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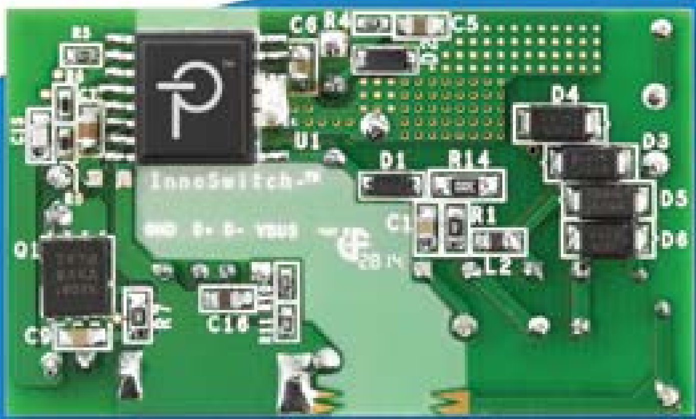
Bodo´s Power Systems®

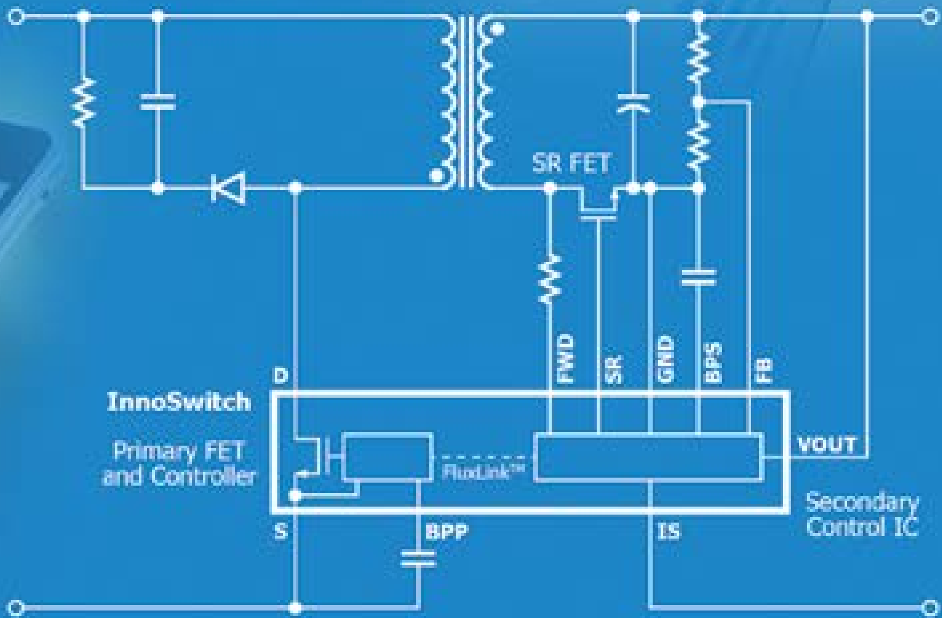
Electronics in Motion and Conversion

April 2015

Simplifying Synchronous Rectification in Flyback Power Supply Design

Page 22





Read online and search for key subjects from all articles in Bodo's Power Systems by going to Powerguru: www.powerguru.org

powerguru.org

CONTENT

The Gallery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Events

Biricha Analog and Digital PFC Workshop
with TI C2000 MCUs Garching April 2nd
www.biricha.com

SMT Hybrid 2015,
Nuremberg, Germany, May 5-7
http://www.mesago.de/en/SMT/home.htm

CWIEME Berlin 2015,
Berlin Germany, May 5-7
http://www.coilwindingexpo.com/berlin

Power Analysis & Design,
Eching/ Munich, Germany, May 6
http://www.omicron-lab.com/event

PCIM Europe 2015,
Nuremberg, Germany, May 19-21 http://www.mesago.de/en/PCIM/home.htm

Sunny Spring Time

It's so nice, after a long winter, to smell the fresh air warming up for spring. Thanks to the extra sunshine we'll also have more and more solar energy being generated. The world is slowly moving ahead with this safe source of energy. Some countries have had bad experiences with nuclear energy, and what's worse, some have simply renamed facilities which certainly doesn't make them any cleaner or safer. Reworking nuclear material doesn't eliminate nuclear rubbish. Have we already forgotten what happened at Fukushima just four years ago?

We can all be part of the movement to reduce consumption of electric power. Our planet is heating up and we have to acknowledge that global warming is the result our modern lifestyle. Air- conditioning is not a solution, it actually generates more heat. The engineer's task is to build systems that reduce power consumption and lengthen the product life cycle. Power electronics is the key element in improving automobile combustion, in helping efficiency in white goods for the household, and in reducing losses in the fast growing electronic communications market.

The internet is everywhere - whether it makes sense or not, people believe they need smart phones and ever more devices to be "connected." How will this affect human evolution? Will future generations have smaller brains and reduced IQ? Some statistics seem to indicate this. I sometimes have the impression that smart phones and tablets are becoming the remote control of humans. Will we soon link of our brains directly to the internet? Jules Verne's visions seem to be moving closer to reality.

Let's hope that in the future modern electronics attract young people to physics and mathematics, that they become scientists and engineers, and move smart and ethical technology forward. Conferences and expositions are great places for students to experience the exciting smell of things being created that will help to change the world for the positive.

The next great thing for power electronics will be the PCIM Europe, in Nuremberg, in May. I look forward to seeing you there at my traditional podium discussion at the Fach Forum, Hall 6, Booth 345, on Wednesday May 20th from 11:00 to 12:00. This year the headline is: "Reliable Volume Production of Wide Band Gap Semiconductors"

For several years now, articles in Bodo's Power Systems magazine have detailed the generational change we're experiencing from established silicon to GaN and SiC. Volume production with high yield is mandatory for success in applications. Are device producers ready, and how about the users?

Communication is the only way to progress. We have delivered four issues this year. My technical articles are archived on my website and also are retrievable at PowerGuru. 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.bodospowerchina.com.

My Green Power Tip for April:
Be suspicious of what people tell you on April 1st. Don't get trapped by an April Fool's Day prank!

Best Regards

4th Power Analysis & Design Symposium 2015

Take the chance to join Omnicron for a great day packed with lectures, practical examples and demonstrations by international power supply experts. On the evening prior the seminar you are invited to join our "Open Lab" after work measuring event. For sure, the participation in our seminar 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 participate, register for the seminar materials and we will send it to you a few days after the event.) Registration is open until April 24th, 2015
Open-Lab: Tuesday May 5th, 2015 from 16:00 to 19:00
Seminar: Wednesday May 6th, 2015 from 8:30 to 17:00
Location: Bürgerhaus Eching, Roßbergerstraße 6, 85386 Eching (near Munich), Germany

www.omicron-lab.com/event

Excelsys Awarded Engineers Ireland CPD Accreditation

Excelsys Technologies is pleased to announce that the company has been awarded the CPD (Continuing Professional Development) Accredited Employer standard by Engineers Ireland. Excelsys, a leading power supply manufacturer and designer of high efficiency, low profile power supplies for a variety of markets, recognizes the value of CPD as essential in achieving growth and success.
Commenting on the achievement, John Power, Chartered Engineer and Director General of Engineers Ireland said, "Investment in professional development is essential for engineering organizations to gain a competitive edge and achieve results on both a local and international level. Well done to all those at Excelsys who have dedicated time and resources into securing the CPD Accredited Employer status."
Speaking about the award, Gary Duffy, Excelsys CEO said, "We have an uncompromising commitment to maintaining technology leadership and ensuring employees are equipped with training in sustainability issues. Our employees play a vital role in the organization's success and it is important that they are fully involved in delivering the group's organizational vision and goals. The Engineers Ireland CPD framework provides support to assist us in achieving these goals. And we are proud to be accredited."
Excelsys Technologies is a world-class power supply manufacturer supplying best-in-class products to the world's leading OEM's. They are market leaders in high efficiency, high reliability, AC/DC power supplies serving medical, industrial and hi rel industry segments.

www.Excelsys.com

650V IGBTs with Highest Efficiency for Fast Switching in Electric and Hybrid Vehicles

Infineon Technologies AG has announced a family of robust 650V IGBTs that can deliver highest efficiency in fast switching automotive applications. The AEC-Q-qualified TRENCHSTOP™5 AUTO IGBTs will reduce power losses and improve reliability in electric vehicle (EV) and hybrid electric vehicle (HEV) applications such as on-board charging, power factor correction (PFC), DC/DC and DC/AC conversion.

