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Electronics in Motion and Conversion

April 2016

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GvA Power Electronics

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battery university 2016,
Aschaffenburg, Germany, April 5-7
http://www.batteryuniversity.eu

PEMD 2016 Glasgow,
United Kingdom, April 19-21
http://www.theiet.org/pemd

SMT Hybrid 2016,
Nuremberg, Germany, April 26-28
http://www.mesago.de/en/SMT/home.htm

PCIM Europe 2016,
Nuremberg, Germany, May 10-12
http://www.mesago.de/en/PCIM/home.htm

Sensor + Test 2016,
Nuremberg, Germany, May 10-12
http://www.sensor-test.com/press

ISiCPEAW 2016,
Stockholm, Sweden, May 18-20
http://www.swerea.se/kimab

Spring Break,

What a wonderful time for a short holiday from school and university. We were surprised a few years ago when we stayed at a hotel during spring break, and fondly remember very happy young people, who kindly helped us find our way around that big establishment. They were enjoying an education that will prepare them for the next steps that are coming their way in life. It's an exciting event before they move ahead into a professional job. A good education is what counts most to help ensure a peaceful world.

It is a shame to see refugee children behind fences. Countries who have decided to close their borders are making a choice which will prevent young people from enjoying the benefits of education. The children, along with their parents, are trying to escape war and seek a better life, and it is imperative that we all behave like humans and help. Predications say we can expect 2 to 3 million refugees will migrate to Europe, but this on a continent of 500 million people. Some countries are against accepting refugees, and act as if we are fighting a war against these unfortunate people. Are they all crazy? Some EU politicians act like they, as adults, are in kindergarten. Where did they get their education and experience? They need to learn from history and not repeat the mistakes of the past.

It is good to see that the older generation in Germany is more accepting of refugees. The generation aged 70 and older have seen how war can destroy life, across the whole continent. World War II led Austria and Germany into a disaster, and while Chancellor Angela Merkel is offering a humanitarian vision to help, most of the rest of Europe is still debating. It's unfortunate, as the very foundation of the European Union is based on all countries sharing both duties and benefits. We must give young people a perspective for the future. Granted, it is a huge challenge, but also an opportunity for us all. If we ensure that the children and their families are quickly integrated into our societies, and given the chance to develop professional skills, they will make a positive contribution.

The CIPS conference in Nuremberg focused strongly on wide-band-gap semiconductors, as will a number of upcoming events. Clearly the semiconductor industry is moving rapidly forward on SiC and GaN. Many players are now well-established.

Mark your calendar now for the PCIM Europe show and conference to join my podium discussions on wide band gap devices. The podium discussions will take place at the Fach Forum in Hall 6, Booth 248, on Wednesday the 11th of May. This year we have two sessions, both on the new Semiconductors:

- From 12:00 to 13:00 we have "SIC – Volume, Production and Cost"
- From 13:00 to 14:00 we have „GaN – Volume, Production and Cost"

Conferences and shows always provide a great forum for discussing progress in technology. We had a great start for 2016 at APEC in Long Beach, California.

This is the fourth issue for 2016. All technical articles are archived on my website. Bodo's Power Systems reaches readers across the globe. If you speak the language, or just want to have a look, don't miss our Chinese version: www.bodoschina.com

My Green Power Tip for April:
Put full size mirrors on all your walls. That way you can redirect energy and save heating costs. For cooling, turn the mirrors around!

See you at PCIM
in Nuremberg!

Best Regards

Power Electronics Conference "The Power Awakens"

As part of SEMICON Europa, 25-26 October 2016 / Grenoble, France, the conference offers the possibility to establish connections among device designers/manufacturers, equipment suppliers, and system integrators, all while discovering the latest processes, materials and integration methods. The power awakens in Grenoble as one of the emerging hot-spots of power-semiconductor research in Europe. The conference offers a unique possibility to get an overview of important areas of power electronics, including applications, advanced devices, reliability, and testing.

The target audience are device designers, power-semiconductor material specialists, designers of power electronic systems, process specialists, foundry service providers and others interested in the growing field of power electronics.
Please submit your abstracts, biography and a photo via internet until 29 April 2016.
The conference language is English.
The abstract should have between 1.000 and 2.000 characters
Abstracts will be peer-reviewed. We encourage application related presentations, i.e. on joint projects between users and suppliers. Papers are to be non-commercial and focus on the technical/economical merits of a process rather than the individual company's product benefits.
Selected presenters will be notified by 19 July 2015.

The Power Electronics Program Committee is build by Lea Di Cioccio, CEA-Leti Pierric Gueguen, Yole Developpement, Henry Güldner, TU Dresden Arnost Kopta, ABB Thomas Neyer, Fairchild Oliver Pyper, Infineon (chairman), Joe MAI, JEM Europe
contact Christina Fritsch, by email cfritsch@semi.org

www.semiconeuropa.org

Mouser's Smart Warehouse to Get Smarter and Bigger

Mouser Electronics, Inc. announced that the major expansion of its global headquarters in Mansfield, Texas, is now nearing completion. The first phase, due for completion on schedule this quarter, adds an extra 250,000 square feet to the distributor's global distribution facilities, supporting strong worldwide growth, significantly in excess of the industry average. The enhanced facility allows Mouser to maintain its leadership in shipping products faster to customers around the world. Already pretty smart, the new Mouser warehouse will be even smarter. New equipment, including a new mobile app for the warehouse management system, a state-of-the-art packing machine and a heavy duty turret truck for maximizing palette storage, makes it easier for the company to serve its expanding customer base – currently serving over 520,000+ Engineers & buyers around the world.
Receiving has moved to the new building where 20 stations have been added to handle the thousands of boxes that arrive daily. There are 18 huge receiving/shipping doors for Fed-Ex, UPS, DHL and other transport trucks to pull up. Conveyor belts now take the incoming inventory, sort it and send it to the receivers' station to be entered. "We've re-designed it to truly be 'smart receiving,'" said Tina Sears, Mouser Vice President of Warehouse Operations. "The goal is to accommodate growth and maximize efficiency."

http://www.mouser.com

Intersolar Europe 2016

From June 22–24, 2016, manufacturers, suppliers, distributors and service providers are once again meeting at the world's leading exhibition for the solar industry and its partners – Intersolar Europe. The exhibition and its comprehensive accompanying program focus on the newest trends, services and products for the energy supply of the future. The Innovation and Application Forum provides information on current topics, from the operation of PV installations to the latest business models for marketing solar power. In the new Smart Renewable Energy Forum, visitors will learn everything they need to know about the technologies and systems for smart energy supply. The Intersolar Europe Conference addresses current topics such as financing models for PV installations, hybrid power plants and the situation across international markets. In 2016, the prestigious Intersolar AWARD is once again honoring innovative technologies and projects.

Solar and smart – that's what modern energy supply looks like. Digitalizing the energy industry and connecting various technologies are the essential challenges of a modern and sustainable infrastructure. Visitors can learn everything they need to know about the technologies required to face these challenges at the Smart Renewable Energy Forum (hall B2, booth B2.131), which is taking place at Intersolar Europe for the first time. Several sessions at the Intersolar Europe Conference also shed light on the topic of smart energy systems. The changing energy market forms the backdrop to Intersolar Europe, which is taking place from June 22–24 at the Messe München this year.
Intersolar Europe 2016 takes place from June 22–24, 2016 at Messe München.

www.intersolar.de/en

Higher Dividend Payment to shareholders

At the 16th Annual General Meeting, the shareholders of Infineon Technologies AG accepted the proposal for the appropriation of net profit made by the Management Board and Supervisory Board: they approved a dividend payment of €0.20 per share. Compared with the last fiscal year, this is an increase of more than 10 percent. As a result, a total of €225 million will be paid out to the shareholders, who thus participate in the company's success. All the other proposals put forward by the boards were approved by a large majority. The acts of the Management Board were approved with 99.9 percent and those of the Supervisory Board with 97.8 percent of the votes.

http://www.infineon.com

CE+T Power Crowned Winner of Google Little Box Challenge

CE+T Power have won the Google and IEEE Little Box Challenge. The company was awarded the $1 million prize at the ARPA-E Energy Innovation Summit in Washington D.C. after its winning design was chosen over 18 other finalists and hundreds of applicants from all over the world.

The Little Box Challenge was launched in 2014 after Google teamed up with the Institute of Electrical and Electronics Engineers (IEEE) in search of a new technology that could successfully shrink an inverter from the size of a cool-box to the size of a small laptop.
CE+T Power's innovative solution is a huge improvement on the competition's original specification of 50W per cubic inch. Boasting a powerful 145W per cubic inch, the CE+T Power winning design is also only 13.77 cubic inches in size – smaller than a block of post-it notes, which is far smaller than the brief requested – and uses technology already available on the market.
Google invited Robert Eyben, CEO at CE+T Power, to represent CE+T Power in Washington D.C. and accept the award.
"Winning the Google Littlebox Challenge presents us with a unique head-start to address the crucial improvements required in power backup," said Mr. Eyben. "We identified some critical and necessary design alterations and through this innovation, we will change the future of electricity, power and even Smart Home technology."
CE+T Power plans to use its winning design – and 20 years' experience in the field – to improve power backup solutions for business critical applications. Currently, power is stored in Direct Current (DC) but is produced, transported and used as Alternating Current (AC). In order to convert DC to AC, an inverter is required, which is why re-sizing was a priority.
The team began working on their designs in September 2014, and the final stage of the competition saw it being rigorously tested at the National Renewable Energy Laboratory (NREL) in Golden, Colorado between October 2015 and January 2016.
CE+T Power was the first company to introduce the concept of a modular inverter in the late 1980s and then a completely digitally controlled inverter system in 1996. This pioneering system is now a standard approach for other industry participants and later won CE+T Power a Frost & Sullivan award for Product Line Strategy Leadership and demonstrating the most insight into customer needs and product demands within its industry.

http://www.cet-power.com/

Want to Know More about Capacitors?

Mouser Electronics, Inc. has announced that it is sponsoring free technical seminars across Europe with KEMET Corporation. Attend a KEMET Technology Workshop Sponsored by Mouser.
The KEMET Institute of Technology (KIT) is a technology workshop based on classroom instruction and live discussion. The workshop includes information on how capacitors are made, how they work, and how engineers incorporate them into different applications. The topics covered in KIT workshops are geared toward engineers with varying degrees of technical expertise.
KEMET holds KIT sessions worldwide, including all across Europe. The courses are held both at KEMET's facilities and at conference centres. Attendees of KIT sessions at KEMET's facilities can also tour the manufacturing process in addition to the technical application training. In addition to public events, KEMET can also provide private training at corporate locations.

http://www.mouser.de/kemet-kit/.

DAkkS Accredits Batteryuniversity for Battery Tests

Batteryuniversity has been accredited as test laboratory for batteries by the Deutsche Akkreditierungsstelle GmbH (DAkkS) with effect from 26 January 2016. The successfully completed approval procedure certifies the company's competence to perform test series according to DIN EN ISO/IEC 17025:2005 in compliance with the criteria of the UN manual"UN ST/SG/AC.10/11/Rev. 5 and 6, part III, Section 38.3 Lithium metal and lithium ion batteries" (so-called UN transport test).
Batteryuniversity is one of the few German test labs that is allowed to use the listed standardized test methods based on the different dates of issue of the relevant standards without prior information or approval by DAkkS. The test reports are internationally recognized. The combined symbol of ilac-MRA and DAkkS on the test reports serves as evidence.
"Batteryuniversity is not only the organizer of the internationally well-reputed Battery Experts Forum which will take place for the 10th time from 5 to 7 April this year. Our key competence is to support developers and users of batteries with the most different individual services in their daily work – a mission accomplished by a dozen highly qualified experts, in electrical engineering, chemists and physicists. These services include in-house trainings, technical analyses, expert opinions and the development of own test devices as well as the performance of standard based or customized test series in our own lab. We provide long-standing experience in testing batteries according to the statutory provisions for the most different safety, transportation and environmental concerns. The accreditation according to DIN EN ISO/IEC 17025:2005 represents a further significant milestone on our way to one of the leading test laboratories for batteries in Europe" Dr. Jochen Mähliß, CEO of Batteryuniversity GmbH, is pleased.

www.batteryuniversity.eu

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- Reverse battery protection and robust over temperature performance for car body electronics and lighting systems

- Higher reliability based on transient performance, ultra-low dropout and ultra-low Iq for infotainment and cluster systems

To see TI's complete LDO-portfolio enter into your browser: ti.com/ldo

Texas Instruments

5th Power Analysis & Design Symposium April 21st, 2016

Take the chance to join us for a great day packed with lectures, practical examples and demonstrations by international power supply experts. On the evening prior the symposium you are invited to join our "Open Lab" after work measuring event.
Open-Lab: Wednesday April 20th, 2016, 15:00 - 19:00
Symposium: Thursday April 21st, 2016, 08:30 - 17:00
Venue: Bürgerhaus Eching, Roßbergerstraße 6, 85386 Eching (near Munich), Germany
For sure, the participation in our symposium is free of charge and includes lunch and refreshments during the breaks. However, the seats are limited, so you better register sooner than later. (Even if you don't have time to attend, register for the seminar materials and we will send it to you a few days after the event)
We're looking forward to welcome you at the 5th Power Analysis & Design Symposium!
Registration closes on April 8th, 2016

www.omicron-lab.com/event

USCi and Elettromeccanica ECC S.p.A.to sign Distribution Agreement

United Silicon Carbide Inc. (USCi) a leading manufacturer for SiC devices located in Monmouth Junction, New Jersey announces a distribution agreement with Milan located distribution Elettromeccanica ECC S.p.A. for Italy.
"With over 25 years of experience in distribution, ECC has a strong network within the Italian power electronics community", says Christopher Rocneanu, Director of Sales Europe. "USCi is focused to work with Design In oriented distributors like ECC which are not only selling one product but who are selling the whole system and offer an excellent technical and logistical support to the customer"
Maurizio Maitti, General Manager ECC added: "With its leading edge SiC Technology USCi is the perfect partner for us to serve current customer and extend our customer base to new applications. "

www.unitedsic.com

Innovation Award 2016 and the Young Engineer Award

The jury has decided to give the SEMIKRON Innovation Award 2016 to a researcher team from Erlangen for its innovation on ´Zero Tolerance - Silicon Carbide Device Technology for the Smart Grid of the Future´.

Photo: (f.l.t.r) Bettina Martin (SEMIKRON Stiftung), Prof. Leo Lorenz (ECPE), Dr. Patrick Berwian (Fraunhofer IISB), Larissa Wehrhahn-Killian (Infineon Technologies AG), Dr. Michael Krieger (Friedrich-Alexander-University Erlangen-Nürnberg), Dr. Steffen Oppel representing Dr. Michael Schütz (Intego GmbH), Prof. Dr. Elena Lomonova representing Erik Lemmen

The researcher team includes Dr. Michael Schütz (Intego GmbH), Larissa Wehrhahn-Kilian (Infineon Technologies AG), Dr. Patrick Berwian (Fraunhofer IISB) and Dr. Michael Krieger (Friedrich-Alexander University). They have developed and evaluated a new technology for quality assurance during SiC device manufacturing using UV photoluminescence imaging in order to detect harmful material defects in SiC on a full wafer scale. This novel inspection technique detects material defects which are the root cause for later device degradation at an early stage in a fast, contactless and non-destructive way.
This innovation significantly contributes to SiC device reliability which is an important topic in industry. The method has been successfully proven and it is on the way to be adopted by industry. The economic impact and societal benefit of the innovation is related to the energy efficient power electronics based on SiC power devices. The innovation was developed within the SiC-WinS joint project funded by the Bavarian Research Foundation.
The SEMIKRON Young Engineer Award 2016 is given to Mr Erik Lemmen from University of Technology Eindhoven, The Netherlands for his contributions to the development of an ´Extended Commutation Cell - A Path Towards Flexible and Reliable Multilevel Power Conversion´.
The new modular commutating circuit leads to converter topologies for high voltage-ratio power conversion and multilevel conversion offering more flexibility in electric power applications. The functionality and flexibility of the extended commutation cell has been demonstrated for very relevant conditions with a 4.4kW eight-level inverter prototype using off-the-shelve half-bridge IGBT modules and drivers. The innovation offers high quality waveform, flexibility in control and the possibility for step-up and step-down conversion. The economic impact and societal benefit of the innovation is related to the addressed renewable energy applications as well as to more cost effective and reliable motor drives.

www.semikron-stiftung.com

Multi-Phase 55V Synchronous Boost Controllers Simplify Automotive Power System Design

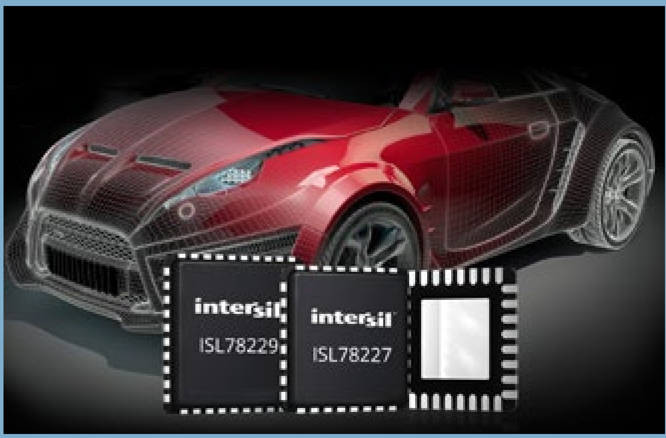
Intersil Corporation, a leading provider of innovative power management and precision analog solutions, announced two 55V two-phase synchronous boost controllers with integrated high-side and low-side MOSFET drivers. The ISL78227 and ISL78229 are the industry’s most robust and highly integrated boost controllers available to simplify the design of high power automotive applications.

Intersil is “investing to win in Automotive”. This sector, currently with a share of 12% of the company´s turnover, is the fastest growing division of Silicon Valley-based Intersil with 1,100 employees and a revenue of $522M in 2015. According to Niall Lyne, Automotive Product Line Director, a double-digit growth is projected in 2016, based on a market leadership in rear-view camera systems, ADAS components as well as HEV/EV battery management systems, 48V DC/DC controllers and multi-phase boost and buck controllers.

The new devices, operating from a 12V battery supply, boost the output voltage to 24V, 36V or 48V for premium 200W to 800W trunk audio amplifiers, start-stop systems, and headlamp LED strings. Both controllers also address the rigorous demands of industrial and telecom applications where a step-up DC/DC converter must deliver high power in a small solution size.

The ISL78227 and ISL78229 enable a modular design for systems requiring power and thermal scalability. They support wide input and output ranges of 5V to 55V and deliver greater than 95% efficiency to reduce power loss and heat dissipation. The ability to interleave two controllers for a four-phase application effectively doubles the output power and reduces input/output ripple, allowing power supply designers to use smaller capacitors to save board space and lower their bill of materials cost. Numerous protection features keep the ISL78227 and ISL78229 operating under virtually any condition. Their unique soft-on function ensures smooth transition from discontinuous-conduction mode (DCM) to continuous-conduction mode (CCM) after completing a soft-start, keeping the power supply safe under all start-up conditions.

The ISL78227 and ISL78229 also offer a unique envelope-tracking feature that dynamically adjusts or scales the output voltage on the fly to meet all system load demands. For example, whenever the battery supply is low, power consumption of various components such as the audio amplifier must be limited, especially if the radio is on while the engine is off. Transient events such as the start-stop system restarting the engine also require on-the-fly voltage adjustments. And to simplify the task of attaining the ISO 26262 automotive safety integrity level (ASIL) rating, the ISL78229 offers a digital PMBus™ interface



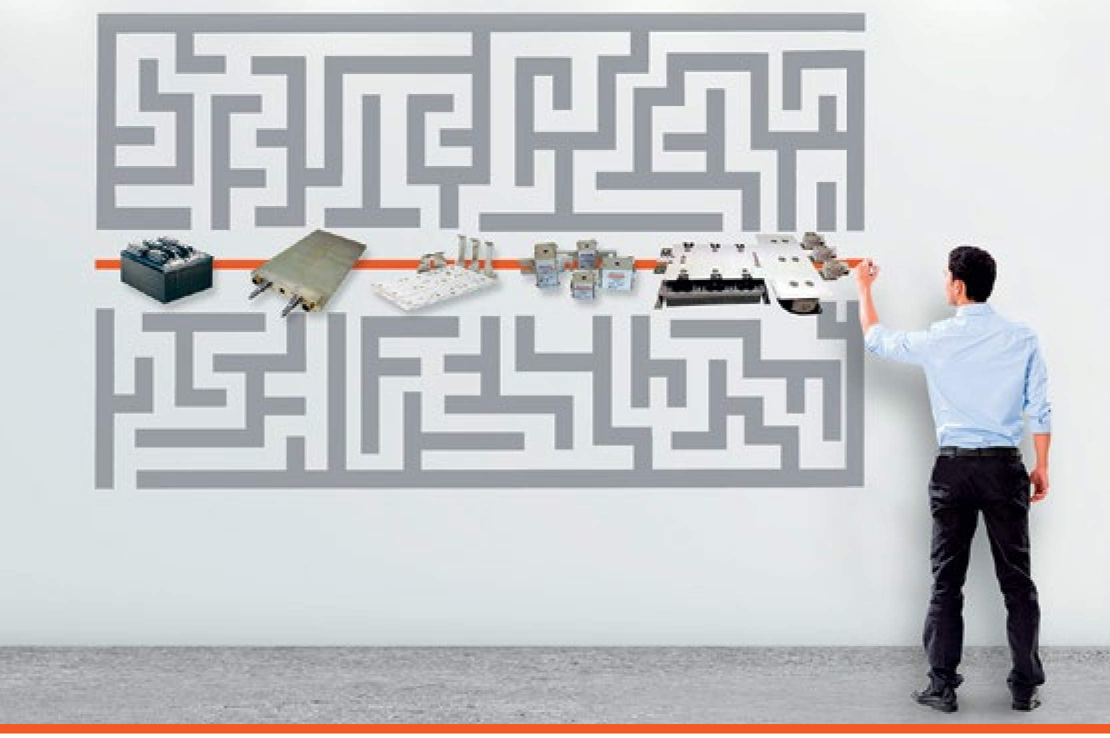
for advanced control, telemetry and diagnostics. Having the PMBus interface on-chip eliminates the need for dedicated telemetry circuitry required to configure fault types, system recovery and monitoring.
"The ISL78227 and ISL78229 enable high power step-up applications in a small solution size that deliver high efficiency and offer multiple layers of power supply protection," said Philip Chesley, senior vice president of Precision Products at Intersil. "A unique combination of innovative features, integrated tracking and a PMBus option provides customers with robust and easy to use solutions for their high voltage designs."
Key Features and Specifications of ISL78227 and ISL78229:

- Provides input/output voltage from 5V to 55V, and withstands transients up to 60V
- Supports synchronous or standard boost topology, and uses peak current mode control for fast line response with adjustable slope compensation
- Configurable for single phase, 2-phase and 4-phase operation, enabling high efficiency
- Adjustable switching frequency from 50kHz to 1.1MHz, and external synchronization
- Two layers of over-current protection prevents inductor current run-away system damage
- Negative current protection prevents large currents that can damage the high-side FET
- Average current limiting allows high current for brief heavy load periods, and prevents longer periods that can cause overheating
- Soft-on capability provides a smooth transition from soft-start to full operation in CCM
- Adaptive and programmable dead-time control prevents shoot-through current
- Selectable diode emulation and phase dropping optimizes light load efficiency
- AEC-Q100 qualified for operation from -40°C to +125°C
- Wettable flank QFN package allows optical inspection of solder joints for lower manufacturing cost.

