power applications including hearing aids,



activity trackers, smart headphones, smart jewelry and clothing, low power industrial, portable medical equipment, and LED fixtures.
"The Semtech LinkCharge LP wireless charger represents exemplary use of our high-grade coils and we are pleased about this important reference," explains Jörg Hantschel, Business Development Manager Wireless Power at Würth Elektronik eiSos. "The coil used in LinkCharge LP is also suitable beyond the Qi standards, which primarily focus on consumer electronics."
"Semtech's LinkCharge LP platform was designed to enhance the overall user experience by allowing people to charge multiple devices at once without the hassle of cables," said Ruwanga Dassanayake, Power Management Product Line Manager for Semtech's Power and High-Reliability Products Group. "Würth Elektronik's WE-WPCC transmission coil is a key component of LinkCharge LP and makes it possible for our solution to give our customers a unique experience."

www.semtech.com

www.we-online.com

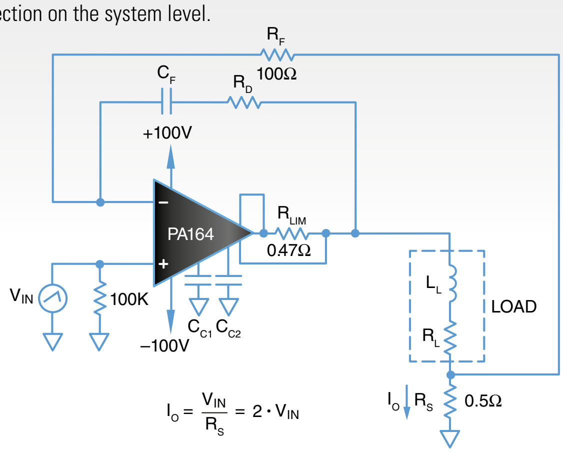


Size Does Matter!

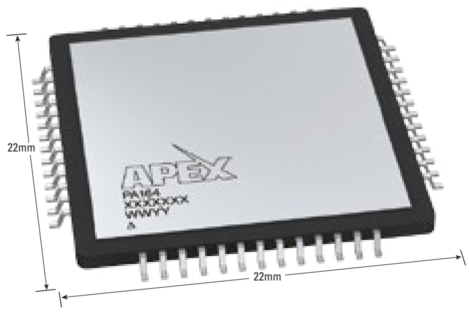
High Density, Multi-Purpose Power Amplifiers Pack New Levels of Performance in a Compact Footprint

NEW ICs RATED 10A PEAK ON 200V SUPPLIES

The PA164, PA165 use proprietary monolithic MOSFET technology and an advanced silicon design to deliver 1A (PA164) and 4A (PA165) output current continuously, and up to 10A PEAK (PA165). Putting this much power in a very small QFP package could mean thermal management challenges. However, power dissipation is decreased by having separate supplies for the amplifier core and output stage, thus allowing a wider output voltage swing. Also, heat sinking capabilities a further enhanced through a large exposed metal top side. This packaging design allows for the efficient heat sinking of individual devices, as well as the mounting of one large heatsink over an "array" pattern of ICs. Additional onboard system protection includes a user-defined, temperature compensated current limit and a temperature sensor output. An output disable function and an over-current flag simplify the implementation of robust failure protection on the system level.



FLOATING LOAD VOLTAGE-TO-CURRENT CONVERSION CIRCUIT



SURFACE MOUNT WITH HEAT SLUG ON TOP
52-PIN QFP PACKAGE STYLE

Footprint 22mm x 22mm

Power up at apexanalog.com/BodoPA164

apexanalog.com/BodoPA164

APEX MICROTECHNOLOGY

IEEE Energy Conversion Congress and Expo - ECCE 2017

ECCE, the premier global conference covering topics in energy conversion provides opportunities for practicing industry engineers, researchers, and students to exchange technical knowledge, network and develop new skills.

By Gary M. Dolny, US-Correspondent Bodo's Power Systems, gary.dolny.us@ieee.org

The 2017 IEEE Energy Conversion Congress and Expo, ECCE, took place from October 1-5 at the Duke Energy Convention Center, Cincinnati, OH, USA. Driven by the growing importance of energy conversion, the annual ECCE conference was initiated in 2009, when the IEEE Power Electronics Specialists Conference merged with the Industrial Power Conversion Systems Department Sessions of the Industry Applications Society Annual Meeting. Since then, the conference has shown steady growth in both number of submissions as well as attendees, with this year's conference attracting 1565 energy conversion professionals, researchers, and students. Co-sponsored by IEEE Power Electronics Society and Industry Applications Society, and with support from Industry Partners Wolong Electric, GE Aviation Systems, and General Motors, ECCE continues to expand its program to address the needs of the entirety of the profession.

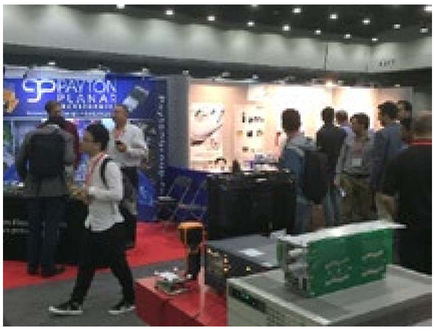


Figure 1: Attendees visit some of the 50 exhibitors during the ECCE Exhibit Hall reception

This year's conference featured a technical program chosen from 1504 digests submitted from around the world. After an intensive peer-review process by 3-to-5 experts in the field, 864 papers were selected for presentations which were organized into 16 parallel tracks of oral sessions each day of the conference plus 3 poster sessions. The resultant 57% acceptance ratio ensured that all the topics and results presented were of high technical quality. All technical papers presented at ECCE will be uploaded to the IEEE Explore Digital Library and will thus be available to the larger research community worldwide.

In addition to the contributed papers the conference featured numerous other venues for professional networking and knowledge exchange. These included special panel sessions, interactive town-hall sessions, tutorials, as well as plenary talks and a large and well-attended vendor exhibition. Networking opportunities included a welcome reception, a Monday evening reception in the exhibit hall, and a conference banquet.

A new feature this year was that the ECCE was co-located with the IEEE Industrial Application Society Annual Meeting. Attendees had the option to register for the ECCE alone or to jointly register for both conferences for both at a reduced rate. This co-location offered attendees the possibility to engage in two programs promoting the growing energy conversion field.

The conference began on Sunday October 1, with a series of 11 tutorial sessions. These sessions featured in-depth discussion of emerging technologies and design techniques on various topics that pertain to the scope of ECCE. Areas of interest this year included topics in converter design, SiC devices and modules, electric machine analysis and wireless power transfer. These sessions emphasized solutions to practical technical problems and were directed toward both students and practicing engineers in the field.

This year's ECCE featured an emphasis on the challenges of aircraft electrification and the solutions that advanced power electronics can provide. This was inspired by the close proximity of the conference site to Dayton, Ohio, home of the Wright Brothers and their trailblazing impact on the aviation industry. The theme was emphasized in the conference plenary session, which featured three keynote presentations on focused topics such as hybrid electric propulsion, and the technologies needed to further advance aircraft with the goals of reducing fuel consumption, noise, and carbon emissions. The plenary speakers presented a seamless vision of the future of aviation as well as challenging the attendees with the mission of creating our aviation future today.

The theme of aircraft electrification was carried into the ECCE special sessions. These sessions consisted of oral presentations only and focused on the latest industrial trends. Four sessions were devoted to topics on aircraft electrification, while others addressed wide-bandgap devices, power electronics applications in utility systems, workforce development and magnetic materials.

A particularly relevant special session presentation was organized by the Power Electronics Industry Collaborative and focused on workforce development and careers in power electronics. The session brought together a cross-section of original equipment manufacturers, material and component suppliers, national laboratories and universities to discuss key problems and opportunities they face in attracting engineering talent to support future design, innovation, and manufacturing needs in this rapidly growing industry.

Wide-bandgap semiconductor devices are at the leading edge of new designs for reduced losses and increased systems efficiency and the interest in these devices continues to grow. This interest was reflected in the ECCE technical program which featured 14 sessions on GaN and SiC devices and their utilization in a wide range of applications.

The low conduction loss and fast switching capabilities of gallium nitride (GaN) based power devices has led to a strong interest in their use as a replacement of silicon devices in power electronic converters for high-frequency applications. However, a major concern is that the high switching speed (dv/dt and di/dt) of GaN devices will lead to parasitic oscillations, increase the EMI emission, and give rise to parasitic turn-on and shoot-through. A number of technical presentations addressed these important issues and proposed solutions to mitigate these problems without compromising GaN's benefits.

Zhao et. al. of Beijing Jiaotong University Beijing, China, studied the operation of cascode-type GaN devices in bridge applications. Based on measurements from a double-pulse circuit, this paper identified two mechanisms for initiation of uncontrollable oscillations One is that large dv/dt and di/dt can cause the driving-side false trigger of the passive transistor by coupling through the gate-to-drain capacitance and parasitic source inductance at high frequency. The other is the fundamental influence of the depletion-mode GaN device in the cascode structure. The paper proposes connecting a ferrite bead in the high frequency loop of the passive transistor as a method to suppress these oscillations [1].

Matsumoto et. al, of Okayama University Okayama, Japan proposed a novel design approach to prevent the oscillatory false triggering. Through use of an analytic model they concluded that oscillatory false triggering can be prevented by designing the ratio of source inductance to gate-drain capacitance within an appropriate range determined by device and circuit parameters. This leads to the surprising conclusion that too small a source inductance can cause parasitic oscillations as well as too large a source inductance. The value of the source inductance needs to be optimized, but not necessarily minimized. This conclusion was verified through experimental measurements [2].

Ishawaki et al. of Shimane University, Shimane, Japan proposed addressing the false turn-on problem by focusing instead on the gate peak voltage. Using a somewhat different analytic approach focusing on balancing the resonance frequencies of the drain and gate wiring path, the RL time constant of the drain and gate loop, and RC time constant of the drain and gate loop, they also concluded that an extremely small source inductance should be avoided in order to minimize false turn-on [3].

SiC technology continues to rapidly mature and as a result multiple conference sessions addressed SiC technology and applications advances. J. Zhang et. al. from Wolfspeed Inc., Durham NC, USA, described a 125 kW photovoltaic converter fabricated using next generation 1700V SiC MOSFETs. These devices exhibited Rds reductions of 50% compared to existing commercial SiC devices. Their design also eliminated the external SiC Schottky diode in favor of using the MOSFET internal body diode during the dead time. They demonstrated increased current rating at operating temperature from 225A to 300A, compared to a previous generation module while maintaining 99% efficiency [4].

A group from IK4-IKERLAN Technological Research Centre, Arrasate-Mondragon, Spain presented the first DC-DC full-SiC converter for railway application which acts as an interface between the DC-link catenary and the energy storage system. The full SiC converter demonstrated a total size reduction of 30%, with a 73% reduction in the inductances, and a 40% reduction in the heatsink. The reduced switching losses of the SiC modules enabled a 10x increase in switching frequency with lower overall power losses compared to an all Si implementation [5].

A group from ABB Research Västerås, Sweden, performed a direct comparison between 3.3 kV/ 400 A SiC MOSFET modules to their Si IGBT counterparts. With a constant current of 400A the SiC modules showed a 1.3V lower voltage drop than the Si IGBT modules. At a supply voltage of 2000V and temperature of 300K, the SiC offered 7.5x reduction in switching losses. However, the SiC MOSFETs failed a short-circuit test performed for a supply voltage VDS=1500 V for 4 µs at 300K due to thermal runaway. The typical Si-IGBT modules were capable to withstand 10 us. The results presented demonstrated performance advantages of the SiC MOSFET with indication that SiC technology has the potential to replace Si-IGBT of similar current and voltage ratings for a diverse range of power applications. However, protection circuits with reduced response time must be developed for SiC MOSFETs in order to accommodate the reduced withstand time to short-circuit conditions [6].

As wide-bandgap materials receive increasing acceptance in high-volume commercial applications understanding and guaranteeing acceptable lifetime and quality levels is an increasingly important requirement. A number of presentations addressed these issues as they relate to both GaN and SiC.

Böcker et. al. from Technische Universität Berlin addressed the well-known dynamic Ron increase in GaN HEMTs in buck converter applications. They noted that the two common mechanisms for Ron increase, temperature and charge trapping both exhibit similar time constants. It is thus difficult to separate the impact of the two effects in a practical application. Since the increase in on-resistance is dependent on many application specific factors including duty cycle, operating frequency, maximum current, maximum voltage and thermal design, a comprehensive experimental loss-analysis for different operating points is required to ensure safe operation. [7]

Li et. al, of Ohio State University, Columbus, OH, USA, presented a series of measurement results on the short-circuit robustness of 650 V E-mode GaN HEMTs' short circuit capability and degradation at various test conditions. Their devices passed the 10 µs short circuit tests for Vdc lower than 350 V but failed at Vdc higher than 375 V within hundreds of nanoseconds [8].

Ugar and Aiken presented a comprehensive reliability and aging analysis of SiC MOSFETs for high temperature applications. They tested devices through repeated exposure to accelerated power cycling, Their measurements indicate that on-state resistance, body diode voltage and gate threshold voltage increase continuously with aging and therefore can be used as failure precursors to estimate the remaining useful lifetime of the power devices. Subsequent analysis indicated that the cause of the degradation to mechanical stresses in the packaging [9].

The 2018 ECCE will be held from September 23-27, 2018 at the Oregon Convention Center, Portland, OR, USA. Once again, ECCE 2018 will co-locate with the IEEE IAS Annual meeting. Attendees will be able to choose to register for ECCE alone, or to jointly register for ECCE and the IAS Annual Meeting at a reduced combination rate

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From Science Fiction to Industry Fact: GaN Power ICs Enable the New Revolution in Power Electronics

Forty years ago, in 1977, two major events changed the lives of many engineers: the movie "Star Wars" was released, and there was a revolution in power electronics. By 2017, we have had many Star Wars movies, many more new engineers and finally, the next revolution in power electronics.

By Stephen Oliver, Lingxiao Xue, Peter Huang, Navitas Semiconductor

Back in the late 1970's, the power electronics industry experienced an extraordinary and disruptive change, with the introductions of new switch technology, new integrated controllers, improved magnetics and the industry validation of previously academic-only power topologies.

The silicon bipolar-junction transistor was surpassed in on-state and switching performance by the development of commercial power MOSFETs such as International Rectifier's 'HEXFET'. With the new, 'fast' powertrain components came advances in magnetic materials. Now, switching regulator topologies or 'switched-mode power supplies' (SMPS), challenged the dominance of traditional linear regulators which had utilized bipolar transistors since the beginning of the electronics era, offering the promise of higher efficiencies, higher densities and possibly even lower cost. Initially, however, they were complex to design and the power industry was unfamiliar with and wary of these new "fast" converters. Device integration, in the form of analog application-specific ICs (ASICs) developed by Silicon General, Unitrode & others, was the catalyst to enable simple, cost-effective and industry-proven designs.

In the following decade, the power supply industry experienced a 5x increase in power density, a 5x reduction in losses and a 3x reduction in costs (Figure 1). The next 30 years saw incremental improvements - for example Si superjunction devices, synchronous rectification, resonant topologies - but no performance shifts as dramatic as the first revolution.

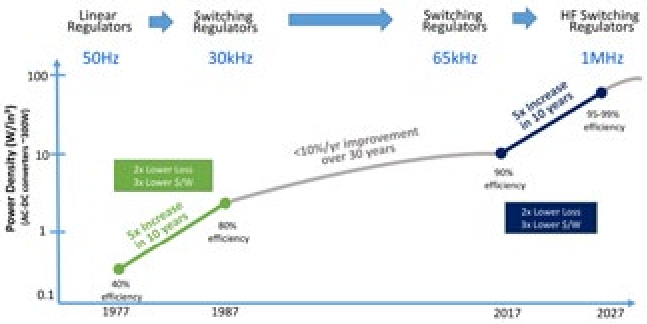

Figure 1: Revolutions in converter speed (switching frequency), performance (efficiency, power density).

Today in 2017, we are again at the start of a new performance revolution, with wide bandgap materials, enhanced high-frequency magnetics, new controllers, enabled topologies and device integration.

Wide Bandgap Gallium Nitride

Gallium Nitride (GaN) is a 'wide bandgap' (WBG) device. This refers to the energy required to free an electron from its orbit around the nucleus and allow it to move freely through the solid. The bandgap determines the electric field that the solid is able to withstand. Si has 1.1 eV, and GaN has a bandgap of 3.4 eV. As WBG material allows high electric fields, depletion regions can be very short or narrow, so device structures can have high carrier density and be packed very densely. A typical 650 V lateral GaN transistor can support over 800 V and has a drain drift region of 10-20 um, or about 40-80 V/um. This is substantially above the theoretical limit of silicon at about 20 V/um, but still well short of the bandgap limit of about 300 V/um. This leaves substantial room for generational improvements in lateral GaN devices in the future. In device-level terms (normalized $R_{DS(ON)}$ x Q_G), GaN can be 5x-20x better than Si, depending on implementation [1].

GaN has been used in light-emitting diode form since the 1990s, in Blu-ray players introduced from 2003 and in RF transmitters / amplifiers. GaN transistors can operate at much higher temperatures and work at much higher voltages than gallium arsenide (GaAs) transistors, so they make ideal power amplifiers at microwave frequencies.

For switch-mode power supplies, power GaN took another 10-15 years to evolve from academic curiosity to industry-proven platform. Substrate selection and the development of low-defect GaN epitaxy have been major issues. Originally, power GaN devices were developed on the same substrate material as LEDs and RF devices, primarily sapphire and silicon carbide respectively. Even with GaN's die-size advantage due to very low specific on-resistance (0.2-0.5 Ohm-mm^2 at 650 V today) compared to state-of-the-art silicon superjunction technology (1-2 Ohm-mm^2), this led to extremely expensive prototypes. Lateral devices were prototyped and GaN-on-SiC showed promise due to improved thermal performance but devices were still too expensive for power applications. Devices using 4" (100mm) GaN-on-Si wafers were developed, applying lessons learned from early RF transistor attempts to achieve lower cost. Initially, these devices were limited to depletion mode (dMode or 'normally-on') types and suffered from the current collapse or dynamic $R_{DS(ON)}$ phenomenon, and trap-related long-term stress instability that prevented their

adoption. Finally, 6” (150 mm) production-quality GaN-on-Si wafers have become available for high performance enhancement mode (eMode or normally off) lateral GaN devices, using existing foundry processes. The result is the manufacture of high-volume, cost-effective switches and power ICs.

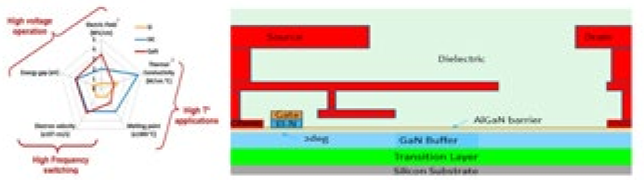

Figure 2: GaN device performance vs Si, SiC, and AllGaN™ GaN-on-Si device cross-section.

For lateral GaN, a two-dimensional electron gas (2DEG) with AlGaN/GaN heteroepitaxy structure (see Figure 2) gives very high mobility in the channel and drain drift region. A 2DEG is the result of the difference in bandgap voltage between the two layers, which induces a quantum well at the interface. This well collects electrons in a sheet of charged carriers that are free to move laterally with extremely low resistance. The lateral device structure achieves extremely low gate charge (Qg) due to the very small fraction of the area covered by the gate. The output charge Q_{OSS} determines the amount of energy required to switch the output state of the transistor and is also very low, due to the small size of the transistor, the insulating GaN epi layer, and the short drain drift region enabled by the high critical electric field.

High-Frequency Magnetics
The revolution of the late 1970’s involved a leap from slow, line-frequency (47-63 Hz) magnetic materials to (at that time) ‘high-speed’ ferrites capable of handling energy efficiently at 10’s of kHz. Even today, the vast majority of off-line power converters still switch at 65 kHz – 100 kHz due to several perceived challenges; the first being awareness of available material. In fact, several companies have introduced high-performance, MHz-switching ferrites over the last 10-15 years, as shown simply in Figure 3, and a comprehensive review and formulation of a modified magnetic performance factor has been introduced by researchers at MIT [2].

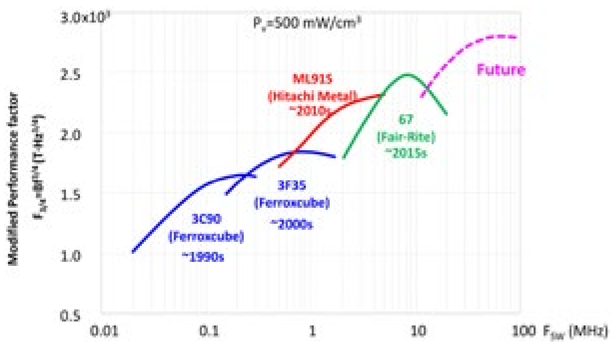

Figure 3: Advances in magnetic materials vs. frequency and time.

EMI is another factor in frequency selection, as the EN55022 regulation has a drop in allowed conducted radiation at 150 kHz, so care must be taken in reference to the second harmonic of the primary switching frequency. However, with careful transformer design, high-frequency systems can be made both to comply with regulations and simultaneously, due to the high frequency, use smaller, cheaper EMI filters [3].

Another factor has been the lack of a fast switch, addressed earlier, and the scarcity of high-frequency controllers, to which we will now turn.

High-Frequency Controllers
For academics investigating and inventing new, high-speed topologies, the availability of high clock-rate digital signal processors (DSPs) offers a convenient way to implement and evaluate new concepts. High-speed, full-power efficiency can be assessed and new power-density metrics achieved [4]. The same DSPs are also used in high power, generally 1kW+, systems which are focused largely on efficiency at medium or full load conditions, achieving various ‘Energy Star’ ratings for server systems. However, in the mobile and consumer markets, a different set of legislative efficiency standards [5], such as the US Department of Energy’s Level VI and the European Union’s Certificate of Compliance (CoC) Tier 2 apply, and where the cost and high standby power draw from DSPs make them unusable. Here, dedicated ASICs are needed to address simultaneous performance and cost concerns.

We have addressed high-power (1 kW+) systems above. For mid-power systems, recent PFC and LLC controllers are commercially available to increase switching frequency by 2x-4x today with further advances on the roadmap. For low powers (20-65 W), new, high-frequency Active Clamp Flyback (ACF) controllers are sampling now and will be in production in 2018.

New Topologies
As the 1970’s saw the tectonic shift from slow, linear supplies to ‘fast’ switched-mode power supplies (SMPS), today’s change is also enabled by ‘academic-only’ topologies (complex, hand-crafted, large, expensive) becoming accepted industry standard practice, with high-performance, low-cost ASICs and complete understanding and validation across all necessary real-world operational conditions and power supply reliability and test procedures.

Resonant topologies have also been around almost as long as electricity has been available to use, but their adoption has been limited to a relatively narrow application space. With GaN FETs, resonant circuits can enable a dramatic increase in switching frequencies while increasing energy efficiencies compared to hard-switching topologies, creating another dramatic increase in power densities. Past resonant designs were complex and expensive. Some, such as LLC and ACF converters, require a second high-performance transistor and fast high-side level-shifters & gate-drivers to create zero voltage switching (ZVS) over the full operating range. Now, just as analog ASICs simplified and lowered costs of the early switching regulators, GaN power ICs are available to integrate the high-side switches, level-shifters & other critical analog circuits to simplify high-frequency resonant designs and deliver system costs that are lower than their low-frequency, hard-switching counterparts.