The IGBTs have a blocking voltage 50V higher than previous automotive IGBTs and achieve their 'best-in-class' efficiency ratings due to Infineon's TRENCHSTOP 5 thin wafer technology. Compared with existing 'state-of-the-art' technologies, this technology reduces saturation voltage ($V_{CE(sat)}$) by 200mV, halves switching losses, and lowers gate charge by a factor of 2.5. Improved switching and conduction losses also support lower junction and case temperatures than alternative technologies, leading to enhanced device reliability and minimizing the need for cooling.
By using TRENCHSTOP 5 AUTO IGBTs, designers of electric vehicles will realize efficiency gains that enable extended cruising ranges or smaller battery sizes. In the case of HEVs, the efficiency improvements can be used to reduce overall fuel consumption and drive down CO_2 emissions. In addition, the performance of the TRENCHSTOP 5 AUTO devices allows also entering MOSFET dominated applications and offering designers a wider spectrum of suitable semiconductor base technologies.
Featuring current ratings of 40A or 50A, TRENCHSTOP 5 AUTO IGBTs are available as single discrete IGBT device or co-packaged with an Infineon ultra-fast "Rapid" silicon diode. In each case the two variants H5 HighSpeed and F5 HighSpeed FAST can be supplied depending on whether optimized switching speed or highest possible efficiency is the overriding design criteria.
Efficiency Gain Example
For a typical PFC used in on-board chargers the replacement of current 'state-of-the-art' technologies by TRENCHSTOP 5 AUTO IGBTs has been shown to deliver an efficiency increase from 97.5% to 97.9%. In the case of a 3.3kW charger this equates to a power loss reduction of 13W. Assuming a charging time of five hours, this would be equivalent to reducing CO_2 emissions by 30g in a single charging cycle.

www.infineon.com/discrete-automotive-igbt.

Mouser, Imahara Unveil Robotics "Empowering Innovation Challenge"

Mouser Electronics, Inc., the global authorized distributor with the newest semiconductors and electronic components, is partnering with celebrity engineer Grant Imahara to call on engineers of all levels to join them on a journey to Empower Innovation Together ™. Engineers worldwide can engage with Grant Imahara through a variety of topics and series of challenges that question and defy innovation in the pursuit of new ideas.

The exciting Empowering Innovation Together program consists of Innovation Spotlight™, Empowering Innovation Challenge™ and the Innovation Hub™. The Innovation Spotlight is a series of webisodes covering many topics, led by Grant Imahara as he visits with engineers who are at the forefront of new innovation and technology. The first webisode topic is about Robotics as Grant talks with professors and aspiring engineers at Carnegie Mellon University.

The Robotics Empowering Innovation Challenge is the first of a series of different challenges on a variety of engineering topics. The Robotics Challenge launches today and is co-sponsored by Platinum Program Partner Texas Instruments. Also joining in the Robotics Challenge sponsorship are Molex and Panasonic as Diamond-Level partners.

Mouser and Grant are asking the engineering community to submit a picture or video and share their robotic creations. It allows engineers worldwide to share and discover the newest and most innovative ideas. Additionally, the engineering community will help Grant decide who has the top engineering concept based on which ideas receive the most votes. Each challenge provides an opportunity for engineers to prove their genius and earn bragging rights, plus the chance to win some cool swag and prizes along the way.

www.mouser.com/empoweringinnovation

Silicon Carbide Semiconductors Distributed by Digikey

"We at Global Power Technologies Group are proud to have an exclusive franchise with Digikey for all of our products and customer needs world wide" said Michael DiGangi VP of Business Development at Global Power Technologies Group.

Global Power Technologies Group is a full service low cost Silicon Carbide Semiconductor manufacture for the commercial Power market. Products made by GPTG are 100MM and 150MM Epi wafers, SiC Discrete Diodes, SiC Discrete Mosfets, SiC Modules and Sub-Systems for multiple market sectors.

Global Power Technologies Group is a vertically integrated company. Under this structure, SiC technology is expected to be fully and economically deployed to meet the market pull by the industry segments which desperately seek power system efficiency improvements. Because of vertical integration GPTG cost for SiC products will reach Silicon price points in the next couple of years.

www.gptechgroup.com

Europe's Biggest Measurement Fair – Middle of May in Nuremberg

The 22nd international SENSOR+TEST trade fair will be held from the 19th to the 21st of May 2015 at the Nuremberg Exhibition Center. The SENSOR+TEST is a must-go venue for developers, engineers, and users from all industries as well as for engineering and science students. State-of-the-art sensor and measuring technology is crucial for the development and sustainability of devices, machines, systems, and processes. Moreover, without the latest testing technology, the ever-increasing demands on the reliability of products and processes could not be met.

There is no comparable platform in Europe where innovative users can meet so many innovative suppliers of sensor, measuring, and testing technology from all over the globe. The AMA Association for Sensors and Measurement backer and AMA Service organizer count with 550 exhibitors and approximately 8,000 visitors.

Focal Topic for 2015: Environmental Monitoring

Environmental protection in industry as well as in general is hardly possible without reliable measuring values. Whether we want to avoid health hazards, optimize industrial processes, or comply with new statutory requirements: Precise monitoring of ambient conditions is now a more important task for sensing, measuring, and testing technology than ever before.

This is why the Exhibitors Committee in cooperation with the Executive Committee of the AMA Association for Sensors and Measurement chose Environmental Monitoring as the Special Topic for the SENSOR+TEST 2015. The spotlight is to be on systems for measuring air quality. Visitors can get a concentrated overview of new relevant products and solutions at the Special Forum in Hall 12, Stand 12-485. Moreover, the Presentation Forum in Hall 12 is to be dedicated to "Environmental Monitoring" on Tuesday, 19 May 2015.

Product Overview of the SENSOR+TEST 2015

The following text is based on the preliminary information given by the exhibitors to AMA Service, the fair organizers, up to early February 2015. It comprises a preview of products, services, and trends presented at this year's SENSOR+TEST. The structure follows the trade fair's nomenclature.

http://www.sensor-test.de/press

Choose from the industry's widest, most comprehensive LDO portfolio

Features & Benefits:

- Robust power protection features for powertrain, HEV and passive safety
- High precision accuracy, low-noise and fast transients for advance driver assistance systems (ADAS)
- 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

Co-Chairs the 2015 iNEMI Solid State Illumination Industry Roadmap

Alpha, the world leader in the production of electronic soldering and bonding materials is proud to announce that the Alpha Energy Technologies team co-chaired the 2015 iNEMI Solid State Illumination Roadmap.

Gyan Dutt, Technical Marketing Manager for LED co-chaired the roadmap and Amit Patel, Project Management Engineer for LED, led the section on LED Materials.