PowerNavigator™ GUI Simplifies Digital Power Designs
Intersil's PowerNavigator software simplifies the ISL78229's PMBus configuration, validation, monitoring, and telemetry. The tool makes it easy to change features and functions of a digital power supply design without writing a single line of code.
The ISL78227 and ISL78229 can be combined with the ISL78206 40V/2.5A synchronous buck controller, ISL78310 1A LDO, and ISL78233 3A synchronous buck regulator to provide a complete power solution for an automotive audio amplifier power supply.

Pricing and Availability
The ISL78227 55V synchronous boost controller is available now in a 5mm x 5mm, 32-lead WFQFN package and is priced at 3.45 USD in 1k quantities. An ISL78227EV1Z evaluation board can be purchased for 127 USD each.
The ISL78229 55V synchronous boost controller with PMBus is available now in a 6mm x 6mm, 40-lead WFQFN package and is priced at 3.95 USD in 1k quantities. An ISL78229EV1Z evaluation board can be purchased for 172 USD each.

http://www.intersil.com



Is Only Full SiC the „Real“ SiC?

By Stefan Häuser, Product Marketing International, Semikron

Whenever we talk about Silicon Carbide and its applications, our thoughts jump to Silicon Carbide MOSFET power modules, the so called “Full SiC” module. This mental bridge is the result of the well-known dynamic performances of a SiC MOSFET. Unipolar SiC MOSFETs switch much faster with lower switching losses than any other silicon device, allowing drastically increased switching frequencies with reductions in overall power losses and increased efficiency in power output. Therefore, the overall power density is significantly increased.

This means that when SiC components are used in applications that require magnetics for output voltage filtering, such as solar inverters or UPS systems, the benefits can be enormous. By increasing the switching frequency the magnetic components can be reduced in size, which in turn lowers material costs. The same rings true for DC/DC converters with a galvanically isolated transformer. Reducing the overall lower losses brings an additional benefit by reducing the system’s cooling requirements, leading to smaller heatsinks and housings. In some cases, it might even be possible to change from forced cooling to a convection cooling method.

All of these benefits lead to substantial overall system cost savings despite the increasing costs of the power module itself. A SiC power module is more expensive than a Si module to produce because Silicon Carbide requires a different process to the Silicon. Firstly, the raw material is expensive to produce. SiC ingots grow very slowly and have to be formed from the vapour phase. SiC is one of the hardest known materials and the wafers can only be cut and ground using expensive diamond tools. Additionally, the majority of the chips nowadays are still produced on 4 inch wafers, with the prospect of changing to 6 inch in the coming 1 to 2 years (nowadays the Silicon IGBT chips are available on 8 or even 12 inch wafers). This wafer change will reduce material costs, and thus the SiC chip cost. Nevertheless, the cost per mm² will always be higher than silicon.

In low power applications (<30kW), the full SiC approach is being adopted due its overall benefits. However, this is not the case in medium power range applications where SiC chip prices do not linearly scale when chip area is increased. Hence, a solution is required to adopt SiC technology to medium range power applications and push converter performance barriers, while keeping an economically viable solution. From a cost perspective, the goal should be to use as little SiC chip area as possible in any given application. A proper requirements assessment can help to correctly estimate the size of the SiC chip area.

An additional option to gain SiC performance benefits but keep power module costs low, is to use a “Hybrid” Silicon Carbide solution instead of a full Silicon Carbide SiC. Hybrid simply means: Keep the switch Silicon, most likely IGBT, and use Silicon Carbide for the freewheeling diode only. This will not provide the full benefits of a SiC MOSFET solution, but it’s cheaper and effective if the IGBT is selected to match the SiC Schottky diode’s performance. Let’s have a closer look.

SiC Schottky diodes are also unipolar devices, using only majority carriers (electrons) to transport the charge. The benefit of unipolar devices is faster switching and contrary to bipolar silicon diodes, no minority carriers are present to recombine with electrons in blocking mode. This recombination causes the so called ‘reverse recovery’ tail current in a silicon diode, a current that flows in blocking direction of the diode while the voltage arises over the diode junction. This voltage and reverse recovery current causes power losses which can easily reach about 35% of the overall switching losses. With SiC Schottky diodes, the reverse recovery is not present, only a small capacitive current can be observed that’s caused by the SiC chip’s junction capacitance.

But there is a second significance of the Si diode’s reverse recovery current: the current does not only flow through the diode, but also through the complimentary IGBT that is just about to turn-on when the diode goes into blocking mode, causing additional turn-on losses in the IGBT chips. Assuming that this current is considerably smaller with SiC Schottky diodes, the turn-on losses will be reduced. As a rule of thumb, a reduction to up to 40% of the original value of the turn-on losses can be assumed while the IGBT turn-off losses are not affected. Now, when you apply a fast switching IGBT with naturally

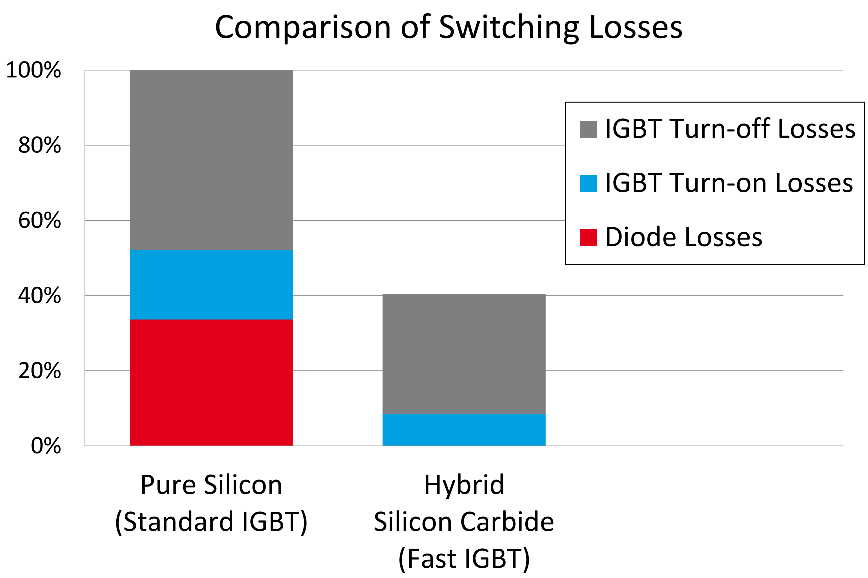


Figure 1: Simulation Results

lower switching losses, the overall reduction of the switching losses can easily be in the range of up to 60% compared to a standard IGBT combined with silicon free-wheeling diodes.

So what does this mean for your application?
SEMIKRON has implemented the Hybrid SiC technology outlined above in a medium power stack, designed and optimised for medium power Solar and Energy Storage applications. The core of the stack is SEMIKRON's solderless 6-pack SKiM module, a baseplate-less power module with sintered chips and a low inductance design. SEMIKRON has also implemented fast IGBTs to maximise the benefits of the Si-SiC combination.

This hybrid module can cover various configurations and be utilized as a three phase inverter (i.e. solar) or interleaved three phase bidirectional DC/DC converter (i.e. ESS). It can also be scaled up for higher power application by parallel operation across three phases.

On a given Solar application, the change from pure Silicon to Hybrid Silicon Carbide and a faster IGBT doubles the switching frequency from 8 to 16kHz at constant power. This provides the right headroom to reduce the size and weight of the magnetic components by 30% to compensate for the moderately higher cost of the power module. Together with the smaller magnetics, the systems space requirements also reduce, resulting in additional savings thanks to a more compact housing design.

The lower losses of the hybrid power module allow for up to 60% higher output current at 10kHz when compared to a silicon only system, all without pushing the IGBT or SiC Schottky diode thermally to their limits. The overall efficiency increases by roughly 1% to 98.5%, without any additional efforts.

In Summary, SiC Schottky diodes almost completely eliminate adverse reverse-recovery effects found in Si devices, reducing IGBT switching losses by up to 60% using fast IGBT devices in hard switched conditions. By combining Silicon and SiC chips in the same package, performance improvements can be achieved at medium power levels while using cheaper wide band gap material.

This solution is one way to overcome the high cost of SiC and depending on the application drivers, the solution can offer designers various options to capitalise the benefits of hybrid Si-SiC module:

a) Switching frequency doubling.
b) Power density improvements (i.e. 60%)
c) Efficiency improvement (i.e. 1-1.5 point).

Another advantage of the hybrid Si-SiC module is that the gate drive driver does not need to be modified, eliminating additional development efforts and their associated costs.

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Embedded World 2016 – Ever More Successful

Embedded technologies all around: The "embedded world 2016" Exhibition&Conference in Nuremberg end February was bigger than ever, with more exhibitors (939 from 38 countries) and more exhibition space booked.

By Roland Ackermann, corresponding editor Bodo's Power Systems

After three days, more than 30,000 expert visitors (+17%, about 10,000 from outside Germany) had attended the annual summit meeting of this industry segment and became familiar with the current trends and new concepts. The special areas – M2M, electronic displays and new safety&security – focused on three important topics for the industry, bridging the gaps between scientific expertise, practical innovation and pioneering products and services at the exhibition halls.

The embedded community has discussed future challenges for embedded system technologies in the conferences accompanying the exhibition, and in the halls themselves. Naturally, as with all events these days, the Internet of Things and Industry 4.0 were the dominating topics, in close combination with everything that´s prerequisite to make these plans and dreams come true: components, innovative solutions, safety and security, and not to forget: efficiency and power.

Embedded Award

For the 12th time in succession, the Embedded Award has recognized innovative products and solutions that make a special contribution to the advancement of the entire sector of embedded systems and the IoT. And the winners were:

Keolabs wins in the hardware category with IoTize – a flexible communication solution that can contribute to the continued growth of the Internet of Things. This solution uses common communication interfaces (e.g. NFC, Bluetooth, Bluetooth Low Energy and WiFi), but also existing embedded solutions that do not currently have a network connection. Neither expert knowledge nor changes to current hardware and software are needed to connect IoTize. IoTize uses the system processor's debugging interface to record relevant communication data.

QNX Software Systems impressed in the software category with QNX OS for Safety – a special operating system that has been pre-certified up to IEC 61508:2010 SIL 3 in order to effectively support developers in this task. The system enables solutions to be rapidly developed for industrial systems, railway systems, robotics, medical diagnostics, surgical techniques and automotive applications. QNX OS for Safety is built on a highly reliable software architecture proven in nuclear power plants, train control systems, laser eye-surgery devices and a variety of other safety-critical environments.

Goepel electronic triumphs in the tools category with JEDOS (JTAG Embedded Diagnostics OS), embarking on a completely new path to embedded system diagnostics. This specially developed test and diagnostics operating system is able to perform functional circuit tests on the native processor in real time. No special test software or flash-resident firmware is required. JEDOS features maximum fault coverage and comprehensive diagnostics for digital, analogue and mixed-signal components.

Conference Session "Ultra-Low Power"

Power specialists were especially interested in the conference session Ultra Low Power. The proceedings included five papers with the following titles:

- Selecting Microcontrollers for IoT and Other Battery-Powered Applications
- Seven Essential Low-power Software Techniques for MCU Embedded Developers
- Affordable Energy Autonomous Wireless Sensor for Day and Night
- Vibration Energy Harvesting Sensor Node with Bluetooth Smart Communication
- Increased Efficiency in a Vibration Based Energy Harvesting System by Using a SSHI Circuit.

Small Selections of New Products Exhibited:

Prismatic Semi-Smart Standard Battery Packs with Chargers

RRC power solutions has enhanced its standard battery pack series to include two single-cell prismatic Li-Ion batteries. There are characterized by a slim and compact design with high energy density.

The special feature of both 1S1P configurations consists in the use of smart technology features in combination with a prismatic Li-ion cell. The electronics contain a gas gauge and security features, e.g. voltage, current and temperature monitoring. This data can be transferred via I²C interface between the battery and the application. The RRC1120 and RRC1130 are standard Li-Ion Smart Single Cell Packs with 3.7V at 2000 mAh and 7.4 Wh for the RRC1120 and 3.8 V, 3880 mAh and 14.7 Wh for the RRC1130. The battery packs come standard with worldwide approvals.

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Embedded Success dSPACE

Compatible battery chargers also are available. The RRC-SCC1120 and RRC-SCC1130 are 5 Watt desktop chargers that are custom tailored to the battery packs. Comprehensive approvals will allow worldwide usage.

Power Solutions Portfolio

Specifically addressing 40V power for industrial applications, Exar has a range of solutions that include its XR76203/05/08 Synchronous Step-Down Constant on-Time Regulators, its XR79203/06 High Current Power Modules and its XR77129 Single-Chip 40V Programmable PMIC. These parts feature industry-leading performance: regulators with exceptional line/load regulation, modules with the highest power density and smallest size and controllers that solve unique and difficult power conversion challenges.

Industry's Smallest IO-Link Transceiver Reduces Power Dissipation by More Than 50%

Maxim Integrated's MAX14827 enables intelligent sensors with reduced maintenance and increased uptime with continuous diagnostics and monitoring.

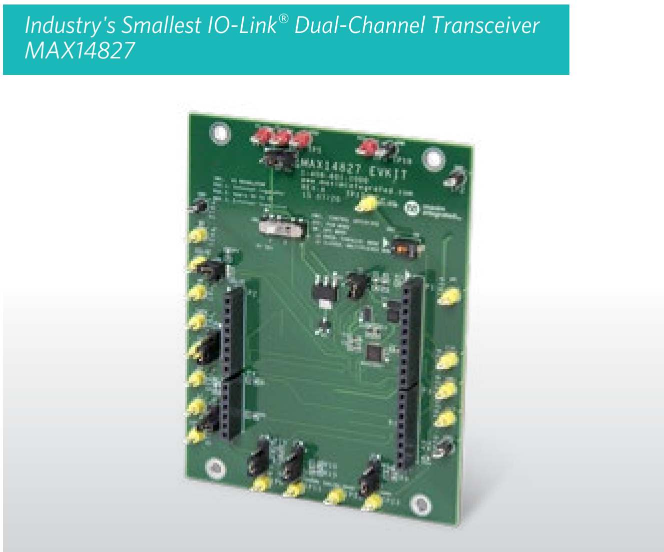

Figure: Wireless power transmitter IC with a 15W transmission capability

Industrial systems designers now have a robust IOLink dual-channel transceiver that dissipates the lowest heat in the smallest package with the MAX14827 from Maxim Integrated Products, Inc. (NASDAQ: MXIM).
The Industry 4.0 revolution is enabling smarter factories to increase productivity and manufacturing flexibility. IO-Link sensors enable this revolution by bringing intelligence and control down to the factory floor. Sensors are getting smaller and need to deliver more functionality, while ensuring robust communications. Power is also critical because these sensors are small and it is difficult to dissipate heat. The MAX14827 dual-channel, 250mA transceiver meets these requirements, while also integrating high-voltage functions commonly found in industrial sensors, including drivers and regulators. It features two ultra-low power drivers with active reverse-polarity protection to reduce downtime.

Extended Wireless Power Range with 15W Transmitter IC

Toshiba Electronics Europe has launched a compact and efficient. In combination with a host microcontroller, the TC7718FTG realises a wireless power transmission system compliant with WPC Qi version 1.2[1].

Built on Toshiba's proprietary, cutting edge CD-0.13 semiconductor process, the TC7718FTG combines a small package with high efficiency. This simplifies system integration and ensures charging systems with small footprints. A 15W wireless transmitter system based on the new IC will recharge devices quickly, at a rate equal to or faster than wired chargers.
The new IC is ideal for smartphone and tablet charging stand applications. In addition, the 15W rating of the device extends the possibility of wireless charging to industrial products and other higher power applications that may require more energy or longer charging times than consumer devices.

World's Smallest and Lowest Power 64-bit ARM-based Processor

NXP Semiconductors has introduced the tiny QorIQ LS1012A processor, delivering enterprise-class performance and security capabilities to consumer and networking applications, all in a package size normally associated with microcontrollers. Combining a 64-bit ARMv8-based processor with network packet acceleration and QorIQ trust architecture security capabilities, the device features line-rate networking performance at 1W typical power in a 9.6mm x 9.6mm package. This new NXP processor is designed to enable the creation of entirely new classes of products which combine battery-powered operation with line-rate networking. The QorIQ LS1012A is also ideal for a range of established and fast-growing applications including next-generation IoT gateways, portable entertainment platforms, high performance portable storage applications featuring mobile HDD, and mobile storage for cameras, tablets and other rechargeable devices.

Ambient Energy Manager

Belgian start-up e-peas semiconductors introduced its highly efficient, dual regulated output, ambient energy manager. The AEM10940 is an ambient energy harvesting chip dedicated to wireless sensor nodes applications, harvesting the available input power from 1 µW to 50 mW.. With the lowest power cold-start – it can start operating with an empty storage element at an input voltage as low as 380 mV and an input power of just 11 µW – and the smallest footprint on the market, it is particularly suited for low-light indoor applications.
The AEM10940 extracts DC power from PV cells or TEGs to simultaneously store energy in a rechargeable element and supply the system with two independent regulated voltages. This allows product designers and engineers to extend battery lifetime and ultimately get rid of the primary energy storage element in a large range of wireless applications like industrial monitoring, geolocation, home automation or wearables. Also presented was the dedicated AEM10940 power-IC platform (see photo).

Tiny 3W DC/DC Converter

Power-specialist Recom introduced its new RI3 3W DC/DC converter in a SIP4 package as small as 11.5mm x 10.2mm, i.e. with the same dimensions as the 2W version. Power density is 3.365 W/cm³; depending on the load, the device can be operated at -40 to +85°C or even +100°C without derating. In derating mode the module reduces its power to prevent overheating. Efficiency goes up to 90%. With an I/O isolating voltage between 1 and 3kW DC the devices are available with input voltages of 5, 12, 15 and 24V.

The Future of Power Semiconductors

Rugged and High Performing Silicon Carbide Transistors

The use of SiC based power semiconductor solutions has shown a huge increase over the last years, it is a revolution to rely on. Driving forces behind this market development are the following trends: energy saving, size reduction, system integration and improved reliability.

By Dr. Peter Friedrichs and Marc Buschkühle, Infineon Technologies AG

SiC devices are well placed to meet all the above market challenges. The new wide bandgap technology is more than an evolutionary step forward, as we have seen in previous years with each new generation of silicon power devices, but has the capability to be a real game changer. SiC based systems have the revolutionary capability which can be characterized by a steep change in performance which can make them attractive for designers targeting innovative and disruptive solutions. IGBTs or Super-Junction MOSFETs in combination with SiC Diodes have already become the norm in various applications, such as solar, chargers or power supplies. This combination – a fast silicon based switch matched with a SiC Diode – is often termed a “hybrid” solution. In recent years Infineon has manufactured several million hybrid modules and has seen them installed in various customer products. The first worldwide Hybrid module was developed more than ten years ago based on Infineon’s EconoPACK™ package platform.

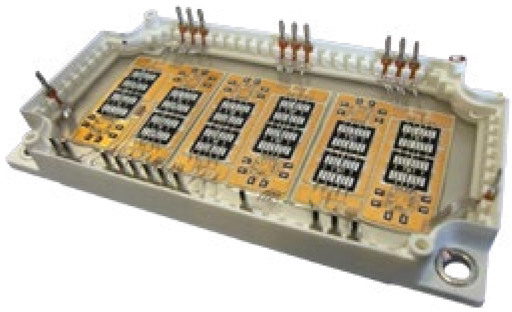

Figure 1: World’s first hybrid module solution, in production since 2006

Certain application segments will always be early adaptors of any new technology. Depending on the actual system value others will follow when cost/performance of the new technology is attractive enough to make a switch to a new higher technology solution. After the already well established designs using SiC diodes in high-end power supplies Infineon has identified solar inverters and boost circuits as the area’s most likely to benefit the most from this new technology. Behind this the associated market segments of Uninterruptible Power Supplies (UPS) and chargers are likely to follow. It is expected that more traditional segments like motor drives, traction and on a long time scale, automotive applications will in the future become very interested in a large scale change over to the new semiconductor technology.

In the past, energy efficiency was the key design and marketing road to success with solar converters. SiC diodes, for example used as part of the booster circuit, were the best solution to achieve efficiency levels of 98 percent or better.

Today, the ongoing major trend in solar designs is the increase of power density based on a reduction of switching losses, enabling smaller heatsinks, and also allowing higher operating frequencies, enabling smaller magnetics. SiC diodes have increasingly become a staple component in modern solar string inverter solutions as well as in micro-inverter applications. Recently, Infineon’s SiC diode technology reached its 5th generation. SiC diodes made further progress by using options for die shrink in order to achieve a more attractive cost position. In addition, new technology features were implemented which will give additional customer benefits compared to the previous generations for example lower forward voltage drop, resulting in lower conduction losses, increased surge current capability and an enhancement of the breakdown behavior. Hybrid solutions are a standard part of today’s solar inverters all around the world. Infineon has become a trusted partner of this technology after more than 15 years availability, a proven track record and dependable high volume production.

With its integrated manufacturing concept – manufacturing of SiC chips utilizing the same production lines as the high volume silicon power chips – Infineon is able to guarantee reliability and process stability at the same level as its silicon products. In addition, this integrated concept brings volume flexibility, a key factor in order to handle needed emerging technologies in fast moving market segments. Based on a deep system understanding and a clear focus on cost performance it has been possible to successfully define products by forming optimized combinations between silicon and silicon carbide based semiconductors. This move, away from a purely semiconductor technology driven definition of products, towards solutions tailor made for the targeted system is seen as a key element for the success of SiC in the future. Based on the experience with the diode technology, a similar roll out of SiC transistors will follow in the next few years. This is an important next step in order to move SiC much closer to the level of a mainstream technology. As listed above, key elements will be:

- proven ruggedness
- attractive cost/performance enabling a measureable system advantage
- volume production capability
- product definition driven by system understanding

During the last years, intensive studies have been carried out mainly in order to understand the system benefits of SiC. The increase of switching frequency for a converter using unipolar SiC transistors can result in dramatically reduced volume and weight of the magnetic components. From an analysis carried out by Infineon, a converter

built on SiC devices is a third of the size and 25 percent of the weight compared to a current Si based reference solution.

Thanks to the significant reduction in volume and weight, the system costs can also be reduced by more than 20 percent.