At high power levels, the hard-switching constant-current mode (CCM) power factor correction (PFC), whether in simple boost format or in ‘bridge-less’ or ‘totem-pole’ variations can be converted to soft-switching critical-conduction mode (CrCM), also known as boundary conduction mode (BCM) and free the converter to run at high frequencies to shrink inductors. At the same time, this highlights another benefit of eMode GaN vs. superjunction Si, in that GaN’s extremely-low Q_{OSS}, E_{OSS} figures of merit enables cool running in stark contrast to Si’s non-linear capacitance and extreme overheating at increased frequencies [6].

Device Integration

In the 1970's, device integration meant the introduction of commercially viable controllers to replace discrete operational amplifiers and a host of resistors and capacitors. Initially, this was for ease-of-use but became essential for system performance and then cheaper than the bag of parts replaced. In 2017, this integration addresses the complexity, weakness and cost of controlling and driving discrete GaN FETs.

The earliest GaN power devices were dMode (depletion mode) which meant that they needed an additional Si FET in 'cascode' to keep them off, with subsequent negative results in packaging inductance and cost. Later, eMode (enhancement mode) GaN discrete devices had vulnerable gates and a very low threshold voltage. This made them very susceptible to noise and voltage spikes due to high-frequency and high dv/dt noise from the surrounding switched-mode converter circuit, so required complex and expensive control and gate drive circuits [7]. Additionally, both implementations restricted the high-frequency performance of the GaN switch, to the point where there was minimal, if any, advantage over Si, so limiting market adoption.

First demonstrated at APEC 2015, AllGaN™ is the industry's first GaN Power IC Process Design Kit (PDK) which allows monolithic integration of 650V GaN IC circuits (drive, logic) with GaN FETs [8]. Other functions can also be included, such as hysteretic digital input, voltage regulation and ESD protection – all in GaN, as shown in Figure 4. This monolithic integration of drive and switch is impossible using vertical GaN, dMode GaN or SiC.

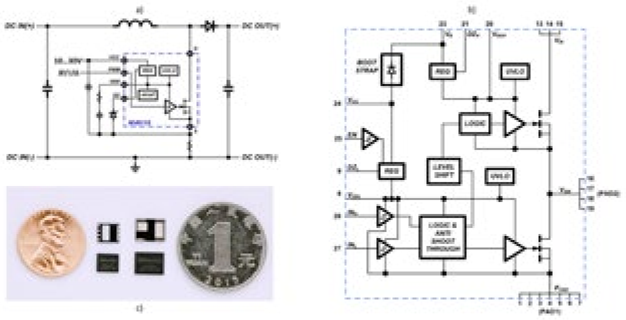

Figure 4: a) Single GaN Power IC with AllGaN monolithic integration of FET, drive and logic, b) Half-Bridge GaN Power IC adds level-shifter, bootstrap-charging circuit, shoot-through protection, etc., c) QFN packages for single (5x6 mm) and half-bridge (6x8 mm) GaN Power ICs.

Now, device integration means that the eMode GaN gate has a precisely-controlled drive voltage to ensure optimum device performance while at the same time – and with no gate-drive loop impedance ensures fast, controlled switching, and as a bonus, the gate is internal to the power IC structure, protecting it from any external or parasitic-induced noise [9]. For this revolution, integration not only makes it simple for the power designer, it also makes it work.

Using the AllGaN PDK, single 650 V-rated GaN Power ICs have been introduced with all the benefits of high-performance eMode GaN (low $R_{DS(ON)}$, low Q_G, zero t_{rr}) but now with the essential advantages of a power IC, for example 1 kV ESD protection, robust 200 V/ns dV/dt slew-rate capability and programmable dV/dt. Taking the concept still further, complete, 2 MHz-rated half-bridge GaN Power ICs have been introduced with two FETs, two drivers, level-shifter, bootstrap charging, shoot-through protection, and many more features, as shown in Figure 4b [10]. In all cases, the power ICs approach the concept of the 'ideal switch' with excellent on-state and switching performance. With standard 3.3 V, 5 V or 12 V low current logic inputs – they are flexible, 'digital-in, power-out' functional building blocks.

In addition to speed and control benefits, the integrated GaN level-shifter enables a smaller, higher-efficiency and lower-cost solution vs. inductive- or capacitive-coupled techniques, to the ubiquitous high-voltage half-bridge circuits found in the majority of modern applications [11]. A 20x reduction in PCB area and an 80% reduction in parts-count can be achieved [12].

Now all of the elements are in place, let's look at a practical example for the new power electronics revolution, with a special focus on a high-volume consumer / mobile application with extreme performance, legislative and cost demands.

A Revolutionary Converter

While laptop computers have advanced tremendously in cost, capability and features over the last 10-20 years, the AC-DC power adapter or 'brick' has largely remained large and heavy, still utilizing low-frequency, hard- or quasi-hard-switching topologies, slow Si FETs and large magnetics, with efficiencies around 85%-90% (at 90 V_{AC}, full load) and power density around 5-10 W/in^3.

As market demand for small size, plus the ease-of-use / flexibility of Universal Serial Bus Type C Power Delivery (USB-PD) has increased, along with simultaneous legislative efficiency requirements such as DoE Level VI and Euro CoC mean that the designer staying with old, slow Si-based switching topologies is forced into more extreme and complex construction / thermal techniques with increase costs.

Thankfully, the new revolution in power conversion liberates the designer from their struggle. Let's revisit the elements of switch, magnetics, topology, controllers and integration and how they combine to achieve a performance breakthrough for a 65 W, USB-PD laptop adapter.

For converters up to 65 W (the adapter PFC/THD threshold), the Quasi-Resonant Flyback (QRF) has been the dominant solution but its inherent snubber circuit and partial hard-switching mean that performance improvements over the last 10 years have been asymptotic with diminishing returns vs. invested effort. The ACF [13] is not a new topology, but only now in late 2017, with the arrival of high-speed and low-cost GaN Power ICs have ACF ASICs been introduced that are high-performance, enable industry / legislative standards and are cost-effective as parts of a high-frequency solution. A first step switching frequency to 300 kHz (with standard bobbin-based transformer) is used in this 65 W example, with later steps to 600 kHz and 1 MHz forecasted using planar magnetics. At 300 kHz, there are several magnetic materials available from Hitachi Metals, TDK, etc.

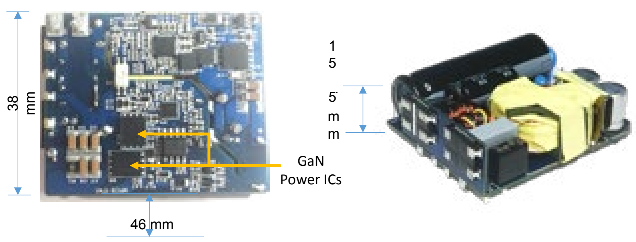

Figure 5: 65 W USB-PD ACF adapter using GaN Power ICs

The high level of device integration and high switching-frequency results in a very compact design, only 38 x 46 x 15.5 mm for PCB and components, with a total size of 27 cc uncased, or 45 cc cased. The power density of 2.4 W/cc (39 W/in^3) uncased, and 1.5 W/cc (24 W/in^3) cased is 3x-5x better than typical adapters and is the world-wide best-in-class. The adapter is shown in Fig. 5. Note that unlike other converters, the GaN Power IC-based design, demonstrated at CPSSC 2017 [14] meets all USB-PD, DoE and CoC requirements with a simple, standard, low-cost construction.

Figure 6 shows overall efficiency, noting high 93.4% at the critical 90 V_{AC}, full load point, and figure 7 shows compliance with DoE, CoC requirements. Standby performance is 25 mW at 115 V_{AC}, and 40 mW at 230 V_{AC} (vs. CoC specification max of <=75 mW, <=210 mW respectively). Figure 8 shows an example waveform with compliance to USB-PD.

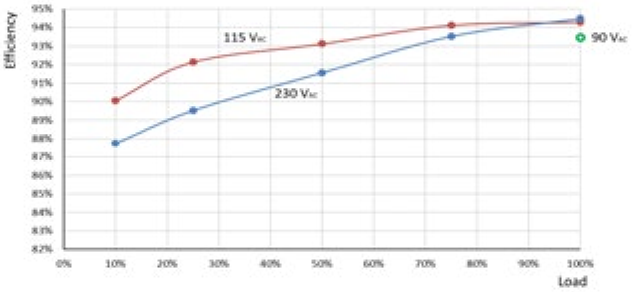

Figure 6: Efficiency vs. load, vs. AC line voltage (measured at PCB, room ambient, no airflow, no heatsink).

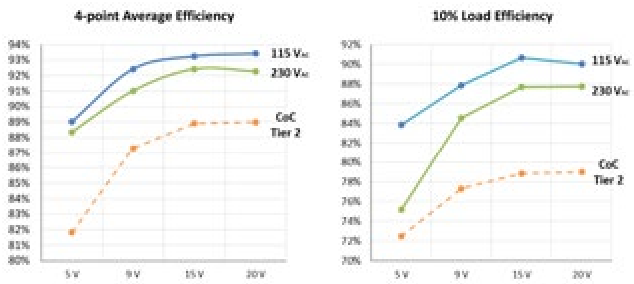

Figure 7: a) Compliance with European Union CoC T2 4-point average efficiency vs. USB-PD output voltage, b) Compliance with CoC 10% load efficiency.

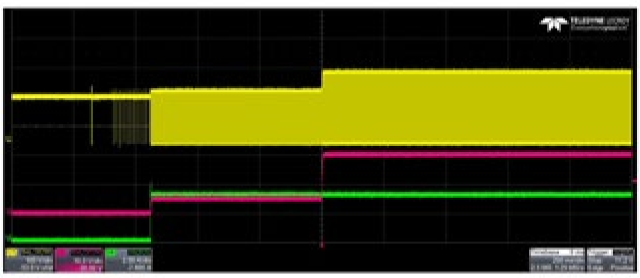

Figure 8: 65 W USB-PD startup waveforms at 115 V_{AC} with a 20 V-capable PD sink. Yellow: switch node voltage; Red: output voltage; Green: output current. Converter first outputs 5 V and then increases to 20 V after high power setting has been negotiated.

Conclusion

Forty years after Star Wars and the first revolution in power electronics, we are now at the start of the second major change. The critical combination of switch, magnetics, topology, control and integration liberates the power designer to stretch beyond the old, slow converters to achieve once again the major leaps in efficiency, power density and cost. This is only the beginning of the new revolution. From previously unimagined, ‘science fiction’ concepts, GaN Power ICs deliver ‘industry facts’ with proven performance.

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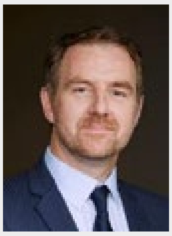

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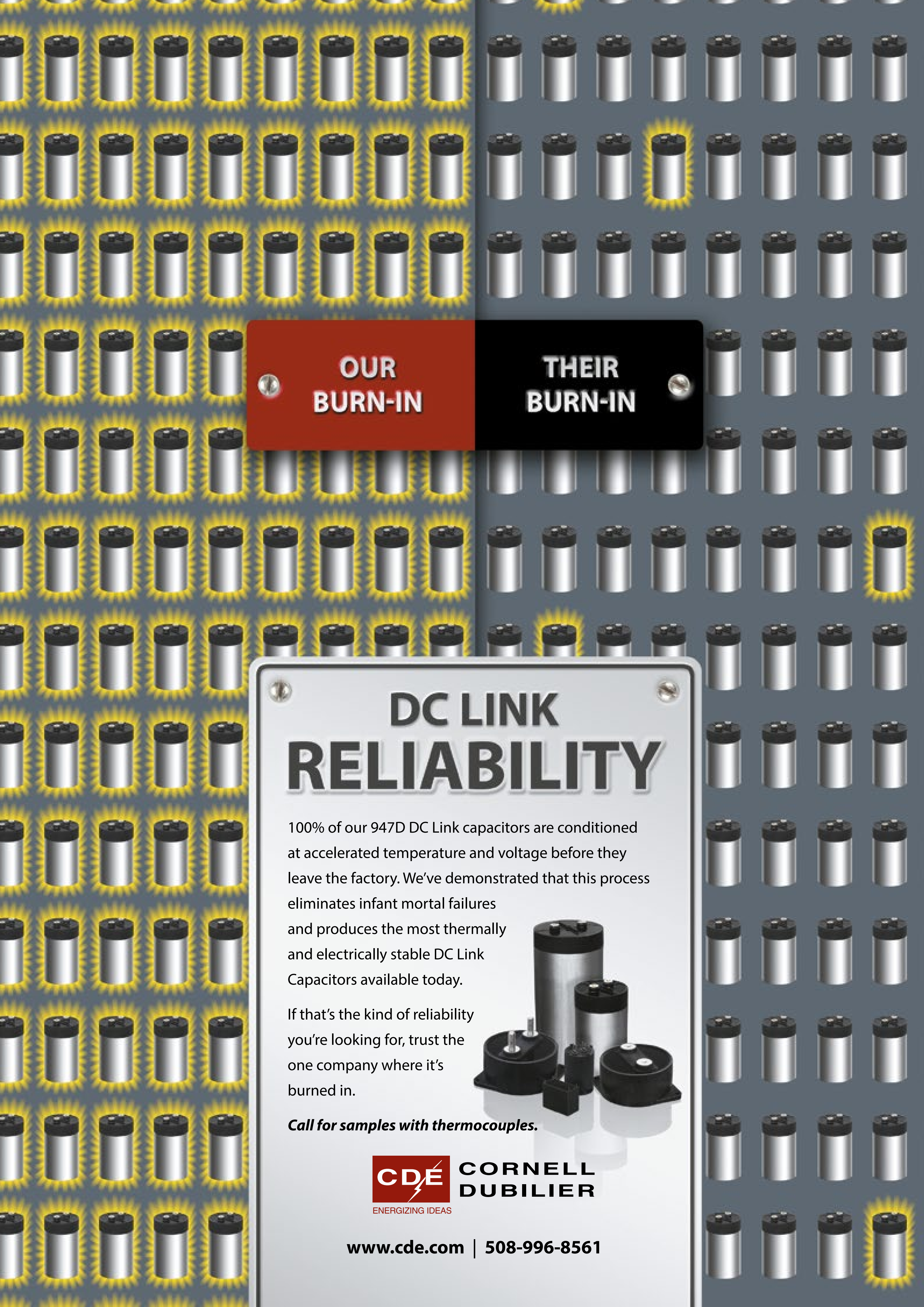
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Magnetics Design – Simple or Complex?

Magnetics present a very special challenge in the field of power electronics. Inductors and transformers are part of a technology which is almost 200 years old.

By Dr. Ray Ridley, Ridley Engineering Inc.

Practical Design Versus Theory

Inductors and transformers are formed by the very simple process of wrapping wire around a core, and engineers have been doing this with varying degrees of success since their invention. Building a magnetic part is almost absurdly simple. However, making it work properly, with a proper understanding of the loss mechanisms involved, can be as difficult as you want it to be.

Part of this is due to the vast divide between the theory and practice of making a part that works, and the difficulty in understanding the complex interactions of the 3-dimensional structure that results from the very simple construction.

Academic Study of Magnetics

At every APEC conference [1], the magnetics presentation sessions are always very popular. Attendees at the session are there to learn what the secret is to the “magic” that seems to make up a transformer or an inductor. The sessions are packed with academic treatises of the analysis of the magnetics parts by enthusiastic graduate students from around the world.

Figure 1: Young graduate students come with advanced analysis skills and an impressive grasp of equations and theory.

At the end of the APEC magnetics sessions, most engineers come away more puzzled than when they went in. It simply isn’t possible to follow the mathematics presented during these intense papers, and the “magic” bullet for solving understanding magnetics is never quite disclosed in a discernible format. The secret of magnetics design continues to be elusive.

Core Loss Analysis

A transformer or inductor is composed of a core, a bobbin (usually), and wire. There are several things that determine proper operation and success of the magnetic part. Firstly, the component must not saturate during its normal range of operation. Some very straightforward equations make sure that the saturation region is avoided, and we will cover that in a later article in this series.

Once saturation is avoided, the next big question to answer concerns the efficiency of the magnetics device, or, how much heat does it generate? This is where choices arise – how much analysis do you wish to do versus practical testing of the part in a circuit?

There are just two elements to the loss of the magnetics – the core, and the copper. Overheating transformers have been the limitation to density and power level since very early days, and much work has been done to improve performance. The first century of magnetics development put a lot of focus on dealing with core losses. The frequency of operation was low (50 or 60 Hz) and iron losses in the transformer were hugely important. Very quickly, the cores moved from being a solid iron structure to laminated assemblies formed of thin sheets of steel. This was done to drop the heating due to eddy currents in the core. Practical solutions like this were found, and the analysis followed behind them to match empirical observations and to try and improve designs further.

Steinmetz introduced his famous core-loss modeling approaches in the 1890s, and even today, this is the basis of much advanced modeling work at very high frequencies compared to original transformer operation. Steinmetz equations were based on observations of measured loss, and he managed to find mathematical equations that were able to fit the observations to some extent. When you look through the math, you will find equations such as those below in figure 1, which are excerpted from reference [1].

$$\overline{P_v} = \frac{1}{T}\int_0^T k_1 \left|\frac{dB}{dt}\right|^\alpha |B(t)|^{\beta-\alpha} dt \qquad (12)$$

We denote (12) as the generalized Steinmetz equation (GSE).

To check that the GSE is in fact consistent with the Steinmetz equation for sinusoidal waveforms, we substitute $B(t) = \hat{B}\sin\omega t$, resulting in

$$\overline{P}_v = k_1\omega^\alpha \hat{B}^\beta \int_0^T \frac{1}{T}|cos\omega t|^\alpha |sin\omega t|^{\beta-\alpha} dt \qquad (13)$$

With $T = 2\pi/\omega$, the integral here is independent of ω, and so this result can be made equal to the Steinmetz equation (1) with the appropriate choice of k_1

$$k_1 = \frac{k}{(2\pi)^{\alpha-1}\int_0^{2\pi}|cos\theta|^\alpha |sin\theta|^{\beta-\alpha} d\theta}. \qquad (14)$$

Figure 2: Modern use of Steinmetz equations continues to be researched in graduate schools around the world. The mathematics is far beyond that used by working engineers.

Over 100 years later, work continues based on the Steinmetz equations. Researchers all over the world are finding new and complex ways to apply analysis to the observed phenomena, with varying levels of success. While this provides plenty of opportunity for doing more research, the results are not used by working engineers. At the most, they will work with the core loss curves provided in data books, but they regard the university work with some level of bemusement.

Despite the lack of application of this work, there is still a lot of energy being poured into the research. The predicted and observed losses of many magnetics materials still do no match very well, and this makes design difficult. Temperature changes have a huge effect on the losses and there is a gaping absence of data with respect to the types of waveforms that are applied. Much remains to be done, but insufficient funding is available to finish the work properly.

Winding Loss Analysis

Core loss is just the first part of the problem in characterizing the magnetics. The second area of research and concern is the winding loss. In academia, the mathematics of winding loss are of the highest level. They start with Dowell's equations, which were first published in 1966, and move on from there. Industry is far behind – in our course on magnetics, we always ask attendees how many of them use Dowell's equations – and the answer is less than 1%.

This is not surprising. The level of math comprehension is just too high, as you can see in figure 2 below.

$$\underline{\hat{A}}_{z1}(x,y) = \underline{\hat{A}}_0 + \underline{\hat{B}}_0 x + \sum_{n=1}^{+\infty}\left[\underline{\hat{A}}_n \frac{\cosh(\lambda_n x)}{\cosh(\lambda_n s)} + \underline{\hat{B}}_n \frac{\sinh(\lambda_n x)}{\sinh(\lambda_n s)}\right]\cos(\lambda_n y) \tag{4a}$$

$$\underline{\hat{A}}_{z2}(x,y) = \frac{1}{2}\mu \underline{\hat{J}}_0 [x-(s+c)]^2 + \sum_{n=1}^{+\infty}\underline{\hat{E}}_n \frac{\cosh\{\lambda_n [x-(s+c)]\}}{\cosh\{\lambda_n [s-(s+c)]\}}\cos(\lambda_n y) \tag{4b}$$

are found. With the eigenvalues $\lambda_n = 2\pi n N_g / b$ and the parameters

$$\underline{\hat{B}}_0 = -\mu_0 \underline{\hat{J}}_0 c$$

$$\underline{\hat{A}}_0 = \frac{1}{2}\mu \underline{\hat{J}}_0 c^2 - \underline{\hat{B}}_0 s$$

$$\underline{\hat{B}}_n = -\frac{\mu_0}{\lambda_n}\underline{\hat{J}}_0 \frac{bc}{l_g}\frac{2}{\pi n}\sin\left(\frac{\pi n l_g}{b}\right)\sinh(\lambda_n s)$$

$$\underline{\hat{E}}_n = \underline{\hat{B}}_n\left[1-\tanh^{-2}(\lambda_n s)\right]\left(1+\frac{\mu_0}{\mu}\frac{\tanh\{\lambda_n c\}}{\tanh(\lambda_n s)}\right)^{-1}$$

$$\underline{\hat{A}}_n = \underline{\hat{E}}_n - \underline{\hat{B}}_n$$

the proximity losses of the winding area 2 in Fig. 2 can be calculated using Poynting's theorem.

Figure 3: While the mathematics for core losses is daunting, the solutions for winding loss are even more complex. Only approximated structures can even be modeled analytically, resulting in the expressions shown above. The true 3-D structure can only be analyzed using finite-element computer programs.

Practical Transformer Design

Analysis of magnetics continues to be a hot topic. However, in industry, companies cannot wait for solutions to emerge. They have to make transformers and inductors to meet their immediate product needs. So who does the designs? It is not recent graduates. They are perhaps very skilled in analytic techniques, but they typically have little idea of what the real-world needs of magnetics design are. Specification and fabrication of the parts is usually done by experienced long-term engineers and technicians who have been practicing their art for decades. You won't usually find many equations in their toolboxes, but they are able to make some high-performance parts. Experience is everything.

Summary

In magnetics, there remains a huge divide between the world of academia and industry practice. This is a 200-year-old technology where experience and practicality determine how products are built. There is very little incorporation of the findings of academia by working engineers. Much work remains to be done in terms of characterization of materials, and education on both sides of the fence. Students could benefit greatly from more exposure to real-world practical magnetics practice. And engineers in the workplace desperately need better tools from the research world that don't require a PhD to use and apply.

Figure 4: Seasoned engineers or technicians are often the ones tasked with actually MAKING transformers from scratch. At good companies, they can turn out very good magnetics designs without resorting to the world of complex mathematics.

Our work at Ridley Engineering strives to bridge this gap. We teach hands-on design and construction so new graduates at companies worldwide understand properly the real-world constraints of design. We provide both our beginning and advanced engineering students with the tools they need to start implementing complex analysis techniques without having to dive deeply into the mathematics. This elevates the level of design for every engineer that learns to apply these techniques. In this series of articles, we will elaborate further on the combination of theory and practical design that we have taught to thousands of engineers in the industry.

www.ridleyengineering.com

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- Join our LinkedIn group titled Power Supply Design Center. Non-commercial site with over 7500 helpful industry members with lots of theoretical and practical experience.
- Join our new Facebook group titled Power Supply Design Center. Advanced in-depth discussion group for all topics related to power supply design.

BMW Brilliance Automotive Opens Battery Factory in Shenyang

German Carmakers Take Battery Initiative

Most of the batteries as one of the most important parts of German electric cars have so far come from Asia: according to the National Platform for Electric Mobility (Nationale Plattform Elektromobilität), Japanese battery cell manufacturers (market share 26 percent) were the leaders four years ago, followed by Korean (24), Chinese and American (22 percent each) producers.