The 2015 iNEMI Solid State Illumination Roadmap was developed to provide an overview of the most critical technologies driving the commercial launch and market diffusion of SSI products, addressing both LED and OLED based technologies. The iNEMI Roadmap has become recognized as an important tool for defining the "state of the art" in the electronics industry as well as identifying emerging and disruptive technologies. It also identifies gaps in technologies and infrastructure, and identifies industry level R&D priorities over the next 10 years.

The International Electronics Manufacturing Initiative (iNEMI) is a not-for-profit R&D consortium of approximately 100 leading electronics manufacturers and suppliers with cumulative member revenues exceeding $750 billion, associations, research institutes, government agencies and universities. iNEMI's mission is to forecast and accelerate improvements in the electronics manufacturing industry for a sustainable future. The iNEMI roadmap influences R&D investments and technology deployment as well as industry-level collaborative programs that iNEMI organizes. The 2015 Roadmap was developed by 19 Technology Working Groups (TWGs), in response to inputs from representatives of OEMs in 5 Product Emulator Groups (PEGs) covering the landscape of the electronics industry. More than 500 people from 280 organizations in 20 countries helped develop the 2015 Roadmap's 1900+ pages. The 2015 iNEMI Roadmap is available to iNEMI members now and will be available for purchase to non-members in April 2015.

www.inemi.org.

www.alpha.alent.com

CUI Announces Acquisition of Tectrol Inc.

CUI Inc and its parent company CUI Global, Inc. (NASDAQ:CUI), announced that they have entered into a definitive agreement under which CUI will acquire specific assets of the privately held Canadian equipment manufacturer Tectrol, Inc, a leading designer and manufacturer of standard and custom power solutions.

Tectrol is a family-owned, Toronto, Canada-based company that was founded in 1968. For over 40 years, the Company has consistently been one of the most flexible and most respected providers of power products with the unique ability to accommodate design challenges for low, medium and high volume applications. Its customer list includes some of the most iconic electronics, networking, medical and technology companies in the world.

The acquisition will greatly expand CUI's power product portfolio along with its engineering and manufacturing capabilities. Already a leader in the digital power space, the Tectrol line will add a standard portfolio of high-density, high-efficiency ac & dc power supplies ranging from 200 W to 3000 W along with modifiedstandard and custom capabilities. The acquisition will also significantly boost CUI's power design and manufacturing resources with the addition of Tectrol's advanced 74,000 sq. ft. Toronto, CA facility.

CUI's President, Matt McKenzie commented, "We believe this transaction is a step forward for our company as we look to deliver our customers the most advanced power solutions from the ac front-end all the way to the dc point of load. We are very excited about the synergies between the companies and are confident that the integration will immediately enhance the capabilities of our Power group."

www.cuiglobal.com

Eckard Wendt joins Alpha's Die Attach Sales Team for Europe

Alpha, the world leader in the production of electronic soldering materials, has announced the appointment of Eckard Wendt to the role of Die Attach Sales Manager for Central Europe.

In his new role, Eckard will continue to develop Alpha's expanding die attach related activity in Central Europe by developing strong relationships with key decision makers, with a particular focus on power semiconductor manufacturers. The main focus of this role will be to develop effective commercial strategies and provide key support for their valued clients.

Eckard comes to Alpha with over 18 years of power semiconductor manufacturing experience at IXYS and over 4 years of senior level management experience with Kulicke & Soffa. He holds a Masters Degree in Engineering from the University of Applied Sciences in Wedel, Germany.

Eckard's combination of technical and commercial experience will significantly strengthen Alpha's capabilities in the region and also provide tremendous value for their European client base.

www.alpha.alent.com.

Digital Point-of-Load Standard for High Current Released by Architects of Modern Power

Building on the four initial standards it published in November 2014, the Architects of Modern Power (AMP Group) consortium announced a further standard aimed at establishing common mechanical and electrical specifications for the development of advanced power conversion technology for distributed power systems. The 'teraAMP™' standard, designed for non-isolated digital point-of-load (POL) dc-dc converters, will extend the current range from 90 to 120 A while supporting both vertical and horizontal mechanical configurations.

The new 'teraAMP' standard adds to the previous 'microAMP™' and 'megaAMP™' standards for digital POLs that covered 20 to 25 A and 40 to 50 A designs respectively. All these allow for both horizontal and vertical configurations. The first products meeting this new 'teraAMP' standard are due to be introduced by AMP Group members at next month's APEC 2015 Applied Power Electronics Conference and Exposition (Charlotte, NC from March 15-19).

"The teraAMP standard is the next step in high density, high complexity power design support," commented Mark Adams, AMP Group spokesperson. "As chip architectures continue to reduce and on-board power requirements increase, it is imperative that the power industry keeps pace by providing high current density solutions at the point of load," Adams concluded.

The formation of the AMP Group, announced in October 2014, recognized a need for true multi-sourced but technically advanced and highly efficient power supplies for distributed power architectures. Initially this requirement was driven by telecom and datacom companies but is now proliferating into other industries. Previous attempts to standardize power supplies typically only addressed the mechanical aspects of their design, i.e. the physical dimensions and pin locations. What the AMP Group has done is to extend its standardization to embrace electrical specifications and performance, including the monitoring, control and communications functions made possible by the adoption of digital controllers. This allows AMP to define common configuration files to enable plug-and-play interoperability between products from its member firms, which currently comprise CUI, Ericsson Power Modules and Murata.

Alongside the digital POL standards, AMP has also defined two standards for advanced bus dc-dc converters: the 'ABC-ebAMP™' standard relates to advanced bus bricks measuring 58.42 x 22.66 mm and ranging from 264 to 300 W, while the 'ABC-qbAMP™' standard covers quarter-brick supplies, measuring 58.42 x 36.83 mm and ranging from 420 to 468 W. These standards detail mechanical footprints, features, and configuration files.

www.cui.com

www.murata.com

www.ericsson.com/ourportfolio/products/power-modules

Efficiency and Cost Savings Using Current Sensors

Energy efficiency and optimization are part of the biggest global challenges we face today and major companies are at the heart of this issue.

ABB has long been active in creating products and solutions with low environmental impact and searching for new ways to develop and improve available technologies, anticipating customer's needs.

ABB focused on a simple and efficient approach:

- Less materials = less energy for production and transportation
  ⇒ Integration and Downsizing are the first steps.

Downsize application

As for all systems designed by our customers, the trend of inverter is to be more compact and to lead more power. Concerning current sensors, integration and downsizing of systems mean usually a decrease of performances. As the voltage is based on standard values (E.g.: 690Vrms) the current is increasing and tends to lower sensor performances. The main perturbation parameters are : magnetic field due to busbars configuration, temperature and signal frequencies.

Core & Electronics robustness improvement

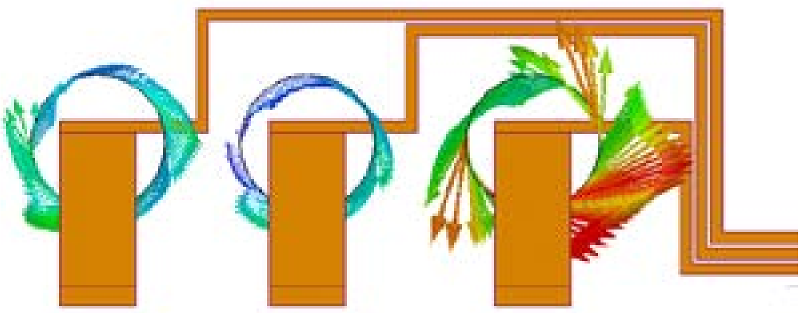
Today, ABB brings you the solution with an upgraded technology of its 1000A & 2000A sensors. Thanks to an optimization of the core and an electronic robustness upgrade these new current sensors reach a very good accuracy within a wide range of frequencies whatever the mounting conditions are.