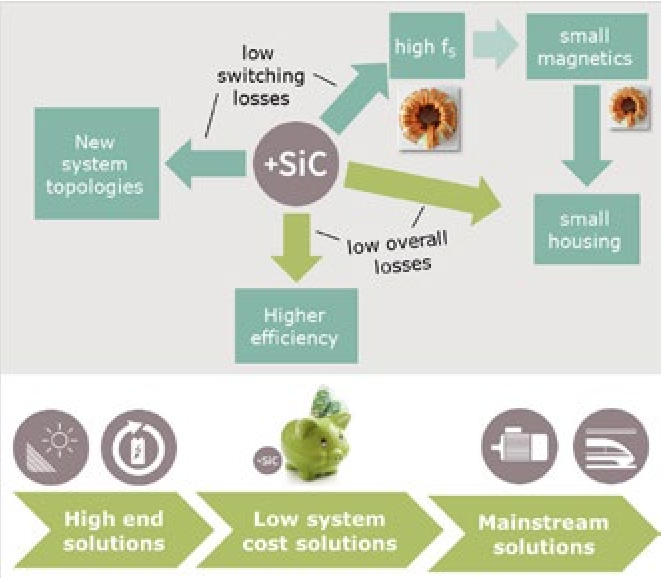

Figure 2: Benefits of SiC depending on use in arenas and applications

Over the next few years, SiC solutions will expand into other application fields such as industrial or traction drives. The reasons for this are the market forces pushing for loss reduction, not only for the sake of improved efficiency but also for smaller packages – resulting from reduced heat sink requirements. As shown in figure 2, SiC is already being used for high end and niche solutions. Today's designs use these benefits to reduce system cost in specific application areas.

In the future, more and more applications will benefit from the overall loss reduction made possible by implementing SiC solutions. In this regards, the next major step forward will be the introduction of SiC switches.

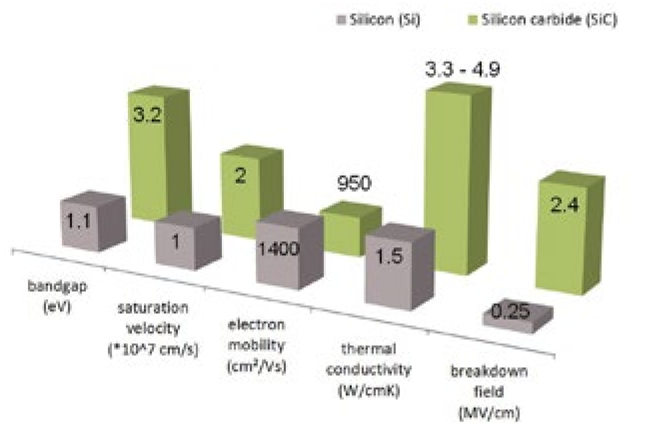

Figure 3: Material property comparison of silicon vs. silicon carbide

To understand the differences between Si and SiC solutions, it has to be made clear that silicon carbide devices belong to the so-called wide bandgap semiconductors. A comparison of Si vs. SiC material properties is shown in figure 3. The voltage range for fast and unipolar Schottky diodes as well as field effect based SiC switches (MOSFET, JFET) can be extended to over 1000 V. This is possible because of inherent properties of the SiC material:

The low leakage current in high voltage Schottky-diodes is possible because of the metal-semiconductor barrier which is two times higher than in Si Schottky diodes.
The very attractive, specific on-resistance of unipolar transistors compared to Si is achieved because of the breakdown field strength which is approximately ten times higher.

Figure 4 shows the minimum specific on-resistance of different semiconductors versus the desired blocking voltage (only the drift region is used here, any substrate contribution to the resistivity is neglected). The end points of each line symbolize the usable voltage range of the specific semiconductor in a unipolar configuration excluding Super-Junction MOSFETS

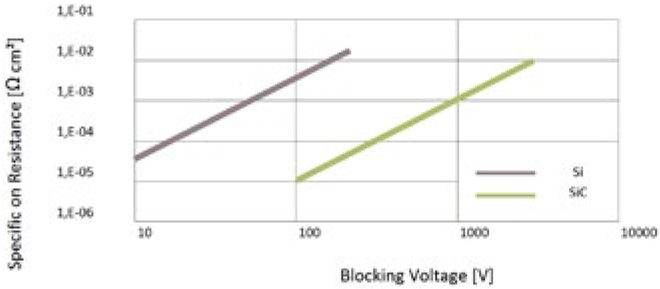

Figure 4: Comparison of on-resistance and blocking voltage of SiC and Si

SiC transistors are about to become an attractive alternative to today's established IGBT technologies in industrial power electronics. The dedicated material properties of SiC enable the design of minority carrier free unipolar devices instead of the charge modulated IGBT devices at high blocking voltages. This is based mainly on the high critical field which is provided by the wide bandgap. The loss restrictions of IGBTs are caused by the dynamics of minority carriers. In MOSFETs those minority carriers are eliminated. As an example, extremely high dv/dt slopes in the range above 100 kV/µs have been measured for SiC MOSFETs. In the beginning, the superior dynamic performance of SiC based transistors compared to IGBTs in the area of 1200 V and higher was seen as the most important advantage. However, recent results indicate a significant future potential in the IGBT technologies, as shown by Infineon's TRENCHSTOP™5 technology.

Taking the long term view, however, the fundamental differences between the IGBT and the unipolar SiC switch will increasingly attract attention. With the two major differences being: first, the linear, threshold free I-V curve of the output characteristic, second, the ability to integrate a body diode with the option of synchronous rectification. Based on these properties, the device offers threshold-free conduction behavior in synchronous rectification mode. In addition, the number of necessary components is reduced by half. This leads to a significant reduction of the required power module footprint.

On system level, the feature of threshold-free conduction behavior offers a significant potential for loss reduction. Many systems are operated for a large portion of their lives under partial load conditions and conduction losses are considerably lower compared to the competing standard IGBT technologies. Even at very low frequencies of less than 5 kHz and unchanged dv/dt slopes it can be seen that a threshold-free switch with integrated body diode, in synchronous rectification mode, offers a potential of 50 percent total loss reduction compared to a commercial IGBT solution available today. The comparison in losses can be seen in figure 5.

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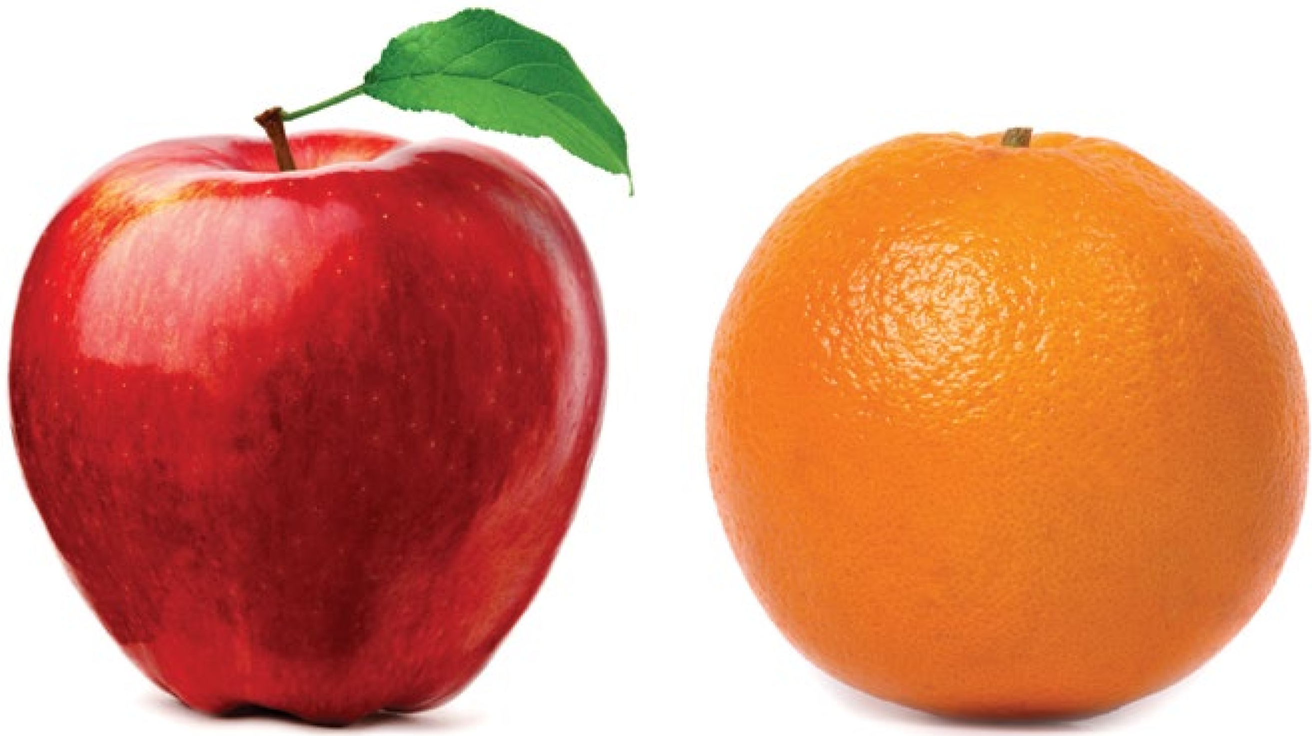

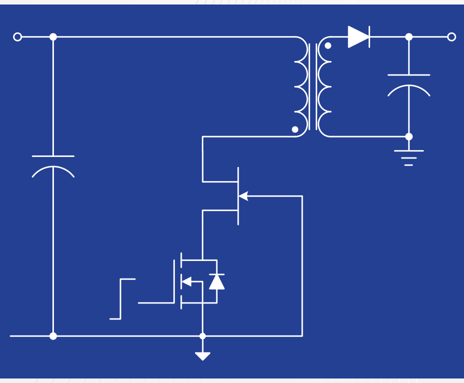

There’s no comparison when it comes to our new USCi 1.7kV, 800mOhm JFET (UJN171K0K) versus other solutions. Ours is a versatile device that can be used in utility power supplies, or combined in series to produce a switch of several kV’s. The lead application for this device is utility power supplies that operate off of 800 Volt rails or higher. The 1.7kV breakdown allows for the use of single device topologies, such as flyback or forward converters. The 1.7kV JFET is designed for use with a low Voltage (25V to 30V) MOSFET in the cascode configuration, which enables standard Gate Drive (0V to 12V).

The use of the cascode also enables the added benefit of a simple startup technique. In the off position, the MOSFET drain Voltage will be a steady state 7 Volts, which can be used to startup a PWM controller. This removes the need for more elaborate high Voltage startup circuitry.

A second application for the 1.7kV JFET is to add an additional JFET to the above circuitry to produce what is known as a super cascode. With this configuration, one can easily produce a 3kV device capable of very fast switching and high pulse energies.

For more information on how to use this component, and others, please see the application notes available on USCi’s website.

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Obviously, the loss reduction will be even higher in applications where there is no dv/dt limitation and at much higher switching frequencies. This is common in DC-DC boost or buck/boost topologies providing the benefit of smaller, lighter and lower cost magnetic components. Various studies have already proven that – even with more expensive power switches – the bill of material can be reduced over a wide spectrum of applications. This number of applications will increase over the mid-term time frame based on the anticipated cost reduction over time for SiC based components.

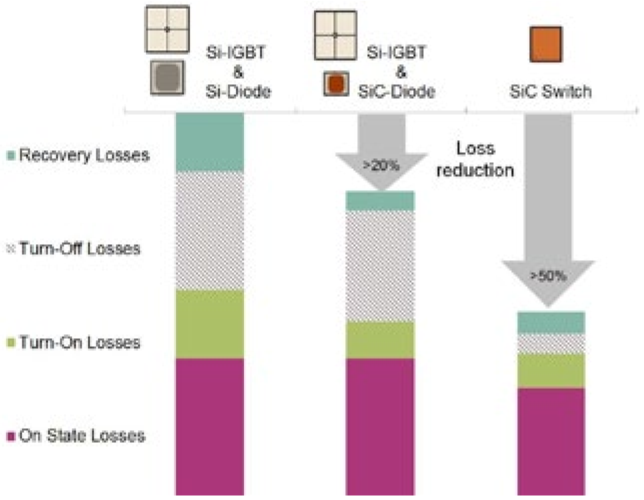

Figure 5: Loss reduction of 50 percent is feasible even with IGBT like dv/dt's operating at 5 kHz.

The objective for a SiC transistor design is for the most parts to achieve the lowest area specific on-resistance. This is quite logical, since this parameter defines cost and also indirectly the remaining dynamic losses which are caused by chip capacitance values. The smaller the die for a given resistance, the lower the capacitance values.

The high defect density is reflected in various idiosyncrasies or traits of SiC MOS based devices. One example is a weak transconductance in comparison to silicon based power MOSFETs, combined with a low threshold voltage.

Another effect is a non-physical temperature behavior of the on-resistance. Physics indicates that the Ron will typically increase at higher temperatures. Components available today sometimes show zero or even negative temperature dependence. This is due to the fact that the defect related resistance contribution has a negative temperature coefficient and thus, a different temperature behavior is observed. The less the Ron increases with temperature, the higher the impact of channel defects on the device performance. A drop of the defect related resistance contribution can be effectively achieved only by increasing the applied field across the oxide in on-state above values being usually used in silicon based MOS power devices. Since high fields across the oxide in the on-state can potentially accelerate the blocking capability wear out it can be deemed a long term reliability risk.

The overall goal is to combine the low Ron-potential offered by SiC with an operational mode where the part remains inside the well-researched safe oxide field conditions. In the on-state this can be achieved by moving away from the planar surface, with its high defect density, towards other, more favorable surface orientations. MOS channels on the so called a-face of SiC offer a factor of at least ten times lower defect densities. For this reason, one possible approach is to use a TRENCH based structure, similar to many modern silicon power devices. Beside the low channel resistance the cell density in such structures can be naturally higher than in planar structures, ending up in a more effective material utilization. Additionally, this would lead to a lower area specific on-resistance. However, in Trench-based components the field stress on the oxide at Trench corners is a critical issue and, especially in SiC, this can be a show stopping argument. This semiconductor chip is proposed to use an about ten times higher electric field compared to Si solutions. There are various possibilities in place to realize an effective shielding of the critical areas, e.g. by deep pn elements. In contrast to the on-state dilemma in the DMOS, the off-state challenge can be addressed by an ingenious design.

A powerful SiC switch offering a proven and established ruggedness similar to silicon based components will have a bright future in power electronics applications – even if new challenges are attached to the new technology. In the beginning, there will have to be additional efforts to utilize the technology in the best and most effective way. Challenges include EMI topics arising from faster switching or cooling challenges caused by much higher power densities. The latter are inevitable and combined with the chip shrink which will not be offset by the expected loss reduction.

To enable a faster penetration of the SiC transistor technology it is beneficial to address these valid concerns. In this regard, it is essential to partner with customers to minimize any design and implementation processes made necessary by the new technology.

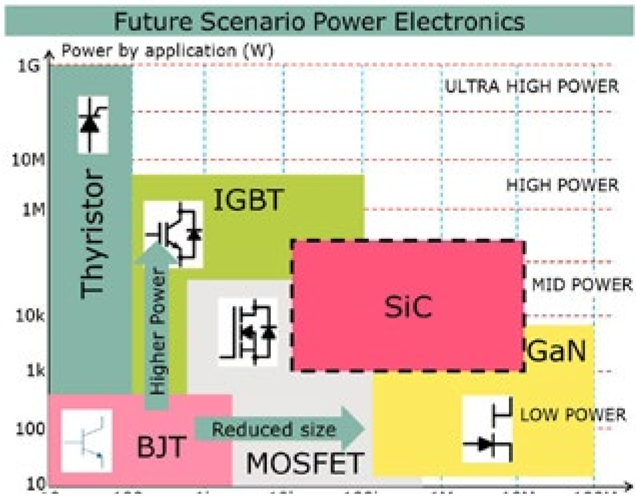

Figure 6: SiC switch market 1kW- 500kW @ 10kHz-MHz

It is axiomatic that new semiconductor technologies will be the key enabler to meet the increasing demands for improved power density and efficiency of applications based on power semiconductors. However, the replacement of silicon based components will not be a matter of the next coming years. Instead, wide bandgap technologies are able to complement silicon based solutions, especially where they can open up new application niches which cannot be addressed by current technologies. SiC is seen here as the major innovation for industrial power applications targeted at components with blocking voltages above 100 V and power ratings up to several hundreds of kilowatt as shown in figure 6. After the successful market introduction of SiC diode technologies, SiC based transistors will be the next major step. By now much higher levels of performance are expected from the wide bandgap material. For a fast market acceptance, ruggedness and system oriented product features are key elements.

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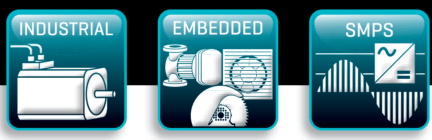

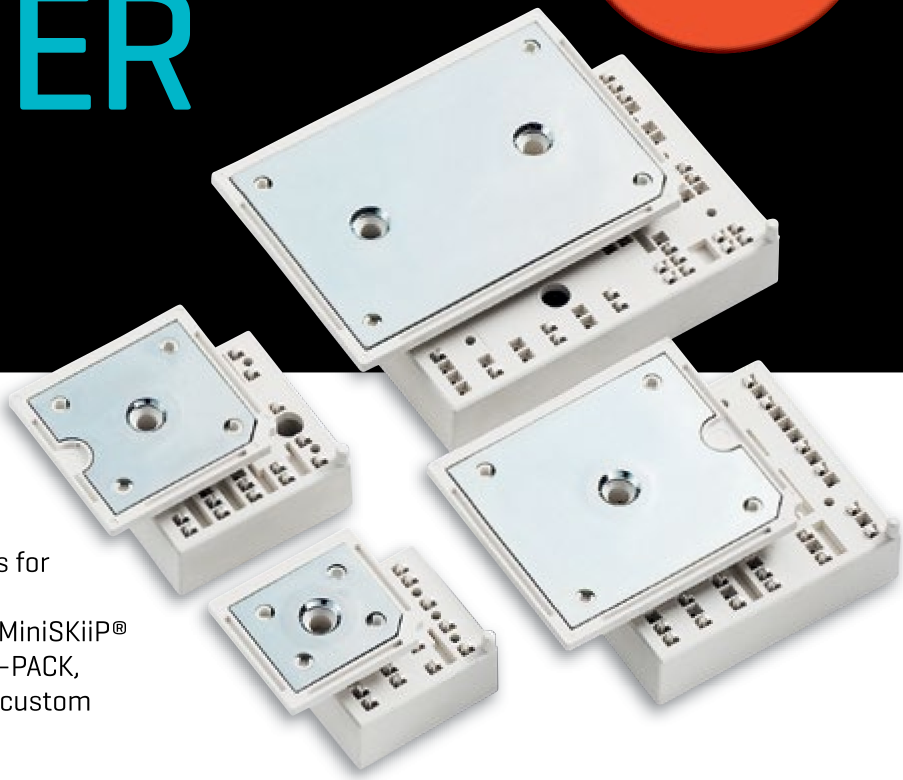

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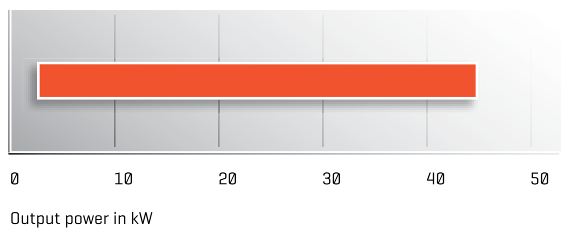

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Power Modules for Combining Innovation, Flexibility and Power Capability in the Various 3-Level Topologies

Three level topologies have demonstrated higher efficiencies, filter optimization potential and the capability of handling high DC-link voltages. To maximize the advantages offered by the 3-level topologies, Mitsubishi Electric offers new power modules which unlock the potential to realize innovative solutions for different power segments.

By Narender Lakshmanan and Thomas Radke, Mitsubishi Electric Europe B.V. and Satoshi Kawabata, Mitsubishi Electric Corporation Japan Power Device Works.

Power conversion applications have always had to deliver high performance while maintaining the required quality of power. The harmonic profile of the output power can be improved by increasing the switching frequency. However, an increase in switching frequency compromises the inverter efficiency. Historically, the conventional 2-level inverters have served the industry with its seemingly uncomplicated topology where developers have always had to strike a balance between efficiency and filter optimization. With the invention of the 3-level topologies, many new avenues are now open for improving the output harmonic profile without compromising on the system efficiency. With the option of being able to apply the 'zero' level, this topology brings with it the following inherent benefits:

1. Efficiency and output power capability [1]: The superior switching loss profile of a 3-level inverter ensures that better efficiencies can be achieved. Thus, for the same dc-link, a 3-level based inverter can deliver a higher output power compared to the corresponding 2-level inverter.
2. AC filtering [5]: For the same switching frequency, the 3-level topology utilizes the availability of the 'zero' level to deliver an AC output of higher power quality than the corresponding 2-level inverter. This naturally allows a significant reduction of the output filter inductance.
3. dv/dt Filter [5]: Since the phase to neutral output of a 3-level inverter shifts between 0V and (+/- Vdc)/2 (unlike the 2-level output), the corresponding dv/dt across the load is naturally reduced by about 50%.
4. Common mode voltage reduction [5][6]: In comparison with 2-level, significant reduction (about 25%) of common mode voltage is possible in the 3-level topology.

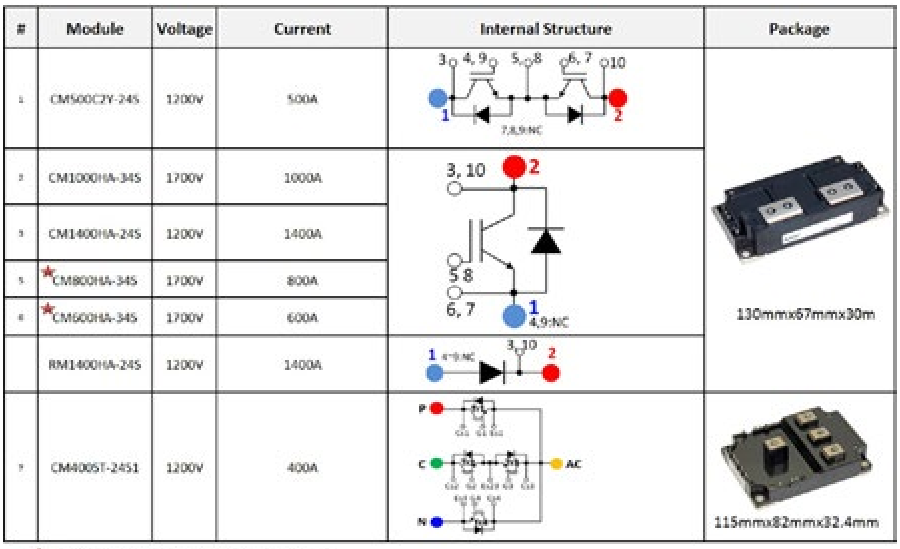
While every segment of the inverter industry can avail the benefits associated with the 3-level topologies, grid connected inverters (Solar, Wind, HVDC), UPS and medium-to-high power drives stand to benefit significantly by employing this innovative approach[3][4].