By Roland R. Ackermann, Correspondent Editor Bodo's Power Systems

This has alerted Germany's carmakers and prompted them to act: Daimler subsidiary Deutsche Accumotive intends to build complex batteries in Kamenz, Saxony, in the future, i. e. to supplement supplied rechargeable batteries with control systems, cooling and housings for the Mercedes-Benz and Smart brands. VW also has plans to build a battery factory in Germany (possibly in Salzgitter). TerraE Holding is planning to build the battery cells for 2019 with a gigafactory of lithium-ion cells with a capacity of 34 GWh by 2028, and the new company is expected to operate the factories as foundry.

Figure 1: Celebration of BMW Brilliance High Voltage Battery Center Grand Opening

BMW, on the other hand, has long since integrated its battery production into an existing vehicle plant. For two and a half years now, employees at BMW's Dingolfing site have been manufacturing storage units and electric motors for the company's electric cars and hybrid vehicles on two of its own production lines.

BMW pushes for in-house construction

The BMW Group is pushing ahead with the expansion of electromobility. Together with its partner Brilliance China Automotive Holdings Ltd. the BMW Group recently opened the new "High Voltage Battery Center" in Shenyang, China. The battery factory supplies the nearby plant of the BMW Brilliance Automotive (BBA) joint venture in Dadong. The BMW 5 Series Plug-in Hybrid will be produced there for the local market in the future.

Oliver Zipse, Member of the Board responsible for Production, comments: "The innovative High Voltage Battery Center in Shenyang represents an important step in the BMW Group's electromobility strategy. It is the first battery factory of a premium car manufacturer in China and already the third in our production network after Germany and the USA."

The BMW Group integrates its battery factories into the existing international production network. Zipse: "For 2025, we expect that the share of sales of our electrified BMW and MINI models will be between 15 and 25 percent globally. This corresponds to a volume of several hundred thousand vehicles per year. It therefore makes sense for us to integrate electromobility into existing production processes." The company can thus react flexibly to the demand for electrified models.

Competitive edge through in-house know-how

The high-voltage accumulator is - together with the electric motor - a central component of semi- and fully electrified vehicles. In-house production gives the BMW Group a decisive competitive edge by securing know-how in new technologies, gaining important system competence and taking advantage of cost advantages. The company already produces electrified vehicles at ten locations worldwide. The high-voltage storage units required for this purpose come from the BMW Group plants in Dingolfing, Spartanburg (USA) and now also Shenyang. The Dingolfing plant plays a leading role as a competence center for electric drive systems within the network.

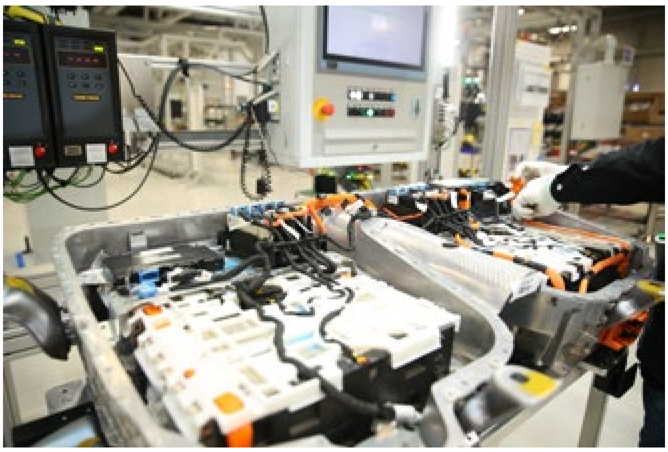

Figure 2: BMW Le iPerformance High Voltage Battery Pack

From the cell to the high-voltage battery
The production of the high-voltage accumulators is divided into two production sections. In a highly automated process, the supplied lithium-ion cells, the size of a paperback book, are first tested and then joined together to form a larger unit, the so-called battery modules.

The battery modules are then mounted together with the connections, control units and cooling units in an aluminium housing. The size and shape of the aluminium housing and the number of battery modules used vary depending on the vehicle variant. This results in an optimally adapted "battery pack" or high-voltage storage unit.

This combination of standardised battery modules and housings flexibly adapted to the vehicle has several advantages: on the one hand, it ensures uniform characteristics and quality standards in the production of high-voltage storage units. At the same time, the modular structure of the high-voltage accumulators forms the basis for a wide variety of electric drive variants. And last but not least, this modular principle creates the prerequisite for being able to react quickly to customer demand and to take advantage of cost advantages.

BMW Group of leading manufacturers of electrified vehicles worldwide
Since the beginning of this year until the end of September, the BMW Group has delivered a total of 68,687 BMW i, BMW iPerformance and electrified MINI vehicles to customers worldwide - an increase of 64.2%. With currently nine electrified automobiles, the BMW Group is one of the leading suppliers of electric vehicles worldwide. By the end of the year, the company plans to sell 100,000 electrified vehicles worldwide.

The production site in Shenyang
The Shenyang site with the Dadong and Tiexi automobile plants and an engine plant with a light-metal foundry play an important role in the BMW Group's global production network. It is part of the strategy of globally balanced growth with production capacities in the respective regional markets.

Figure 3: The production site in Shenyang

The BBA production site in Shenyang produces exclusively for the Chinese market. The Dadong plant in the north-east of Shenyang started production in 2003 and is currently building the BMW 5 Series Long Version. In future, the plug-in hybrid version of the BMW 5 Series and the new BMW X3 will also be produced there. The Tiexi plant in the west of the city, in operation since 2012, produces the BMW X1 long version (including a plug-in hybrid version), the BMW 1 Series Sedan, the BMW 2 Series Active Tourer, the BMW 3 Series Long Version and the BMW 3 Series Sedan. The engine plant, which opened in 2016, produces the latest generation of BMW TwinPower Turbo 3 and 4-cylinder gasoline engines.

The BMW Brilliance Automotive joint venture
The joint venture BMW Brilliance Automotive was founded in 2003 and comprises the production and sales of BMW automobiles in China as well as local development tasks. The joint venture employs over 16,000 people. The BBA supplier network comprises around 350 local suppliers. In 2014, the contract between the BMW Group and Brilliance China Automotive Holdings Ltd for their joint venture was extended prematurely - four years before the end of the current contract - thus creating the basis for a deepening of the existing successful cooperation. The contract extension is valid for ten years (from 2018 to 2028).

The BMW Group Production Network
High customer demand and the launch of new models in 2016 led to very good capacity utilisation of the BMW Group's production network. BMW, MINI and Rolls-Royce vehicles produced a new record figure of 2,359,756 units. Of these, 2,002,997 were BMW, 352,580 MINI and 4,179 Rolls-Royce. The plants in Germany are responsible for around half of the volume, with more than one million vehicles produced.

With its unique flexibility, the BMW production system is the world's leading production system and is ideally positioned for the future. It is characterized in particular by high efficiency and robust processes. The BMW Group's production competence thus represents a decisive competitive advantage and contributes to the company's profitability and sustainable success.

Figure 4: Battery Pack Assembly Production BBA Shenyang

In addition to flexibility, quality and responsiveness are key factors in the BMW production system. Digitisation, standardised building blocks and an intelligent mixed construction method prove the high competence of the production network. At the same time, the production system offers the customer a very high degree of individualization and allows the modification of customer requirements up to six days before delivery.

Greater transparency in the decomposition of cobalt
In addition, the BMW Group aims to further increase the transparency of its battery cell supply chain and to examine options for model projects in the Democratic Republic of Congo.

Cobalt is considered a key component in the production of electrified vehicles and is present in large quantities in high-voltage electric vehicle and plug-in hybrids. Companies working with cobalt as a raw material are confronted with the challenge that violations of environmental standards and human rights cannot be completely ruled out when reducing cobalt.

From the outset - for more than one and a half years - the BMW Group has been involved in the Responsible Cobalt Initiative (RCI) - together with numerous other companies and organisations, the Government of the Democratic Republic of Congo and the Organisation for Economic Cooperation and Development (OECD). The aim of this initiative is to increase transparency and governance and to implement collective measures to deal with social and environmental risks in the cobalt supply chain.

Against this background, the BMW Group has decided to take further steps:
On the one hand, the company will increase the transparency of its own cobalt supply chain by the end of the year. To this end, information on the raw material's melting and countries of origin is made publicly available. These melts are not direct suppliers of the BMW Group, but companies that are named by suppliers of the BMW Group as sources of supply.

In addition, the BMW Group is currently conducting a feasibility study with an independent partner to determine whether the social and ecological situation in model mines in the artisanal mining sector in the Democratic Republic of Congo can be sustainably improved. Specifically, it will be investigated whether pilot projects with the potential for future scalability can be implemented on site.

Ursula Mathar, Head of Sustainability and Environmental Protection at the BMW Group: "The BMW Group does not obtain any cobalt itself, but only obtains this raw material for example by purchasing battery cells. However, we are aware that with the increasing demand for electric vehicles, there is also a responsibility to extract relevant raw materials such as cobalt. As a premium manufacturer, we aim to establish a transparent and sustainable supply chain that meets the highest demands, also in the interests of our customers."

The BMW Group currently assumes that the first steps towards examining a model project on site will take place in December 2017 at the same time as the publication of melts and countries of origin. The BMW Group's activities in the field of battery cell supply chain underline the fact that it is taking a holistic approach to electromobility, taking into account all facets of the value-added chain in order to promote solutions for sustainable mobility.

https://www.press.bmwgroup.com/global/article/detail/T0275323EN/bmw-brilliance-automotive-opens-battery-factory-in-shenyang

www.bmwgroup.com

FTCAP Delivers Broad Spectrum Including Special Solutions

Film capacitors for high-voltage applications: high performance under maximum load

The Husum-based company FTCAP is one of the few manufacturers of high-voltage capacitors: These special film capacitors are available for voltages of more than 120 kV DC, which makes them ideal for use in medical devices, high-voltage power supply units, or even body scanners for building security. The product spectrum offered by FTCAP includes numerous versions with different housing forms and connection technology, including radial designs with wire and solder lugs.

By Jens Heitmann, Account Manager / Marketing Manager, FTCAP GmbH

Film capacitors are manufactured from plastic films that are coated on one side with a thin metal layer. The dielectric strength depends on the thickness of the film that is used – for higher voltages, thick films must be used as the dielectric. The upper limit for a simple film capacitor is reached at a voltage of about 2.5 kV. If capacities for higher voltages are needed, several capacitors can be connected in series. The voltage is then divided and each single capacitor is exposed only to a fraction of the total load. To save the user the work of assembling and connecting several single components, it is possible to combine several capacitor windings in one housing. As opposed to electrolytic capacitors, film capacitors connected in series require no additional balancing resistors. This makes it possible to achieve high voltages without the disadvantage of additional losses.

Figure 1: High-voltage capacitors are available for voltages of more than 120 kV DC, which makes them ideal for use in medical devices Image: ©Trish23 – Fotolia

Instead of connecting single windings, film capacitors offer another, more elegant method of connecting the capacitors in series: A special type of metal coating makes it possible to create a series connection directly on the film. Narrow metal strips are vapour-deposited on the film in longitudinal direction, with free strips in between as insulation. This creates several capacitances, which are connected in series. In this case, each single capacitance – i.e. each metal strip – must withstand only part of the total voltage. If a film is wide enough, FTCAP can implement more than 15 series connections within one winding. It is therefore possible to manufacture single windings that are suitable for voltages of more than 40 kV.

Figure 2: The product spectrum offered by FTCAP includes numerous versions of high-voltage capacitors with different housing forms and connection technology, including radial designs

Figure 3: Because requirements vary widely, FTCAP adapts the high-voltage capacitors to the respective applications as needed

Production with the aid of innovative technologies

The production of high-voltage capacitors involves various challenges, which FTCAP overcomes with the aid of special systems and technologies. The Husum-based capacitor specialist invested in a specially designed potting system for this purpose. The goal is to achieve especially high-quality and homogeneous insulation with a newly developed vacuum potting technology in order to minimise partial discharges. For this purpose, a special potting material for high-voltage capacitors was first subjected to thin-film degassing at 10 mbar. This is necessary, because every air bubble in the capacitor can cause partial discharges. Afterwards, the capacitors are filled with the potting material under vacuum. FTCAP can also use this innovative potting system for potting segments. This technology minimises air inclusions and enables optimal filling of the housing. Another advantage of the custom system: It is very flexible and can also be used for small volumes, which makes it ideal for the production of custom-tailored solutions of different sizes.

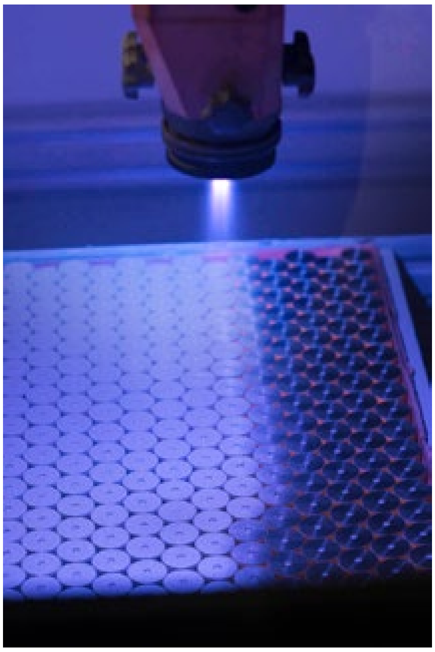

Figure 4: The production of high-voltage capacitors involves various challenges, which FTCAP overcomes with the aid of special systems and technologies

Because FTCAP always strives to convince its customers all along the line, each single high-voltage capacitor is subjected to extensive tests and measurements for quality assurance prior to delivery. This likewise requires special equipment: Due to the broad product spectrum, the measuring equipment must also be very flexible; for example, it must be able to accommodate the special forms of high-voltage capacitors. To prevent stray currents during the measuring process, FTCAP conducts the measurements only in air-conditioned rooms with low relative humidity.

Individually adaptable

Film capacitors for high-voltage applications are also used in medical technology: They generate high voltages in high-voltage cascades in X-ray machines or CT scanners to guarantee good radiation characteristics. They can also perform the same function in body scanners for building security. In addition, the solutions are also used to good effect in high-voltage power supply units that are needed in research or for generating magnetic fields. Accordingly, FTCAP's customers also include numerous technical schools and universities.

The requirements vary widely due to the diversity of possible applications. That is why FTCAP adapts the capacitors to the respective applications as needed: For example, the edge steepness (dU/dt) can be changed on an individual basis. In addition, capacitors can be manufactured in diverse versions to facilitate integration in existing installation spaces. The housings are manufactured at the FTCAP factory in Husum; custom designs are no problem. And that applies not only to high-voltage capacitors: FTCAP is always the right partner for capacitors for special applications in small and medium-sized quantities. The Husum-based company is one of the last enterprises to manufacture all of its products in Germany – customers benefit from higher flexibility, optimal quality and smooth coordination processes.

Info box: Overview of high-voltage capacitors from FTCAP

- Voltage ratings of more than 120 kV for use in medical technology, for example
- Different housing forms and connection terminals are available
- Individually adaptable forms and dimensions
- Robust against partial discharges and high ripple currents
- Available with higher edge steepness (dU/dt) and pulse resistance on request
- Can be interconnected in a block to create a high-voltage cascade
- Manufactured entirely of high-voltage-resistant materials
- Optimised design for a long life
- Advanced production, measuring and testing processes ensure high-quality products
- All materials used for the capacitors are approved for the highest fire class in accordance with UL 94

Deep link:
http://www.ftcap.de/en/products/film-capacitors/high-voltage-capacitors

www.ftcap.de/en

Figure 5: The Husum-based capacitor specialist FTCAP is one of the few manufacturers who still design and produce all of their products in Germany

High Power Density, High Performance X-Series 4500V IGBT Power Modules

Mitsubishi Electric has developed high performance 4500V IGBT power modules providing reliable solutions for medium voltage drive, railway and power transmission applications.

By Eugen Wiesner, Dr. Nils Soltau, Eugen Stumpf, Mitsubishi Electric Europe B. V. and Kenji Hatori, Hitoshi Uemura, Mitsubishi Electric Corporation

Introduction

Originally, Mitsubishi Electric started the development of the 4500V IGBTs in the middle of 90s. The first commercialization of standard IGBT modules in this voltage class was started in beginning of 2000s. It was a more efficient and compact solution compared to existing 4500V GTO press pack devices. Mainly this development was driven by railway and medium-voltage (MV) drive applications. Meanwhile, a wide variation of the 4500V IGBT modules is available, such as: dual diode modules, modules with copper and AlSiC base plate, modules with standard (V_{ISO}=6 kV) and high isolation packages (V_{ISO}=10.2 kV).

Targets of 4500V X-Series IGBT Modules

The newly developed 4500V X-Series is already the third series after H-Series and R-Series of MITSUBISHI ELECTRIC IGBT power modules. The line-up of the new X-Series is expanding the existing line-up towards higher power densities (refer Figure 1). The current rating of the large package (footprint: 190mm x 140mm) increases from 900A to 1350A. On the other hand, the 900A rated current also will be made available in smaller package size of 140mm x 130mm.

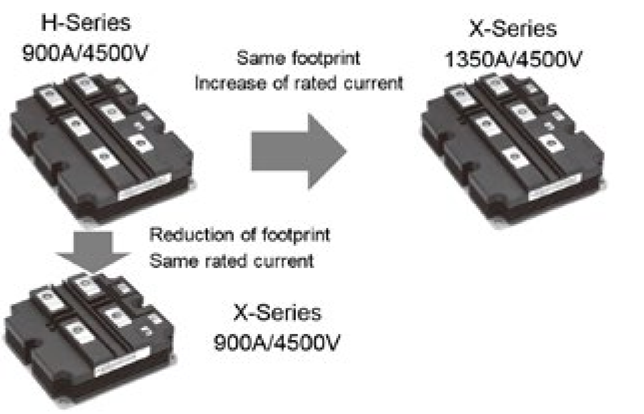

Figure 1: 4500V X-Series line-up expansion

The standard package type is still very important for different applications due to availability of second source from many IGBT device manufacturers and its proven reliability record in the field for many years. Furthermore, the upgrade or increase of the inverter output power is easily achievable by using the widely commercially available components in the market like heatsinks, gate drivers and bus bars.

The targets for 4500V X-Series device development have been defined based on feedback from customers. These were the following:

- Increasing current rating and module power density.
- Reduction of module power losses.
- Suitable for various applications having different switching frequency ranges.

Six modules have been developed [1] to fulfill the above mentioned market requirements. The overview of the developed 4500V X-Series modules is shown in table 1

Isolation voltage	Foot print	Type name
V_{ISO} 10.2 kV	190mm x 140mm	CM1350HG-90X (V_{CCmax}=3400V) CM1500HG-90X (V_{CCmax}=3200V)
	130mm x 140mm	CM900HG-90X (V_{CCmax}=3400V) CM1000HG-90X (V_{CCmax}=3200V)
V_{ISO} 6 kV	190mm x 140mm	CM1350HC-90X (V_{CCmax}=3400V) CM1500HC-90XA (V_{CCmax}=3000V)

Table 1: 4500V X-Series Line-up

Improving the Module Power Density

The most challenging requirement was increasing the module power density. The development target was achieved mainly by using the new 7th Gen. Chipset. The 7th Gen. IGBT chip, shown in Figure 2, contributes several significant cutting-edge features. The Carrier

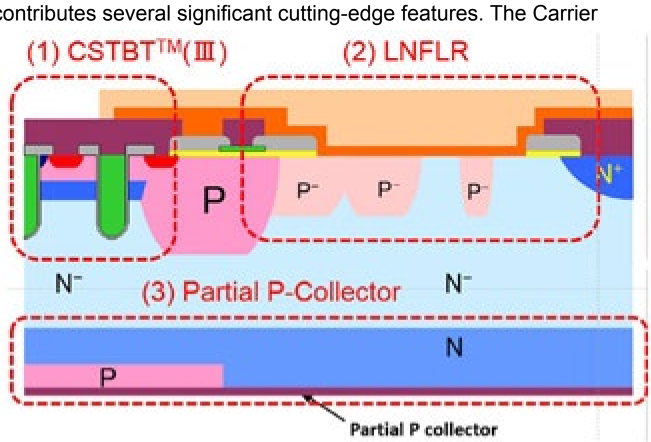

Figure 2: 4500V 7th Gen. Chip structure

Stored Trench-gate Bipolar Transistor structure (CSTBT™) allows reduction of the IGBT forward voltage. The new LNFLR (Linearly-Narrowed Field Limiting Ring) chip termination structure allows for an increase in the active chip area and thereby a reduction of the thermal resistance. Finally, the partial P-Collector technology allows a special capability to manage a wide RBSOA.

Furthermore, the overall packaging technology of 4500V X-Series is improved for managing the increased power density. The optimized internal chip layout reduces the module thermal resistance and increases the power cycling capability. As a result, the junction-to-case thermal resistance was reduced by more than 20% compared to previous R-Series (CM1350HG-90X and CM1200HG-90R). The module performance has been proven and specified for a wide operation temperature range from -50°C to 150°C. The previous 4500V module generations were specified up to 125°C.

Two different 7th Gen chip set are available, optimized for high and low switching frequency applications respectively. The X-Type chip set is designed for high switching frequency application (> 350Hz). The XA-type chip set achieves the lowest possible forward voltage for the IGBT and the diode. The intended switching frequency ranges from 100Hz to 350Hz. The trade-off between the forward voltage and reverse recovery switching energy for X- and XA- diode is shown in Figure 3.

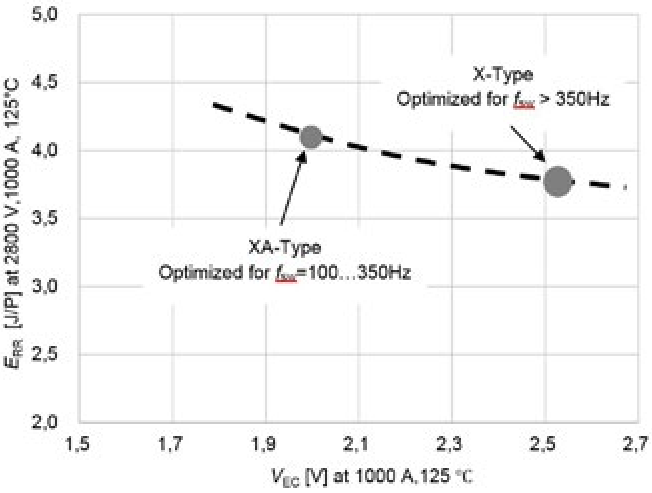

Figure 3: Diode trade-off between X- and XA device type

Safe Operating Area (SOA) for Each Application
The DC-link voltage is one of the most important stress factors influencing the SOA of IGBT module. Some applications do not require high DC-link voltage. For such cases, the SOA and with it the permitted maximum current rating increase.

The 4500V X-Series device is designed to operate at a maximum DC-link voltage of 3400V. In this case, the module's rated current is 1350A (CM1350HG-90X). If the required maximum DC-link voltage is reduced to 3200V, the rated current increase up to 1500A (CM1500HG-90X). Both modules have the same electrical characteristics but have different SOA specifications. Each device undergoes shipping tests according to the defined maximum DC-link voltage respectively.

Example of a 3-level NPC Inverter Application
One of the targeted applications for the 4500V modules is the medium voltage (MV) drive application. For these drives, the output voltage range is between 2.3kV and 13.2kV [2]. The most common voltage levels are: 3.3 kV, 4.16kV, 6kV and 6.6kV. For these output voltages, 3-level topology is widely used. For example, these voltages can be covered by devices such as the CM1500(1350)HG-90X (as shown in Table 2). For output voltage levels higher or equal than 4160V - series connection of 4500V modules becomes necessary.