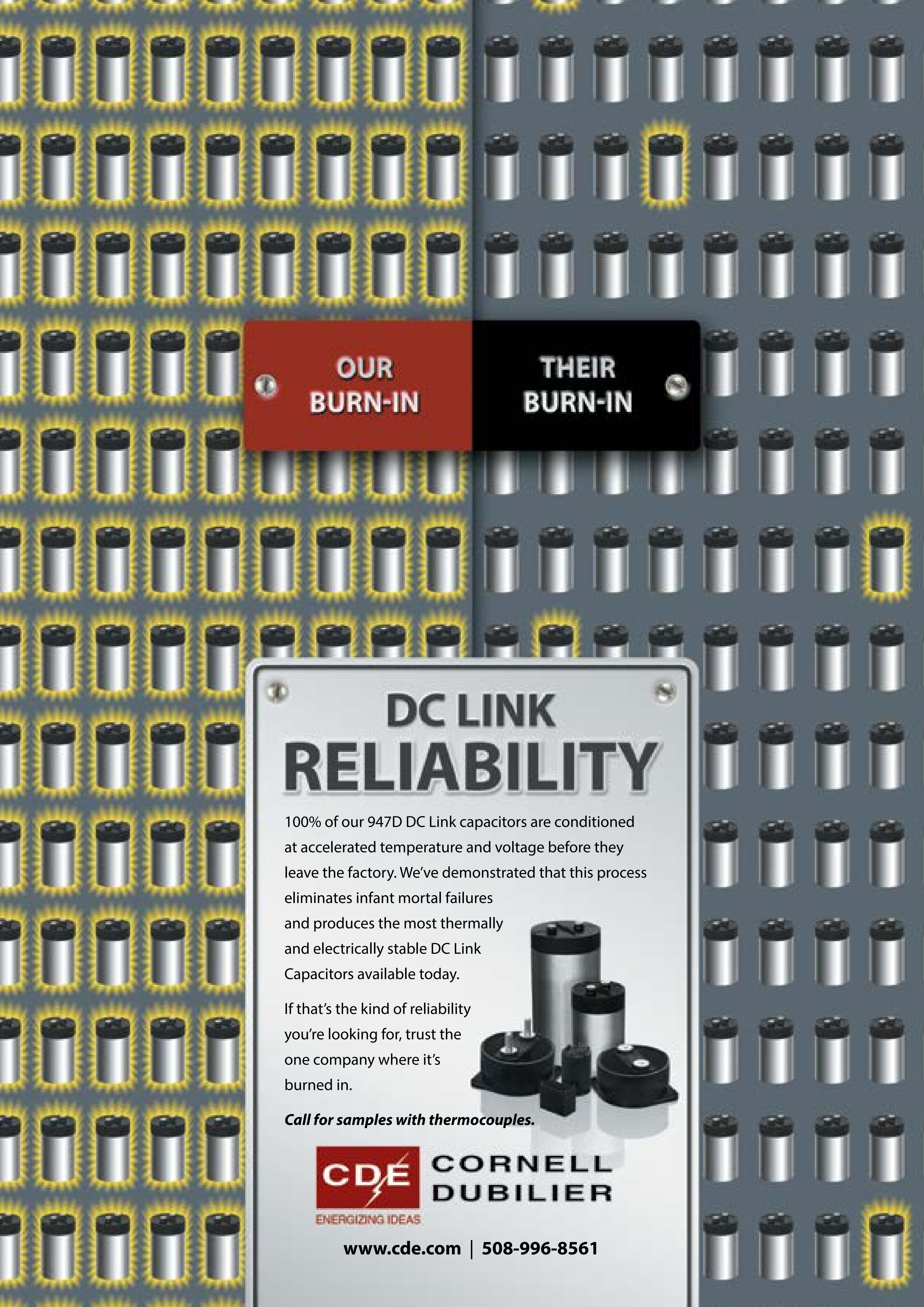
Reduce costs

Not only ABB took up this technical challenge but the solution developed allows our customers to lower their costs by allowing full integration and removing additional accessories previously necessary to reject perturbations and environmental constraints.

You have a dedicate application, we have a dedicated range.

www.abb.com/sensors




OUR BURN-IN
THEIR BURN-IN
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100% of our 947D DC Link capacitors are conditioned at accelerated temperature and voltage before they leave the factory. We've demonstrated that this process eliminates infant mortal failures and produces the most thermally and electrically stable DC Link Capacitors available today.
If that's the kind of reliability you're looking for, trust the one company where it's burned in.
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Battery-Less IoT Connectivity Possible with the Industry's First Multi-Standard Wireless Micro-controller Platform

Texas Instruments announced the new SimpleLink™ ultra-low power wireless microcontroller (MCU) platform that helps customers go battery-less with energy harvesting or enjoy always-on, coin cell-powered operation for multiple years. With this industry-first technology, customers have the flexibility to develop products that support multiple wireless connectivity standards using a single-chip and identical RF design. The SimpleLink ultra-low power platform supports Bluetooth® low energy, ZigBee®, 6LoWPAN, Sub-1 GHz, ZigBee RF4CE™ and proprietary modes up to 5Mbps. This platform expands TI's SimpleLink portfolio, the broadest, lowest power and easiest to use wireless connectivity offering in the industry for the Internet of Things (IoT). For more information, visit www.ti.com/simplelinkulp.

Extending TI's low-power MCU leadership, the SimpleLink ultra-low power platform is the most integrated with an ARM® Cortex®-M3 MCU, Flash/RAM, analog-to-digital converter, peripherals, sensor controller and built-in robust security on chip. The platform is also the easiest to design with through ready-to-use protocol stacks, TI RTOS, Code Composer Studio™ integrated development environment (IDE), development tools, online training and E2E™ community support. Minimal RF expertise is required with available reference designs, which simplify development and layout. Additionally, TI makes it easier for customers to connect to the cloud through the TI IoT cloud ecosystem.

The first members of the SimpleLink ultra-low power wireless MCU platform are the CC2640 for Bluetooth Smart, and the CC2630 for 6LoWPAN and ZigBee. For additional flexibility, customers can use the CC2650 wireless MCU supporting multiple 2.4 GHz technologies including Bluetooth Smart, 6LoWPAN, ZigBee and RF4CE. Leveraging this multi-standard support, customers can future-proof their designs and configure their chosen technology at the time of installation in the field. Additional members of the platform – the CC1310 for Sub-1 GHz operation and the CC2620 for ZigBee RF4CE – will be available later in 2015.

Designed for ultra-low power

The new ultra-low power platform is designed for low power operation, which includes a unique integrated sensor controller that interfaces external sensors autonomously while the rest of the device sleeps. The platform includes radio peak currents below 6.2mA and MCU active current of less than 61uA/MHz. The complete chip can stay in standby at only 1 uA with memory retention and RTC (real time clock) running. This enables the platform to offer half the power of other MCUs according to EEMBC's ULPBench™ with a score of 143.6. Read more about how battery-less operation is achieved in this blog post.