Power Modules from Mitsubishi Electric for 3-level NPC inverters

The CM400ST-24S1 module has already been introduced and presented in good detail ([2] Bodos article Feb'2015). A new series of power modules with innovative packaging optimized for 3-level applications has been developed. The comprehensive line-up is shown in Figure 1. The CM500C2Y-24S is provided as a dedicated neutral clamp switch for efficiently realizing the T type 3-level topology.

These power modules from Mitsubishi Electric are optimized for 3-level topologies with regards to the following parameters:

1. **Compact package size:** For realizing an I type topology, in comparison with its counterparts from other manufacturers, the 1 in 1 modules (each 130 mm x 67 mm x 30 mm in size) offer about 20% reduction in mounting area. This was achieved by taking advantage of the superior thermal behavior of the Aluminium



#	Module	Voltage	Current	Internal Structure	Package
1	CM500C2Y-24S	1200V	500A		
2	CM1000HA-34S	1700V	1000A		130mmx67mmx30m
3	CM1400HA-24S	1200V	1400A		
5	★CM800HA-34S	1700V	800A		
6	★CM600HA-34S	1700V	600A		
	RM1400HA-24S	1200V	1400A		
7	CM400ST-24S1	1200V	400A		115mmx82mmx32.4mm

★ NOTE : New products under development

Figure 1: Line-up of the products dedicated for 3-level solutions

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Leading Chip and Packaging Technology for Highest Energy Efficiency

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- Increased switching frequencies enable optimisation and cost down of filter components
- Reduced power losses lead to increased efficiency and lower system cost and size through smaller cooling devices
- Latest SiC chips of the leading suppliers
- Various packages and connection technologies with optimised chipsets for your application

AC | DC

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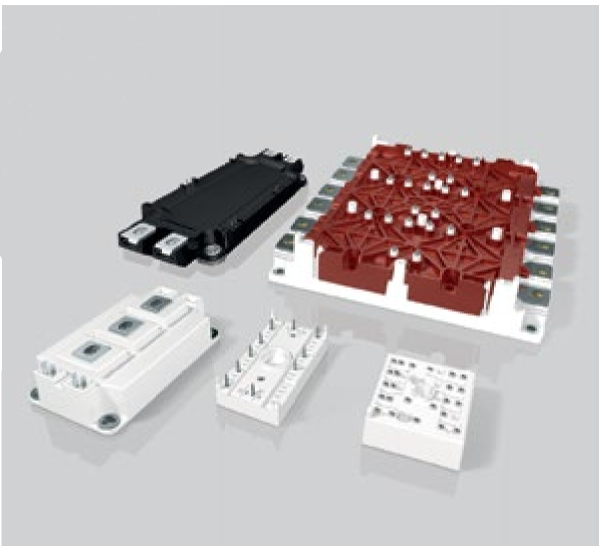

nitride (AlN) substrate and combining it with the CSTBT™ chip technology.

2. **Reduced internal inductance:** The 1 in 1 modules have an internal inductance of only 8 nH. Internal stray inductance plays an important role in 3-level topologies as several elements are connected in series unlike the traditional 2-level topologies.
3. **Reduced overall inductance:** The combination of a low internal inductance, a reduced mounting area and the location of terminals for easy connections ensure a reduced overall inductance for the set-up.
4. **Access to auxiliary terminals:** The module provides access to the auxiliary terminals on two sides for the connecting the gate driver (without having the need to disturb the bus bar arrangement).

An example of how low inductance I-type and T-type 3-level topology bus bar designs can be realized is represented in Figure 2. As shown in this example, it is obvious that these modules are specifically optimized for 3-level topologies, thereby addressing the challenges associated with DC bus bar inductance, power density and flexibility.

Figure 3 shows the different power levels achievable by developing various 3-level topologies employing power modules from Mitsubishi Electric. The power levels are based on a conservative dimensioning of junction-case temperature rise of 25K considering a switching frequency of 2 kHz. Depending on the cooling system and the switching frequency, the output can obviously be further maximized.

Power levels

1. **125 kW to 500 kW range:** For a DC link voltage of 850 V, the CM400ST-24S1 with its inbuilt T type topology can deliver up to 250 kW in stand-alone mode. When used in parallel, about 500 kW output can be delivered.
2. **500 kW to 2 MW range:** When a DC link voltage of 1200V is utilized, two CM1000HA-34S (1000A/1700V) together with two CM500C2Y-24S (500A /1200V) in parallel can be employed to achieve more than 1 MW output. On the other hand, when an 850V DC link is considered, two CM1400HA-24S (1400A/1200V) can be employed together with two CM500C2Y in parallel to achieve more than 1 MW output power. With a DC link of 2400V, six CM1000HA-34S can be employed to develop a 1.8 MW inverter. Remarkably, utilizing a 1700V DC link, more than 2 MW output can be achieved by employing four CM1400HA-24S modules along with two RM1400HA-24S (neutral clamp diodes).

3. **Extended Megawatt range:** It is obvious that by paralleling the options provided above, extended megawatt range inverters can be realized. An alternative solution for this class is to employ multi-level topologies.

As a result of these new products being available, the designer can choose the best fitting solution considering the power and DC voltage requirements. The designer is thus able to evaluate and accordingly select a suitable system voltage to achieve significant system level benefits and thereby maximize overall efficiency.

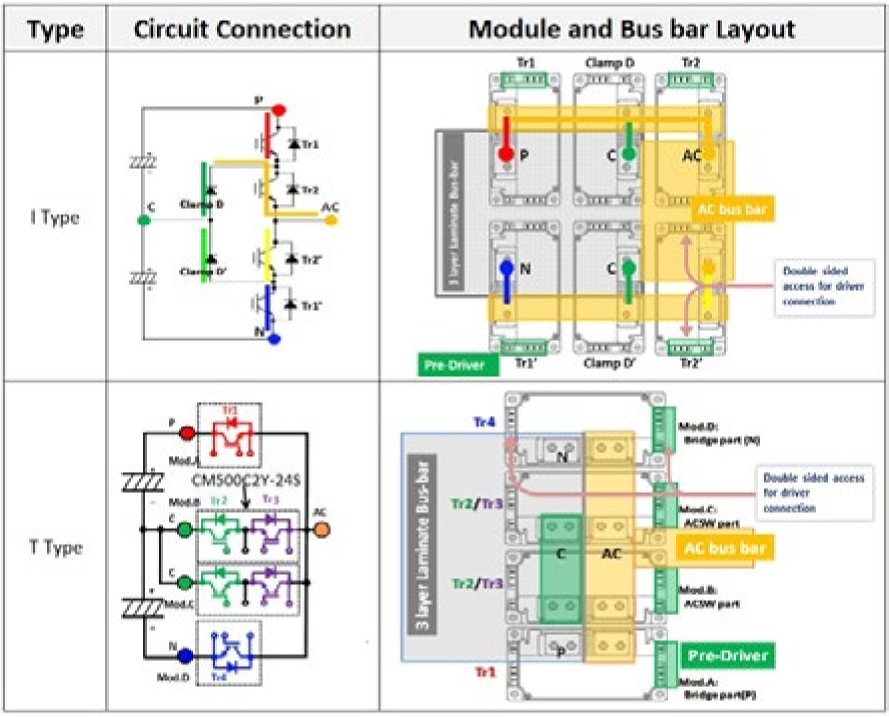

Figure 2: Sample 3-level constructions which can be realized for using Mitsubishi Electric power modules

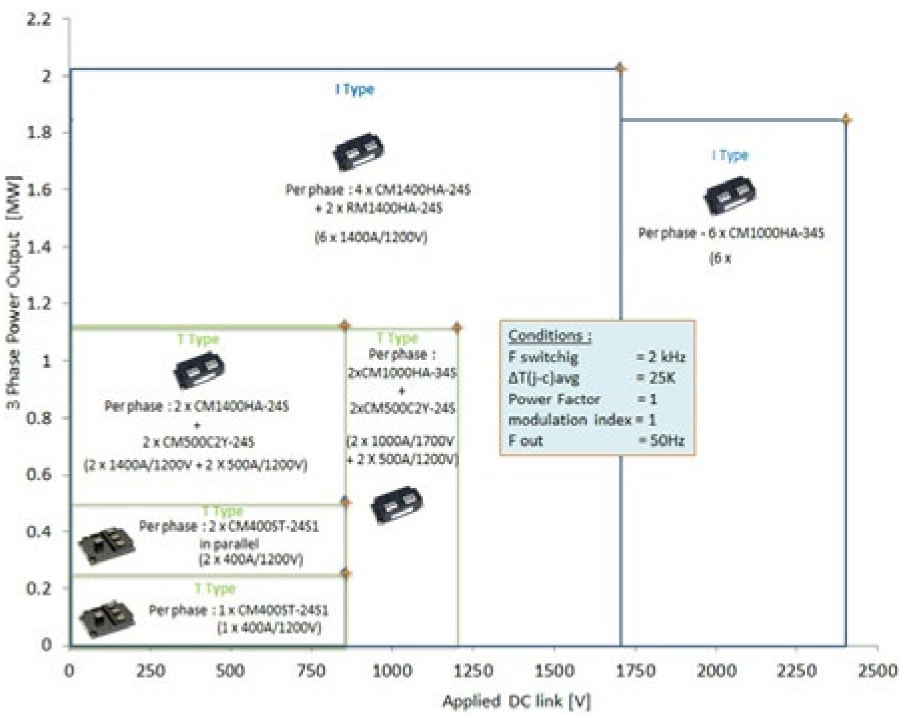

Figure 3: Power capability matrix for different 3-level solutions

Employing the appropriate solution

Figure 4 shows that for an inverter with 1200V dc-link voltage, the maximum output current achievable for different switching frequencies for a maximum allowable ∆T(j-c) avg = 25K (imposed on the first element in any module to reach this limit) depends on the topology employed. The T type topology has advantages with respect to a lower part count and the corresponding volume reduction. However, the equivalent I type topology brings forth interesting system level benefits. Considering a fixed switching frequency of 3 kHz, it can be seen that the I type inverter is capable of delivering 1.41 times more current than the equivalent T type topology. Such benefit in power capability can also be used to allow an increase in the switching frequency (a factor of 2.66 for the 800A range) bringing significant benefits in passive component reduction. Depending on the weightage allocated to passives dimensioning and device count, an appropriate decision can be made.

Conclusion

While each module is designed to deliver the best electrical performance, the module packaging itself and the layout as well is optimized for 3-level inverter design. Combining these aspects with the variety of combinations possible using these different modules, designers now are allowed greater flexibility in realizing solutions which cater to their specific needs. To sum things up - it is clear, that there is flexibility in mechanical layout and flexibility in system level design parameters (choice of DC-link, filter). By addressing the specific needs of individual applications, it is obvious that solutions based on Mitsubishi Electric 3-level modules help achieve the maximum possible overall efficiency along with the best possible performance.

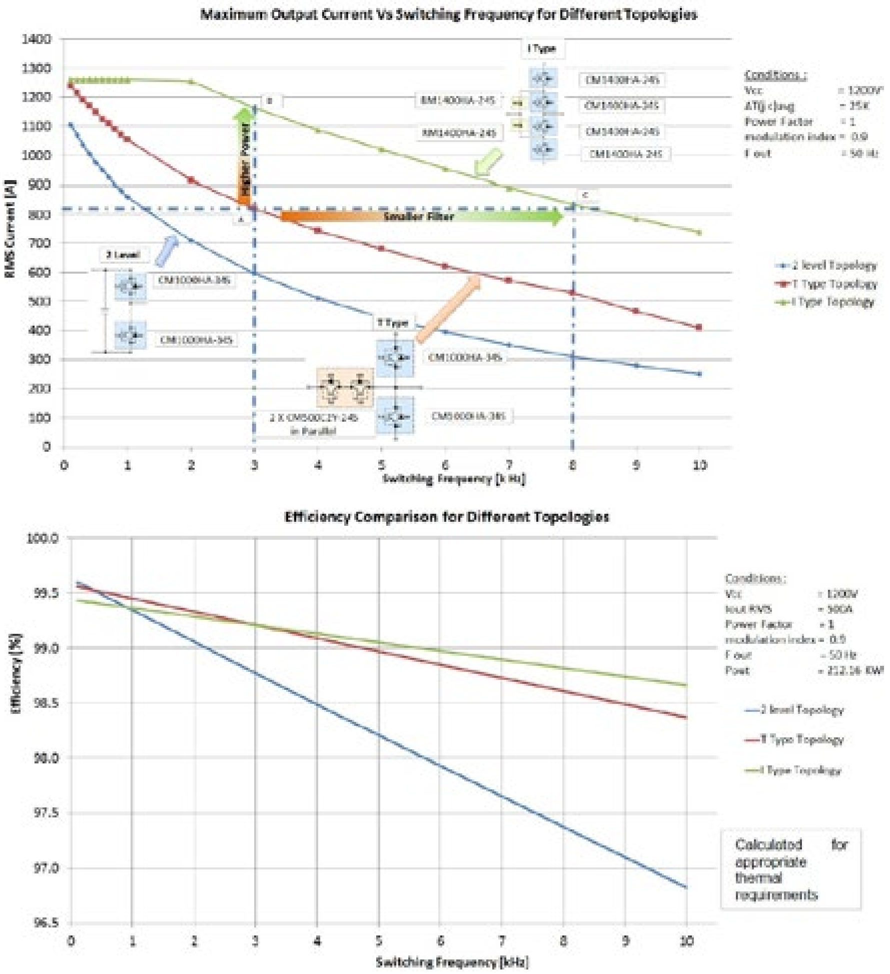

Figure 4: Analysis and comparison of performance using 3-level and 2-level topologies

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[1] MELCOSIM: IGBT thermal and loss simulation software, available at www.mitsubishielectric.com/semiconductors/simulator/

[2] Marco Honsberg and Thomas Radke : “4in1 400A/1200V Module with T-type Topology for 3-Level Applications” Bodos Power Feb’2015, pages 26-28.

[3] Marco Honsberg, Thomas Radke : “3-level IGBT modules with Trench Gate IGBT and their thermal analysis in UPS, PFC and PV operation modes” - EPE 2009 – Barcelona - ISBN: 9789075815009

[4] Marco Honsberg and Thomas Radke : “A family of 3-level IGBT modules from 10A to 600A equipped with Trench Gate IGBT and their thermal performance under typical conditions for UPS and PV inverter operation” PCIM 2009 ISBN: 978-3-8007-3158-9

[5] L. Caballero, S. Ratés, O. Caubet, S. Busquets-Monge: Advantages of ac-ac power converters based on ANPC topology for wind applications”

[6] International Journal of Conceptions on Electrical & Electronics Engineering Vol. 1, Issue. 2, December 2013; ISSN: 2345 – 9603 : “Reduction of common mode voltage in three level neutral point diode clamped multilevel inverter using space vector pulse width modulation”

[7] Application note : 3-level application using 1 in 1, 2 in 1 and the 4 in 1 modules.

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Innova Macroprocessors©

Empowered By Silicon Power

Silicon Power Corporation (SPCO) has introduced novel thyristor-based devices that dramatically outperform the previous state of the art. These devices increase surge current densities by a factor of 10, increase speed (di/dt) by a factor of 100, and turn on with so little loss that they can operate in soft-turnoff circuits at resonant frequencies above 100 kHz. SPCO has achieved these advances by applying integrated circuit manufacturing technology to 4-layer devices and by adding novel packaging.

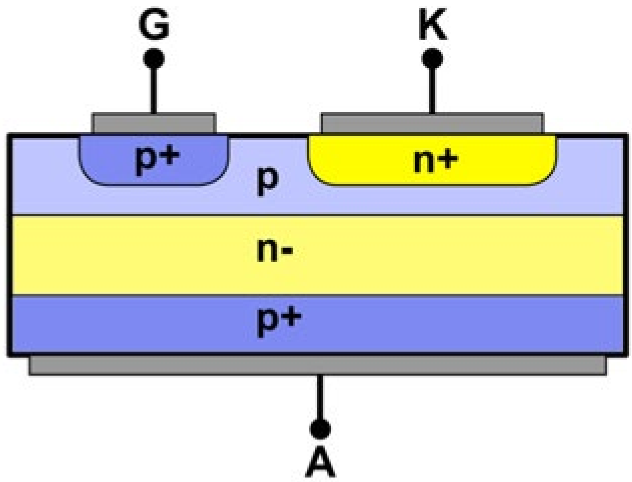


Figure 1: Schematic Diagram of a GTO

Standard GTOs (Gate Turn-Off Thyristors): To provide a context for the discussion of SPCO innovations, we briefly discuss standard GTOs (see Figure 1) and their limitations. Manufacturers typically fabricate these 4-layer npnp devices on a 4-inch n- wafer (one device per wafer, see Figure 2). They implant boron into the p region layer at the top and the p+ player at the bottom. They diffuse both sides to depths of about 100 microns. They bevel the edge of the wafer at an angle to 2 to 3 degrees to increase the breakdown voltage of the device. They deposit a metal anode layer on the bottom of the wafer, and they pattern a metal cathode and gate layer on the top.

GTOs turn off when a negative voltage appears at the gate terminal. These devices require a highly interdigitated gate electrode to minimize resistance in the p layer. A standard GTO contains about 2000 cells, each cell measuring about 800 microns in diameter, each having its own gate. A distance of about 400 microns separates each cell from its neighbors. The device contains 50 cells per square centimeter.

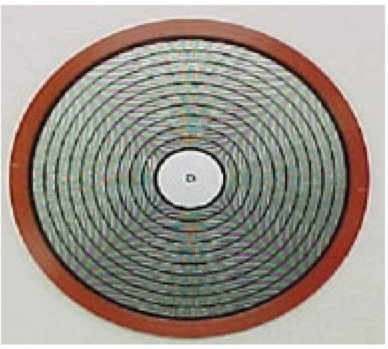


Figure 2: Standard GTO 4 Inches in Diameter with 50 Cells/cm²

In principle, each cell in a standard GTO can turn off 10 amps. However, manufacturers typically under-rate devices by a factor of 5; in practice, a 2,000-cell GTO turns off no more than 4,000 amps. Manufacturers often under-rate the devices because they cannot create sufficiently uniform conditions throughout the p layer. If, for example, the resistance of the cells varies, then the current flows preferentially to those with the least resistance when the device turns off. If the current to a given cell exceeds a certain threshold, that cell might not turn off at all.

Super GTOs: To create uniform conditions throughout the p layer, Silicon Power Corporation has shrunk the cell dimensions and begun to fabricate GTOs at an IC foundry.

We refer to these new devices as Super GTOs or S-GTOs. S-GTOs contain cells only 15 microns in diameter spaced 5 microns apart (see Figure 3).

This approach increases the cell density by a factor of 2,000, from 50 to 100,000 cells per square centimeter.

We diffuse boron into the p-regions at depths of only 10 to 20 microns. S-GTOs can operate with such shallow diffusion profiles because we no longer have to bevel the edges to increase the breakdown voltage; instead, we increase the breakdown voltage via a proprietary process.

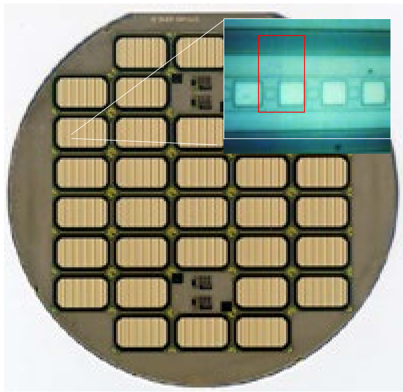


Figure 3: Super-GTO Chips on a 6-inch Wafer with 100,000 Cells / cm²

When compared with a standard GTO, a Super GTOs offers three main advantages:

- Lower forward drop, attributable to the S-GTO's exceptional upper transistor (see Figure 4, bottom).
- Higher di/dt, attributable to the 2000x higher density of cells, all of which turn on simultaneously within 200 nanoseconds.
- Higher turnoff capability (more than 2x that of a standard GTO of the same size). All the cells turn off within a 100-nanosecond window. This high turnoff capability renders S-GTOs particularly desirable for high-voltage motor drives and power supplies.

Modern simulation tools confirm our experience that if we make the upper base layer of the S-GTO as narrow as the equivalent layer in an IGBT, then the S-GTO achieves the same physics-based triple tradeoff among blocking voltage, switching speed, and forward drop as a p-i-n diode with the same voltage capability. The S-GTO achieves a conduction loss similar to that of a diode, much lower than that of an IGBT.

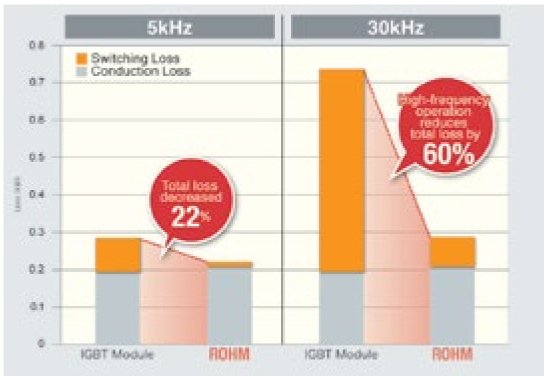
300A FULL SiC POWER MODULE

Higher Voltage | Higher Current | Lower Switching Loss

ROHM Semiconductor now offers a 300A full SiC power module, BSM300D12P2E001, that enables support for larger power applications such as power supplies industrial equipment.

High frequency operation through reduced switching loss

- Switching loss is significantly reduced compared with similarly rated IGBT modules

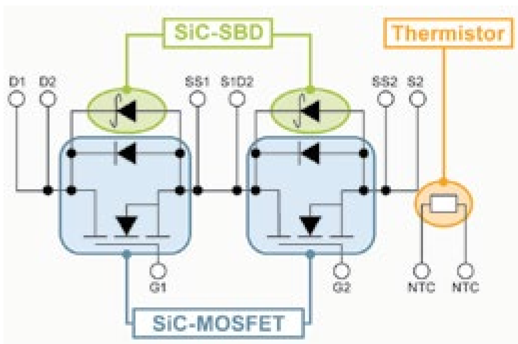


Safer design supports larger currents

- Original design technology reduces inductance by half, enabling the development of 300A rated products.
- Integrated thermistor prevents excessive heat generation.

Device Configuration

- Full H-Bridge SiC module integrates a SiC SBD and SiC MOSFET into a single package
- Equivalent package as standard IGBT modules
- Built-in thermistor
- Tjmax = 175 °C



Full SiC Power Modules Lineup

Part No.	V_{DSS} (V)	I_D (A)	Tjmax (°C)	V_{isol} (V)	Package	Construction
BSM080D12P2C008 *	1200	80	175	2500	C-Type	DMOS+SBD
BSM120D12P2C005	1200	120	150	2500	C-Type	DMOS+SBD
BSM180D12P3C007 *	1200	180	175	2500	C-Type	UMOS+SBD
BSM300D12P2E001	1200	300	175	2500	E-Type	DMOS+SBD+Thermistor

* no online sample ordering possible, please contact ROHM Sales

Ultra-High Current Packaging – Foundation Of The Innova Macroprocessor©

SPCO invented the ThinPak, a device package that can handle cathode and gate currents an order of magnitude higher than those of a standard GTO. We added to the device second-metal (M2) layer stripes that run at right angles to the 10-µm wide metal-1 (M1) emitter and gate fingers that carry current to and from each S-GTO cell. We solder a stamped copper bus to the top lid metal to provide both the gate and cathode external electrodes, as well as pins for gate and gate return.