Inverter output voltage V_{OUT} [Vrms]	Total required inverter DC-Link voltage V_{DC_link} [V]	IGBT blocking voltage V_{CES} IGBT [V]	IGBT Series connection	IGBT DC-Link voltage V_{CC_IGBT} [V]
3300	4800	4500 (CM1500HG-90X)	No	2400
4160	6200	4500 (CM1500HG-90X)	Yes	1600
6000	8800	4500 (CM1500HG-90X)	Yes	2200
6600	9600	4500 (CM1500HG-90X)	Yes	2400

Table 2: Example for 4500V IGBT module based 3-level NPC configurations

Scalability towards lower power ranges can be realized with the CM900HG-90X device or the H- and R-Series modules. The following example shows the potential of the new X-Series compared to the first H-Series in terms of power loss reduction. For the V_{OUT}=3300V output voltage, the necessary DC-Link voltage is about 4800V. In 3-level NPC-configurations, the IGBT module would experience the half the total DC-Link (2400V). In case the heatsink potential would be connected to the middle of the DC-Link the IGBT Module isolation voltage of 10.2 kV(rms) would be sufficient to cover in Table 2 mentioned inverter output voltages.

Figure 4 shows the power loss simulation versus output current for CM900HG-90H H-Series device and CM1350HG-90X X-Series device. The simulation conditions are:

- Switching frequency fsw=0.5kHz,
- Power factor p.f.=0.85,
- Modulation index m=1,
- Junction temperature T_J=125°C.

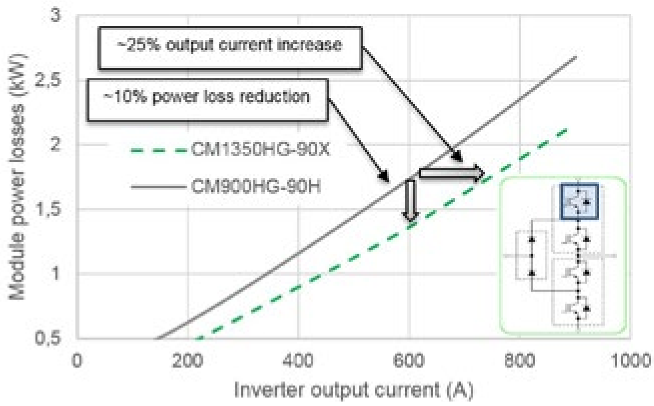

Figure 4: Comparison of the power loss simulation result using the H- and X-Series 190mm x 140mm modules.

There are two possibilities for utilizing the performance of new X-Series power modules. One possibility is a reduction of the IGBT module power losses. The power losses decrease by about 10% compared to the H-Series. The other possibility is increasing the inverter output current. The output current can be increased by about 25% compared to the H-Series. In addition, 150°C operation of X-series enables to increase even more output current than 125°C operation.

Conclusion

The newly developed 4500V X-Series enables significant increase in the inverter output power. Key enabling factors are an increased maximum junction temperature of 150°C, an improved thermal management and reduced power losses in the module. A large line-up and backward compatibility to H-Series and R-Series ensures a flexible converter design and an easy design-in. Furthermore, two different chip sets (X-type and XA-type) facilitates the optimal operation at required switching frequencies.

References

[1] Mitsubishi Electric Corporation, "Mitsubishi Electric to Expand Lineup of X-Series HVIGBT Modules," Press Release No. 3094, May 2017

[2] Prof. Dr. M. Hiller, "Leistungselektronik mit Si-Bauelementen für die Mittelspannung", Tagungsband des 1. Industriearbeitskreis Mittelspannungs-Leistungelektronik [Proceedings of the 1. Industry Working Group Medium-Voltage Power Electronics], Fraunhofer ISE, Berlin, Germany, 2016.

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Ramping up to Create Timing Sources

Mary Iva Rosario Salimbao from Microchip Technology Inc. explains how a programmable ramp generator peripheral can be used to create reference signals and timing sources.

By Mary Iva Rosario Salimbao, Applications Engineer, Microchip Technology Inc.

The Programmable Ramp Generator (PRG), featured on several recent 8-bit PIC® microcontrollers from Microchip Technology, is a highly flexible analog peripheral that is intended to simplify applications that require a linear change in voltage. As its name implies, the PRG is able to produce rising, falling or alternating rising/falling ramps on its output under the control of software. However, once configured, the peripheral is able to operate independent of the core, freeing up the Central Processing Unit (CPU) to work on some other task, enter a lower power mode or otherwise take on a more supervisory role in the system. Rise and fall times can be adjusted dynamically by controlling an integrated constant current source. Flexible input and output options offer the designer freedom to interconnect with off-chip signal sources or with signals from other peripherals on the microcontroller. This often provides a more responsive system while minimizing potential noise sources and application size by reducing external component count. Figure 1 shows a block diagram of the peripheral.

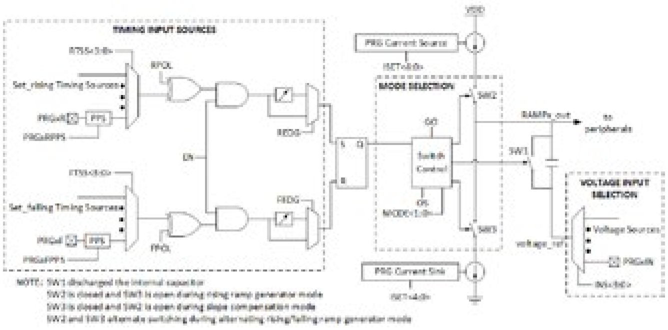

Figure1: Simplified PRG module block diagram

A useful tool for configuring the PRG is the MPLAB® Code Configurator (MCC), a user-friendly plug-in for the MPLAB X Integrated Development Environment (IDE), see figure 3. It generates drivers for controlling and driving peripherals of Microchip PIC microcontrollers such as the PRG. Different functions can be implemented with the PRG and each can be set up using MCC.

Triangular wave generator

A Triangular Wave Generator (TWG) produces a periodic, non-sinusoidal waveform with a triangular shape of equal rise and fall times. To produce a triangular wave, the PRG must be configured in an alternating rising and falling mode. The MCC allows the configuration of the Rising (RS) and Falling (FS) timing input sources. The PRG determines the output oscillation frequency using these two voltage references that trigger the rise and fall of the ramp. These references also determine the minimum and maximum voltage peaks of the triangular wave signal.

When the PRG output is below the voltage level set by a Digital-to-Analog Converter (DAC), the RS input of the PRG is triggered and the internal capacitor is charged by the current source. When the PRG output exceeds the fixed voltage reference (FVR), the FS input is triggered and the internal capacitor is charged by the current sink.

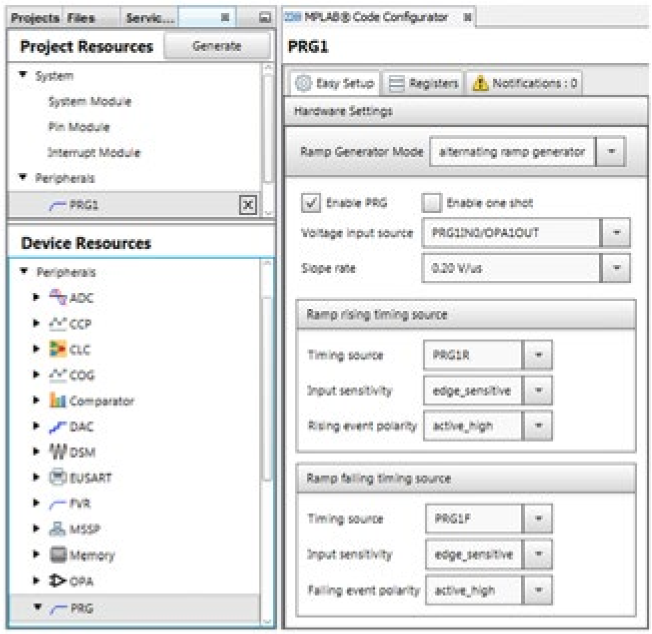

Figure 2: MCC – PRG module hardware settings

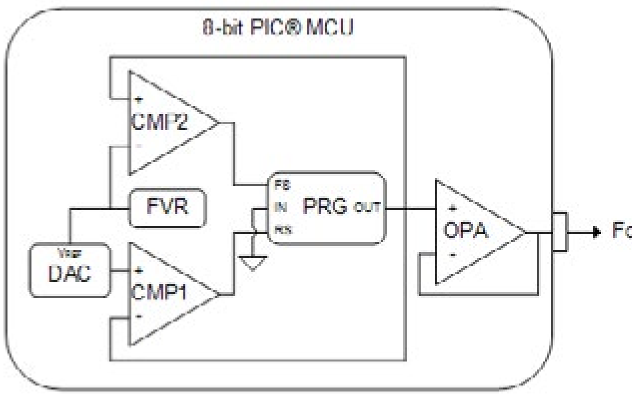

Figure 3: Peripheral integration for a Triangular wave generator

WSince the PRG does not have a designated output pin, the output of the PRG is buffered through a unity gain configured op amp. The output frequency can be calculated, but its accuracy may be affected by different factors such as the parasitic resistance of the capacitor, noise, production variance and temperature.

The value of the frequency varies by changing the output level of the DAC or the PRG's slope rate (SR). The SR of the output ramp is configured through the PRG's current settings.

Figure 4 shows the ideal behavior of the implementation. In general, the generated triangular wave consists of periodic and symmetrical alternating rising and falling ramps.

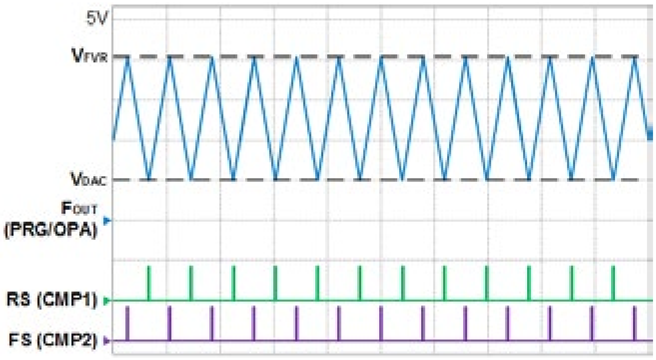

Figure 4: Triangular wave generator timing diagram

The maximum and minimum voltages are defined by VFVR and VDAC, respectively. The rise and fall triggers are set when the signal reaches either maximum or minimum voltage. Changing the slope rate setting in the MCC can be used to adjust the frequency. A change in VDAC also results to a change in frequency, but the minimum voltage will increase or decrease accordingly.

The oscillation frequency of the PRG depends on the selected current sink and source, the internal capacitance and the set rising and falling triggers. By placing additional capacitance on the output of the PRG, lower frequency ranges can be achieved.

With an added Configurable Logic Cell (CLC) and external capacitor C1, the voltage trip points set by the DAC and the FVR can trigger the rising and falling events, respectively. C1 is added at the output of the op amp and effectively in parallel with the PRG's internal capacitor.

The additional capacitance drags out the time between trigger events, producing a lower frequency for FOUT.

Connecting the CLC at the output of the comparators lets the wave generator produce square waves and pulses. The CLC is configured as an SR latch and the low frequency FOUT is taken from its output. Similar to the PRG, the voltage references trigger the set and reset inputs. FOUT is set when the voltage at C1 (OPAOUT) falls below the DAC voltage level. Once OPAOUT rises above the FVR, FOUT is cleared.

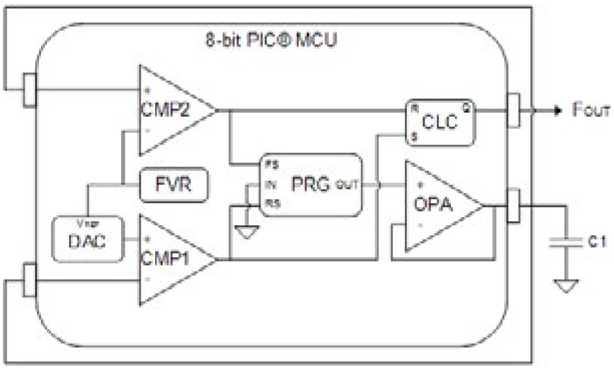

Figure 5: Adding CLC and a capacitor for lower frequency outputs

Voltage-controlled oscillator

A Voltage-Controlled Oscillator (VCO) is an electronic oscillator in which an input control voltage determines its frequency of oscillation.

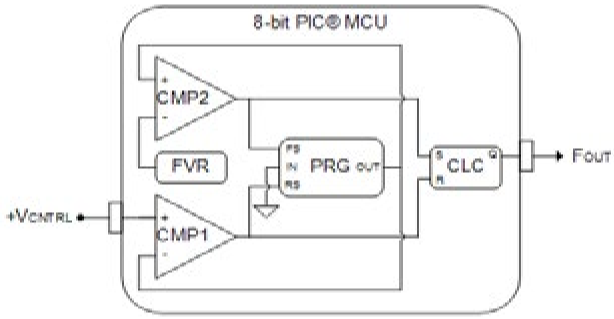

Figure 6: Configurations for a Voltage-controlled oscillator

The instantaneous frequency of the VCO is usually designed to be in linear proportion with the instantaneous voltage; the higher the input voltage, the greater its oscillation frequency. The PRG's operation for the VCO implementation is similar to the TWG, except the output frequency is taken from the CLC's slope rate latch and a variable voltage VCNTRL sets the RS input of the PRG.

A higher input for VCNTRL decreases the time needed to retrigger the rising event. Consequently, the switching between current source and sink becomes faster and the oscillation frequency increases.

The relationship between the control voltage and output frequency is shown in figure 7 with three PRG slope rate values. The SR value can be varied for a desired range of frequencies. Lower SR values can produce frequencies ranging from a few hertz to around 500 kHz. Larger SR values, however, can reach up to the megahertz range.

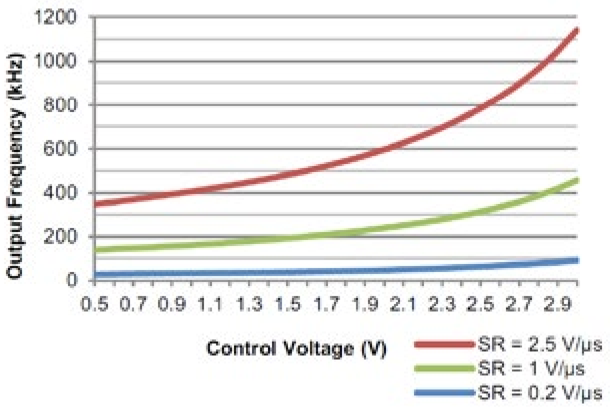

Figure 7: VCO output frequency versus control voltage

With two control voltage values and a constant slope rate, a decrease in VCNTRL reduces the VCO frequency out of the CLC.

Voltage-controlled duty cycle oscillator
A standard VCO circuit directly modifies the oscillator frequency. For a Voltage-Controlled Duty Cycle Oscillator (VCDCO), its control voltage modifies the duty cycle of the output pulses.
A similar set-up to the VCO is implemented for the VCDCO with the exception that a time base triggers the start of the output pulse. The PWM and TMR modules determine the period and frequency of the oscillator while the PRG through VCNTRL determines its duty cycle. The rising edge of the PWM triggers the PRG RS input and sets the CLC. When the PRG output exceeds VCNTRL, the FS input is triggered, the PRG capacitor is shorted and the CLC is reset. The PRG and CLC output will remain low until the next TMR overflow and PWM positive edge.

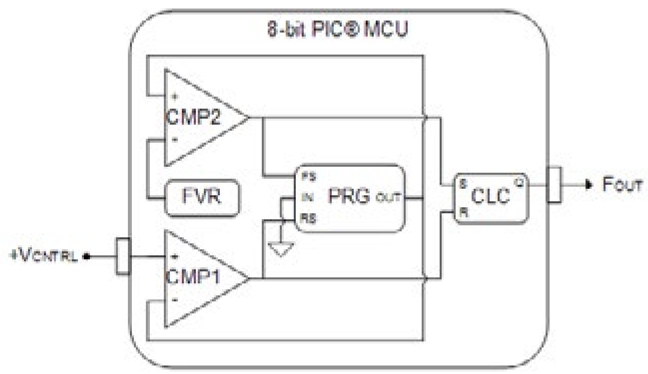

Figure 8: Using a time-based trigger for a voltage-controlled duty cycle

Increasing VCNTRL prolongs the rise of the ramp and the output's positive pulse width.

The duty cycle is computed as a ratio of VCNTRL to VMAX. To increase the range of duty cycles, the timer period should be equal to the rise time of the ramp when it reaches VMAX with the given slope rate.

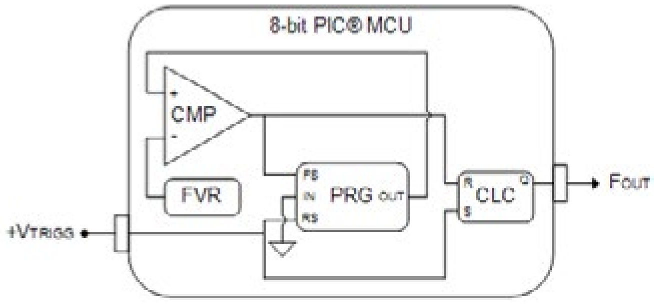

Figure 9: Using an external trigger for one-shots

When two different values of VCNTRL are used, the RS trigger sequence can be uniform in both conditions due to the constant period of the timer and PWM. However, there can be an additional delay before the FS trigger due to the constant slope rate and higher VCNTRL.

The PRG slope rate and TMR2 period values depend on the required frequency and duty cycle range of the VCDCO. The duty cycle of the PWM can be set low enough to trigger the RS input of the PRG. FOUT is still taken from a CLC SR latch. The PWM and CMP outputs also provide the set and reset inputs for the CLC.

Asynchronous one-shot
An Asynchronous One-Shot (AOS) produces a single-output pulse when it is triggered externally. Commonly known as monostable multivibrators, the AOS has one stable state. If its stable state is low, an external trigger drives the output high for a specific period. At the end of one period, the AOS returns to its stable state and will wait for the next trigger event.

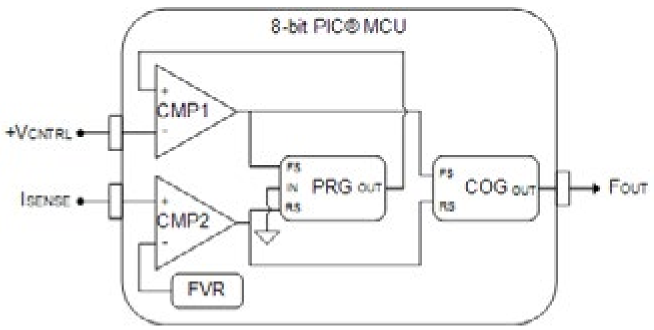

Figure 10: Configurations for a voltage-controlled one-shot

The reset state of the CLC is the stable state of the AOS. An external trigger sets the RS input of the PRG and sets the output of the AOS out of the CLC. When the PRG reaches the FVR, the FS input source is triggered, the internal capacitor in the PRG is shorted and the CLC output is reset. The duration of the pulse width depends on the FVR voltage and PRG slope rate.

An external voltage trigger can replace the PWM and TMR modules to remove the periodic trigger sequence of the PRG RS input and CLC set sources. The output pulses are taken from the CLC output.

Voltage-controlled one-shot

This next example is an upgrade of the previous one-shot. One input acts as a trigger, while an additional input determines the one-shot period. One application of the one-shot controls the on-time of a Critical Conduction Mode (CrCM) PFC controller.

The input voltage VCNTRL determines the one-shot period or on-time of the output. A higher value on VCNTRL produces a longer on-time. When the rising ramp signal of the PRG reaches VCNTRL, the PRG capacitor is shorted and the complementary output generator (COG) duty cycle is completed. The output remains low until a signal retriggers the PRG rising ramp and the beginning of the COG period.

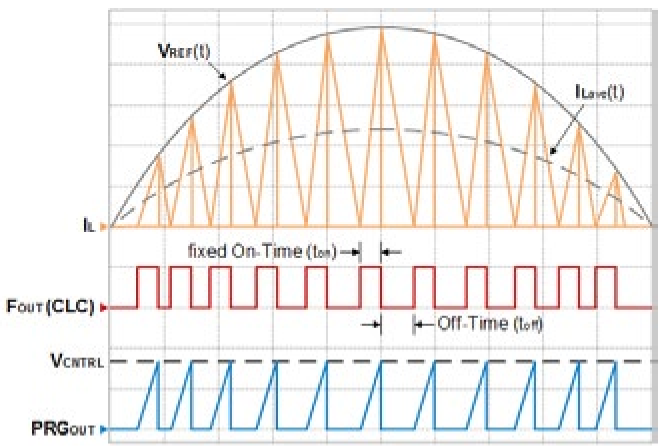

Figure 11: Inductor current waveform for a fixed on-time CrCM controller

In a critical conduction controller, the COG controls the switching of the power metal-oxide-semiconductor field-effect transistor (MOSFET). The feedback signal from the error amplifier is fed to VCNTRL. A constant feedback signal will result in a fixed on-time. During on and off states, the inductor current ramps up to the input reference voltage and falls back to zero, respectively. Fig. 11 shows the typical behavior of the inductor current for a CrCM controller.
To configure the peripherals with the MCC, replace the PWM and TMR modules with a second CMP. On the list of positive and negative input sources, select a CINx+ pin and the FVR, respectively. In place of the CLC, select a COG module and set the comparators as the rising and falling event sources. For a power converter application, the COG peripheral is more suitable as an output driver.

Conclusion

The functions of the PRG show the convenience of generating voltage ramps as reference signals or timing sources. These functions can be easily configured with the user-friendly MCC. Together with several other peripherals in Microchip PIC microcontrollers, more applications based on the PRG can be explored.

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Additional resources:

- Sample Functions Implemented with the Programmable Ramp Generator Application Note: http://ww1.microchip.com/downloads/cn/AppNotes/cn587053.pdf
- Microchip MPLAB Code Configurator (MCC) graphical programming environment: http://www.microchip.com/mplab/mplab-code-configurator

1700 V LoPak1 IGBT Power Module by Holistic Design Approach

Throughout the past years the efforts in power semiconductor development were targeted to increase the power density for a given application. A higher power density can be translated either to a maximized reliability keeping decent margins to the maximum ratings or a very cost efficient approach on the other hand by fully utilizing the capability of the device.

By Sven Matthias, Samuel Hartmann, Athanasios Mesemanolis, Raffael Schnell
ABB Switzerland Ltd. Semiconductors

In this article we present the LoPak1 (Figure 1) module created by a holistic design approach. The challenging performance targets were achieved by reduced losses, increased safe operating area and maximizing the allowable junction temperature during operation by employing the latest generation of our planar SPT++ chip-set technology and proper material design for the package. In addition we focused on an elaborate virtual prototyping phase to achieve minimized resistive losses, minimized internal stray inductance, balanced coupling among the IGBTs, resulting in balanced current sharing in static and dynamic operation for the IGBTs and diodes by pure design measures. This is to enable the full utilization of the LoPak1 capability.

Figure 1: The LoPak1 (standard footprint of 62mm x 122mm) module using the third generation ABB SPT++ chipset for high temperature module.

The virtual prototyping was done by building the module's mechanics in CAD taking all design elements including chips and bond-wires and the substrate-layout into consideration. The complex model is complemented with all material properties and the tailored full SPICE models of the SPT++ IGBT and diode chipset. The LoPak1 module was conceived with two possible layout configurations for the IGBTs and diodes for the highest current rating of 450A. The first design (Figure 2, top) features an alternating topology of the IGBT and diode, while for the second design (Figure 2, bottom) a parallel topology was implemented. It is important to note the labelling convention for the paralleled IGBTs and diodes for low and high-side.