The SimpleLink Bluetooth Smart CC2640 wireless MCU

The CC2640 is designed for a broad range of Bluetooth Smart applications including health, fitness and medical wearables, mobile accessories, beacons, industrial automation and more with:

- Easy development with comprehensive design support: Complete robust, royalty-free software stack with over-the-air (OTA) update capability, wiki guides, reference designs, low-cost tools and software starting points
- Lowest power Flash-based Bluetooth 4.1 solution with multi-year operation on smaller coin cells
- Complete one-chip Bluetooth Smart system in a finger-tip, 4x4 mm size that integrates a Flash-based MCU, Bluetooth Smart radio

To get started, customers can purchase the next-generation Bluetooth Smart SensorTag (CC2650STK) or the CC2650DK development kit and download the latest BLE-Stack. For full information see the CC2640 product page and datasheet.

The SimpleLink 6LoWPAN and ZigBee CC2630 wireless MCU

The CC2630 is designed for 6LoWPAN or ZigBee technologies for applications in LED lighting control, home automation applications such as security systems, appliances, smart plugs and wireless sensor networks with:

- Ultra-low power operation on a coin cell battery to power a light switch for 10 years and enable battery-operated mesh networks or energy harvesting-based sensor nodes
- A versatile portfolio of IEEE 802.15.4-based networking solutions provides support for the largest networks connecting 1,000's of nodes in homes, buildings and cities
- Easy IP and cloud connectivity through 6LoWPAN operation where each device includes an IPv6 address

To get started, customers can purchase the CC2650DK. For ZigBee, developers can download the appropriate Z-Stack™. Additionally, the device is 6LoWPAN capable with the appropriate software. For full information see the CC2630 product page and datasheet.

Additional members of the SimpleLink family will include the Sub-1 GHz CC1310 wireless MCU for operation in 315 MHz, 433 MHz, 470 MHz, 868 MHz, 915 MHz and 920 MHz ISM bands and the ZigBee RF4CE CC2620 wireless MCU for advanced TV, set-top box and home entertainment remote controls.

www.ti.com/simplelink

Win a Microchip dsPIC33EV 5V CAN-LIN Starter Kit from Bodo’s Power!

The dsPIC33EV 5V CAN-LIN Starter Kit (DM330018) features the dsPIC33EV-256GM106 Digital Signal Controller (DSC) for automotive and motor control applications.

The Starter Kit contains serial data ports for CAN, LIN and SENT, a self-contained USB programming/debug interface, and an expansion footprint for flexibility in application hardware development. This board allows users to explore three popular automotive and industrial serial data formats (CAN, LIN and SENT). The PICkit On-Board (PKOB) USB programmer and debugger allows simple programming without the need for an additional hardware interface.

With 5V operation up to 150°C Microchip’s dsPIC33 “EV” Digital Signal Controllers (DSCs) provide harsh applications with robust performance as well as integrating peripherals for safety-critical functions, motor control, CAN, SENT and touch sensing.

The dsPIC33 “EV” family is the first to offer Error Correcting Code (ECC) Flash for increased reliability and safety. For safety-critical applications, Cyclic Redundancy Check (CRC), Deadman Timer (DMT), Windowed Watchdog Timer (WWDT) peripherals as well as a backup system oscillator and certified Class B software.

For the chance to win a dsPIC33EV 5V CAN-LIN, visit:

http://www.microchip-comps.com/bodo-dspic33ev-can-lin

Welcoming in a New Generation of Power Systems

By Girvan Patterson, President, GaN Systems

As Spring arrives in the Northern Hemisphere, nature's power of renewal and reinvention can be seen all around us and we humans look forward to the stimulus of the year's new challenges. In our industry, 2015 promises to be an exciting one as we welcome in a new generation of power systems driven by advances in power semiconductors.

Over the past eight years or so, there has been much talk of the need to replace silicon devices as they reach their performance limits and of possible technologies which might achieve the necessary leap forward. GaN and SiC emerged as contenders and both have been the subject of large amounts of investment, much inspired thinking and a great deal of developmental work by companies large and small around the world.

Silicon carbide (SiC) has better physical properties for power than silicon but is very costly and its properties are inferior to that of gallium nitride. GaN offers orders of magnitude improvement in switching and conduction performance – its unique material and electronic characteristics include high dielectric strength, high operating temperature, high current density, very high speed switching and low on-resistance. The excitement about GaN is its ability to achieve devices with power losses cut between 50% and 90%, system size and weight reductions of up to 75% and decreased BoM costs while dramatically increasing performance. GaN switches operate 100's of times faster than silicon switches; have lower resistance per area and forty times better overall performance.

For energy-hungry applications such as data centers, this step change in performance is long overdue. In order to keep up with the pace of processor innovation and the explosion of cloud computing demands, data center designers now need to put 1.5 times the power conversion into the same space and have run out of options to accomplish this. Similarly, major automotive manufacturers are challenging their designers to halve the size of their onboard vehicle chargers and dramatically increase power electronics efficiency to meet cost, range and performance roadmaps. The same size and efficiency demand is consistent across industries and GaN is seen as the only cost-effective solution capable of meeting these rising performance demands.

Of course, there have been challenges to overcome in terms of device design and packaging and achieving a commercial price point.

2014 was the year several major milestones were attained. Firstly, recognition that a step change was imminent and the broad acceptance of GaN wide bandgap semiconductors as the enabling technology to usher in the new age of power electronics. No less an entity than Google joined the IEEE Power Electronics Society and has put up a USD1M prize to the team that can shrink a power inverter from the size of a large picnic cooler to less than that of a laptop and achieve an output of at least 50kW per cubic inch. Wide bandgap semiconductors are suggested as a promising technology to

help achieve this and suppliers were invited to add a linked page for participants to contact to obtain parts.

The second milestone was commercial launch of devices onto the market. As one of the suppliers invited to supply a linked page for the Google/IEEE challenge, GaN Systems launched 650V and 100V parts in the first half of the year and had made sample parts available through global distributors by the end of the year.

So, what can be expected during 2015? Clearly, adopting new technologies is a learning curve and it is up to device manufacturers to ease the path of design engineers looking to build GaN high power switching devices into their latest designs. GaN Systems for example, has developed near chipscale, proprietary packaging, GaNPX™, which has no wire bonds, limiting inductance and eliminating a common reliability issue with semiconductor devices. The company's Drive Assist™ on chip drivers simplify circuit design and solve device driving issues at the same time as improving the switching speed and noise immunity.

Which products will be among the first to incorporate GaN transistors? Until recently, the perception has been that early adopters would include automotive manufacturers, (EV and hybrid vehicle power train drive electronics, EV and hybrid vehicle car chargers), manufacturers of solar and wind energy products, switching power supplies, and other large transportation and industrial products. However, one surprise, at least for GaN Systems, has been the interest from the consumer sector. On reflection this should not have been unexpected – NPD cycles are generally shorter in consumer electronics as companies strive to be first with the latest "must have" tech gadget and gain market advantage. Towards the end of 2015 we are very likely to be admiring a new generation of super-thin TVs and be able to order one in time for Christmas. The generational change from silicon to gallium nitride has arrived – as design engineers it is up to us to embrace it.

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Electronics Industry Digest

By Aubrey Dunford, Europartners

Gartner forecasts that about one in five vehicles on the road worldwide will have some form of wireless network connection enabling new in-vehicle services and automated driving capabilities by 2020, amounting to more than 250 million connected vehicles. The increased consumption and creation of digital content within the vehicle will drive the need for more sophisticated infotainment systems, creating opportunities for application processors, graphics accelerators, displays and human-machine interface technologies. Connected cars will form a major element of the Internet of things, and Gartner forecasts that 4.9 billion connected things will be in use in 2015, up 30 percent from 2014, and will reach 25 billion by 2020. Through 2018, there will be no dominant IoT ecosystem platform; IT leaders will still need to compose solutions from multiple providers.