We mate the S-GTO's M2 layer to a 4-mil copper-clad ceramic lid with a mil or two of high-temperature solder, effectively changing each 2.5-µm thick aluminum M2 stripe into an effective on-device power current bus. We feed these stripes through the lid to the top surface; i.e., to the two cathode pads and center gate pad seen in Figure 5. The turn-off waveform on the right of Figure 5 shows both gate and cathode at 7.6 kA. The base cell turn-off capability at 200V (with overshoot to 500V) exceeds 7 kA, a tribute to the combination of narrow cell width and ultra-low, highly uniform gate-cathode cell current loop inductance.

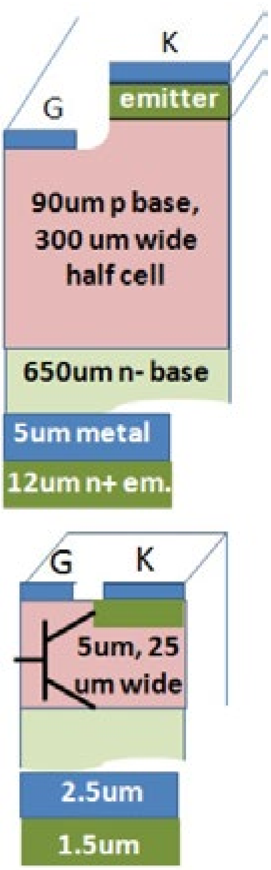


Figure 4: Standard GTO (top); SGTO (bottom)

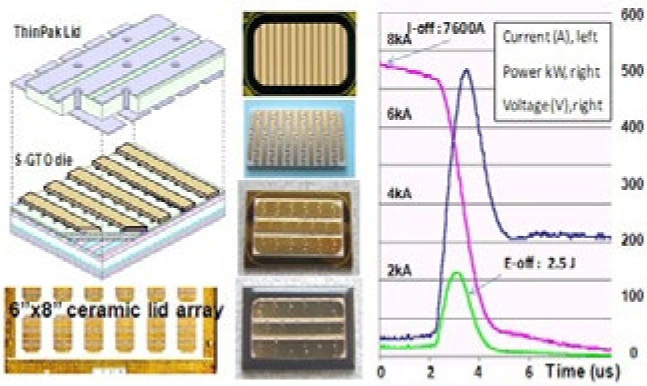


Figure 5. ThinPak lid concept (upper left) and practice. Center: Metal-2 (top) collects current from 10 um cell level gate and emitter metal-1 stripes. We solder it at high temperature to a 4-mil copper underside lid metal (next), resulting in a lidded S-GTO. We then passivate the edges with RTV or epoxy for termination strike and creep (bottom). Lower left shows part of a prescribed panel of lids for this 600 x 900 mil device. Right: Turn-off at 200V, 7.6kA!

The large size and arrangement of the lid-top pads cancels magnetic far fields and leads to a measured lid inductance of about 0.6 nH, just small enough to turn off 500 A at temperature and voltage by merely shorting the gate with a lid-mounted, 0.5-mΩ array of FET's that occupy less than half the lid surface (see Figure 6).

The ThinPak also conveys a mechanical advantage: the lid constrains the device, reducing thermal expansion stresses by about 40%. As a result, the device offers a higher cycles-to-failure ratio by about two orders of magnitude, compared with an unlidded large die mounted on an AlN substrate.

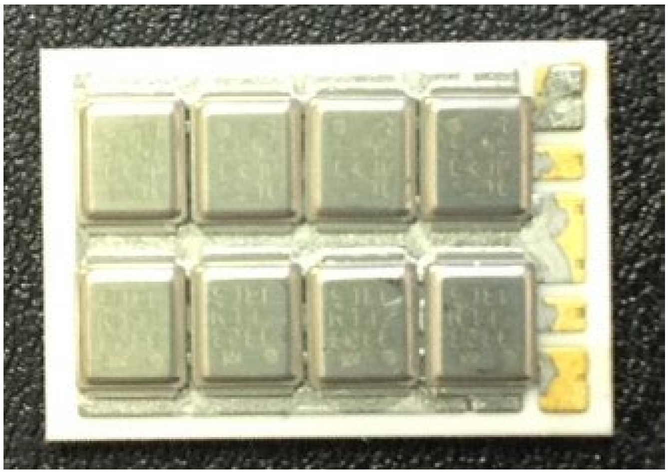


Figure 6: MTO Configuration with Lid Mounted FETs

Innova Macroprocessors© Applications

Herein, we present some of the many applications for S-GTO modules: scalable power supplies, power systems to reduce NOx emissions from coal power plants, utility current limiters, utility-transfer switches, and pulse switchgear assemblies.

Application – Reduction of NOx emission

Globally nations are seeking to implement stricter guidelines for NOx emissions fired by coal plants and are collaborating with multiple industries to identify new advanced technologies to accomplish cleaner flue gas emissions.

One approach is to develop a reliable system to bombard flue gasses with a high frequency electronic beam to break the molecular bonds of nitric oxide and nitrogen dioxide (NOx, see figure 7) leaving clean oxygen (O_2) and nitrogen (N_2) instead.

The concept has been proven on a small scale using a mixture of just NOx and nitrogen. When the powerful pulse of electrons leaves the cathode it hits the NOx which absorbs the energy and breaks the bonds. Firing is made in short pulses – several times a second for long durations.

Considering NOx bonds typically break at 4 at 4 electron volts (eV) of energy, we can expect a 400,000 volt electron beam to break 100,000 bonds making it highly efficient low cost – low maintenance solution.

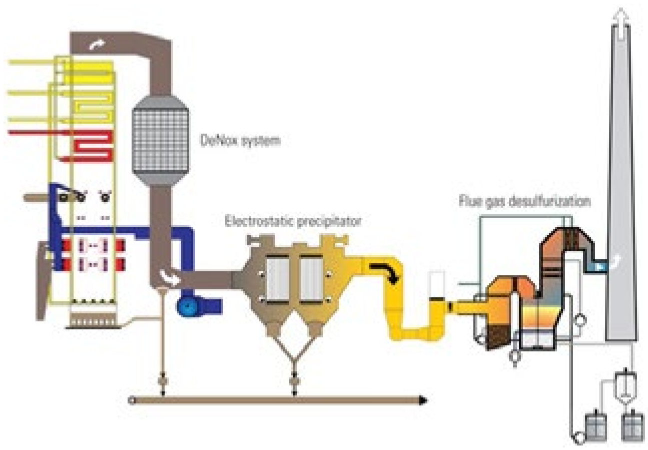
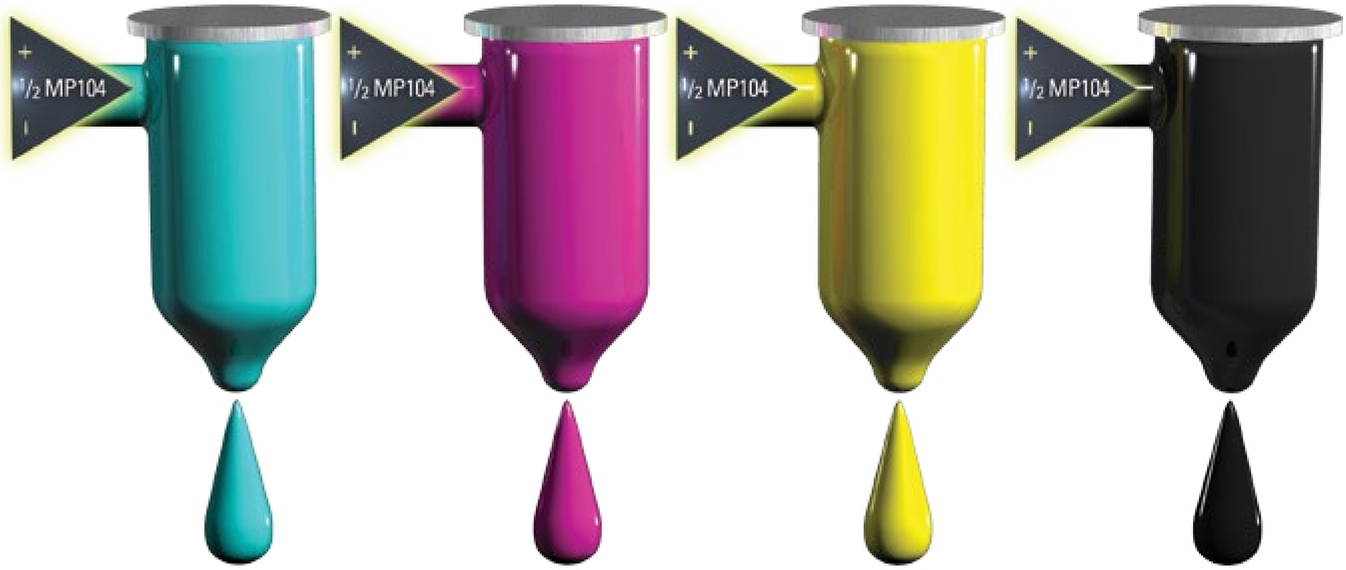


Figure 7. Industrial Level NOx System

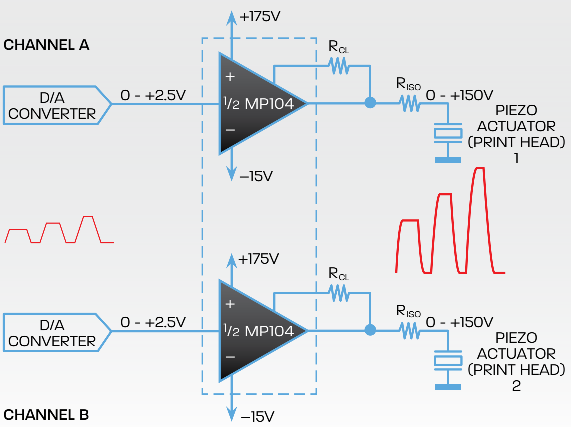


Dual Channel Jet Driver!

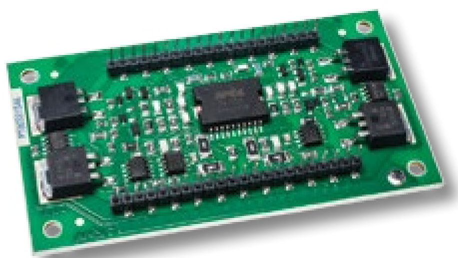
The MP104 Drives Multiple Inkjet Printer Heads with Speed, Current and Voltage

PROVIDES SPACE SAVINGS, COST SAVINGS

The Apex MP104 is a low cost, dual channel power amplifier designed to drive multiple piezoelectric loads with a single, space saving device. The enhanced circuitry of the MP104 delivers a balanced performance in providing >10A PEAK output current per channel as well as a reduction in crosstalk. The MP104 operates on supply voltages up to 180V and references the output to ground and not the negative supply rail ($+V_S$ to GND) to reduce the requirements for expensive power supplies. The MP104 also features a low current negative supply (≤50mA) to allow input to zero volts without violating the common mode input range.



A SINGLE, DUAL CHANNEL MP104 DRIVES TWO PRINTER HEADS
(For Design Discussion Purposes Only)



Open Frame Product Technology

42-PIN KF PACKAGE

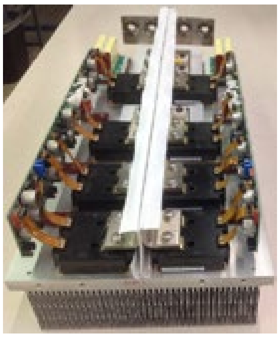
Footprint 91.4mm x 50.8mm

Power up at apexmic.ro/bpsMP104

apexmic.ro/bpsMP104

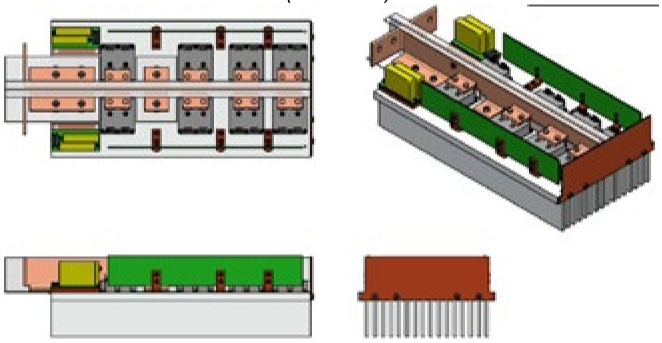
APEX MICROTECHNOLOGY

Utility Innova Macroprocessor© (IM): Standard Building Block (SBB)



This configuration of the Innova Macroprocessor targets medium voltage grid inverter/converter and motor drive applications. It has served in both hard and soft switched applications. It finds grid application in StatCom (Static Compensator) or HVDC systems.

Figure 8: SGTO-Based 8-Module, H igh Frequency SSB Innova Macroprocessor© 3.5kV/1kA at 10-20kHZ (air cooled)



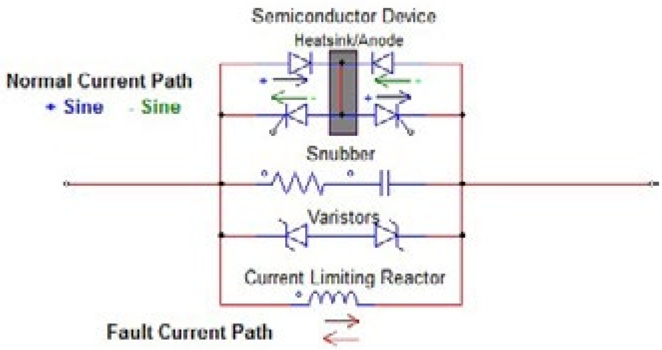


Figure 9: Solid-State Fault Current Limiter Single Line Schematic

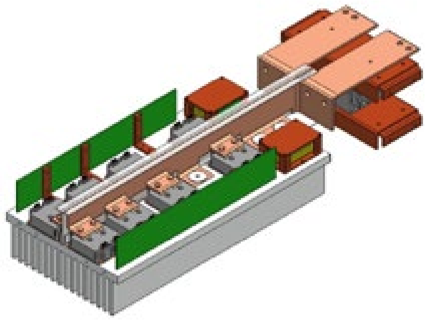


Figure 10: SGTO-Based Standard Building Block (SBB) 3kV/1.2kArms Continuous/4kApk Controlable

Test Parameter	Pulse Position	Mod 4-Driver 23			Mod12-Driver 23			Mod 14-Driver 23		
		2500Vpk	*3000Vpk*	*3500Vpk*	*2500Vpk*	*3000Vpk*	*3500Vpk*	*2500Vpk*	*3000Vpk*	*3500Vpk*
tdon, nsec	1	34	38	36	54.4	44	48	34	40	40
tdoff, nsec	1	416	420	428	450	456	464	432	436	448
Eon, uJ	1	8.22	70.33	110.6	643.3	746.9	936.6	0.8038	2.212	20.57
Eoff, uJ	1	15340	26150	37300	11080	18100	30030	12310	18140	24870
I, Apk	1	22	26	31	22	26	30	18	22	26
tdon, nsec	2	94	120	116	116	128	106	144	148	168
tdoff, nsec	2	416	412	424	422	436	464	428	440	460
Eon, uJ	2	6588	10030	13360	7790	10750	14710	6155	9316	11900
Eoff, uJ	2	12120	27900	43240	8295	24830	29940	15080	21640	27220
I, Apk	2	33	39	45	33	39	45	27	32	38

Table 1: Some characteristics of Modules used in a High Frequency Utility Innova Macroprocessor©

Innova Macroprocessor © Solid-State Fault Current Limiter (SSFCL)

The Solid-State Fault Current Limiter (SSFCL), a FACTS (Flexible Alternating Current Transmission Systems) based system, limits the fault current to a safe manageable level when a fault occurs (e.g., in a power distribution or transmission network) without completely disconnecting source from the load. The S-GTO-based Silicon Power SS-FCL limits the fault current safely within 100 microseconds by inserting a current-limiting reactance in series with the fault current path. It thereby allows the standard grid resources to deal with the reduced fault current as they were designed to do without being overpowered and allowing a level of grid control unavailable until now.

Figure 9 shows a single-line schematic of a grid-level SSFCL placed in series between the source and load to limit fault currents. Figure 10 shows an air-cooled Standard Building Block (SBB). Figure 11 shows a typical waveform from an SBB interruption test.

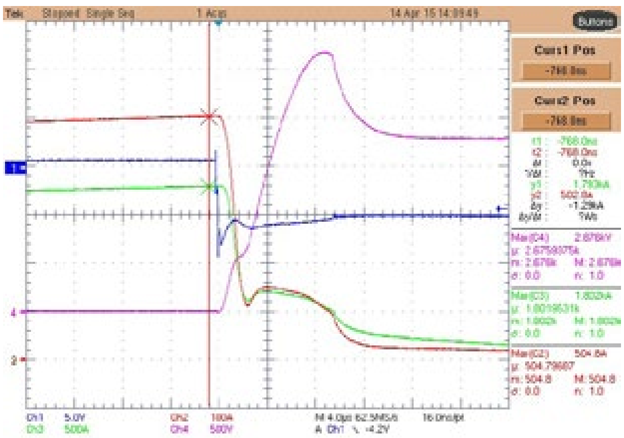


Figure 11: SBB-1 Factory Test for SSFCL: 2.4kVpk/1.8kApk Interruption in < 4us capable of 2.4kVpk/3.6kApk

At grid level, systems must handle hostile environments and shipping and installation stresses. Figure 12 shows a three-phase 15.5kV/1.2kA NEMA (National Electric Manufacturers Association) enclosure for SSFCL. Figure 13 shows the inside of that packaged SSFCL (one of its three phases). Figure 14 shows the KEMA, a power test lab, run interruption test for a single phase.

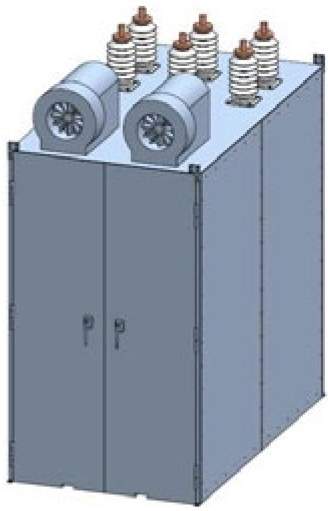
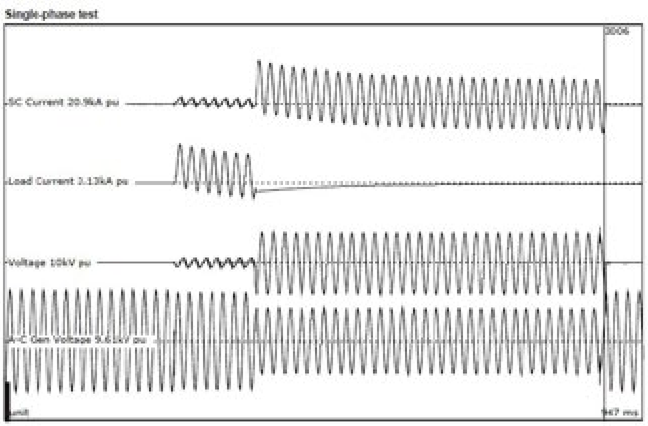


Figure 12: Air Cooled 3-Phase 15.5kV/1.2kA SSFCL

Figure 13: Inside of Air Cooled 3-Phase 6-Level Stack Assembly for a 15.5kV/1.2kA SSFCL



Test number: 150605-3006

Phase		
Peak value of current	kA	23.2
Symmetrical current, beginning	kA	9.50
Symmetrical current, middle	kA	9.47
Symmetrical current, end	kA	9.47
Symmetrical current, average	kA	9.43
Current duration	s	0.523
Current (Load)	A	1196
Duration (Load)	ms	118

Figure 14: Single Phase 9kV@23kA Applied Fault Current SSFCL KEMA Full Power Current Interruption Test

Innova Macroprocessor © Solid-State Static-Transfer-Switch (SSSTS/STS)

Silicon Power designed its SSSTS/STSs for medium voltages from 2.4kV to 68kV and currents from 400A to 4000A. When these systems detect a disturbance, they transfer the load from one source to another with sub-millisecond/sub-cycle reaction times. During a voltage sag, the SSSTS transfers from one source to the other within 100 µsec, and the STS does so within ¼ cycle. The complete SSSTS/STS systems consist of three-phase, properly series/paralleled solid-state thyristor ac switches, sensors (CTs & PTs), Silicon Power's proprietary controller, disconnect breakers, and bypass breakers. We connect a static switch to each source. The third static switch operates as a tie switch. The outputs of the switches connect to each other and furnish power to two load buses. Figure 15 shows a three-phase 15.5kV/4kA SSSTS or STS. Figure 16 shows a single line diagram of the Silicon Power SSSTS/STS Split-Bus topology.

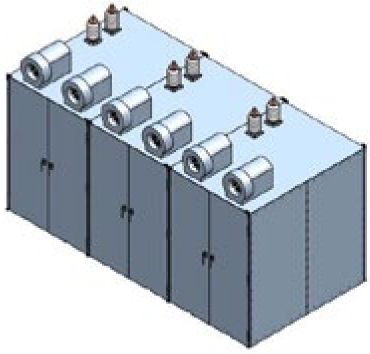


Figure 15: Three Phase 15.5kV/4kA SSSTS or STS

The Silicon Power's proprietary controller executes all automated operational functions of the SSSTS/STS. The controller also provides external status and control interface to SCADA systems via a Modbus TCP interface. The bypass and isolation breakers make it possible to perform maintenance, repairs, electrical tests, and emergency shutdowns without disturbing the loads. When the SSSTS/STS is bypassed (either thru SSSTS/STS controls, SCADA control or manually) the existing customer switchgear will function as an electromechanical changeover switch.

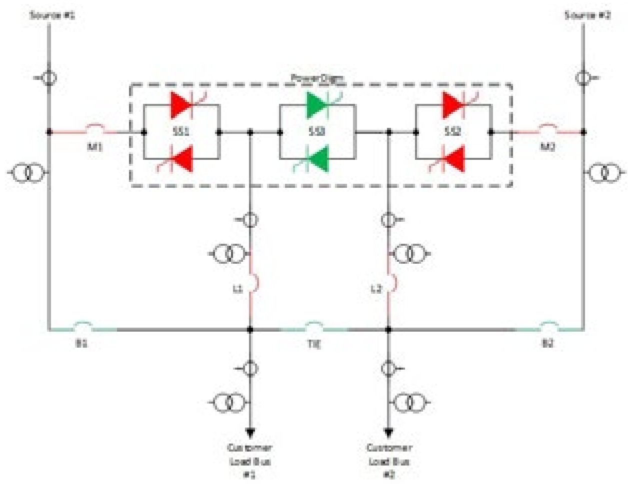


Figure 16: Innova Macroprocessor © Solid-State Static-Transfer-Switch (SSSTS/STS) Single line Schematic

Pulse Switch Assemblies: Leading metalugy foundries and casting manufacturing centers have asked us to research and develop a Pulse Switch Assembly (PSA) for 400-kA, 10-kV capacitor discharge with a short tqq recovery time (tqq).