The thermal simulation reveals that the version1 layout supports a slightly lower junction temperature for the same heating conditions compared to version2. In the simulated case the difference is about 1K. The parasitic extraction confirms that the layout versions do not impact the inductance of the module of about 25nH or the resistance of around 1mOhm. However, the static current sharing exemplarily shown for the high-side shows a significant imbalance for the two layout versions (Figure 3). The currents through IGBT1 and IGBT2 (see fig. 2 for labelling convention) are almost equal and the delta between the minimum and maximum current is in the range of about 1A for version1 and 2A for version2, respectively. In contrast to this, this

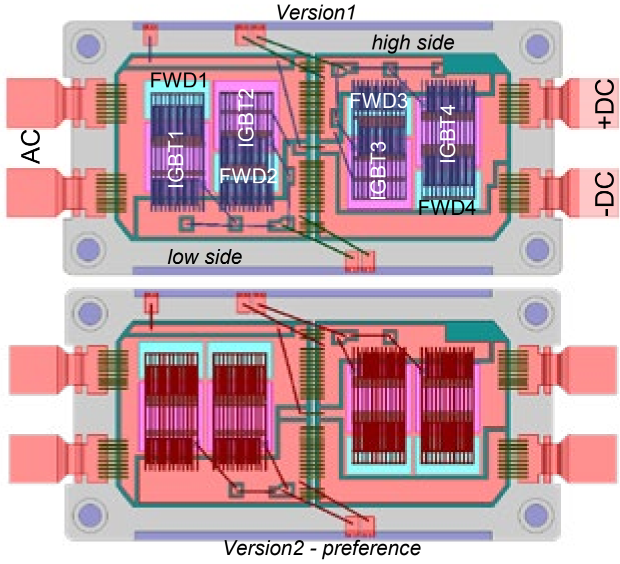

Figure 2: CAD pictures of the power modules version1 (top) including the labelling of the various chips and version2 (bottom).

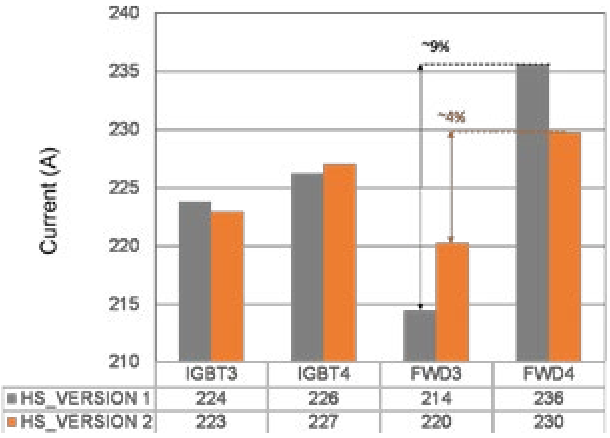

Figure 3: Static current sharing for the design version1 and version2 based on simulation for high-side switch.

delta for the current through the free-wheeling diodes reaches 22A corresponding to 9% of the nominal current of the individual diode for version1, while version2 layout supports a way lower distribution of 4%. A similar result in the static current sharing among the IGBTs and diodes is seen also on the low-side substrates for both design variants.

The impact of this unbalanced current sharing was investigated further and confirmed experimentally resulting in distorted waveforms [2]. Following the ambitious targets the preferential choice is obviously version 2, which is hence consequently used for all further measurements. Figure 4 shows the IGBT chip turn-off capability of two parallel chips in the LoPak1 measured at Tcase=175°C without an active clamp.

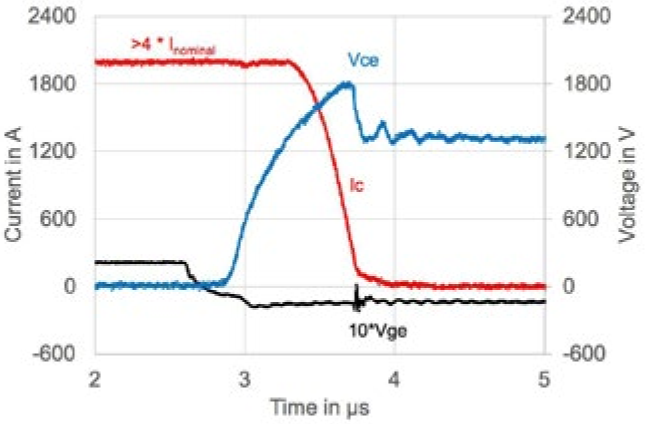

Figure 4: Measured maximum rating for reverse bias safe operating area conditions: Vdc=1300V, Ic>1900A, Tj=175°C, Ls=50nH, Rg=0.47Ohm.

The chip withstands a phase of dynamic avalanche regime, turning off a current exceeding four times the nominal value, safely and reliably. Figure 5 shows the reverse recovery safe operating area for the diode at Tcase=175°C. The diode turns off safely the double nominal current at an elevated dc-link voltage without any oscillations. The commutation speed exceeds 9kA/µs and highlights the possibility of a fast switching of the module under harsh conditions. These figures confirm the outstanding robustness of the device realized by a homogeneous and balanced switching of the chips.

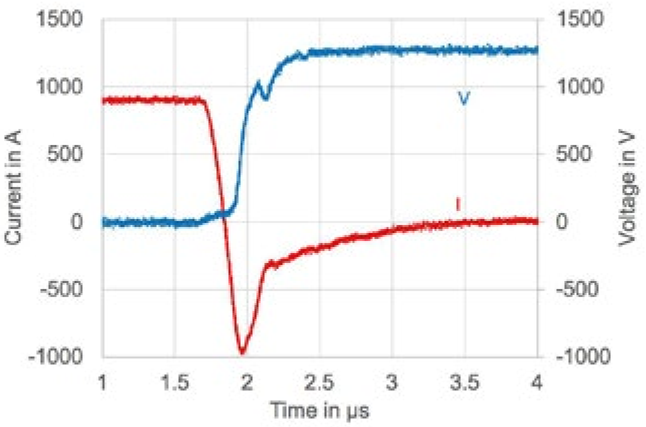

Figure 5: Measured maximum rating for diode safe operating area conditions: Vdc=1300V, Ic=900A, Tj=175°C, Ls=50nH, Rg= 0.2Ohm, Vge=19.5V.

Finally, figure 6 shows the simulated maximum output current as function of switching frequency of the LoPak1 (5SNG 0450R170300) at a junction temperature of 150°C and at 175°C in comparison to a competitor module rated 450A and 600A, respectively at 150°C for both inverter and rectifier mode. The simulation shows that the module output current in inverter mode (Figure 6a) and rectifier mode (Figure 6b) exceeds the competitor's performance in the full frequency range for the 450A rated variant. While the LoPak1 module outperforms the competitor's module only by a few percent in inverter mode, the difference in rectifier mode is exceeding 10%. This is attributed to the better thermal resistance as a consequence of the larger chips used. The ability of the ABB LoPak1 to be operated up to 175°C gives enough margin e.g. in case of over-load situations, to boost the output current by another 10% compared to 150°C operation and push it even beyond the 600A rated competitor module that is limited to an operating temperature of 150°C. Hence, ABB's LoPak1 offers the best inverter performance!

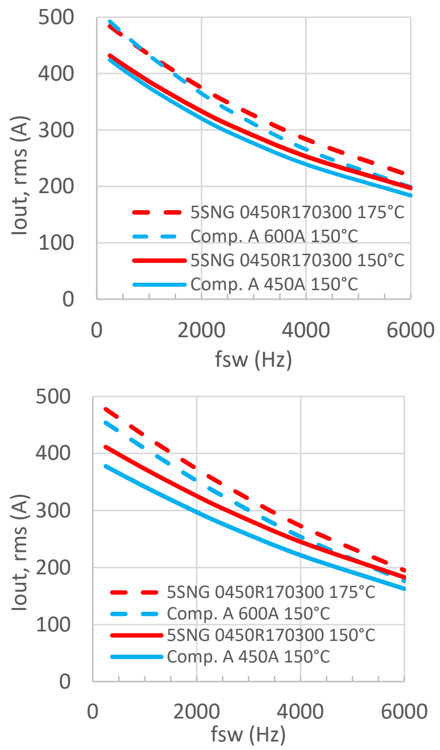

Figure 6: Simulated output current for the two operation modes. a) Inverter mode, conditions: Vcc=900V, m=0.9, cos phi=0.85, fout=50Hz, TA=50°C, Rth(h-a)=10K/kW. b) Rectifier mode, conditions: Vcc=900V, m=0.9, cos phi=-0.9, fout=50Hz, TA=50°C, Rth(h-a)=10K/kW.

By the help of this holistic design approach we combined the latest generation of ABB's planar 1700V SPT++ chipset for high-temperature operation of 175°C and realized an outstanding high Safe-Operating-Area (SOA) capability with a module featuring minimized self-inductance, low resistive losses, symmetrical high-and low-side switching. This allows our customers to fully utilize the switching capability of the IGBT with reduced cooling system requirements.

[1] Matthias et al. PCIM 2017, Nuremberg, Germany

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Accelerating Custom Capacitor Design with Simulation Apps

Engineers at Cornell Dubilier Electronics use simulation apps to evaluate and optimize custom capacitor designs. These apps allow design and manufacturing engineers to quickly explore configurations on-site, bypassing the complexity of the underlying computational model.

By Sarah Fields, COMSOL Inc.

Capacitors are ubiquitous across common electrical devices used today, as well as in applications where extreme conditions must be considered. In each of these applications for which capacitors are necessary, the requirements can vary greatly. A capacitor may require an exact power specification, may need to function within a certain temperature range, or be made of specific materials.

One of the biggest manufacturers of custom capacitors used around the world, Cornell Dubilier Electronics, develops capacitors for some of the most demanding military and aerospace applications, including fighter jets and radar systems, as well as civilian applications such as wind turbines and solar energy. Engineers at Cornell Dubilier use mathematical modeling and custom simulation apps to fine-tune the design of custom capacitors.

"By using COMSOL Multiphysics and its Application Builder I can create high-fidelity multiphysics models and build apps based on them, which allows my colleagues in other departments to test different configurations and pick the best design," comments Sam Parler, research director at Cornell Dubilier.

When Things Heat Up

Cornell Dubilier's capacitors are specific to the application for which they are designed and can comprise one or more elements, such as electrolytic windings composed of aluminum foils and cellulosic separators; electrostatic windings of offset, metallized dielectric films; or interleaved, stacked plates of metal foils and dielectrics such as mica (Figure 1).

Figure 1: Aluminum electrolytic capacitors. The windings are composed of aluminum foils and cellulosic separators, and exhibit thermal anisotropy.

One matter at the forefront of the issues considered by capacitor designers is heat. Passing current through the aluminum foils of the windings results in Joule heating, which must be taken into consideration during the design to gain a full understanding of the thermal profile within the capacitor. Too much heat dramatically shortens the capacitor lifetime, which halves every 6-10 degrees hotter the capacitor's core is run. Engineers at Cornell Dubilier use simulation to minimize heat generation and to optimize dissipation of heat.

In optimizing heat generation and heat dissipation, the complex materials of the capacitor must be accurately represented. One capacitor can easily include as many as six materials, some of which have anisotropic properties. In one design, the winding is composed of cellulosic separators and aluminum foils, and exhibits anisotropy of thermal conductivity over two orders of magnitude higher in the axial than in the radial direction.

Parler is able to accurately capture the thermal profile of capacitors with Comsol Multiphysics® thanks to the flexibility that allows him to directly input the thermal conductivity tensor. For example, a typical simple capacitor tensor of a z-oriented cylindrical electrolytic winding can be approximated as orthotropic with a diagonal thermal conductivity tensor of {1,1,100} [W/m/K].

In one case, Parler considered two power capacitors of similar size and ripple current rating, but with entirely different construction: that of a metallized polypropylene (plastic) film capacitor and an aluminum electrolytic capacitor (Figures 1 and 2).

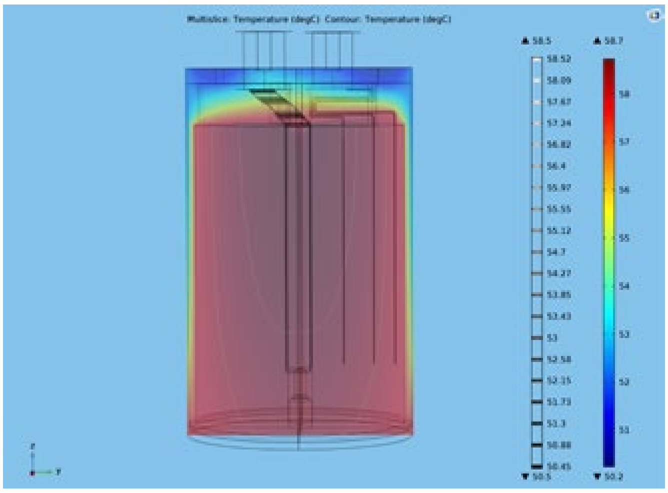

Figure 2: The aluminum electrolytic temperature distribution simulated in COMSOL Mulitphysics at approximately 76x120 mm and dissipating 5 watts in a 45°C environment.

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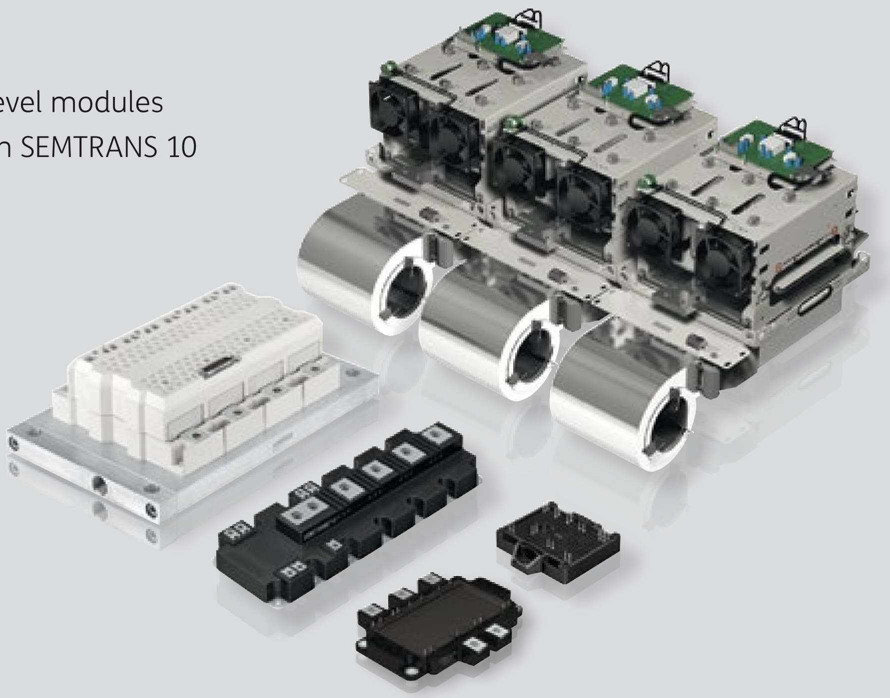

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The plastic film capacitor has a much lower axial thermal conductivity than the aluminum electrolytic capacitor. Using multiphysics simulation, Parler was able to quantify how much hotter the plastic film capacitor becomes compared to the aluminum electrolytic capacitor for a given dissipated wattage.

Demystifying the Microstructure with shape Optimization

As the capacitors developed at Cornell Dubilier are often new technological developments, in some cases, it is necessary to characterize the impedance of cutting-edge materials in house. In designing one large aluminum electrolytic capacitor, Parler needed to represent the impedance of an aluminum oxide (Al2O3) dielectric with a complex microstructure. This dielectric was produced in an anodizing bath on the tortuous surface of highly etched aluminum foil (Figure 3).

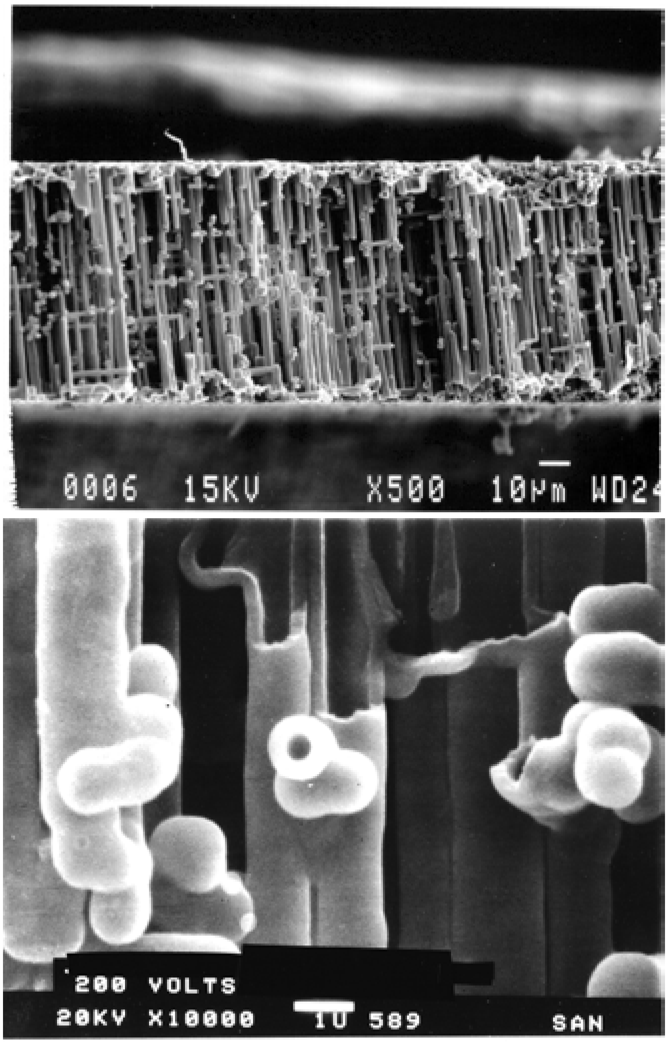


Figure 3: Coaxial microstructure of large aluminum electrolytic capacitors. The dielectric is aluminum oxide (Al2O3), grown in an anodizing bath on the tortuous surface of highly etched aluminum foil. In the images here, the aluminum surrounding the alumina dielectric tubes has dissolved away.

While a zero-dimensional electrical circuit simulation carried out in a different software could reproduce the frequency response, it was not able to perform the transient simulation due to 'noncausality' errors arising from the limitation of its internal inverse-Laplace-transform algorithms.

Using a shape optimization technique with the Comsol software, Parler was able to calculate the correct transient solution for a customer. He began with a single cylindrical, electrolyte-filled capacitive pore, applied a known excitation at the opening, and used the sparse nonlinear optimizer solver (SNOPT) available in the software to find the solution to his nonlinear optimization problem where the shape of the axisymmetric pore wall needed to be varied until the experimental impedance data was fitted.

The resulting geometry (Figure 4) demonstrated that the software could accurately reproduce the time-dependent pulse-current response that was measured experimentally, allowing further design work based on a validated mathematical model.

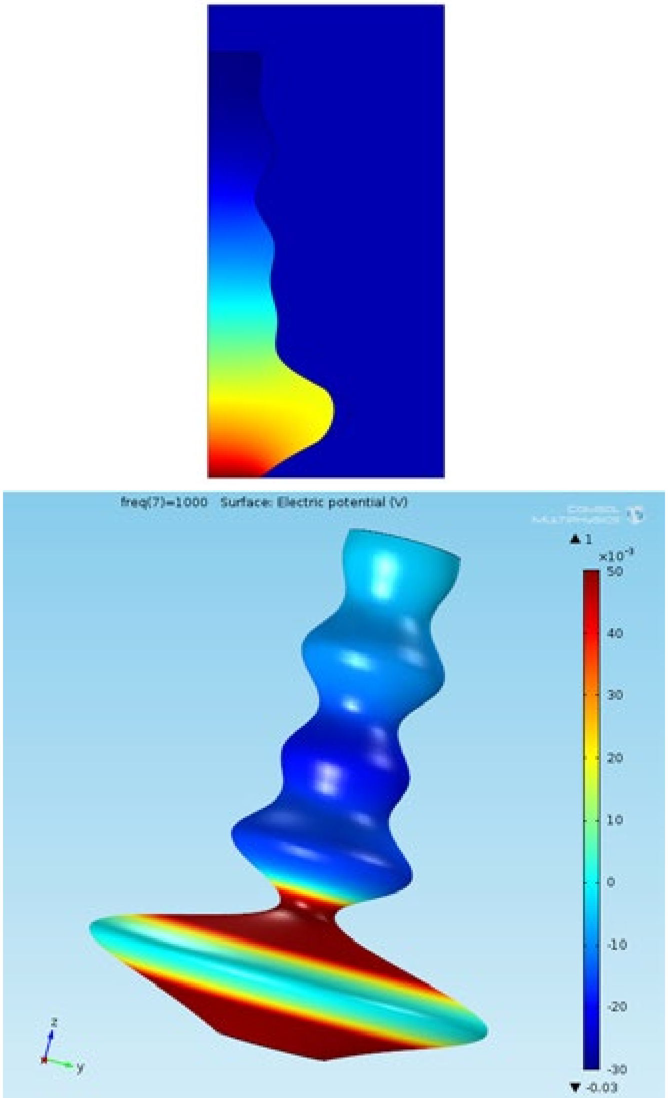


Figure 4: An alternative approach to capturing the electrical behavior of the coaxial microstructure of the dielectric material is to use shape-optimization techniques. Optimized microstructure is shown.

A Family of Apps for Electrical Optimization

After using Comsol to create models to analyze their designs, Parler and his team convert the models into simulation apps that are ready to be deployed to design engineers and manufacturing sites to assist in the design process.

Using one simulation app for a power film capacitor, a design engineer can enter the film width (typically a few centimeters), film length, surface resistances, and transition region location into the interface to determine the capacitance and resistance of a segment of the metal film (Figure 5). The result is scaled to yield a reported capacitance and resistance for the entire winding, providing engineers with an initial validation of their design.

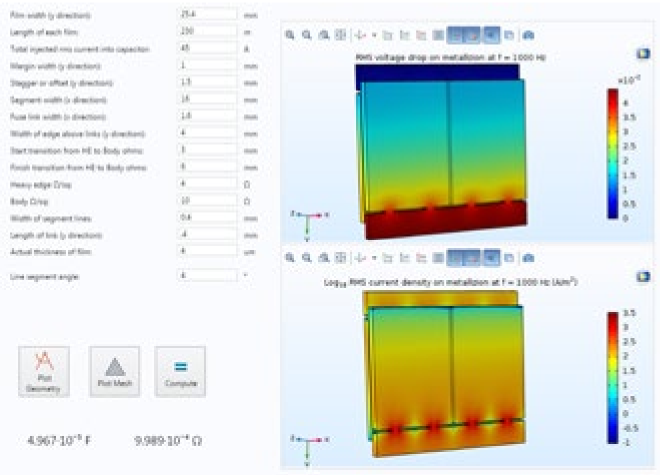


Figure 5: A design app for a power film capacitor used to determine capacitance and resistance.

Another app calculates power density for the metal film in a cylindrical capacitor. It also predicts the core temperature distribution, including throughout the tabs and terminals, taking into account the customer's operating conditions, such as ripple current, ambient temperature, and air velocity (Figure 6).

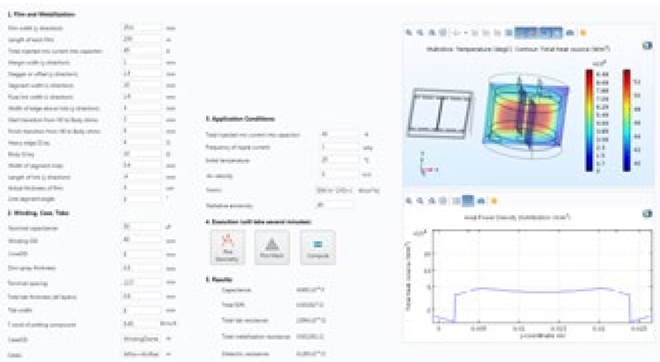


Figure 6: A simulation app that predicts the core temperature distribution and the power density for the film of a cylindrical capacitor with tabs and terminals.