SEMICONDUCTORS

The global semiconductor industry posted record sales totalling $ 335.8 billion in 2014, an increase of 9.9 percent from 2013, so the WSTS. Logic was the largest semiconductor category by sales, reaching $ 91.6 billion in 2014, a 6.6 percent increase compared to 2013. Memory ($ 79.2 billion) and micro-ICs ($ 62.1 billion) – a category that includes microprocessors – rounded out the top three segments in terms of sales revenue.

2014 has seen a major change in the automotive supply chain, so IHS. It has been a great year for Infineon, which enjoyed double digit revenue growth and a 9.8 percent market share. Infineon, which was lagging more than $ 500 M behind Renesas in 2013, has now taken the lead over Renesas, who had been leading the market for many years. IHS indicates this change is largely due to fluctuation rates between the Dollar and the Yen, but it does not take into account the acquisition of International Rectifier, which was still in process in 2014. Now that the acquisition is complete, Infineon will further increase its lead over Renesas.

Ixys, an international power semiconductor and IC company, has signed a definitive agreement to acquire RadioPulse. Based in Seoul, Korea, the fabless semiconductor company develops wireless network technology solutions based on the ZigBee protocol (which combines MCUs and RF). RadioPulse offers a complementary product portfolio to Ixys' MCU product lines, which include those of Zilog, a supplier of embedded system-on-chip (SoC) solutions and microcontroller units for the industrial and consumer markets.

PASSIVE COMPONENTS

TDK has combined its two European sales channels for Epcos and TDK products under the roof of TDK Europe. To this end, the relevant sales units at the Epcos Group have been carved out and integrated in TDK Europe. Despite this move, the Epcos Group, which was combined with TDK's components business in 2009, remains a distinct entity within the TDK. The sales activities of TDK Europe span both the entire spectrum of passive TDK and Epcos components, modules and systems and all the company's business with TDK magnets, wireless charging components and transparent conducting films. Power supply units will continue to be sold directly by TDK-Lambda. TDK Europe is headquartered in Munich, employs 380 people and operates an extensive sales network with 18 sales offices in Europe. TDK Europe will be headed by Rudolf Strasser and Philippe Rogeon – both seasoned professionals with many years' experience of selling TDK and Epcos products.

Cornell Dubilier has acquired the assets of Illinois Capacitor. The company sees this acquisition as a strategic move to grow its board-level power capacitor business. Illinois Capacitor supplies aluminum electrolytic, film, conductive polymer, and electric double layer capacitors. Cornell Dubilier's strength is in electrolytic, AC and DC film, and mica capacitors for power electronics. Illinois Capacitor traces its history back over 80 years, with Cornell Dubilier's roots extending over 105 years!

DISTRIBUTION

The European semiconductor distribution industry displayed unusual strength in low-season Q414 and ended 2014 at a healthy growth rate. According to DMASS (Distributors' and Manufacturers' Association of Semiconductor Specialists) semiconductor distribution sales in Q4/14 grew by 10.3 percent to € 1.57 billion. The full year closed with sales of € 6.34 billion, 7.7 percent up on 2013 and close to record 2011. The major regions in Q4 in detail: Germany grew 8.5 percent to € 474 M, Eastern Europe by 23.7 percent to € 192 M, Nordic by 6.8 percent to € 161 M, Italy by 6.7 percent to € 139 M, UK & Ireland by 12.3 percent to € 135 M and France by 6.5 percent to € 122 M. On an annualised basis, Germany remains the biggest market with over € 2 billion of sales, representing 32 percent of DMASS..

Arrow Electronics is initiating an all-cash tender offer to acquire the shares of Data Modul for a purchase price of € 27.50 per share. Headquartered in Munich, Germany, Data Modul was founded in 1972 as a distributor and manufacturer for flat panel displays and subsystems and has operations in Europe, Middle East, Asia, and North America. Sales in 2014 are estimated to be € 160 M. The purchase price assuming all shares are tendered would be approximately € 94 M.

GaN Systems, a developer of gallium nitride power switching semiconductors, has signed an exclusive distribution agreement with Ecomal Europe to promote and distribute its gallium nitride (GaN) high power switching transistors.

Mouser Electronics has expanded its global distribution agreement and partnership with Fairchild Semiconductor to include Xsens. An independent subsidiary of Fairchild, Xsens is recognized worldwide as an innovator in 3D motion tracking technology.

This is the comprehensive power related extract from the «Electronics Industry Digest», the successor of The Lennox Report. For a full subscription of the report contact:
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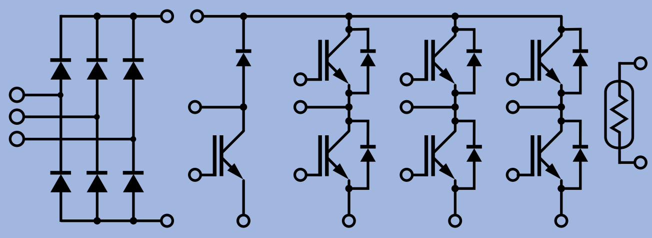
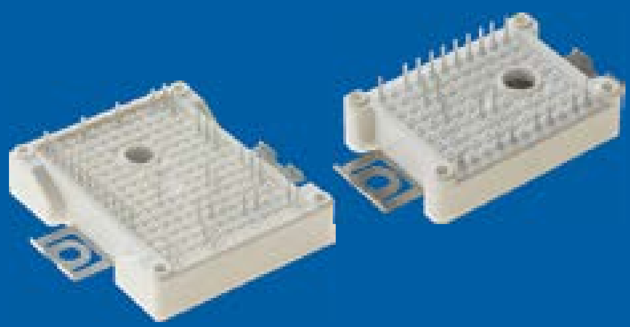
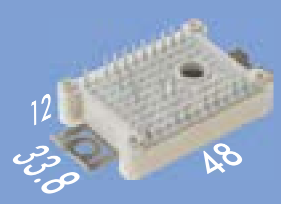
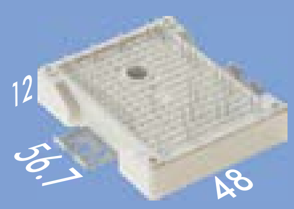
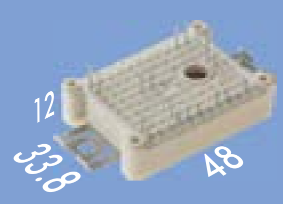
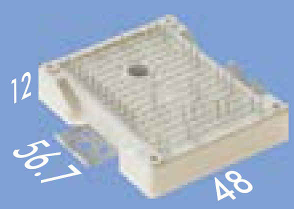




With Solder Pins

Package	I_C	600V	1200V
	10A	●	●
	15A	●	●
	20A	●	
	30A	●	
	15A		●
	25A		●
	35A		●
	50A	●	

With PressFit Contacts

Package	I_C	600V	1200V
	10A	●	●
	15A	●	●
	20A	●	
	30A	●	
	15A		●
	25A		●
	35A		●
	50A	●	

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Optimizing Control of Both the Synchronous Rectifier and Primary MOSFET in Flyback Power Supplies Improves Efficiency and Reliability

Overcomes the limitations of Schottky diode rectifier designs without the complexity of traditional synchronous rectifier implementations

By Silvestro Fimiani, Senior Product Manager, Power Integrations

Designers of flyback power supplies have generally used Schottky diode rectification in the output stage due to its simplicity and low cost. Diode-rectifier designs have proven adequate in meeting the efficiency demands of yesteryear, particularly for low current (0.5-1 A) outputs.