We are finalizing the PSA shown in Figure 17. It contains 192 20-kA high-voltage ThinPak S-GTOs.

In the module shown at lower right, we paralleled eight die, each rated at 5 kV. At 20 kA per device, the module has a potential capability of 160 kA.

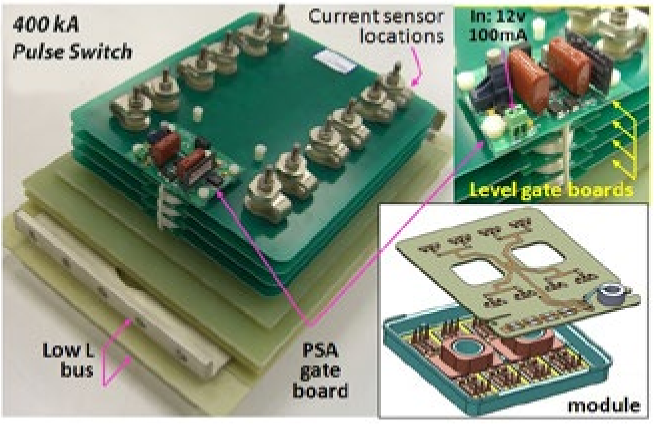


Figure 17: 400kA, 10kV Pulse Switch Assembly (PSA). Module assembly ~ 4-liters, Sensor ~ 2-liters, bus ~ 6-liters. Clamp rods return current through 4-series, 6-parallel modules for very low inductance.

We have confirmed 120 kA experimentally, giving us a factor of two application margin in both voltage and current. The module gate circuit board doubles as the module cover. It includes gate-shorting resistors for low recovery time < 10us tqq) and series resistors for enforcing gate sharing and simultaneous turn-on. The gate drive derives from a secondary single turn through the board-mounted ferrite toroid and level voltage sharing with 4 series pairs of very high impedance resistors. Although the PSA is simply gated by a single turn threaded through the level toroid by a sub-microsecond gate pulse, it fits the Innova Microprocessor test - input power at ground, optically isolated and, at 1Hz, is convection cooled as well. Our PSA gate current exceeds by a factor of about 2000 the minimum current needed to turn on a single SGTO (~ 2 A compared to 1 mA), and the primary di/dt is > 1 kA/microsecond. These specifications definitely fall into the category of over-achievement; they virtually guarantee that all 192 devices will turn on within nanoseconds of each other.

To assure very low inductance, we designed the modules to allow the clamping rods to double as the current return within the module. The low-inductance bus is 50% larger than the module assembly. We can easily configure the modules in various series/parallel combinations.

Summary:
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Current Measurement Methods that Deliver High Precision Power Analysis in the Field of Power Electronics

Various power electronics applications demand high-precision power (current and voltage) measurement of such characteristics as the power conversion efficiency of power conditioners, the efficiency of inverters and motors, and reactor losses. This paper narrows the focus of the discussion to current measurement methods and introduces some of Hioki's expertise as a longstanding developer of both current sensors and power analyzers leveraging proprietary technologies.

By Hajime Yoda, Assistant Chief Engineer, Hiroki Kobayashi, Assistant Chief Engineer and Shinya Takiguchi, Senior Staff, Hioki E.E. Corporation

Current Measurement Methods

Power analyzers generally measure current by means of either the direct connection method (Figure 1[a]) or the current sensor method (Figure 1[b]). The following provides a detailed description of the characteristics of each approach.

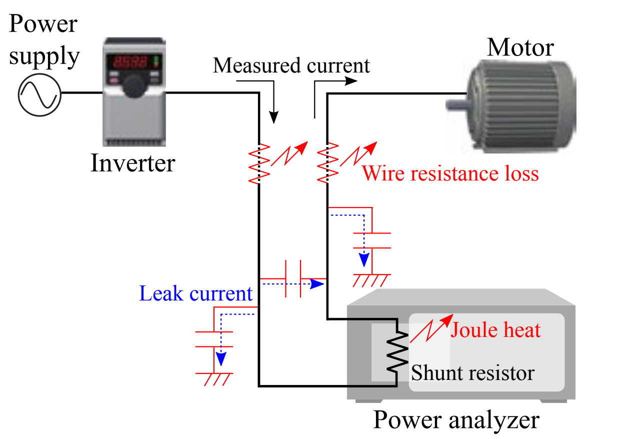

Figure 1a: Direct connection method

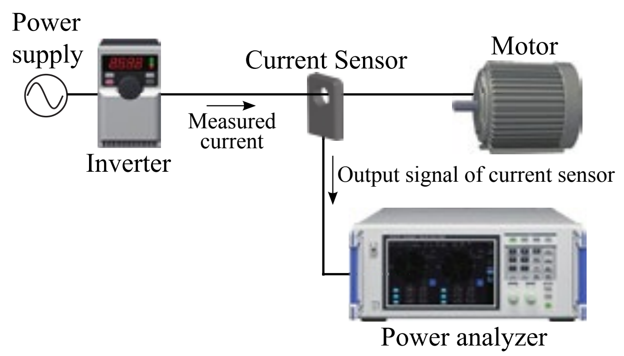

Figure 1b: Current sensor method

Direct Connection Method

In the direct connection method, current is measured by routing wires from the measured object to the power analyzer and connecting them to the instrument's current input terminals. The measurement principle itself is extremely simple, with the advantage of enabling a power analyzer to be used to measure current on a standalone basis, making it the de facto method for many years. However, since the current wires must be routed over a long distance and the current input portion of the power analyzer must be inserted into the measured object's circuit, the following disadvantages exist:

i) Conditions differ from those that characterize actual operation
ii) There is increased loss due to the wire resistance of the long wires.
iii) Capacitance coupling occurs between individual wires and between wires and the ground, causing high-frequency leakage current to increase.

For example, concerning the effect described in ii) above, a 5-meter run using No. 6 AWG wire would have a wire resistance of approximately 6.5 mΩ. If the current under measurement were 30 A, the loss resulting from this wiring resistance would be 5.85 W. Although it is impossible to make any judgment concerning the magnitude of the loss based solely on this value, it would be too large to ignore for some measured power values.

In addition, when using the direct connection method, current usually is measured by means of a shunt resistance. This shunt resistance method suffers from the following disadvantages:

i) When current flows into the shunt resistance, Joule heat proportional to the square of the current occurs in the resistance. In addition to instrument loss attributed to the joule heat, the self-heating will change the resistance value of the shunt resistance itself, which will further worsen the measurement accuracy.
ii) To limit this heating, a shunt resistance with a low resistance value is used. However, when a small shunt resistance is used to

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measure a large current, even slight inductive components cannot be ignored, which degrades the frequency characteristics.

Each of these disadvantages significantly worsens current and power measurement precision, dictating caution when measuring large currents.

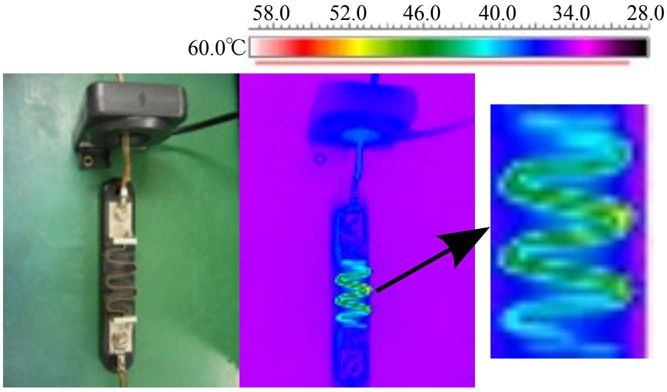

Figure 2: Self-heating of shunt resistance

Figure 2 illustrates the process of self-heating that occurs when a current of 20 A flows through a 2 mΩ shunt resistance. For comparison purposes, a Hioki CT6862 current sensor with a rating of 50 A has been connected to the circuit. You can see that the temperature of the shunt resistance rises to about 50°C due to self-heating caused by Joule heat. By contrast, the current sensor is mostly unaffected by Joule heat and associated self-heating, and instrument loss and effects of the sensor's own temperature characteristics on measurement precision are negligible.

As demonstrated by the above discussion, the direct connection method is well suited for the measurement of very small currents of about 1 A where the effects of the shunt resistance's Joule heat are sufficiently small, for example measurement of the standby power of electronic devices or measurement of the power consumption of LED lighting.

Current Sensor Method

The current sensor method is a method for measuring current whereby a current sensor is connected to the wires on the equipment under test, and the output signal (current or voltage) from the sensor is input into the power analyzer.

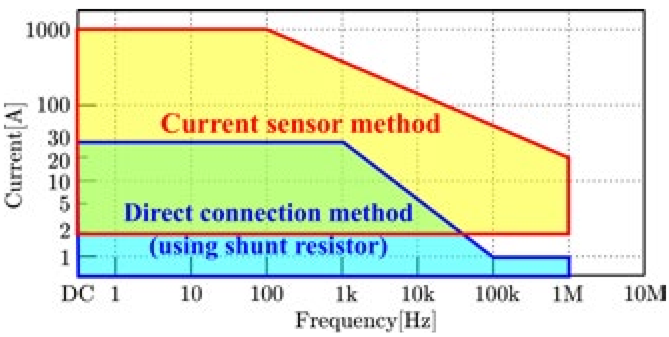

Figure 3: Direct connection method and current sensor method: Approximate ranges of current values and frequency bands that can be measured at high precision

**Exclusion from the ranges shown in the figure does not necessarily mean a value cannot be measured.*

The current sensor method can be used to measure a target in its operating state, and the almost complete lack of self-heating when measuring large currents means that there is no effect on measurement accuracy. The current sensor method is better than the direct connection method at measuring large currents of about 5 A or greater with a high degree of precision, and it is generally used in the power electronics field.

Figure 3 illustrates the approximate range of current values that can be measured with a high degree of precision and the associated general frequency band for both the direct connection method and the current sensor method. Please note that just because a value falls outside the range shown in the figure does not necessarily mean that it cannot be measured using the method in question.

High-Precision Power Measurement using the Current Sensor Method

As described above, it is typical to use the current sensor method when measuring currents in excess of 5 A. While the current sensor method does not suffer from the same disadvantages as the direct connection method, there are nonetheless a number of precautions that must be borne in mind in order to measure current at a high level of precision. This section outlines those precautions.

Selecting a Suitable Current Sensor

High-precision, highly reproducible power measurement using the current sensor method presumes selection of a suitable current sensor. Specific selection criteria include the following two considerations:

i) The current sensor's rated current value must be appropriate for the magnitude of current to be measured.
ii) All frequency components of the current to be measured must fall within the current sensor's measurable frequency band.

Furthermore, the following considerations should be borne in mind:

iii) The current sensor must provide a sufficient level of measurement accuracy that is defined across the entire measurable frequency band.
iv) All error factors, for example output noise, temperature characteristics, conductor position effects, external magnetic field effects, magnetization effects, and common-mode voltage effects for the current sensor, must be defined and sufficiently small in magnitude.

A sufficient level of caution is required when selecting a current sensor. In particular, concerning consideration iii), amplitude and phase accuracy for most current sensors are only defined for DC and 50/60 Hz frequencies, and accuracy for other frequency ranges is provided only for reference purposes only.

It is important to note that high-precision current measurement using the current sensor method hinges on the availability of both current sensors and a power analyzer with an adequate level of performance.

Overall Optimization of Power Measurement Systems Including Current Sensors

Simply selecting a suitable current sensor as described above is not a sufficient condition for high-precision power measurement using the current sensor method. In addition, it is necessary to optimize the entire power measurement system, including the current sensor. Even if the current sensor detects the target current with an exceptionally high degree of precision, it will be impossible to measure the current with a similarly high degree of precision if the sensor's output signal is degraded before reaching the power analyzer.

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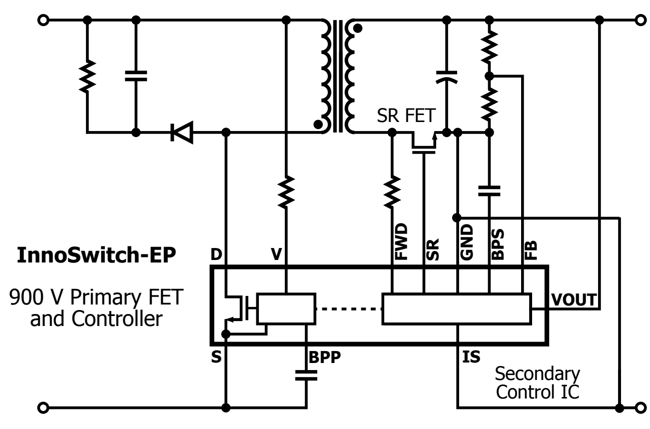

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Figure 4 illustrates a typical power measurement system that includes a current sensor. As described above, some current sensors generate current output, while others generate voltage output. Since current-output sensors are more commonly used than voltage-output sensors, this discussion will assume use of a current-output sensor.

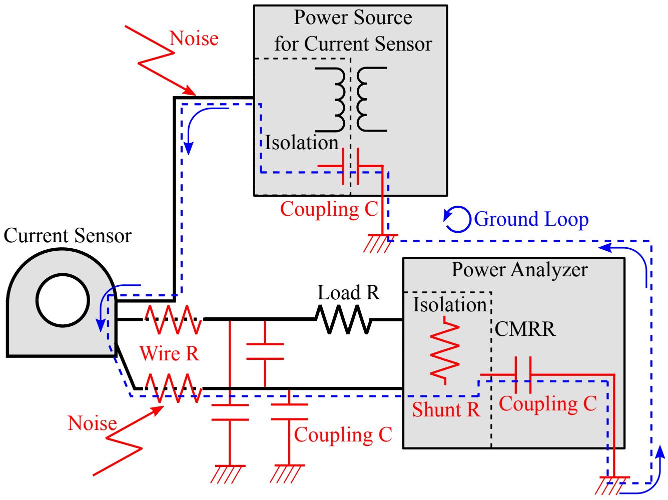

Figure 4: Typical power measurement system

The following conditions must be satisfied in order to ensure that the current sensor's output signal can be transmitted to the power analyzer without degradation.

i) A high-quality power supply must be used for the sensor, and it must be properly grounded.
ii) Coupling capacitance between multiple cables and between cables and ground must be low, and the noise resistance of the cables must be high.
iii) The power analyzer's current inputs must offer good frequency characteristics with little heating and high insulation performance (high CMRR and low leak current). In addition, the instrument must provide high noise resistance, and it must be properly grounded.

In general, power is measured with current sensors, a power supply to drive the sensors, and a power analyzer that are all from different manufacturers, and the cable type as well as wiring method are dependent on the user's discretion. In light of this, it goes without saying that it is extremely difficult for current sensor manufacturers, power analyzer manufacturers, and sensor power supply manufacturers to guarantee that all of the conditions listed above will be satisfied for any given setup, that the current sensor's output signal will reach the power analyzer without suffering degradation, and that the target current will in fact be measured at a high level of precision.

On the other hand, Hioki is the only test and measurement instrument manufacturer in the world that independently develops and designs both current sensors and power analyzers, giving us the ability to deliver all of the components necessary for building a complete power measuring system.

Hioki power measurement systems provide the following features:

i) We use voltage-output current sensors for which accuracy has been defined across the entire measurable frequency band.
ii) Power analyzers' current inputs are designed specifically for use with voltage-output current sensors, and both sensor output voltage levels and input voltage levels for power analyzers' current inputs have been optimized.
iii) Power analyzers have a built-in sensor power supply that drive the sensors with power whose quality is identical to that used at Hioki when determining accuracy. By applying a number of meaningful design features such as using the same ground for the power analyzer and the sensor power supply and eliminating the causes of ground loops, we have vastly improved measurement precision and reproducibility.
iv) In addition to using shielded wires to carry sensor output as a way to counteract noise, Hioki has built in functionality for adjusting sensor output gain to compensate for the minuscule voltage drop-off caused by the cables.

Furthermore, Hioki subjects current sensors and power analyzers together to evaluations of measurement accuracy and noise testing both in-house and by third-party certification authorities.

Figure 5 portrays a power measurement system consisting of Hioki current sensors (CT6862, CT6863, 9709, CT6841, CT6843, and 3274) and a power analyzer (PW6001) undergoing immunity testing by a third-party certification authority.By carefully designing each individual element and qualifying them in combination in order to optimize the system as a complete set, Hioki is poised to deliver a world-class power measurement system to our customers.

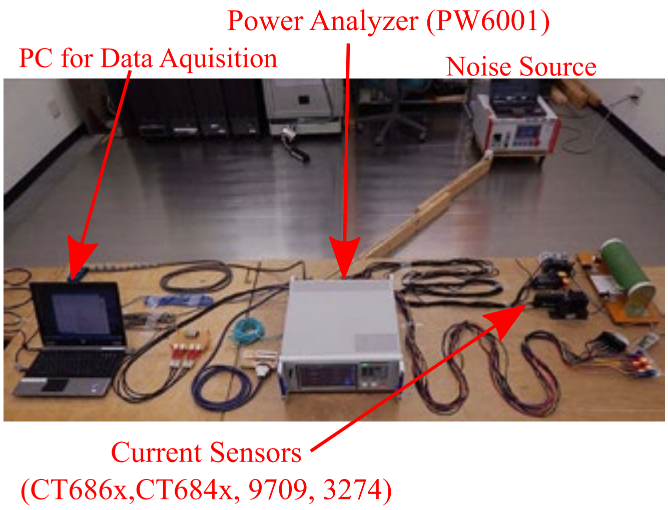

Figure 5: Immunity testing of a Hioki power measurement system by a third-party certification authority

Conclusion

In addressing high-precision power measurement as required in a variety of settings in the power electronics field, this paper focused on current measurement methods and briefly introduced some of Hioki's expertise as a longstanding developer of both current sensors and power analyzers leveraging proprietary technologies. Due to the constraints of space, it was unable to cover, or was only able to mention in passing, many of the more detailed aspects of this subject. Hioki looks forward to providing similar information to readers in the future.

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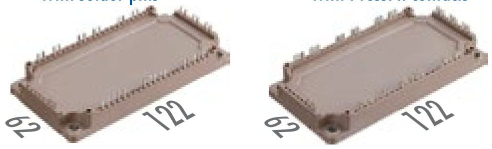
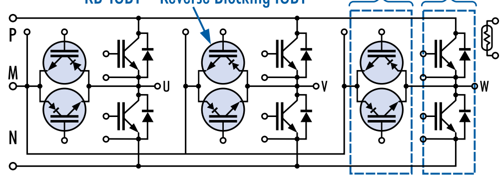
3 Phase

T-Type

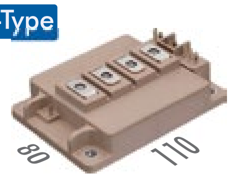


Ic	Inverter	AC-switch
50A	1200V	600V
75A		
100A		

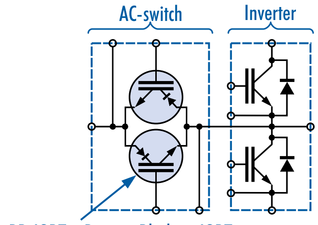


1 Phase

T-Type

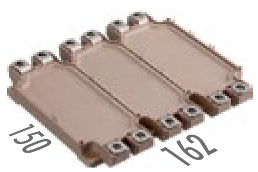


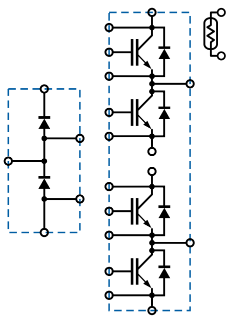
Ic	AC-switch	Inverter
220A	1700V	1200V
300A	1200V	600V
	1200V	900V
340A	1200V	600V
400A	600V	600V
	1200V	600V



1 Phase

I-Type





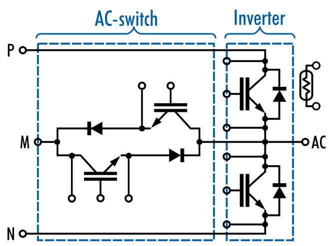
Ic	1200V
600A	●

1 Phase

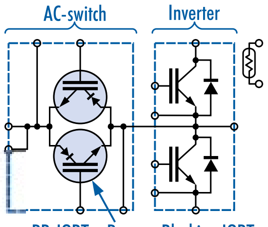
T-Type

With PressFit contacts

Ic	Inverter	AC-switch
300A	1200V	600V
400A	1200V	600V



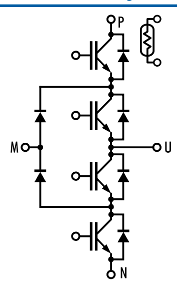
1 Phase



T-Type

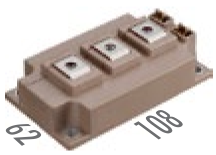
Ic	Inverter	AC-switch
450A	1200V	900V
650A		
900A		
450A	1700V	1200V
600A		

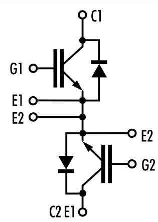
I-Type



Ic	1200V
600A	●

AC-switch





Ic	1200V
450A	●

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Increased Packing Density Thanks to Double-Sided Power Semi-Conductor Cooling

The problem is as old as power electronics. How do I continue to miniaturize and build smaller electronics while reliably dissipating the steadily increasing thermal power loss? A new concept is the creation of a second cooling path on basis of liquid cooling.

By Roland Dilsch, Application Engineer, CeramTec GmbH

Trying to reduce the thermal resistance between the heat source, the chip, and the heat sink, even with liquid cooling and optimized components the physical limits can quickly be reached. With the “chip-on-heat-sink” technology, a first step in the right direction has already been taken. Here the thick copper conductor tracks of 150 up to 300µm are sintered directly onto a ceramic heat-sink.

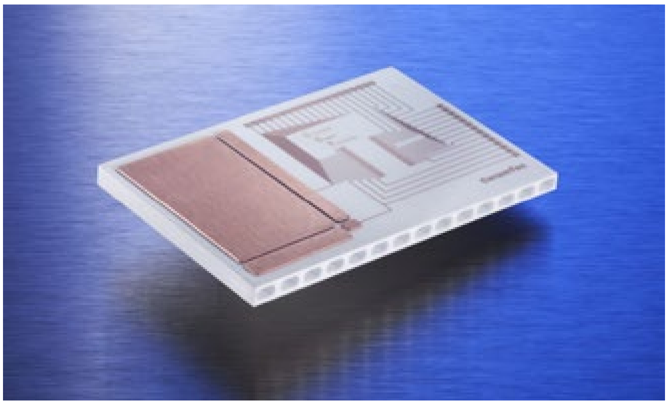

Figure 1: Chip on Heatsink Technology

This eliminates thermal interfaces and thermal resistance is greatly reduced compared to conventional solutions in which a power module is mounted onto a liquid cooled heat-sink.