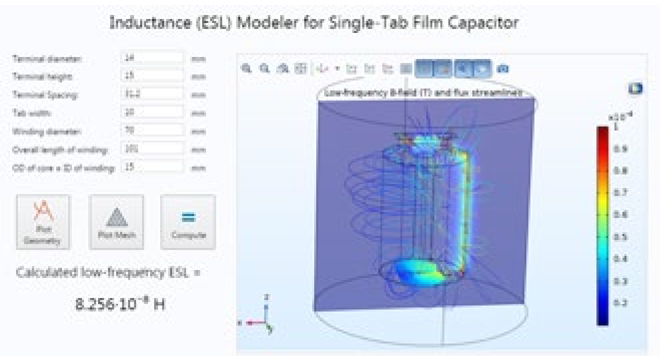


Figure 7: An app used to calculate effective series inductance (ESL) of a single-tab film capacitor.

A third app is used to calculate the effective series inductance (ESL) of a single-tab film capacitor (Figure 7). Geometric parameters such as the terminal diameter, terminal height, terminal spacing, tab width, winding diameter, and the outside diameter of the core can all be modified by the app user. The underlying model utilizes a frequency-domain study and the electromagnetic modeling capabilities of Comsol. The ESL is a key aspect of the design of any capacitor, and is directly linked to capacitor performance.

Apps Guide the Future of Manufacturing

With multiphysics simulation, Parler's team is able to accurately predict the performance of their capacitor designs, speeding development and ensuring reliability of their products.

Simulation apps based on the underlying Comsol models allowed other members of the design team and engineers at a manufacturing site to adjust key parameters of the simulation through a simplified user interface to test how their capacitors will perform and show the effect of design adjustments. This spreads the power of simulation throughout the design and manufacturing process.

Parler concludes, "The ability to build multiphysics models and simulation apps has streamlined our capacitor design process and sped the development of customized capacitors for customers all over the world."

Figure 8: Left to right: David Leigh, staff scientist; Sam Parler, research director; Trent Bates, capacitor designer; Cornell Dubilier

www.comsol.com

A Low-Profile IPM with Optimized Heat Dissipation for Use in Restricted Environments: CIPOS™ Nano IPM

In the modern world, some applications are placed in space-constrained environments; for example a motor with an embedded PCB. As a result of the limited space, there is no airflow and no room to apply additional cooling, such as a heatsink.

By Simon Kim, Pengwei Sun & Danish Khatri, Infineon Technologies, Korea & USA

Restricted environments need an innovative approach

Products used in these applications need to have sufficient thermal margin and be able to effectively dissipate the excess heat due to power losses within the increased ambient temperatures that occur during operation.

In this article, we will introduce the CIPOS™ Nano IPM that functions in space-constrained environments by dissipating heat via the PCB.

Figure 1: Example of a restricted environment where the PCB is mounted inside the motor

Single-phase 220 V AC applications

Some small motors have the PCB mounted inside the motor body itself. This is typical for motors used in applications such as air conditioning, ceiling fans, air purifiers or ventilation, as shown in Figure 2. In these applications, the rated motor power ranges from 40-60 W.

Figure 2: Examples of typical applications for a 40-60 W motor

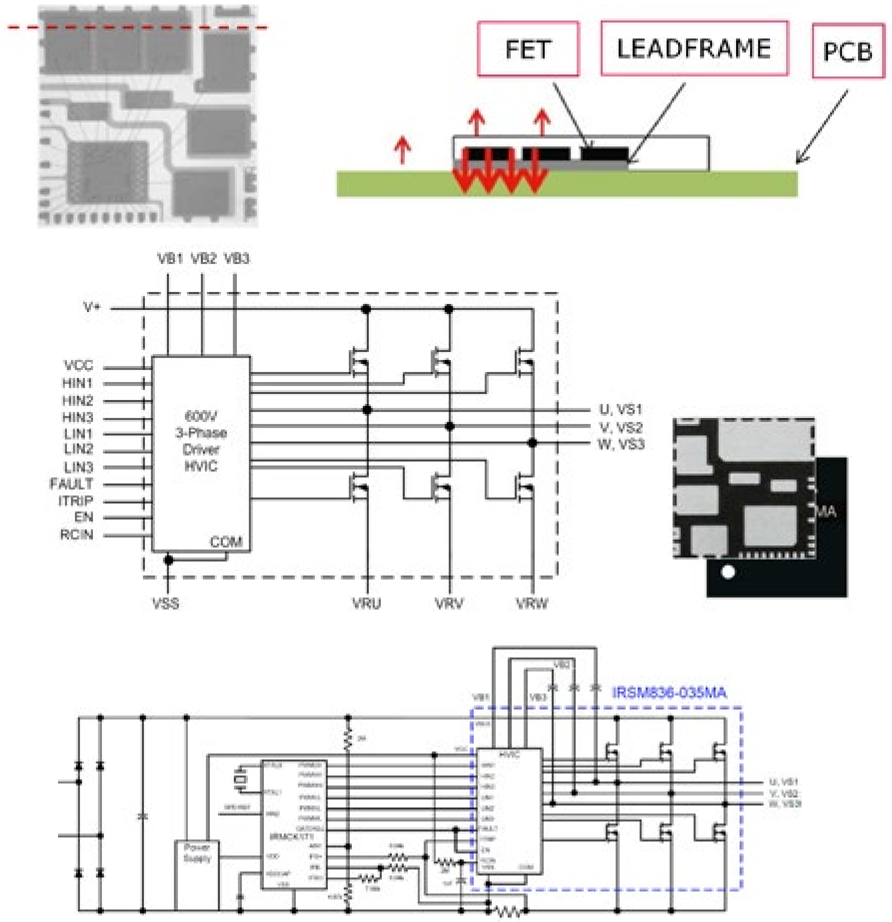


Figure 3: (a) The Nano IPM dissipates heat directly via the PCB (b) The Nano IPM in a 12 mm x 12 mm PQFN package (c) Application circuit example

These applications often operate with the motor running with very little or no air to dissipate heat by means of convection. Therefore, thermal dissipation will be conducted through the surface of the PCB. When an IPM is used in a space-restricted environment then the thermal calculations must be performed carefully.
Figure 3(a) shows how the heat from power FETs is dissipated through the PCB. The design of the IPM ensures that the lead frame attached to the FETs directly contacts the PCB, allowing generated heat to be dissipated directly through the PCB.
Infineon's small 3-phase CIPOS Nano IPM (12 x 12 x 0.9 mm) was selected for its thermal dissipation characteristics. This family of IPMs comprises a six-channel gate driver and six MOSFETs in a in a single package (as shown in Figure 3(b)).

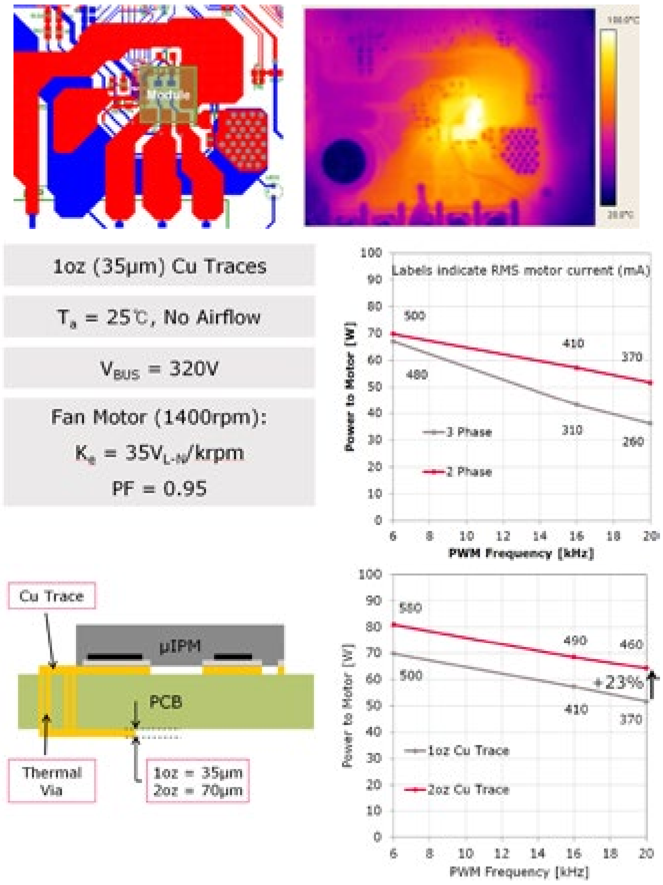


Figure 4: (a) PCB layout and thermal camera measurement result (b) Max. motor power on 1 oz. copper PCB traces (c) Increased motor power on 2 oz. copper PCB traces

The 500 V CIPOS™ Nano parts can be used for 220 VAC motor drive applications due to VDC being around 311 V. The IPM offers overcurrent protection and its fault clear time can be determined by setting R and C values.
Figure 3(c) demonstrates an application circuit for a sensorless motor drive circuit that includes an Infineon IRMCF171 appliance motion control IC. In this circuit example, the IPM's fault pin is connected to the GATEKILL pin of the IRMCF171 allowing the controller to shut down all gate signals whenever a fault occurs.

Power capacity measured by a thermal test

As mentioned above, the heat from the Nano IPM is dissipated via the PCB. However, this requires verification by thermal measurement. Figure 4(a) shows the PCB layout and the results of thermal measurement conducted with a thermal camera. This CIPOS™ Nano IPM on a PCB, with 1 oz. copper traces at an ambient temperature of 25°C with no airflow, can run a motor with an output current of 500 mA using discontinuous Space Vector PWM (SVPWM) operation. In three-phase SVPWM operation, the IPM can handle output currents up to 480 mA. In this case, the switching frequency is 6 kHz and the electrical power output to the motor is around 65 W as shown in Figure 4(b).

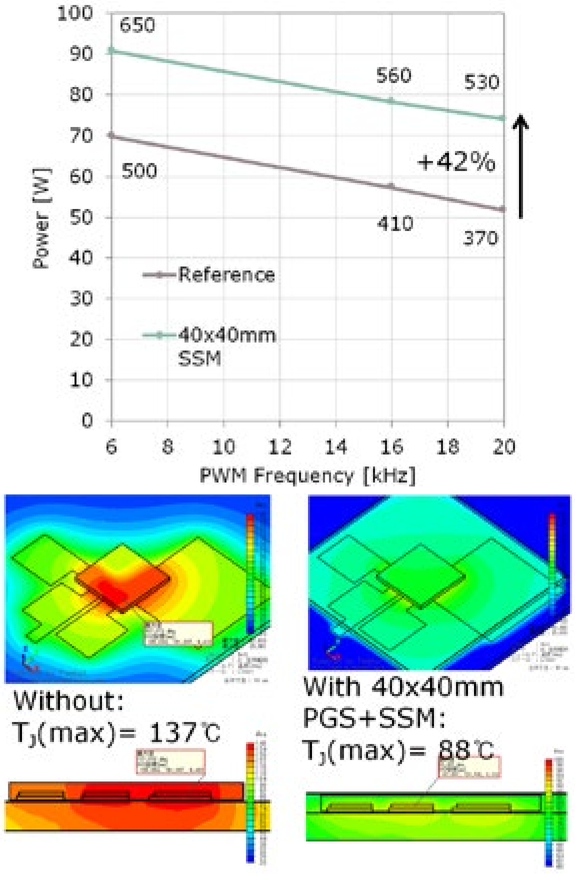


Figure 5: (a) Max. power with isolated thermal film, PGS+SSM (b) Using the film reduces junction temperature from 137°C to 88°C

When using a 2 oz. copper PCB, more current can be delivered. For a switching frequency of 6 kHz, the IPM can increase current capacity from 500 mA to 580 mA; representing an increase of 16%. If the switching frequency is 20 kHz, current capacity can be increased from 370 mA to 460 mA - a 23% increase.
For greater current capacity, isolated thermal film can be applied directly to the PCB.
When 40 x 40 mm isolated thermal film was applied, the junction temperature reduced from 137°C to 88°C as seen in Figure 5(b). At a switching frequency of 6 kHz, current capacity can be increased from 500 mA to 650 mA, a 30% increase. For switching frequencies of 20 kHz, current capacity can be increased from 370 mA to 530 mA, an increase of 42%.

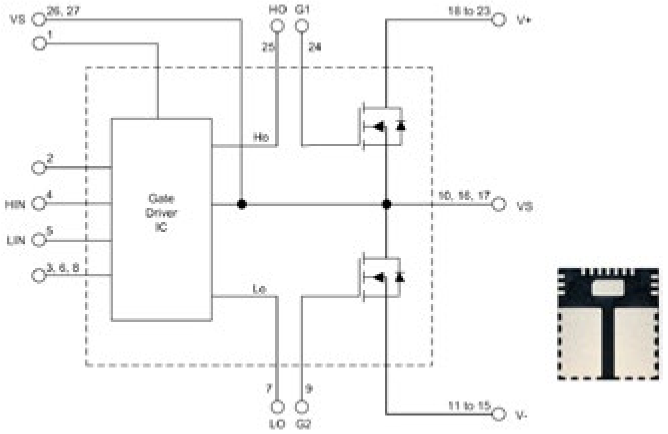
Low-voltage fan or battery-driven motor application

Some motor applications require a low-voltage fan rated under 100 V DC. The fan is operated by a DC voltage of 24 V or 48 V or a battery voltage under 60 V. For this type of application, a low-voltage IPM such as the 40 V, 80 A, IRSM005-800MA or the 100 V, 30 A, IRSM005-301MA half-bridge CIPOS Nano IPM is needed. The mechanical design concept for these IPMs is the same as the 3-phase Nano IPM. Similar to the devices mentioned earlier, these devices also have direct thermal contact between the lead-frame and the package surface (and, therefore, the PCB).

Designing with IRSM005 IPMs simply requires addition of a bootstrap diode, capacitor and gate resistor. These IPMs are suitable for single-phase applications, h-bridge or 3-phase applications by choosing different half-bridge configurations with the CIPOS devices.

Conclusion

In this article, we have shown that a motor application with embedded PCB in a space-restricted environment needs a proven solution that overcomes the lack of airflow and heatsink. System design demands an adequate thermal margin that must be calculated and measured, using a thermal camera or other technique.



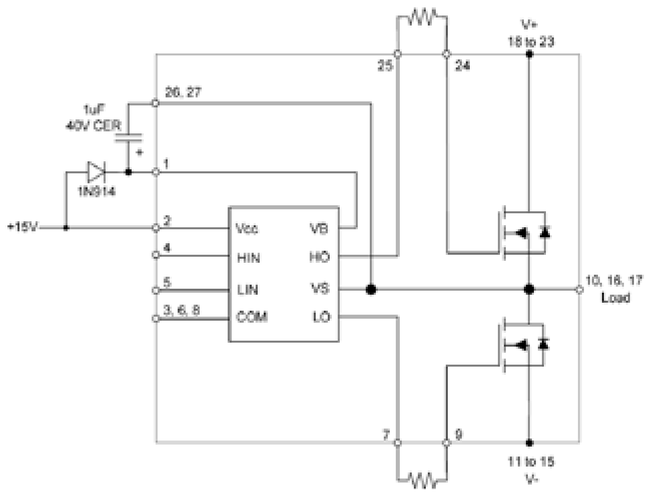


Figure 6. (a) Low voltage Nano IPM in a 7 x 8 mm PQFN package (40 V or 80 A half bridge IPM & 100 V 30 A IPM) (b) Application circuit with bootstrap diode, capacitor & gate resistor

References:

[1] IRSM836-035MA, 3 Phase Nano IPM (500 V 3 A IPM) data sheet

[2] IRSM005-800MA, half bridge Nano IPM (40 V 80 A IPM) data sheet

[3] IRSM005-301MA, half bridge Nano IPM (100 V 30 A IPM) data sheet

[4] IPM Presentation File

[5] Application Note AN-1168

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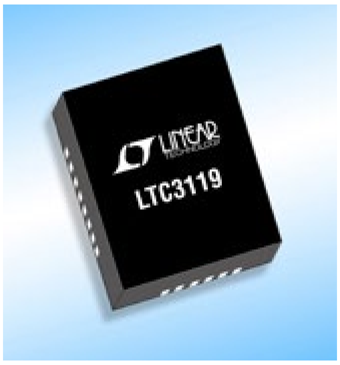
Wireless Medical Instrumentation Benefits from New Power ICs



As with many other applications, low power precision components have enabled rapid growth of portable and wireless medical instruments. However, unlike many other applications, this type of medical product typically has much higher standards for reliability, run-time and robustness.

By Tony Armstrong, Director of Product Marketing Power Products, Linear Technology Corporation, Now Part of Analog Devices

Background

Much of this burden falls on the power system and its components. Medical products must operate properly and switch seamlessly between a variety of power sources such as an AC mains outlet, battery back-up and even harvested ambient energy sources. Furthermore, great lengths must be taken to protect against and tolerate faults, maximize operating time when powered from batteries and ensure that normal system operation is reliable whenever a valid power source is present.

One of the current key trends fueling growth in the potable and wireless medical instrumentation is patient care. Specifically, this is the increased use of remote monitoring systems within the patient's own home. The reason for this is trend is purely economic in nature – the costs associated with keeping a patient in a hospital are simply too prohibitive. As a result, many of these portable electronic monitoring systems must incorporate RF transmitters so that any data gathered from the patient can be sent directly back to a supervisory system within the hospital for later review and analysis by the governing physician.

Given the above scenario, it is reasonable to assume that the cost of supplying the appropriate medical instrumentation to the patient for home use is more than offset by the cost of keeping them in the hospital of observation purposes. Nevertheless, it is of paramount importance that the equipment used by the patient be reliable and fool-proof. As a result, the manufactures and designers of these products must ensure that they can run seamlessly from multiple power sources and have high reliability in their wireless data transmission of the data collected from the patient. This requires the designer to ensure that power management architecture is robust, flexible, compact and efficient.

Power IC Solutions

There are many applications in medical electronic systems that require continuous power even when the mains supply is interrupted; a key requirement is low quiescent current to extend battery life. Accordingly, power IC makers have been producing switching regulators with standby quiescent current less than 30mA since 2010. In fact, some of Linear Technology's recent product introductions have taken this figure down to a mere 2.5mA. As a result, these products are well positioned for adoption in battery backed-up medical systems.

Although switching regulators generate more noise than linear regulators, their efficiency is far superior. Noise and EMI levels have proven to be manageable in many sensitive applications as long as the switcher behaves predictably. If a switching regulator switches at a constant frequency in normal mode, and the switching edges are clean and predictable with no overshoot or high frequency ringing, then EMI is minimized. A small package size and high operating frequency can provide a small tight layout, which minimizes EMI emissions. Furthermore, if the regulator can be used with low ESR ceramic capacitors, both input and output voltage ripple can be minimized, which are additional sources of noise in the system.

As the number of power rails in many feature-rich patient monitoring medical devices has increased, operating voltages have decreased. Nevertheless, many of these systems still require a broad range of voltages from 1.xV to 8.xV for powering motors, low power sensors, memory, microcontroller cores, I/O and logic circuitry.

Traditionally these voltage rails have been supplied by step-down switching regulators or low-dropout regulators. However, these types of ICs are not optimized for configurations that also incorporate a back-up battery in the system, should the main supply fail. Therefore, when a buck-boost converter is used (it can step voltages up or step them down) it will allow the battery's full operating range to be utilized. This increases the operating margin and extends the battery run time as more of the battery's life is usable, especially as it nears the lower end of its discharge profile.

Correspondingly, DC/DC converter solutions utilized in portable medical instrumentation which may also incorporate a primary battery cell as well should have the following attributes:

- A buck-boost DC/DC architecture with wide input voltage range to regulate VOUT through a variety of battery-powered sources and their associated voltage ranges
- Ultralow quiescent current, both in operating mode and shutdown, to increase battery run time
- The ability to efficiently power system rails
- Current limiting for attenuating inrush currents thus protecting the cells
- Small, lightweight and low profile solution footprints
- Advanced packaging for improved thermal performance and space efficiency

A new power IC that meets these requirements is the LTC3119 from Linear Technology. It is a synchronous current mode monolithic buck-boost converter that delivers up to5A of continuous output current in buck mode from a wide variety of input sources, including single- or multiple-cell batteries, unregulated wall adapters, as well as solar panels and supercapacitors. The device's 2.5V to 18V input voltage range extends down to 250mV once started. The output voltage is regulated with inputs above, below or equal to the output and is programmable from 0.8V to 18V. User-selectable Burst Mode® operation lowers quiescent current to only 31μA, improving light load efficiency while extending battery run time. Its proprietary 4-switch PWM buck-boost topology provides low noise, jitter-free switching through all operating modes, making it ideal for RF and precision analog applications that are sensitive to power supply noise. The device also includes programmable maximum power point control (MPPC) capability, ensuring maximum power delivery from power sources with higher output impedance including photovoltaic cells. See Figure 1 for its simplified schematic.

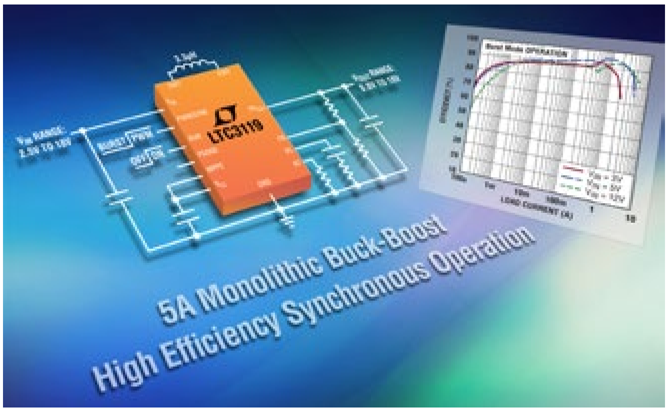


Figure 1: LTC3119 Schematic Showing a High Level of Integration & Performance

The LTC3119 includes four internal low RDSON N-channel MOSFETs to deliver efficiencies of up to 95%. Burst Mode operation can be disabled, offering low noise continuous switching.
External frequency programming or synchronization using an internal PLL enables operation over a wide switching frequency range of 400kHz to 2MHz, which allows for the tradeoff between conversion efficiency and solution size. Other features include short-circuit protection, thermal overload protection, less than 3μA shutdown current, and a power good indicator. The device's combination of tiny externals, wide operating voltage range, compact packaging, plus low quiescent current makes the LTC3119 well suited for RF power supplies, high current pulsed load applications, system backup power supplies and even lead-acid battery to 12V conversion systems.

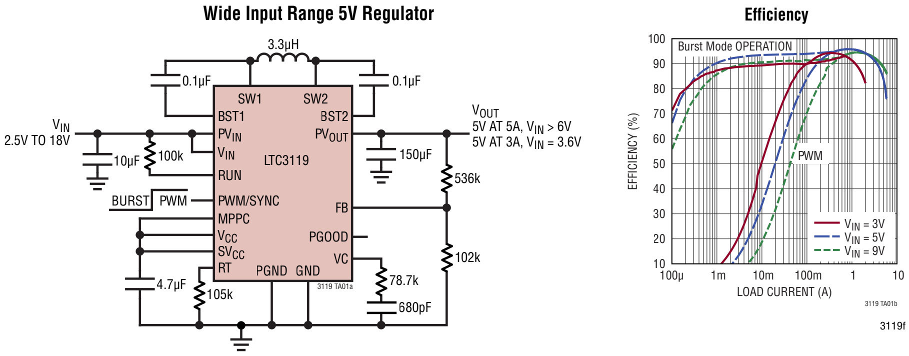


Figure 2: Wide Input Range 5V Regulator and Efficiency

Many portable medical systems require being powered from multiple input sources including single or multi-cell battery configurations, wall adapters and supercapacitor stacks.