New market requirement

However, as regulators take aim at the operating efficiency of small power supplies used in stand-alone charger/adapters and as bias-supplies for high power applications, the impressive performance of synchronous rectification becomes very attractive. Smart phones with larger screens and much higher performance provide a great example of a device that requires an increase in power and a tightening of efficiency rules, while enjoying a phenomenal rise in popularity. Smart phone battery size has increased by more than 300 % from a typical capacity of 700-900 mAhr just a few years ago to around 3000 mAhr today. For phablets and tablets it is even higher, ranging from 6000 to 10,000 mAhr. This is driving an increase in the power supply rated current - up to 400% in some cases - from 5 watts USB (5 V, 1 A) for traditional adapters to 10-20 watts (5 V, 2-4 A) for rapid charging devices.

In addition to the higher power and current, new stringent efficiency regulations such as mandatory DOE-6 (Department of Energy - Level 6) in USA and CoC V5 Tier 2 regulation in Europe have now created a pressing need for much higher efficiency.

This combination of higher power requirement, higher performance and compact size with low external touch-temperature - while still meeting the new efficiency regulations - has challenged Schottky rectifier implementations in both performance and cost.

Schottky diode vs. SR (Synchronous Rectifier):

Schottky diodes typically have a forward voltage drop of 0.4 to 0.5 V which means that in a standard 5 V output just the Schottky diode alone can result in a power loss of up to 10 %.

Synchronous Rectification (SR) can be used to boost the efficiency and reduce the heat by eliminating the lossy Schottky diodes and replacing them with an actively controlled SR MOSFET. This is made possible by the very low resistance, $R_{DS(on)}$ of SR MOSFETs when conducting – down to below 10 mΩ. So the forward drop in a SR MOSFET can be just 20-40 mV for a 2-4 A output current. In high current applications, this represents a dramatic reduction in power loss from 10 % for a Schottky diode to less than 1 % for a SR FET – a 10-fold improvement. Therefore, a SR technique together with secondary side regulation control is suited to enable improvements in efficiency and thermal performance. However the complexity and cost of traditional SR has prevented its wider adoption, restricting it to complex and higher power designs.

Limitations of traditional Synchronous Rectifier (SR) alternatives:

The complexity of traditional SR architecture stems from the fact that the timing control in a traditional SR FET architecture is very difficult. When comparing non-synchronous and synchronous rectifiers, it is important to understand that the synchronous rectification MOSFET doesn't simply replace the traditional Schottky diode: complex control circuitry is also required to sense and then drive the MOSFET at the correct instant to allow current to flow only in the correct direction.

Any time that the primary side FET turns on before the secondary side FET has turned off, it will cause simultaneous conduction in both the secondary and primary circuit. This effective short-circuit across the primary transformer winding results in the dreaded "shoot-through" that will destroy the primary FET. On the other hand, once the primary FET turns off if there is a delay in turning on the secondary SR FET the result is a reduction in efficiency. So designers are faced with a difficult dilemma and a significant increase in design complexity is required to overcome these design challenges.

Traditional SR solutions deploy a separate secondary-side controller to drive the SR FET. This adds cost and complexity to the circuit, restricting its uptake due to the extra cost burden. Also, with two separate controllers these designs include a delay period, called "dead-time", providing margin and preventing switching overlap of the primary and secondary MOSFETs (shoot-through) that can result in highly destructive cross-conduction currents. The synchronous rectification MOSFET contains an integral, parasitic body diode that operates during this dead time. Unfortunately, this body diode is also lossy and slow to turn off, so it too can contribute a 1 % to 2 % drop in efficiency. To overcome this loss in efficiency a small Schottky diode, which conducts only during the dead time, can be placed in parallel with the synchronous rectification MOSFET, ensuring that the body

diode never conducts. The Schottky diode used in this way is smaller and cheaper than the part required for a diode rectification design because the average diode current is low, however an efficiency loss of >0.5 % can still be expected.

So although traditional synchronous rectification (SR) has some obvious advantages, it can be very difficult to implement because the timing of the MOSFETs turn-off signal is so critical. For optimum performance it is necessary to know exactly when the primary switch is on and off. Although the state of the MOSFET can be inferred from the secondary winding, this approach does not provide the accuracy required. If a conservative prediction is made efficiency suffers; if an overly-aggressive prediction is made, shoot-through can occur. This is challenging during normal operation but it becomes increasingly difficult to guarantee shoot-through doesn't occur under transient conditions such as output short- circuit, start-up, AC line drop outs and load steps.

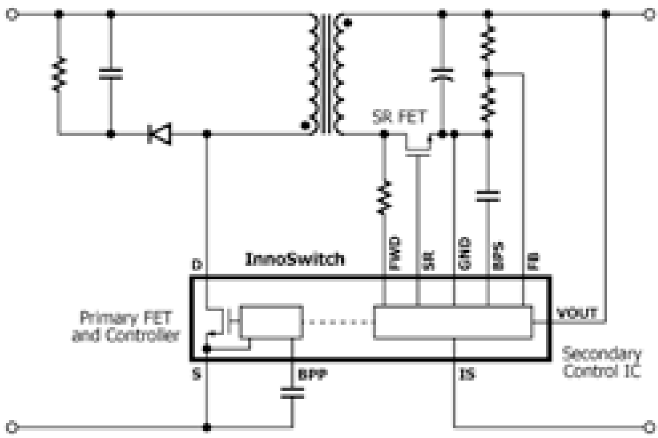

Figure 1: InnoSwitch – Single IC with integrated SR and feedback

An Innovative new approach:
But this is about to change with Power Integrations' new InnoSwitch™ family of ICs. For the first time, users have a shoot-through-proof design with the simplicity of a single integrated IC (Figure 1) that completely controls both the primary and secondary FET rather than two separate primary and secondary controller ICs with optocoupled SSR (secondary side regulation). This single IC also incorporates a very high bandwidth communication link between the primary and secondary controllers - called Fluxlink™. This high speed digital communication link is incorporated in the device package through a magnetic coupling but without any magnetic cores. The material used for the manufacture of the IC package remains the same. The

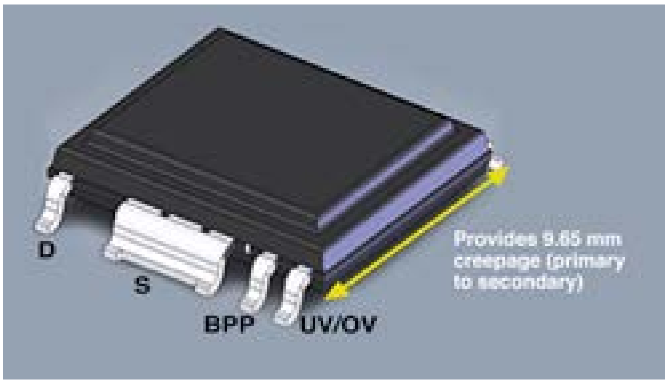

Figure 2: InnoSwitch ICs enable designs to meet all global safety standards

secondary controller acts as the master which initiates the switching process for both the secondary and primary MOSFETs, so no prediction or inference as to the state of the two MOSFETs is required. It is shoot-through-proof because the two MOSFETs are controlled deterministically and never turned on simultaneously. Using this innovative and near instantaneous communication afforded by FluxLink technology provides the secondary controller precise control of both primary MOSFET and the secondary SR MOSFET. The system achieves almost optimum turn-on and turn-off times across the entire load range, whether the power supply is operating in discontinuous mode, continuous mode, and even under fault conditions. Therefore, the power supply is intrinsically safe and it is always working at maximum efficiency.