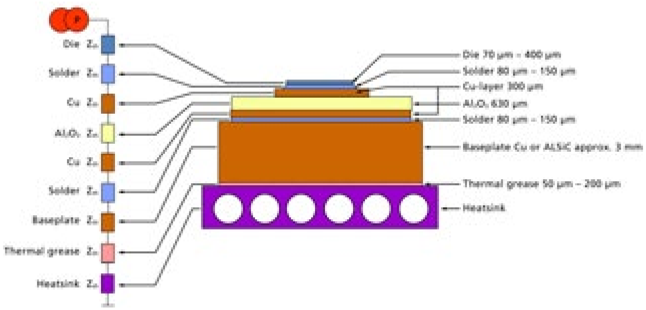

Figure 2: Conventional Cooling Concept

In the example outlined above, a ceramic liquid cooler made of aluminum nitride is directly metalized and the chips are soldered right onto it. This creates an optimum thermal connection between the power semi-conductor and the coolant, thereby achieving electrical insulation. But the challenge now lies in further increasing cooling power to achieve even higher packing densities.

Traditional cooling concepts only lead power loss away from the bottom of the chip. Virtually no heat is dissipated from the top of the chip, with the exception of the minimal amount of heat transported via the bonding wires and a minimal amount of thermal radiation.

Unlike classic cooling concepts, this new concept described here has a new approach with mounting a second liquid cooler on top of the heat sources, like e.g. a chip. Following this approach, a second heat dissipation path is created. However, there are a number of issues to consider here:
The full load current flows across the top of an IGBT or MOSFET, and should therefore be electrically contacted across the entire surface.
A minimum clearance must be kept between the top and bottom heat-sink conductor tracks. For one thing, because the gate of course has to be contacted and for another because dielectric material must be inserted between the top and bottom conductor levels in order to ensure insulation voltage. A specific gap width is needed as a result of its adhesion and viscosity.
Another aspect which implicitly has to be considered is the coefficient of thermal expansion. The same problem exists on the top of the chip as on the bottom. A solution is needed with a CTE as close as possible to that of silicon.

In summary:
In order to cool the top surface, a material is required that
1) Has a certain thickness
2) Is highly electrically conductive
3) Is highly thermally conductive
4) Has a CTE close to that of silicon.

While a metal, such as copper, can meet the first three criteria, the fourth is more difficult to address. Most metals are unsuitable because they have a CTE that is much higher than that of silicon.
A promising solution is a metal-ceramic composite similar to using DCB as a circuit board. Analogously, a ceramic cuboid can also be bonded with a metal, preferably copper. The solution consists of an aluminum nitride cuboid. The cuboid is perforated with holes, which are then filled with conductive copper paste to create vias. The paste is printed across the entire surface of the top and bottom of the cuboid, connecting all of the vias.
The exterior sides of this cuboid can likewise be printed with a film of conductive copper paste.
Aluminum nitride with a very good thermal conductivity of approx. 180W/mK was selected as material for the ceramic cuboid. Due to its physical properties, the aluminum nitride determines the thermal

expansion coefficient of the cuboid. At ~ 4.5 ppm it is very close to that of silicon.

This results in a cuboid with good electrical and thermal conductivity that can easily be soldered onto the top of the chip due to its adapted CTE or, if properly pretreated, can also be sintered on with silver.

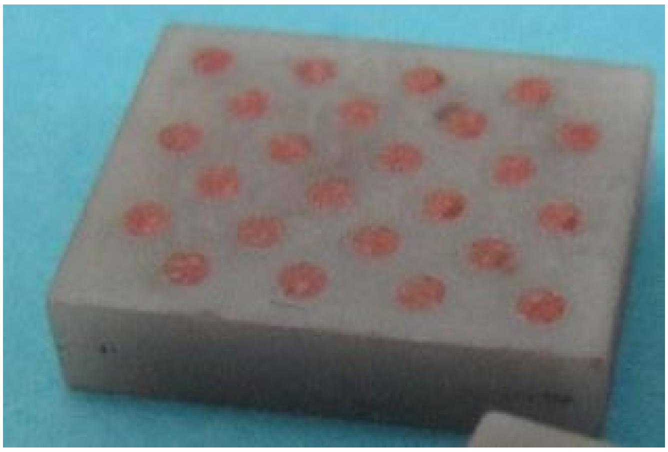

Figure 3: Ceramics with Vias and filled with copper, top and bottom not metalized so that Vias are visible

Figure 4: Cuboid sintered on top heat sink

The resulting cuboid should now be optimally electrically and thermally bonded to the circuit board. An initial, possible approach for the top might be to solder it to the conductor tracks on the top heat-sink. However, this would be counterproductive if the aim were to create a

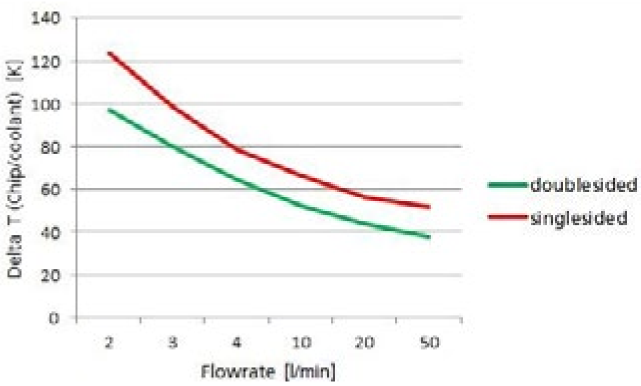

Figure 5: Comparison between single and double sided cooling

second cooling channel with the lowest possible thermal resistance. Common SAC solders are relatively poor heat conductors. This would result in additional thermal resistance, which would be far from negligible in the context of the system as a whole.

This problem is solved by the use of the metal pastes. They can be joined prior to sintering using a "wet-on-wet" technique. Resultant, a monolithic metallic body is created during sintering. This is why an aluminum nitride heat-sink printed with 300 µm of conductive copper paste was used for the top circuit board. The process is similar to the conventional thick layer technology, the only difference being that the metal paste (in this case copper) is applied in a much thicker layer in order to ensure high electrical conductivity. Then the heat-dissipating cuboid is placed onto the copper on this top heat-sink and they are sintered together.

This results in an object with both a high thermal and electrical conductivity.

Initial analyses indicate that this second cooling path improves the overall R_{th} by around 35%.

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Roland Dilsch,

Application Engineer,

CeramTec GmbH

r.dilsch@ceramtec.de

Tel +49 (0) 9231 69-643

Compensation-Free Voltage Regulators:

The continuing evolution of digital compensation

By Bruce Rose, Principal Applications Engineer, CUI Inc

FEEDBACK AND COMPENSATION OF VOLTAGE REGULATORS

Traditional power supplies and voltage regulators are able to produce stable output voltages due to the incorporation of control loops with negative feedback. A major challenge to properly implement negative feedback is to provide the correct frequency compensation associated with the feedback network. Initial implementations of voltage regulators employed analog circuitry for the control and feedback circuits. Later improvements in technology have allowed digital circuits to replace almost all of the analog functions in voltage regulators and power supplies. The incorporation of digital circuits has allowed the development of automatic compensation algorithms to ease the burden on the power design engineer. Auto-compensation is a great improvement over traditional topologies but still has some limitations due to the requirements of the circuits to determine the compensation parameters. Recent developments in digital voltage regulator controllers have created "compensation-free" topologies. These compensation-free designs provide superior voltage regulation while eliminating the issues associated with determining compensation parameters.

ANALOG VOLTAGE REGULATORS

Analog voltage regulators require the design engineer to determine the values for compensation resistors and capacitors and then to solder these components onto the PCB. The selection, placement and modification of the discrete compensation components adds delays and risks to power delivery designs. Some vendors simplify the compensation component selection process by allowing the user to select a single resistor and a single capacitor to compensate the regulator. While this option simplifies the user tasks, it reduces the probability that the resulting load current transient behavior of the power supply is acceptable. The design and implementation of analog voltage regulators is a manually-intensive process and thus carries undesirable risks and costs.

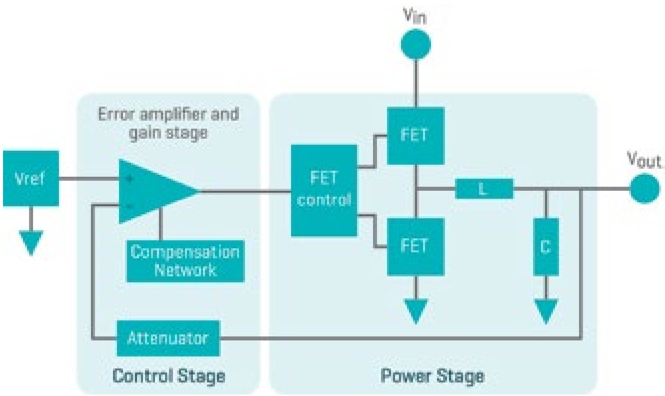


Figure 1: Analog Switching Voltage Regulator

ANALOG VOLTAGE REGULATORS WITH DIGITAL WRAPPERS

When an IC vendor adds a digital wrapper to an analog voltage regulator there are benefits in the ability to configure, control and monitor some of the characteristics of the power supply. Selecting analog voltage regulators with digital wrappers improves upon the challenges and delays in designing with a traditional analog voltage regulator, but the risks and costs associated with the compensation components still exist.

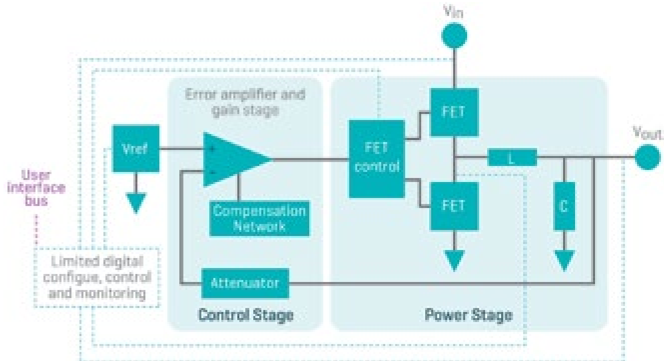


Figure 2: Analog Switching Voltage Regulator with 'Digital Wrapper'

DIGITAL VOLTAGE REGULATORS

A digital voltage regulator topology can allow the user complete configurability, controllability and monitoring capability of the power supply via a software interface. Many digital voltage regulators are designed in a manner that allows the user to select proportional, integral and derivative (PID) tap coefficients rather than physical compensation components to provide compensation for the voltage regulator feedback loop. With these topologies, the risks and delays of soldering (and unsoldering and then re-soldering) discrete compensation resistors and capacitors are eliminated since the PID coefficients are entered and altered as software functions. The software compensation techniques reduce many of the delays and risks associated with soldering components but the design engineer still needs to have extensive knowledge of compensation theory in order to produce an optimized design.

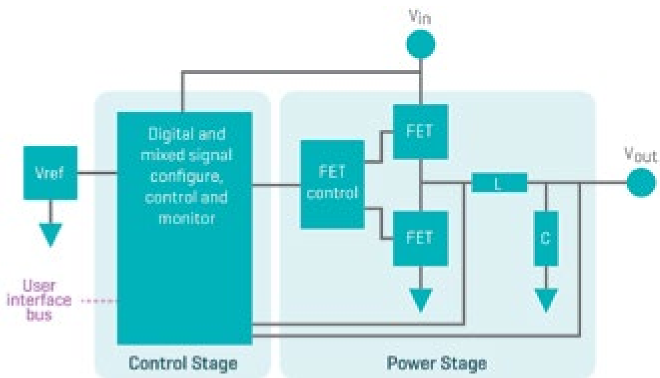


Figure 3: Digital Switching Voltage Regulator

DIGITAL VOLTAGE REGULATORS WITH AUTOMATIC COMPENSATION

Recent advances in digital voltage regulators include the incorporation of an automatic compensation topology that eliminates the need for the user to have knowledge and experience in compensation techniques. These regulators are able to determine the optimum compensation (values for Kp, Ki and Kd) for the circuit when power is applied to the regulator or at any other time that a software command is sent to the unit to re-calculate the compensation. Automatic compensation eliminates the costs, risks and delays associated with topologies that require a design engineer to determine the compensation values.

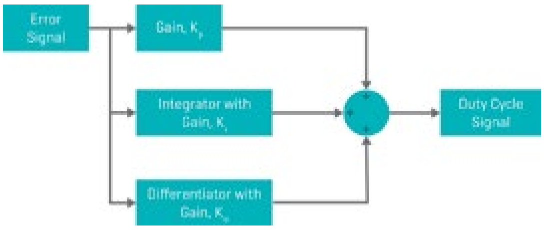


Figure 4: Digital PID Compensator

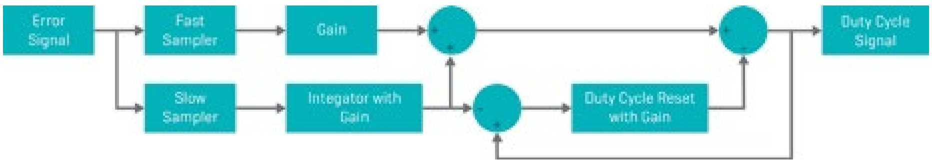


Figure 5: Compensation-Free Digital Compensator

COMPENSATION EVOLVES AGAIN WITH COMPENSATION-FREE DESIGNS

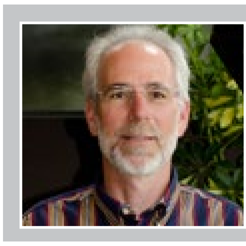
A superior digital voltage regulator topology to those that provide automatic compensation is one that requires no compensation at all. CUI offers families of digital point-of-load (POL) modules which are based upon the compensation-free technology; the NDM3Z-90 POL modules are the latest example. These modules determine the load current transient response by monitoring and adjusting the charge delivered to the load on a cycle-by-cycle basis. This technique allows the voltage regulator to optimize the load transient response each switching cycle of the regulator without the use of feedback loop compensation. The compensation-free topology is a superior technology due to the low latency involved in the load transient response. Low latency is achieved by the implementation of a faster signal path in the compensator in addition to the traditional slower signal path. The cycle-by-cycle charge delivery architecture also incorporates non-linear transient response characteristics to provide superior output voltage regulation of the POL modules as compared to what could be achieved with more conventional feedback loop compensation. One benefit of low latency and non-linear transient response techniques is the reduction in output decoupling capacitors required. Decoupling capacitors provide transient control at frequencies above those to which the voltage regulator can respond. The low latency and non-linear transient response of the no compensation architecture extend the effective frequency range of the voltage regulator and thus minimize the number, area and cost of the decoupling capacitors required to achieve the desired transient response of the digital POL module.

SUPERIOR POWER DELIVERY SOLUTIONS WITHOUT POWER SUPPLY EXPERTISE

Compensation techniques have come a long way since the days of the manual "trial and error" methods employed in purely analog designs. The complexities of powering today's advanced semiconductors coupled with increasingly short design cycles has driven an evolution in compensation methods. The latest compensation technology employed in many CUI digital power modules, coupled with an easy-to-use Graphical User Interface also supplied by CUI, now allows for rapid design cycles without the need for advanced power supply knowledge.

For more information regarding CUI's compensation-free POL modules, please visit:

www.cui.com



Bruce Rose
Principal Applications Engineer
CUI Inc

A New Commercial High Temperature Capacitor Dielectric for Power Applications

Teonex® HV is a new dielectric predestined for DC link and snubber power capacitors operating at high temperatures with highest energy densities.

By Lucien Schosseler, DuPont Teijin Films, Luxembourg

Power electronic applications more and more demand miniaturization, reliability and efficiency improvements and therefore operation at increased power densities. As a consequence, high temperature requirements are set on the different elements of the power conversion inverter modules such as passive components, more precisely DC-link and snubber film capacitors. Si and SiC based semiconductor switches operation temperatures are increased in the range of 175 °C and above and film DC-link and snubber capacitors are required to function at temperatures above 105 °C [1,2,3,4].

Common film dielectric used in power capacitors is based on the Polypropylene (BOPP Biaxial Oriented Polypropylene) technology. This material is known as a reliable reference solution for power capacitors as it operates at high specific voltage in the range of 150 to 200 V/µm in the capacitors [5]. Drawback of BOPP film technology is the limited temperature range up to 115 °C continuous operation [9], as a result of the polymer's low melting temperature (at 165 °C).

Polyester film technology, based on PET (Polyethylene Terephthalate) and PEN (Polyethylene Naphthalate), operates at 125 °C resp. at 150 °C but is limited to low specific operating voltage in the capacitors [5] and therefore has only limited access to power applications as the capacitors will not cope with the power electronics trend of miniaturization.

Other high temperature film options, operating continuously above 125 °C, such as PPS or PI, suffer from low voltage strength and poor self-healing capability which rules them out from power applications. Indeed the aromatic structures giving the high temperature capabilities of the polymers are responsible for the limited intrinsic electrical strengths [6].

DuPont Teijin Films has overcome these physical limitations with the development of the film dielectric Teonex® HV combining the high temperature capability of polyester PEN with excellent electrical breakdown strength performance.

Properties of Teonex® HV

Teonex® HV is a high temperature material with a melting temperature Tm at 265 °C and a glass transition Tg at 145 °C making an continuous operation in a temperature range up to 175 °C possible.

The electrical breakdown strength of the Teonex® HV film is comparable to BOPP and function of the film thickness: a voltage strength on film sheet over 500 V/µm at room temperature is achieved as indicated in figure 1. Electrical performance is improved relative to polyester films (PEN,PET) and far superior (2.0 x) than other high temperature materials such as PPS,PEEK and PI.

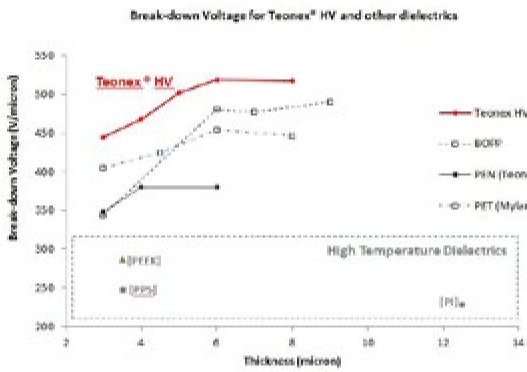


Figure 1: Electrical breakdown strength of Teonex® HV compared to BOPP and other dielectrics [13]

Teonex® HV break-down strength shows on film sample, as presented in figure 2, a voltage derating of 12% at 125 °C and 19 % at 150 °C .

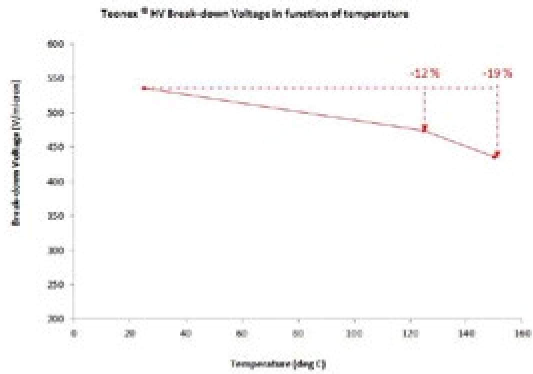


Figure 2: Electrical breakdown strength of Teonex® HV in function of temperature as per method [14].

The dielectric constant is 3.05 at 25 °C and increases to 3.73 at 175 °C. The permittivity increases with temperature showing an improved charge storage capacity with temperature (figure 3).

The film dissipation factor is stable up to 125 °C and inferior to 0.45% and less than 1.0 % for 150 °C (for frequencies ranging from 1-10 kHz). The total dissipation factor of the capacitor is the result of the dissipation of the leakage current in the dielectric film and the current flow through the contacts and the metal electrode. In the DC link capacitor, to assure the dielectrics optimum self-healing, high resistivity metal electrodes are of common use and the resistance of the metal electrode becomes then the predominant factor in the total equivalent serial resistance (ESR) and the dissipation factor of the capacitor.

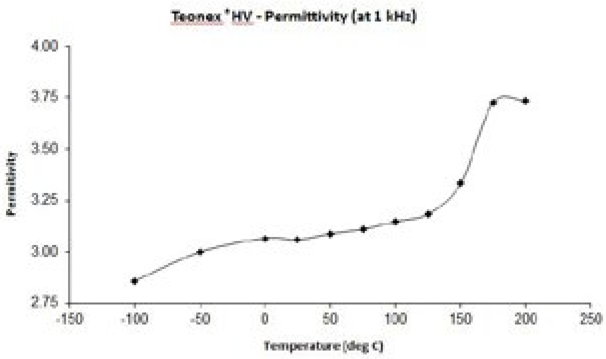


Figure 3: Permittivity at 1 kHz of Teonex® HV.

The Teonex® HV film has an outstanding energy density, outcome of the material's dielectric constant and the high electrical voltage strength in the capacitor. Especially above 105 °C operation, Teonex® HV shows the highest energy storage density of all dielectric materials (fig.4).

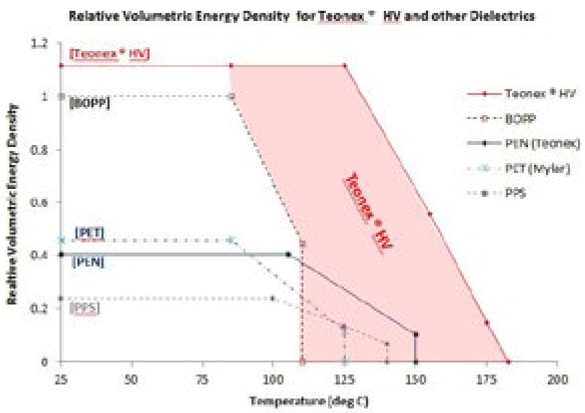


Figure 4, Theoretical Energy density of Teonex® HV compared to other common dielectrics.

In power capacitors, the dielectric's ability to self-heal is of key importance for safe capacitor operation and end of life behaviour of the passive component [8]. In case of an electrical breakdown related to a weakness in the metalized film, the discharge energy evaporates the polymer and metal electrode and creates a hole in the polymeric film surrounded by a de-metallized area and so the defect is insulated.

To assure the optimum self-healing capability, the dielectric must operate in real condition below a certain interlayer pressure limit or with an equivalent minimum air layer. Above this threshold, the film loses its self-healing function: the dielectric is damaged and the clearing energies are too low to adequately evaporate the dielectric and the adjacent metal electrode and consequently result in the capacitor short circuit [7].

Manufacturing of Teonex® HV capacitor requires soft winding and flattening process to reduce the processing interlayer pressures and to withstand the electrostatic pressure component resulting from operation at nominal voltage. Support by modelling, the impact of the winding and flattening conditioning on the capacitors electrical performance, is given on request for the Teonex® HV dielectric film.

In the optimum scenario, the dielectric Teonex® HV can operate at specific voltage up to 150 V/µm at 125 °C, pending on employed metallization and manufacturing technology; above this temperature a derating should be applied.

The film can be used with state-of-art, Zn or Al or Zn/Al metallization (as known from BOPP capacitor) in wound or stacked power capacitor technology as well as in film foil or impregnated capacitor device.