Conclusion

A large opportunity has presented itself for designing a wide range of battery-powered and/or battery backed-up medical systems. At the same time, system designers have faced difficult challenges in selecting the right power conversion solution that meets the key design objectives, including spanning the input-to-output voltage constraints, power levels and ease of design, without compromising efficiency, run time, meeting emissions specifications and solution size.
Designing a solution that meets the system goals without performance compromises can be a daunting task. Fortunately, there are a growing number of buck-boost converter solutions from Linear Technology, which simplify the design, offer best-in-class features and have the ability to maximize run times in-between battery recharging cycles due to their high efficiency operation across a wide range of loads.

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Cleaning Requirements for Improved Efficiency and Reliability

Today, power modules are widely used in high power applications such as hybrid electric vehicles, solar inverters, medical equipment, and UPS (Uninterruptable Power Supplies) devices. For energy efficiency reasons, high power devices such as MOSFETs, IGBTs and DCBs are subjected to increased performance requirements with greater packaging density and involves various metal material mix.

By Thomas Kucharek, Zestron Europe, Ravi Parthasarathy, M.S.Ch.E.and Jigar Patel, M.S.Ch.E., Zestron Americas

HIGH POWER ELECTRONICS:
Moreover, they oftentimes are subjected to elevated temperature and power cycling environments, extremely high current flow and extreme thermal transfer requirements. Accordingly, even the slightest contaminants remaining on the surface will impede the reliability required in these critical and highly sensitive applications.

During the power module manufacturing process, contaminants including oxide films and flux splatter remain on the substrate and chip surfaces. In order to guarantee the highest process reliability, these contaminants must be completely removed from the surfaces through a cleaning process.

There are several process flows for power module production and thus various process steps that require cleaning. Although the production process may vary based on the application, design and functionality of the power devices, typically cleaning is required following die attach to copper substrate prior to wire bonding and after heat sink soldering prior to further processing such as bonding and molding.

Figure 1: Cleaning Applications in Power Module Production

This paper, originally presented in Bodo's Power Systems, details power module applications including typical qualification tests, failure mechanisms and considerations for cleaning processes [1]. Subsequent to its release, engineered aqueous-based cleaning agents have been incorporated into power module manufacturing processes. Several customer case studies highlighting this cleaning alternative and the reliability impact on the process are detailed within the complete paper that is available online (www.zestron.com).

BACKGROUND
There are several process flows for power module production and thus different stations, where cleaning is usually required. The production process flow may differ due to the field of application, such as for automobile and industrial operation, as well as due to the design and functionality as defined by the end customer.

Usually, the first production step is the die attach to the copper substrate by soldering, for example of IGBTs and diodes (Figure 1). Afterwards, production flows may vary. In any case, there are two points where cleaning is highly recommended. The first point would be after die attach by soldering to prepare the modules for wire bonding and the second would be after heat sink soldering before the modules are further processed, for example molded, wire bonded and/or connected to frames.

Irrespective from the process flow and final module structure, contaminants such as oxide films and flux spatter remain on the chip and

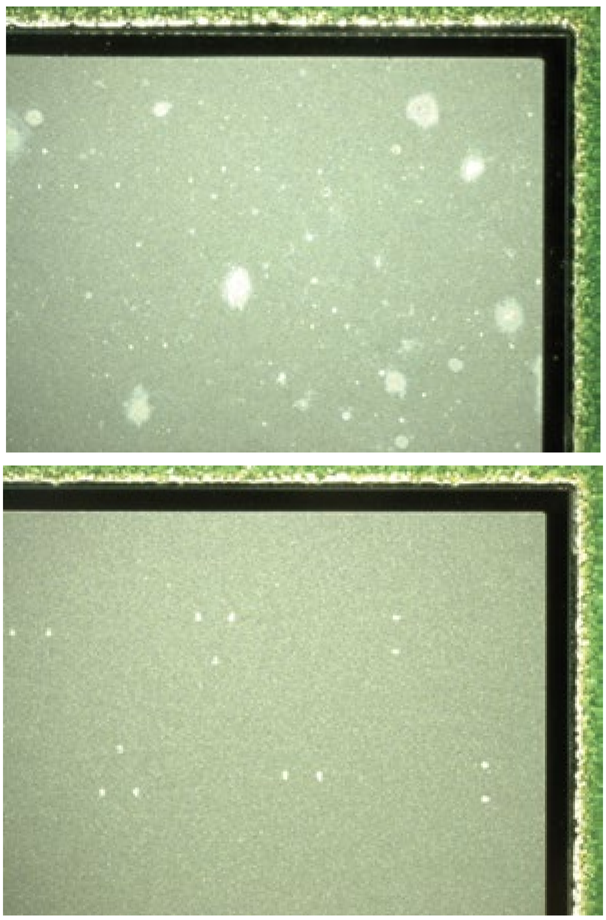

Figure 2: Diode uncleaned (Top) and cleaned (Bottom)

substrate surface after soldering. These residues have a negative impact on subsequent processes such as wire bonding or molding. Wire bond adhesion is often impaired when flux splatter remains on surfaces. Residues on the substrate and chip surfaces can impair achievable shear values for copper, diodes and IGBTs. Since these values are often used for the cleanliness qualification, it is necessary to completely remove all residues in a suitable cleaning process.

Qualification Procedure

Typically, extensive qualification testing is performed to determine the reliability of power modules. This enables manufacturers to qualify products in accordance with internationally accepted tests. Examples of standard qualification tests based on IEC and CENELEC standards are detailed in Table 1 (See Appendix in the complete paper that is available online).

Advantages of an Optimized Cleaning Process

Although solvents were traditionally used to clean power electronics, aqueous-based cleaning processes have become the norm over the past few years. Aqueous-based cleaning agents specifically developed for power electronics provide excellent cleaning performance while ensuring material compatibility and long-term reliability of the power modules at the same time. They offer additional benefits such as significantly lower VOCs (Volatile Organic Compounds) and greatly improve health and safety.

Field data has confirmed that an optimized aqueous-based cleaning process offers numerous advantages with regard to wire bond quality and reliability, as determined through shear tests and power cycling as well as molding and material compatibility.

Wire Bonding Quality – Shear Tests

There are two main issues that influence wire bond quality. These are flux residues on the substrate after soldering and more importantly, flux spatter remaining on the chip surfaces (Figure 2).

Bonding on uncleaned chips leads to insufficient quality and often results in either unnecessary high bonding power which leads to heel cracks, chip defects, or lift offs due to poor wire connection. Reference Figures 3-5.

Ideally, power modules require visually flawless and spot-free substrates and chip surfaces. However, the soldering process or unsuitable cleaning agents, amongst other things, can lead to heavily oxidized parts. These oxide layers on the surface can lead to problems during bonding and can impair the production yield (Figure 6).

A suitable cleaning process must achieve excellent cleaning performance in order to remove all flux residues from soldering and be able to activate oxidized surfaces. With a cleaning process optimized for power devices, the surfaces are optimally prepared for bonding. Field data has demonstrated that aqueous-based, pH neutral cleaning media can achieve these results as compared to traditionally flammable solvents thereby producing excellent bond yields and visually flawless parts.

The quality of the wire bonds is usually evaluated by shear testing. A stable process with high shear values and low standard deviation is required for production yield as indicated by Figure 7, referencing an ideal cleaner. Modules failing to pass shear tests can negatively impact process efficiency and costs, especially if the substrates are already soldered to the heat sink.

In conjunction with customer projects, ZESTRON investigated the effect cleaning had on shear values as part of an internal study [2].

Wire bond yield comparisons were made on substrates that were not cleaned and cleaned with a micro phase cleaner. Results proved that micro phase cleaning agents greatly increase shear values as compared to those achieved with uncleaned power modules (Figure 8).

Given an optimized aqueous-based cleaning process, even plasma treatment, which has been typically necessary, can be eliminated thereby leading to significant cost reduction potential.

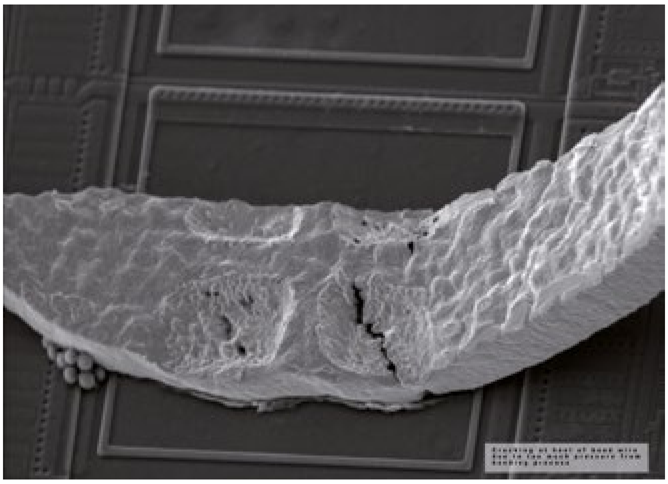

Figure 3: Heel cracks

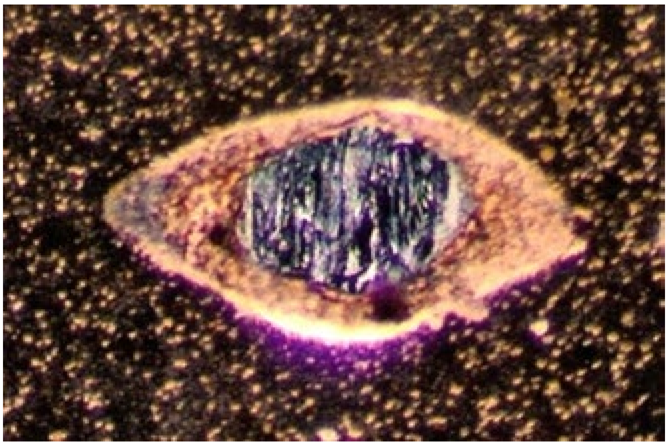

Figure 4: Chip defect

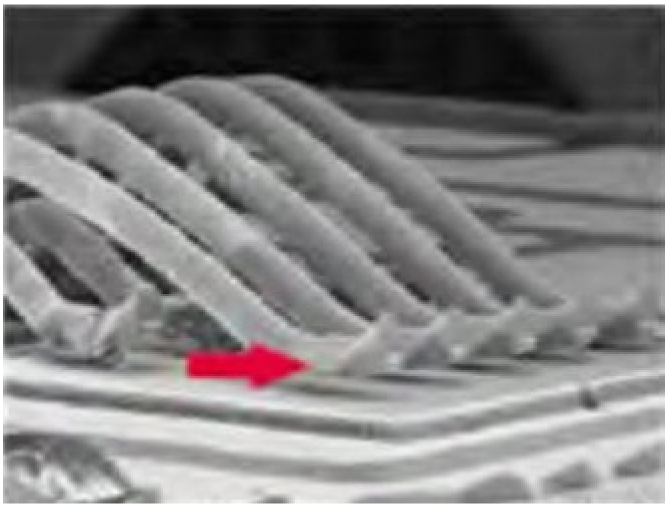

Figure 5: Bond lift off

Long-term Reliability – Power Cycling Results

The aim of cleaning is always to guarantee long-term reliability of the power modules. The widely used method to qualify the long-term reliability or lifetime is power cycling. Typical qualification test methods include: thermal shock, mechanical shock, humidity, vibration, low and high temp storage, moisture resistance, HTRB, HTGB and intermittent operations. The modules are stressed based on specific life cycle models of their dedicated application with their lifetime typically measured in cycles.

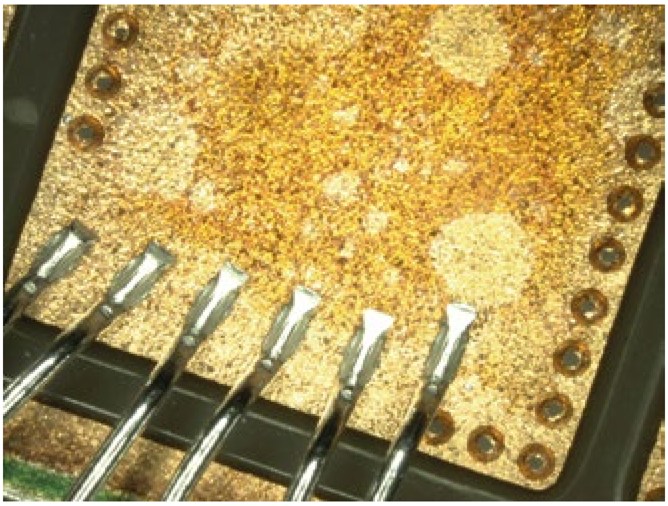

Figure 6A: Bonds on heavily oxidized Cu substrate

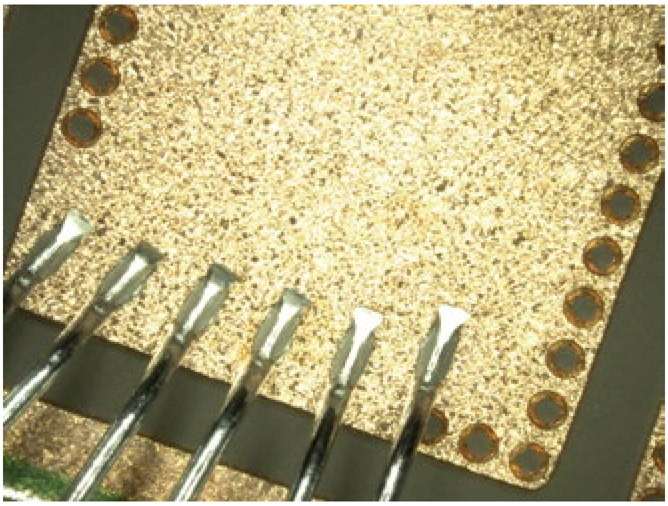

Figure 6B: Bond on Cu substrate activated by cleaning

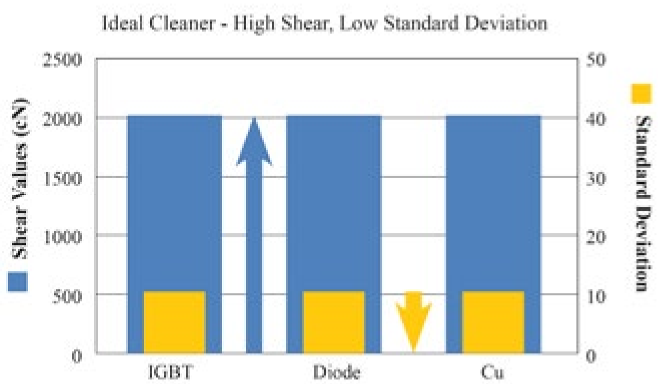

Figure 7: Shear value comparisons: Ideal cleaner

If the modules have not been sufficiently cleaned and contaminants still remain on the chip and substrate surfaces, they oftentimes will fail power cycling tests. The most common failure are bond lift-offs caused by poor bond connections due to residues. Once a bond connection fails, the stress on the others is raised, usually leading to an exponential increase in the number of bond failures finally resulting in the breakdown of the power module.

Cleaning the modules prior to bonding has a significant impact on the power cycling results. If the residues from soldering are removed completely through an optimized process, the bond quality is thereby improved, long-term reliability is increased yielding excellent power cycling results. In comparison, modules cleaned in a conventional process statistically show shorter life times.

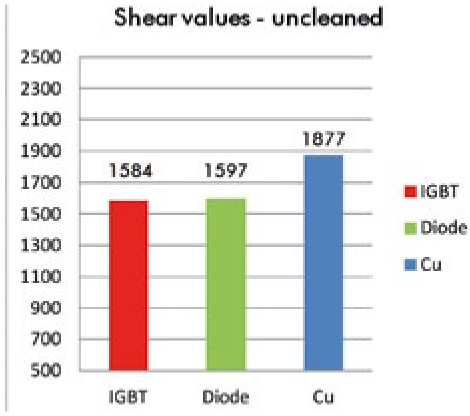

Figure 8A: Shear value comparisons: Uncleaned power module

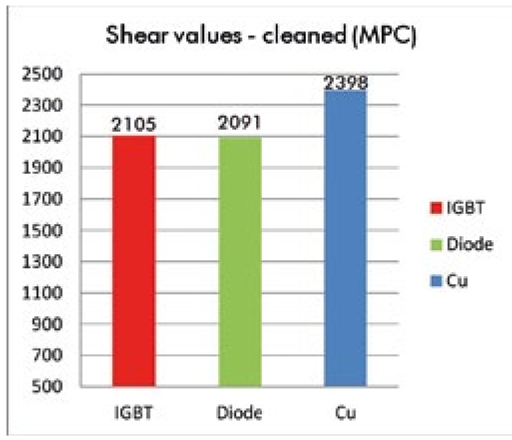

Figure 8B: Shear value comparisons: Modules cleaned before bonding

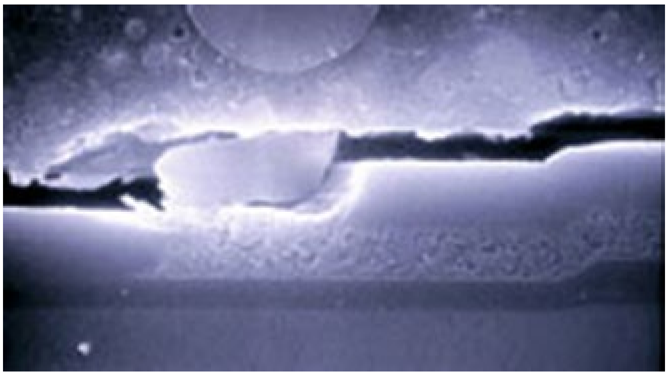

Figure 9: Delamination

Molding Adhesion

The cleaning process also impacts molding quality. In many cases, molding is applied to the bonded substrates to protect them from environmental influences. Contaminants play a decisive role with regard to molding adhesion and thus reliability. Flux residues on the substrate surface reduce molding adhesion forces, which in turn may lead to delamination. Reference Figures 9-10.

They may also lead to electrochemical migration beneath the molding resulting in field failures. In the course of several cleaning projects, it was proven that cleaning increases the adhesion forces while limiting delamination defects and thereby improves the molding reliability.

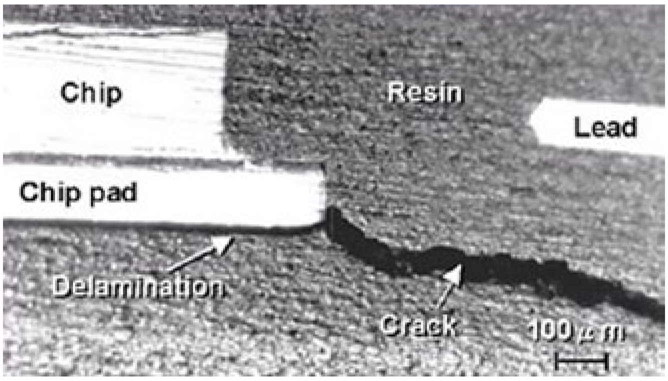

Figure 10: Delamination

Material Compatibility

When seeking a cleaning process for high power devices, the cleaning performance is usually the main point of interest with regard to bonding and production yield. However, another important aspect is often neglected, that is the compatibility of the cleaning process with power module materials.

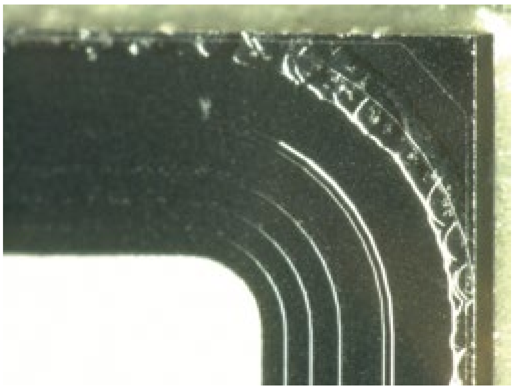

Figure 11A: Attack by an unsuitable cleaning agent

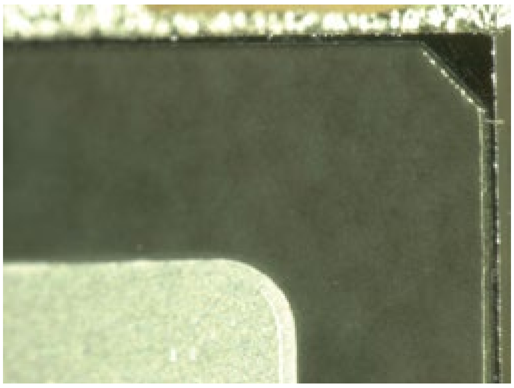

Figure 11B: Optimally cleaned using suitable cleaning agent

Cleaning agents for power modules must meet exceptional material compatibility requirements. Thus, the cleaning agent selection is critical to ensure it does not affect various chip passivations or the substrate surface itself. Unsuitable cleaning agents attack the passivation layers thus leading to the impairment of the chip function. The adverse effect of a cleaning agent on glass passivation of a thyristor is represented in Figure 11.
Additional material compatibility issues that could possibly arise are detailed in Figure 12 and Table 2.

Area	Metal Material Mix	Possible Issues
A	Nickel Substrate	Discoloration
B	Bath Copper	Oxidation
C	Solder Side	Oxidation
D	Insulated Material	Destroy
E	Aluminum Die	Oxidation

Table 2: Material Compatibility Issues

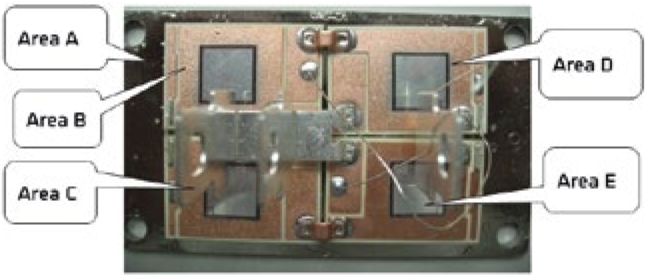

Figure 12: Material compatibility issues

It is therefore recommended to test not only the cleaning performance of the cleaning agent, but also to ensure that it is fully compatible with different metal material subsets before a process is implemented. Two case studies, featuring global OEMs, highlight the reliability impact of utilizing engineered cleaning agent processes for the power module manufacturing process are detailed in the complete paper that is available online. One OEM produces electronics for the energy, automotive and information technology sectors and the other for power and photovoltaic systems.

Summary

Cleaning power modules before bonding is a must to ensure their long-term reliability. Adjusted processes with cleaning agents specifically developed for power modules ensure highest cleanliness levels and thus increase bond and mould quality. At the same time, they ensure compatibility with chip passivations and substrate materials. Significantly improved results of the shear test and power cycling qualification finally lead to an increase in production yield. ZESTRON has already implemented several high volume processes in this area for automotive and industrial applications and is ready to support you with the selection or optimization of your power electronics cleaning application.
Originally published in the proceedings of SMTA International Conference on Soldering and Reliability, Toronto, Canada, May 9-11, 2016

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www.zestron.com

Why not Measure Signals Also in the Time Domain to Understand and Design EMI Filters?

The design of EMC filters for drives are often based on experience. One of the main condition to have a well working interference suppression are related to the switching frequency of the inverter. For understanding this it is very helpful to measure voltages and currents also in the time domain, what is quite unusual during EMC measurements.

By Günther Herrmann, ThyssenKrupp Elevator Innovation

Frequency inverters have high conductive related interference levels due to the switching mode of operation. In order to reduce this, an EMV filter is provided at the line input. The EMC filter typically consists of one or more filter stages with capacitors and current-compensated chokes.

The measurement setup for conductive emission measurement is quite troublesome, since a motor generator set and the EMC measuring devices with line impedance stabilization network (LISM) must be setup in a standardized manner. If the required limits for the emissions are exceeded, the filter is modified and measured again.

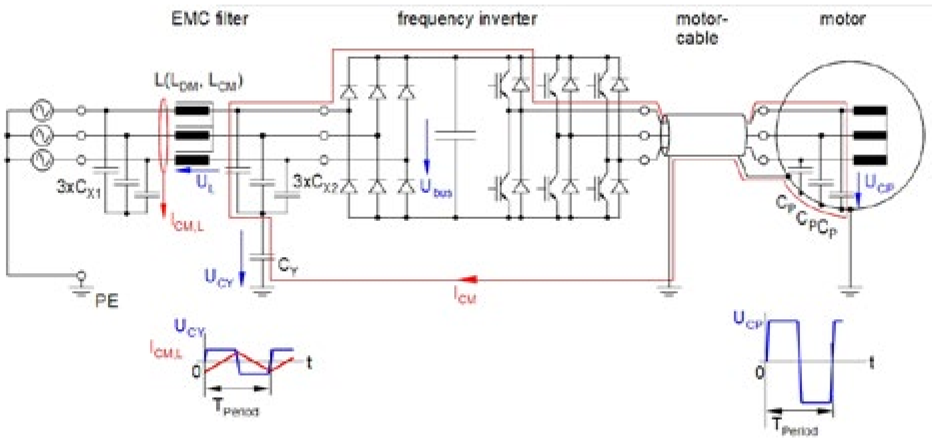

Figure 1: Capacitors CP and CY form a simple voltage divider

Often only one of many possible frequency inverter-motor combinations can be measured. It remains unclear whether the limit values can also be maintained in combination with other motors.

The following describes a method by which the EMC filters can be designed and optimized in a systematical manner. The main focus in this article is the behavior of the filter in the frequency range from the switching frequency of the frequency inverter up to about 1 MHz. It is assumed that typical high-frequency requirements of the filter design are taken into account.

Operation-mode of the drive

To assess the EMC situation, the knowledge of the pulse pattern generated by the frequency inverter is important. According to the state of the art, the so-called SpaceVectorModulation (SVM) is often used. This type of modulation generates, for example, an average output voltage of 0V by switching the zero vector „7“ (all upper IGBT‘s „on“) with 50% duty cycle and the zero vector „0“ (all lower IGBTs „on”) also with 50% duty cycle. Therefore, the common mode voltage corresponds to the DC-link voltage (respective + / - DC-link-voltage / 2). This operating point represents the one with the highest common mode voltage. Thus a distinctive operating point is found. At this operating point, the capacitors CP and CY (see Figure 1) form a simple voltage divider for alternating voltages in the range of the switching frequency of the frequency inverter.

$U_{CY} = 3{*}C_P/C_Y{*}U_{bus}$ (1).

Modulation methods with low common mode voltages are also known [1], [2]. However, the ripple currents in the motor windings are then increased.

Design of the EMC filter

The necessary insertion attenuations can be determined by interference level measurements without an EMC filter in order to fall below the desired interference level. In addition, the differential mode (DM) and common mode (CM) interference level can be measured with the aid of an RF current measuring clamp [3] or a DM / CM separator [4], [5] and the ratio of the differential mode component to the common mode component can be determined. Thus the values for CX1 * LDM, CX2 * LDM and CY * LCM can be calculated.

Despite knowledge of these values, it occurs often that the EMC filter does not have the desired insertion damping. The data sheets of many EMC filters contain attenuation values, which were measured with network analyzers. These analyzers are far from reflecting the operating mode of the filter in use with the frequency inverter drive. The saturation current (see also [5]) is still missing for the current compensated choke.

The magnetization of the core due to the differential mode current can be estimated as follows ([5], [6]):

$B_{DM} = Lsigma*I_{DM}/(N*A_{Fe})$,
Where N is the number of turns and A_{Fe} is the effective magnetic cross-section of the core, and L_{sigma} is the leakage inductance of the current compensated choke, and I_{DM} is the current at the network input.

The magnetization due to the common mode current can be determined approximately by means of the alternating voltage at U_{CY}.
From:
Results with $U_L = U_{CY}$:

$$I_{CM,L} = (T_{Period}/2)*U_{CY}/L_{CM}. \quad (2)$$

With (1) follows:

$$I_{CM,L} = 3*C_P*(T_{period}/2)*U_{bus}/(C_Y*L_{CM}) \quad (3)$$

The values T_{period} and U_{bus} are known from the operating conditions of the frequency inverter, CY and LCM or the product CY * LCM is determined by the necessary interference suppression. The value for CP is still missing. It is possible to measure this value directly or measure the voltage at CY. If the measurement setup corresponds to the final arrangement (shielded motor cable, ...), this measurement includes all parasitc capacities to PE. With the help of the voltage profile at CY, the magnetization current ICM for the current-compensated choke can be calculated:

$$B_{CM} = U_{CY}*T_{Period}/2\ /(N*A_{Fe}) \text{ bzw.} \quad (4a)$$
$$B_{CM} = L_{CM} * I_{CM} / (N*A_{Fe}) \quad (4b)$$

The demand for the saturation induction results overall
$B_{sat} > B_{DM} + B_{CM}$.

For frequency inverters with space vector modulation, the highest common mode control occurs in the range around the output voltage zero (zero speed), the largest period duration T_{Period}, and the highest DC-link voltage. As already mentioned, this is selected as the first operating point for a disturbance level measurement.
The highest differential mode is to be expected at the highest input current of the frequency inverter. Therefore, this is selected as a further operating point for emission level measurement.
If the operating point with the shortest period duration (which corresponds to the highest switching frequency and thus the highest power density spectrum) as well as a braking operation are also measured, it can be assumed that the EMV filter performs its function at all operating points.
All these operating points occur, for example, in the case of elevator drives.

Optimization of the EMC filter
In order to check the basic functionality of an EMC filter in frequency inverter operation, simple measurements in the time domain can be carried out as shown in Figure 2 and 3 (left pictures). Knowing the saturation limit of the current-compensated choke (measurement of LCM as a function of the current LCM = LCM (I)), it is also possible to estimate the limit of the parasitic Y - capacities. Consequently, the size of the Y-capacitor can be chosen, where as low as possible values are preferred.

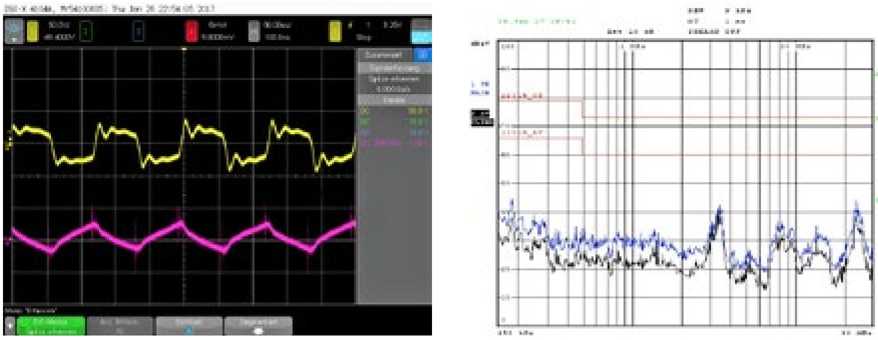

Figure 2: Measurement of UCY (50V / div) and ICM,L (0,5A / div) (left) and noise level (right)

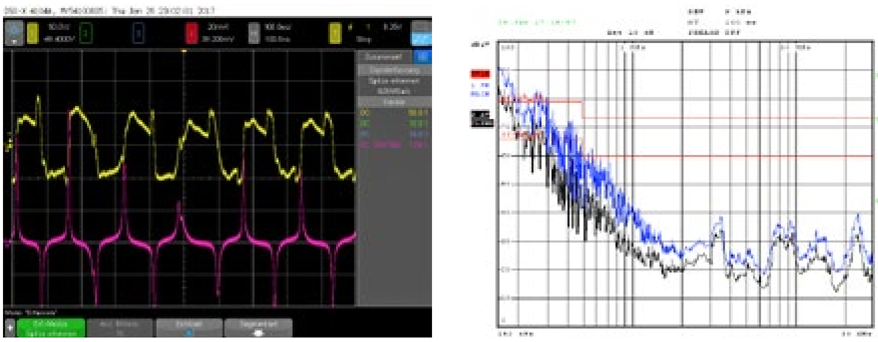

Figure 3: Measurement UCY (50V / div) and ICM,L (2A / div) (left) and noise level (right) in the case of saturation of the current-compensated choke.

EMC and residual current circuit breaker
Today, for the protection of people and equipment the installation of a residual current circuit breaker is required. In order to ensure a high availability of the system, it must be ensured that this residual current circuit breaker does not trigger due to excessive capacitive leakage currents of the frequency inverter drive. If, for example, the EMC filter is not designed for the lowest switching frequency, a residual current circuit breaker may trigger when the frequency inverter reduces the switching frequency due to external conditions (e.g. increased temperature in summer in a glass shaft of an elevator). In the case of leakage currents ICM as shown in Figure 3, for example, a residual current circuit breaker with 30 mA will trip. This is followed by the obvious rule: „If a residual current circuit breaker trips (leakage current too high), the emission level of the system must be checked.“.

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FET Driver Brings Industry's Fastest Switching to GaN Class-D Audio

Peregrine Semiconductor Corp., founder of RF SOI (silicon on insulator) and pioneer of advanced RF solutions, announces the UltraCMOS® PE29102, a high-speed FET driver. With a switching frequency up to 40 MHz, the PE29102 delivers the industry's fastest switching speeds, empowering design engineers to extract the full performance and switching-speed advantages from GaN transistors. In class-D audio amplifiers, this new high-speed FET driver enables GaN technology to deliver superior audio performance with low jitter. "Peregrine's new high-speed driver is a great advancement," says Paul Wiener, vice president of strategic marketing at GaN Systems. "Our customers have validated the improved sound quality with GaN-based circuits, and we see the pairing of Peregrine's driver and GaN Systems' transistors as the superior solution in applications such as class-D audio, bi-directional DC-DC, and push-pull DC-AC power supplies."

Audio systems are challenged to both minimize size and deliver exceptional audio quality to listeners. At the system-design level, better audio performance and sound quality occur when distortion is reduced. MOSFET components have parasitic diodes and gate capacitance that creates jitter and distortion in class-D audio systems, whereas GaN FETs have much smaller gate capacitance and lower parasitics. GaN transistors can beat MOSFET jitter performance by a factor of ten and deliver reduced distortion and smooth sound. However, to reach this performance potential, GaN transistors need an optimized gate driver. The PE29102 is designed specifically for this purpose. Its high switching speeds result in smaller peripheral components and enable innovative designs for applications like class-D audio.

"GaN is disrupting traditional, power MOSFET markets and changing the way we live," says Alex Lidow, CEO and co-founder of Efficient Power Conversion Corporation (EPC). "In class-D audio systems, the audio performance is impacted by the FET characteristics. Our enhancement-mode GaN (eGaN®) transistors enable a significant increase in the sonic quality and higher efficiency. High-speed FET drivers, like Peregrine's PE29102, are critical to unlocking the performance potential of eGaN FET technology in applications like class-D audio."

www.psemi.com

Super High Efficient Power Conversion Module

The quest for improved power conversion efficiency and reduction of energy losses is always on. In close co-operation with Infineon Technologies AG, Eltek engineers have again cracked the code, reducing losses by 50 percent while further improving reliability and total cost of ownership.

Eltek is announcing the launch of the Flatpack2 SHE, a new Super High Efficient power conversion module in the Flatpack2 family. After the revolution Eltek started with the HE technology, there has been a decade with smaller incremental improvements.

To make a significant change in conversion efficiency, reliability and total cost of ownership, Eltek saw the need to bring in new technology. The choice fell on the CoolGaN™ from Infineon; the close co-operation with Infineon throughout the development, verification and industrialization process is unique in the company's history.

"Reaching the 98 percent efficiency target, while improving an already industry leading field performance in a competitive way, will be appreciated by especially our telecom and data center customers," said Morten Schoyen, Chief Marketing Officer at Eltek. "With our customers in focus we have also ensured backward compatibility to all 3 kW Flatpack2 versions. In other words, efficiency upgrades have never been simpler as the older modules can just be replaced," added Mr. Schoyen.

The Flatpack 2 SHE will have a substantial impact on carbon footprint, consumed energy and ultimately the operational expense for Eltek customers. The energy savings are illustrated by the following examples where early versions of Flatpack 2 (92 percent efficiency) were replaced with Flatpack 2 SHE:

- Single mobile base station in Italy, 6 kW load – annual saving: € 576
- Central office site in UK, 250 kW load – annual saving: £ 18,350.

"We always seek to stay ahead of the game on technology, and the ability to take on game changing technology like the CoolGaN™ from Infineon is key to achieve this goal. Besides the efficiency improvement, this technology brings improved reliability as well as manufacturability and other advantages that will enable us to continue to spearhead this industry," said Erik Myhre, Senior R&D Manager at Eltek.

"We are delighted that Eltek is now manufacturing AC/DC power converters featuring our CoolGaN™ technology," said Dr. Steffen Metzger, Senior Director High Voltage Conversion for Infineon Technologies. "They prove the value of GaN devices for achieving the highest electrical conversion efficiency at attractive system cost. We are also encouraged by the results of Eltek's tests which show that the GaN-based systems are rugged and reliable, as expected. This validates Infineon's application specific qualification methodology which allows us to predict useful life of our CoolGaN™ devices in a given application."

www.infineon.com/GaN

Wide-Range Bench Top DC Power Supply

The PWR-01 series from Kikusui Electronics is a new wide-range bench top DC power supply that provides unrivaled testing performance in a compact, user-friendly package.
The PWR-01 is a versatile instrument with models ranging from 400W, 800W and 1200W rated power output and maximum rated voltage up to 650V. Equipped with a 4 times voltage and current variable ratio as well as a 30% increase in power density compared to our previous model, the PWR-01 is guaranteed to satisfy the need for flexible current and voltage in a wide variety of applications. Variable internal impedance is a unique new feature that allows for various types of simulations ideal for automotive, solar panel evaluation, and other battery driven applications. The PWR-01 is also equipped with a soft start function that limits the inrush current, minimizing any harmful effects on DUTs such as DC motors. The user interface has been updated with ergonomic power setting knobs that allow the operator to control voltage and current independently as well as front facing banana plugs designed for optimal safety and comfort. The PWR-01 programmable internal memory feature lets the operator save custom sequences onto the device, eliminating the need to access a PC every time a test is conducted. Synchronized operation allows for more complex sequences over multiple channels for accurate testing of DC-DC converters, simulation of control circuit board start up tests, etc. LAN (LXI), USB, and RS232 interfaces are included as a standard so that the PWR can be operated in almost any testing environment via SCPI commands, LabView, Labwindows/CVI, etc., ideal for system integration. For more information on the PWR-01 series, please consult the Kikusui company website at:

www.kikusui.co.jp/en/product/detail.php?IdFamily=0143

Expanding Space-Saving FLAT® Gas Discharge Tubes

Bourns, Inc. expanded its standard-setting line of volume and space saving FLAT® gas discharge tube (GDT) surge arrestors. The Model 2018 Series FLAT® GDT is a 3-electrode device that delivers a low profile solution for high density and height-restricted PCB-based applications. The new series is lighter weight with a 50 % height reduction compared to standard 8 mm Bourns® GDTs. Bourns designed this latest series as a surface mount device with a large top flat surface, making it ideal for vacuum head pickup in today's high-speed pick and place manufacturing.

The Bourns® FLAT® GDT Model 2018 is an ITU K.12 Class III device rated at 20 kA[1] on an 8/20 µs waveform. The series is offered with DC breakdown voltages ranging from 90 to 500 V and features an innovative flat design that reduces the height of the Bourns® GDT from a typical 8 mm to a low profile of 3.5 mm.
"Besides saving valuable PCB space, these new 3-electrode FLAT® GDT devices help to reduce component count in space-constrained designs. The series provides the ability to protect both Line to Ground and Line to Line with a single Model 2018 FLAT® GDT, which previously required two GDTs," said Kurt Wattelet, product line manager at Bourns, Inc. "As a 3-electrode GDT, transverse voltage limiting performance is enhanced with the ability to share a common center electrode designed to allow both sides of the GDT to turn on quickly resulting in balanced operation."

www.bourns.com

X2 Class Interference Suppressor Capacitors

Illinois Capacitor's all-weather "MPX/MPXB" Series metalized polypropylene capacitors suppress conducted electromagnetic/radio frequency interference (EMI/RFI) before it can be transmitted via power lines to or from other devices. Designed to connect across the input of an AC mains powered device, the MPX meets the demanding 85/85 THB (Temperature, Humidity, Bias) test, as well as a full complement of safety agency X2 Class approvals, including UL, CSA, VDE and others. The MPXB is a specialized version, utilizing more robust construction, for use in AC divider circuits.

ILLINOIS CAPACITOR MPX/MPXB SERIES X2 CLASS INTERFERENCE SUPPRESSOR CAPACITORS MEET 85/85 THB TESTS; SAFETY AGENCY APPROVALS
Data Sheet: http://www.illinoiscapacitor.com/pdf/seriesDocuments/MPX%20series.pdf

The 85/85 THB test is a form of accelerated testing that subjects a part to 85° C heat with 85% relative humidity and an applied bias voltage (240Vac) for 1,000 hours. This demanding test simulates the extraordinarily harsh operating conditions encountered by many commercial and industrial products.

AC line suppression applications are widespread, and include use with motors, AMR (Automated Meter Readers), solar micro-inverters, UPS, power supplies, cash stations, vending machines, industrial controls and appliances. The MPX also can be used as a safe means of coupling a receiving circuit to an external antenna. In the event of a failure, X2 Class devices do not present an electrical shock hazard to users of the equipment.

With self-healing, metallized polypropylene-film construction, MPX/MPXB interference suppressors provide excellent electrical and environmental performance.   Capacitance ranges from 0.01 to 45 mF in 68 stock values, at 275/305 Vac, 50/60Hz.   Overall operating temperature range is -40° C to +110° C. Life expectancy of 100,000 hours at 85° C. Approvals include UL, VDE, ENEC and CQC. RoHS compliant. The solvent-resistant, box-style plastic case and epoxy-seal are both UL 94V-0 flame retardant. The MPX/MPXB is available now from major distributors.

www.illinoiscapacitor.com

No-Neutral Wireless Wall Switches for Smart-Home Lighting

Power Integrations announced a new reference design, DER-622, describing a smart wall switch compatible with wiring conditions most commonly found in residential retrofit installations.

Typically, smart wall switches with wireless connectivity, occupancy/vacancy sensing and/or voice control require a neutral return wire to power the unit, which is not always available in retrofit situations. No-neutral products are available for legacy incandescent bulbs because the small AC input current that is allowed to leak through the load when the smart-switch is in standby mode is insufficient to heat the filament. However, for LED and compact fluorescent designs, high standby-mode current from the smart-switch's internal power supply can lead to unacceptable flicker often known as "ghosting," caused by the leakage energy accumulating in the lamp and initiating intermittent start-up and brief light activation.

DER-622 illustrates a Bluetooth® Low Energy (LE) wall switch consuming less than 500 µA in standby mode. The design is based on Power Integrations' LinkSwitch™-TN2 offline switcher ICs, which have quiescent consumption of less than 75 µA. The ICs' ultra-low current consumption and high light-load efficiency ensure compatibility with energy-efficient LED bulbs rated down to 3 W and are ideal for no-neutral wall switch wiring.

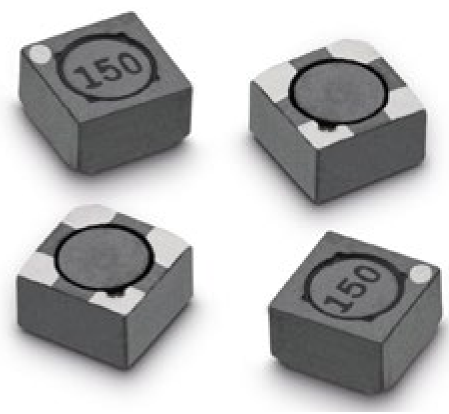
LinkSwitch-TN2 devices may be configured to support flyback or buck topologies and deliver highly accurate output, providing voltage regulation of better than ±3%. The ICs enhance system reliability by incorporating numerous safety features including input and output over-voltage protection, over-temperature, and output short-circuit protection along with a rugged 725 V power MOSFET. In DER-622, the LinkSwitch-TN2 power supply IC is utilized in a non-isolated flyback topology and employs half-wave AC input rectification to reduce solution cost. The power supply provides two outputs – a 12 V rail to drive a relay and a 3.8 V rail to power a Bluetooth LE controller.

www.power.com/der-622

Smallest Coupled Power Choke

Würth Elektronik -DPC HV (Double Power Choke High Voltage) is a magnetically shielded, SMD coupled power choke with two identical windings and a high isolation voltage of 1.5 kV. It is the smallest product of its type in the Würth Elektronik eiSos portfolio. With this power choke in a 5030 package, customers can attain a 40 percent lower DC resistance than products on the market. WE-DPC HV offers a wider inductance range from 1 µH to 47 µH.

WE-DPC HV is ideal solution for SEPIC, flyback, Cuk, zeta and multi-output-buck converters application. It can be used as a power choke in series and parallel connection. WE-DPC HV offers functional isolation for 250 VRMS rated voltage. Free samples of the new SMD power choke are now available. All products are available ex stock.



www.we-online.de

P-Channel MOSFET for USB PD Load Switch

Alpha and Omega Semiconductor Limited introduced AONR21357, the initial product in this P-Channel family. The new AONR21357 uses the improved P-Channel MOSFET process to achieve low power loss and reliable startup. The new device rated at -30V drain-source breakdown voltage (BVDss) and -25V gate-source voltage. It features a maximum on-resistance (RDS(ON)) of 12.3mohm under VGS = -4.5V, and a thermally enhanced 3x3mm DFN package. The new P-Channel MOSFET is ideal for load switch applications in Notebook Adapter-In/ Battery In sockets.

USB Type-C is becoming the de-facto interface for the latest PCs and mobile designs. With that, the USB-PD standard is implemented to cover various power delivery requirements for many portable devices. The load switch circuit is used to switch on/off the power bus according to the power management proxy. The new MOSFET used as the load switch offers extended input/output voltage range, and is robust and reliable enough to accommodate the possible working conditions. AOS' enhanced P-Channel technology offers robustness toward linear mode operation, and low Miller's Plateau (<3.5V) to cover the possible USB-PD voltages.

"The AONR21357 comprehensively addresses the need for -30VDS and -25VGS discrete P-Channel MOSFET. High performance such as low Miller Plateau and low loss of turn-on switching behaviors ensures reliable and secure safe operation area, allowing designers to take advantage of simple design with P-Channel MOSFETs," said Rack Tsai, Director of Marketing for low voltage MOSFET product line in AOS.

www.aosmd.com

Switched Mode Power Supply Testing Made Easy

Aspen Electronics have become the new source for ITECH Electronic Co. ltd, a professional global manufacturer dedicated to finding test solutions for power electronic instruments. Their products find applications in testing power supplies, household appliances, UPS, electronics and motors etc. The IT9121 power analyser is one of their star products and combines high quality with performance.
The IT9121 power analyser can measure voltage, current, power, frequency, harmonics and other parameters. It has a maximum rated input of 600Vrms and 20Arms with measurement bandwidth of 100 kHz. The basic voltage and current accuracy is 0.1%. The standard configuration includes USB, GPIB, RS232 and LAN communication interfaces in addition to interfaces for USB-based peripheral devices. Users can save the measured parameters via an external storage medium.
The IT9121 power meter can measure all AC and DC parameters, including the active power, reactive power, apparent power, power factor, voltage, current, frequency, phase difference, etc. It also has a bandwidth of 100KHz, which can realise high-speed harmonic measurement within a wider dynamic range. In addition, the IT9121 can be used for measurement of multiple harmonics – 50 harmonics of the fundamental frequency can be measured.

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