The film is commercially available in 3,4,5,6 and 8 µm and so a large voltage range from 350 to 1000 V can be covered with single metallization pattern or above (> 1kV) with serial pattern metallization or serial/parallel capacitor design.

Applications

Power converter or inverter use in their intermediate circuit DC link capacitors for ripple filtration and electrical energy storage and delivery [5,8,11].

Inverters are used in automotive (EV/HEV/PHEV), renewable energies (solar and wind), industrial applications (drives, building facilities …), traction as well as energy conversion (HVDC). Use of high temperature capacitor in these inverters will improve their reliability, reduce their cost and size by cooling arrangement simplification and improve their maintenance [8, 9].

The introduction of high frequency switching device such as GaN/SiC in inverter technologies will further reduce the size of DC link capacitors and consequently result in larger power densities and therefore temperature constraints on the passive components [12].

Summary

Modern power electronics trends toward compact, reliable and power efficient designs and will require new advanced high temperature DC-link capacitor and snubber technologies.

Today's major dielectric film technology, based on Polypropylene and Polyesters can only insufficiently satisfy these needs: BOPP operates at high voltage strength and low temperatures while PET is only adequate for low voltage and medium temperature utilization.

The new commercialized DuPont Teijin's Film's dielectric technology Teonex® HV is a possible answer to the future specifications of inverter module requirements.

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Full Bridge PWM Gate-Driver Motor Control ICs

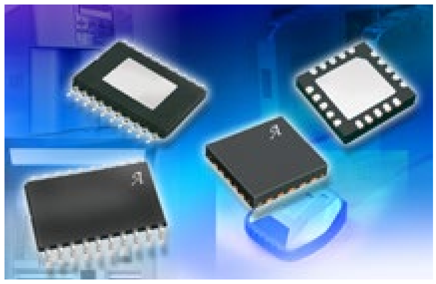
Allegro MicroSystems Europe has introduced a new family of full bridge gate-driver ICs designed to drive a wide range of DC brushed motors with simple logic from a microprocessor.

The new A4955/56 and A5957 devices can support motor supply voltages up to 50 V and load currents of up to 20 A. These devices are targeted for both the industrial and consumer markets in applications such as robotic vacuum cleaners, vending machines, cash dispensing machines, coffee vending machines, ticketing machines, automatic gates and turnstiles, and sewing machines.

Flexible interface options are offered in three individual products, making the devices easy to fit into customers' existing designs with little or no firmware changes.

The A4955 offers parallel control inputs which drive the bridge in forward, reverse, brake, and standby modes; the A4956 offers phase, enable and mode inputs which drive the bridge in forward, reverse, brake and fast decay modes; while the A5957 offers phase, enable, and 'sleep' inputs which drive the bridge in forward or reverse modes with slow decay synchronous rectification.

Unique features of the A4955/56 and A5957 include an analogue output function which



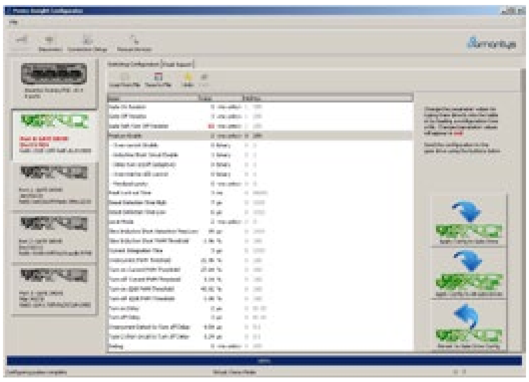
can be used to monitor current through an external sense resistor (if used). A sample-and-hold circuit is used to capture the peak voltage across the sense resistor and hold it during the 'off' time until the next PWM cycle begins. The voltage is amplified by a factor of ten and fed to the analogue output terminal, providing the user with the ability to accurately estimate the current in the load in real time.

Another unique feature is the programmable gate drive. An external resistor sets the magnitude of the current into the gates of the external FET bridge, allowing the user to control the slew rate of the driver to help achieve electromagnetic compliance.

www.allegromicro.com

Launching a Power Insight Configurator

Amantys Power Electronics Limited, has announced the launch of the Power Insight Configurator a Windows PC software tool that enables the design engineer to quickly and easily configure Amantys gate drivers to speed up the process of design and commissioning new converter power stacks.



The Power Insight Configurator complements the Power Insight Adapter, an interface box that provides a physical interface to the gate drive.

Typically the converter power stack designer has needed to disassemble the converter power stack to desolder and replace gate resistors onto the gate drives to manage the rise and fall times of the IGBT, which can be a timely, laborious and error prone process. With the introduction of the Power Insight Configurator the time to make these changes can be reduced from hours to seconds. The need for a separate signal generator with optical output can also be avoided, as the Power Insight Configurator uses the Power Insight Adapter to generate double pulse waveforms simplifying the process of testing the converter power stack.

r Insight Configurator can also download diagnostic data from Amantys gate drivers in order to monitor the occurrence of events such as short circuits, clamps and under-voltage during the long term operation of the gate driver in the field.

The Power Insight Configurator will be included with the purchase of the Power Insight Adapter available from Amantys Power Electronics Ltd., and approved distributors.

www.amantys.com

2 kW HotSwap Ac-Dc Supply Delivers a High Dc Output from 100~410 V

CUI Inc announced the addition of a 2000 W front-end ac-dc power supply to its power supply portfolio. The PFR-2100 series is a blind-mate rectifier with a programmable output voltage range of 100~410 Vdc. Key features include a hotswap blind-docking capability implemented through the use of a single connector that integrates ac, dc and I/O signals. The PFR-2100 delivers high efficiency up to 93% in a package measuring 11.5 x 5.2 x 2.5 inches (292.1 x 132.08 x 63.5 mm). The series is ideally suited for use in data center high voltage dc bus power systems, broadcast amplifiers, and EV battery charging systems.

The programmable dc output voltage delivers a constant current up to 5.125 A with droop current sharing for paralleling up to 12 units. Additional features include power factor correction, remote on/off control, power good signal and front panel LED indicators. The PFR2100 series complies with all applicable EMC requirements to accommodate worldwide applications and offers 60950-1 safety approvals. Protections for over-voltage, over-current and over-temperature are also provided. Samples of the PFR-2100 are available immediately; please contact CUI for more information.

www.cui.com

First Development Kit for integrated 2D Projected Capacitive Touch and 3D Gestures on Displays

Microchip announces the industry's first development kit for integrated 2D projective-capacitive touch (PCAP) and 3D gesture recognition on displays: 2D/3D Touch and Gesture Development Kit (DV102014). The kit will provide designers with easy access to Microchip's patented 2D and 3D GestIC® sensing technology, allowing them to easily integrate 2D multi-touch and 3D hand gesture recognition into their display applications. The use of electric-field based technology now enables hand and finger gestures to be tracked both on the display surface as well as above at a distance of up to 20 cm. In addition, the development kit provides an easy-to-use, 'out-of-the-box' experience that requires no code development. Parameterisation, diagnostics and optional settings are done through Aurea 2.0, a free downloadable graphical user interface (GUI).

The 2D/3D Touch and Gesture Development Kit features Microchip's latest PCAP controller, the MTCH6303, with the MGC3130 3D gesture controller. It includes an eight-inch transparent touch sensor to enable rapid prototyping for widely available displays. The MTCH6303 provides multi-touch coordinates with a five-finger scan rate of 100 Hz. In addition, it has an integrated multi-finger surface gesture suite which makes it a good fit both for Operating System (OS) driven applications as well as embedded systems without an operating system.

The MGC3130 with Microchip's award-winning GestIC technology was the first electrical-field-based 3D gesture controller to offer low-power, precise, and robust hand position tracking at 200 Hz. In addition, GestIC technology uses advanced Hidden Markov Models to ensure that the recognition rate for 3D hand gestures is above 95%. Free-space hand gestures are universal, hygienic and easy to learn, making them ideal for display applications.

www.microchip.com/DV102014-022316b

Higher Temperature Rated MLCCs

Knowles brand, Dielectric Laboratories (DLI), has announced a number of specification extensions to their Ultra-low ESR and High Q MLC capacitors. In both cases DLI have taken the temperature performance to a higher level of 175oc giving engineers more scope in their designs.

These new improved TCC (temperature coefficient of capacitance) figures apply to DLI's highly successful UL ceramic dielectric capacitors in case size C07 (0711) and AH porcelain dielectric capacitors in case size C17 (1111) – both with SMD Compatibility. Applications range from Impedance Matching, Power Handling, DC Blocking, Bypass, Coupling, Tuning and Feedback in circuit designs covering Oscillators, Timing, Filters, RF Power Amplifiers and Delay Lines.

UL is an EIA Class I Stable TC, NP0, Ceramic dielectric, with Ultra Low ESR; High Q, and Low Noise. Parts can now be operated up to +175°C with TCC of 0 ± 60 ppm/ºC (limited to +125°C at 0 ± 30 ppm/°C). They find use in any application where heat generation or signal loss are concerns. They are considered High Voltage in that case size C07 and can be operated at up to 500Vdc over the capacitance range of 0.3pF to 47pF, extending to 100pF if de-rated to 200Vdc.

The AH EIA Class I Positive TC, P90 Porcelain dielectric now achieves the +175°C rating with a TCC of 0 ± 20 ppm/ºC. Applications are where High Q, coupled with Low ESR, is a priority. They have a dielectric constant that increases with temperature (90ppm/°C) giving Established Reliability; Low Noise and High Self-resonance. Useful for temperature compensation where other board components may be losing capacitance with temperature. Capacitance range starts at 0.3pF and climbs to 1000pF over the voltage range 50V, to a high working voltage of 1kV.

www.knowlescapacitors.com

IX2120B Drives Both High Side and Low Side IGBTs or MOSFETs

IXYS Integrated Circuits Division (ICD), Inc., a wholly owned subsidiary of IXYS Corporation (NASDAQ: IXYS), announced the immediate availability of the IX2120B 1200V Half Bridge Gate Driver IC. The IX2120B is a high voltage IC that can drive discrete power MOSFETs and IGBTs that operate up to 1200V. Both the high side and low side outputs feature integrated power DMOS transistors that are capable of sourcing and sinking 2A of gate drive current.

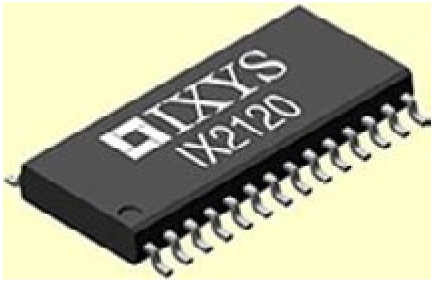
High voltage level-shift circuitry allows low voltage logic signals to drive IGBTs in a high side configuration operating up to 1200V. The IX2120B's 1400V absolute maximum rating provides additional margin for high voltage applications.

"This product complements the full selection of power driver ICs that we have developed and introduced to the power management market in the last 3 years. It is designed and produced in our internal wafer fabrication facility on the proven advanced SOI process," commented Dr. Nathan Zommer, CEO and CTO of IXYS Corporation.

With the IXYS power MOSFET and IGBT products, the ICD drivers offer IXYS' customers the whole system solution in a one-stop shop which includes the Zilog line of MCUs.

The IX2120B is manufactured on IXYS ICD's advanced HVIC Silicon on Insulator (SOI) process, making the IX2120B extremely robust and virtually immune to negative transients and high dV/dt noise.

The inputs are 3.3V and 5V logic compatible. Internal under voltage lockout circuitry for both the high side and low side outputs prevents the IX2120B from turning on the discrete power IGBTs until there is sufficient gate voltage. The output propagation delays are matched for use in high frequency applications.



The IX2120B can drive power discrete MOSFETs and IGBTs in half-bridge, full-bridge, and 3-phase configurations. Typical applications include motor drives, high voltage inverters, uninterrupted power supplies (UPS), and DC/DC converters. The IX2120B complements IXYS ICD's extensive portfolio of high voltage gate drivers, low side gate drivers, optically isolated gate drivers and the full range of IXYS power semiconductors.

www.ixys.com

Introduction of the LH3 Series of Film Capacitors

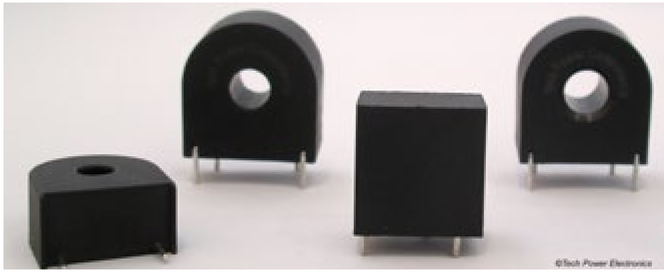
ECI continues to lead the industry with new capacitor products addressing the needs of power electronic designers. The new LH3 series provides the design engineer DC link building blocks enhancing the performance of industrial inverters. The LH3 employs Lo-Henry™ coaxial manufacturing technology, combined with innovative mechanical design techniques, to produce ultra-low ESL and ESR capacitors, providing exceptional power performance and robust construction. The high-strength thermoplastic housing has mechanical mountings integrated into the base. The compact terminal configuration allows reduction of buss bar width. ESL's below 10nH and ESR's typically in the micro-ohm range allow a wide operating bandwidth with elevated resonant frequency and exceptional power handling into the hundreds of amps RMS. Thermal coefficients of 1.6 – 2.2 ˚C/watt dissipated, minimize internal heating, and extend the life and reliability of the capacitors in demanding applications. Capacitors range from 1600 µF at 500 Vdc to 30 µF at 2400 Vdc, with an operating temperature range to 105 ˚C.

www.ecicaps.com

Extending the Range of Nanocrystalline Current Sense Transformers

Tech Power Electronics announces the release of three new nanocrystalline current sense transformers SCTN20, SCTN30, SCTN70. They are designed for power electronic applications which require a highly-accurate current measurement.

In comparison with other soft magnetic materials, nanocrystalline alloys is the best material to be used in toroidal core for current transformers, due to its high magnetic permeability and low core losses. Furthermore current sense transformers made with nanocrystalline



cores offer a reduced size and weight, as well as a larger operating temperature range from -40 to 125°C.

Its range of nanocrystalline current sense transformers is designed for a 50 – 400 Hz frequency range with a 0.2 or 0.5 accuracy class. They are available for rated currents 10A, 12A, 20A, 30A and 70A.

All models are RoHS and Reach compliant. They are housed in a plastic package using UL94 V-0 materials.

The new ranges and other Tech Power Electronic products including sample kits are available at wts // electronic, Germany.

www.wts-electronic.de

flowSPFC 0 – the Symmetric Three-Phase Power Factor Correction Module

Vincotech, a supplier of module-based solutions for power electronics, announced the release of the flowSPFC 0, a new symmetric PFC module aimed to help vendors step up efficiency, drive down costs and make the most of next-gen UPS. This ultra compact module packs a lot of power into a petit housing. With an efficiency rating ranging up to 99.2 %, impressive performance and a remarkably low price, the flowSPFC 0 line goes a long way towards cutting manufacturers' overall system costs.

These modules feature a unique symmetric PFC topology for three-phase applications that deliver 10 to 30 kW. Equipped with the latest high-speed, 650 V IGBT chip technologies, flowSPFC 0 modules can serve to attain switching frequencies up to 75 kHz. Integrated NTC thermistors for temperature monitoring and snubbing capacitors to improve EMC are built right into the housing.

The flowSPFC 0 modules come in compact, low-inductive flow 0 housings 12 mm in height. Press-fit pins as well as phase-change material are available on request. Both make assembly so much easier, and the phase-change material also improves thermal performance.

These modules will be manufactured in series as of early 2016.

www.vincotech.com/flowSPFC-0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Achieve Maximum Accuracy with Hioki's Own Diverse Selection of Current Sensors
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Shiping Industry's First USB-C Buck-Boost Battery Charger

Intersil Corporation introduced the industry's first buck-boost battery charger that supports two-way power delivery in ultrabooks, tablets and power banks using the reversible USB Type-C™ connector. The single-chip ISL9237 Narrow VDC (NVDC) battery charger replaces competitive buck and boost two-chip charger solutions, eliminating a charger IC and inductor to reduce customer bill of materials (BOM) costs by up to 40%. The ISL9237 leverages Intersil's patented R3™ modulation technology for acoustic noise-free operation, excellent light load efficiency and ultra-fast transient response to extend battery run-time.
The USB 3.1-compliant ISL9237 joins the emerging USB-C™ ecosystem as the first battery charger capable of providing buck-mode, buck-boost-mode, and boost-mode for 1-to-3 cell Li-ion batteries. It also supports USB On-The-Go (OTG) with a 5Vout reverse buck-mode, and reduces traditional two-stage charging to a single-stage buck-boost for improved efficiency. The USB Type-C interface connection enables delivery of data, video and power up to 100W over a single cable.
In charging mode, the ISL9237 takes input power from a wide range of DC power sources -- AC/DC charger adapters, USB power delivery (PD) ports and any travel adapter -- to charge battery packs with up to 3-series cell Li-ion batteries. The ISL9237 can also operate connected to only a battery, an adapter, or both. The ISL9237's system turbo-mode helps the battery and charger adapter work together to supply the system load when it exceeds the adapter's capability. In turbo-mode, the ISL9237 quickly turns on the battery BGATE FET to deliver system power. In addition, the ISL9237's wide 5V to 20V input voltage capability helps boost the USB-C ecosystem to support new power bank products. Watch a video on the ISL9237 solution.

www.intersil.com

T-Series Power Modules with 7th Generation IGBT

Mitsubishi Electric Corporation announced the introduction and commercialization of its new T-Series power semiconductor modules featuring 7th Generation insulated-gate bipolar transistors (IGBTs). The Mitsubishi Electric Standard-Type IGBTs for 650V, 1200V and 1700V have been developed for the purpose of highest power density inverters and best-in-class thermal behavior. The T-series Standard-Type is a beneficial combination of latest chip set with latest packing technologies in the well-known conventional half bridge package outline.
The most significant novel features consist of the 7th Generation CSTBT™ and diode chip set which provides high efficiency by reducing both dynamic and static losses and the innovative TMS packaging technology which realizes very low thermal impedance, low package inductance and high thermal cycling capability.
The newly introduced TMS (Thick-Metal-Substrate)-Technology is a packaging technology developed for realizing low inductance and very high thermal conductivity. Instead of the conventional package structure with multi substrate arrangements soldered to a copper baseplate, the Thick-Metal-Substrate contains one common substrate.

This expands the effective mounting area for chips and - by eliminating wire bond interconnections - the internal stray inductance and lead resistance are reduced. The main terminals are connected to the TMS by laminated internal bus bar with increased laminated area and ultrasonic bonding. This reduces the total package inductance by 30%. The TMS contains high thermal conductive silicon nitride ceramic with thick copper layers brazed directly to the top and bottom sides. The thick copper layer underneath the IGBT chip provides low lead resistance and thus allows a higher current density. At the same time, it enables a better heat spreading directly next to the chip. The Thick-Metal-Substrate technology removes the solder layer and increases the thermal cycle life. Finally the total thermal resistivity from junction to heatsink is reduced by more than half compared to other modules.

www.mitsubishichips.eu

8th-Generation IGBTs that Improve System Power Efficiency

Renesas Electronics the availability of six new products in the 8th-generation G8H Series of insulated gate bipolar transistor (IGBT) lineup that minimize conversion losses in power conditioners for solar power generation systems and reduce inverter applications in uninterruptable power supply (UPS) systems. Six new product versions, rated at 650 V/40 A, 50 A, and 75 A, and at 1,250 V/25 A, 40 A, and 75 A, are being released. Renesas has also achieved the industry's first TO-247 plus package for a 1,250V IGBT with built-in diode, which offers system manufacturers greater circuit configuration flexibility.

Drawing on its expertise in designing low-loss IGBTs in the power converter field, Renesas Electronics optimized the 8th-generation IGBTs, adopting an exclusive trench gate configuration (Note 1) in the process structure. Compared to previous IGBT generations, these devices provide faster switching performance, an essential feature to the IGBT performance index, while also reducing conduction loss by lowering the saturation voltage (Vce (sat), Note 2). Additionally, the performance index (Note 3) for the 8th-generation devices has been improved by up to 30 percent compared to previous 7th-generation IGBTs, contributing to lower power loss and better overall performance for user systems. These updates are essential for key markets in the power industry focusing on photovoltaic (PV) inverters, UPS, industrial motor drives and power factor correction (PFC).

In solar power generation systems, there is inevitably some amount of power loss when the direct current (DC) generated from sunlight by solar panels converts to alternating current (AC) by passing through an inverter circuit. Since the majority of this power loss occurs within the power devices used, reducing IGBT power loss has a direct positive effect on the power generation performance of user systems. Similarly, for UPS systems in server rooms and data centers, power must constantly pass through a power converter circuit to monitor if the power supply has been interrupted, meaning that a steady power loss arises whenever the system is operating. IGBT performance is key to reducing this power loss.

www.renesas.eu

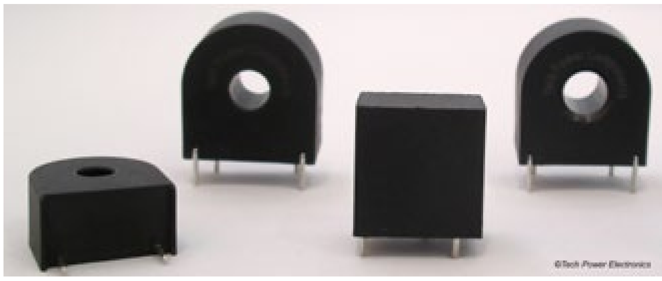
Extending the Range of Nanocrystalline Current Sense Transformers

Tech Power Electronics announces the release of three new nanocrystalline current sense transformers SCTN20, SCTN30, SCTN70. They are designed for power electronic applications which require a highly-accurate current measurement.

In comparison with other soft magnetic materials, nanocrystalline alloys is the best material to be used in toroidal core for current transformers, due to its high magnetic permeability and low core losses. Furthermore current sense transformers made with nanocrystalline cores offer a reduced size and weight, as well as a larger operating temperature range from -40 to 125°C.

Its range of nanocrystalline current sense transformers is designed for a 50 – 400 Hz frequency range with a 0.2 or 0.5 accuracy class. They are available for rated currents 10A, 12A, 20A, 30A and 70A.

All models are RoHS and Reach compliant. They are housed in a plastic package using UL94 V-0 materials.



The new ranges and other Tech Power Electronic products including sample kits are available at wts // electronic, Germany.

www.wts-electronic.de

Advertising Index

Where low losses make the difference

New 4.5 kV / 1200 A single switch module with 3rd generation IGBT technology

Benefits

- Fulfill demanding low loss application requirements
- Optimized semiconductor technology for VSC HVDC topologies
- Robust and reliable module design for applications in harsh environmental conditions

Main features

- Low conduction and switching losses
- High reliability and high power cycling capability based on robust IHV-B module construction
- High power density for compact converter design
- Reduced thermal impedance
- Package material with CTI > 600
- Operating temperature range T_{vjop}: -40°C up to +150°C
- Package compatible to 3.3kV IHV-B

www.infineon.com/IHVB-lowlosses