InnoSwitch ICs also maintain full internal galvanic isolation and are safety approved to UL1577, TÜV60950. They also meet the CQC China 5,000 meter altitude requirement for creepage (see Figure 2). An external pin-to-pin creepage gap of over 9.65 mm is achieved using a custom surface-mount package that has been specially designed for this IC family (Figure 2).

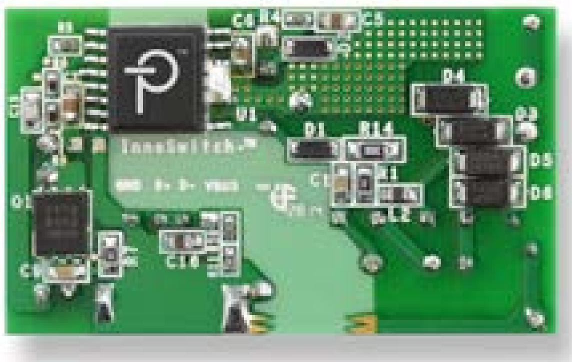

Figure 3: An InnoSwitch IC is placed across an isolation area

Being a recognized safety component the InnoSwitch ICs can be placed in the primary-to-secondary isolation barrier area on the PCB, so effectively the ICs take up no useable space at all (Figure 3). Also, the design allows for direct and simple resistor divider sensing of the power supply output voltage with excellent load transient performance and keeps the no-load power consumption below 10 mW. Direct sensing is significant as it reduces the physical volume of the output capacitors required, critical to fitting designs in ever shrinking enclosure sizes. The power supply output current measurement in an InnoSwitch IC is fully integrated inside the package, eliminating external current sense circuitry altogether. This results in higher power density, reliability and improved manufacturability.

Summary of InnoSwitch Benefits
1. High efficiency: Meets all global safety standards
2. High performance: Fast transient response with secondary side control
3. High reliability: Shoot-through-proof design
4. Very low No-load: Less than 10 mW
5. Low component count: Just 30 components for a 5 V, 2 A adapter design (Figure 4)
6. Improved manufacturability: Simpler and variation-tolerant transformer design
7. Elimination of SR FET parallel diode: Lower cost
8. No extra components required for high output voltages: Forward pin supports 12 V output

Table 1: InnoSwitch IC benefits

Now synchronous rectification can be used safely and reliably in higher power chargers, even those with adaptive voltage outputs such as Qualcomm's Quickcharge™ 2.0 and MediaTek™ PE+. The ability to deliver high currents at high efficiency also makes InnoSwitch an excellent fit for the newly announced USB-PD standard that requires support for 3 A and 5 A output load currents.

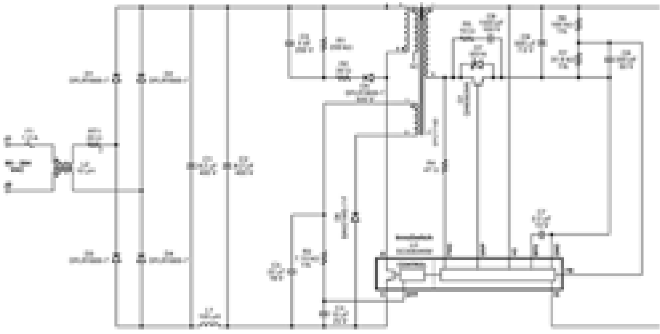

Figure 4: 5 V, 2 A adapter – just 30 components, see sidebar for full details

In summary, InnoSwitch ICs combine the benefit of an advanced Synchronous Rectification (SR) technique with secondary side control and communication link into a single IC to meet new market requirements for higher power, performance, density, reliability and efficiency (see Table 1). These benefits and, indeed, the use of InnoSwitch ICs are not limited to cell phone adapters. This new powerful architecture can also be used in any application that demands greater efficiency with higher secondary currents (>1.5 A).

www.power.com

Smart Mobile/USB Charger Design Eliminates Opto-Couplers & Meets Latest Efficiency Standards at the End of the Cable

RDK-420, a new reference design for a 5 V, 2 A CV/CC USB charger from Power Integrations, showcases the capability of the company's InnoSwitch™-CH family of highly integrated switcher ICs to facilitate the use of synchronous rectification techniques simply and cost-effectively, enabling safe, efficient isolated power supply design. The circuit schematic is shown in figure 4.

Primary

One side of the transformer primary is connected to the rectified DC bus, the other is connected to the integrated 650 V power MOSFET inside the InnoSwitch-CH IC (U1). A low cost RCD clamp formed by D1, R1, R14 and C1 limits the peak drain voltage due to the effects of transformer and output trace inductance. The IC is self-starting, using an internal high voltage current source to charge the BPP pin capacitor (C6) when AC is first applied.

During normal operation the primary side block is powered from an auxiliary winding on the transformer. The output of this is configured as a flyback winding, rectified and filtered (D2 and C5) and fed in the BPP pin via a current limiting resistor R4.

Output regulation is achieved using On/Off control, the number of enabled switching cycles are adjusted based on the output load. At high load most switching cycles are enabled, and at light load or no-load most cycled are disabled or skipped. Once a cycle is enabled, the power MOSFET remains on until the primary current ramps to the device current limit for the specific operating state.

Secondary

The secondary side of the InnoSwitch-CH provides output voltage sensing, output current sensing and drive to a synchronous rectifier MOSFET. The secondary of the transformer is rectified by Q1 and filtered by C10. High frequency ringing during switching transients that would otherwise create high voltage across Q1 and radiated EMI is reduced via snubber components R7 and C9.

The gate of Q1 is turned on based on the winding voltage sensed via R5 and the FWD pin of the IC. In continuous conduction mode operation the power MOSFET is turned off just prior to the secondary side commanding a new switching cycle from the primary. In discontinuous mode the MOSFET is turned off when the voltage drop across the MOSFET falls below a threshold. Secondary side control of the primary side MOSFET ensure that it is never on simultaneously with the synchronous rectification MOSFET.

The MOSFET drive signal is output on the SR/P pin.

The secondary side of the IC is self-powered from either the secondary winding forward voltage or the output voltage. During CV operation the output voltage powers the device, fed into the VO pin. During CC operation, when the output voltage falls the device will power itself from the secondary winding directly. During the on-time of the primary side MOSFET the forward voltage that appears across the secondary winding is used to charge the decoupling capacitor C7 via R5 and an internal regulator. The unit enters auto-restart when the sensed output voltage is lower than 3 V.

Output current is sensed internally between the IS and GND pins with a threshold of 35 mV to minimize losses. Once the internal current sense threshold is exceeded, the device adjusts the number of enabled switching cycles to maintain a fixed output current.

Below the CC threshold the device operates in constant voltage mode. The output voltage is sensed via resistor divider R8 and R9 operation with a reference voltage of 1.265 V on the FB pin when at the regulation output voltage

Input EMI Filtering

Fuse F1 provides protection against catastrophic failure of components on the primary side. An inrush limiting thermistor (RT1) is necessary due to the low surge current rating of the rectifier diodes (D1-D4) and the relatively high value and therefore low impedance of the bulk storage capacitors C2 and C4.

Physically small diodes were selected for D1-D4 due to the limited space, specifically height from PCB to case. Capacitor C2 and C4 provide filtering of the rectified AC input and together with L1 and L2 form a p (pi) filter to attenuate differential mode EMI. A low value Y capacitor (C8) reduces common mode EMI.

New 800A/1200V Full SiC Module

By using SiC-based semiconductors the performance of power electronic systems can be drastically improved.

By Eckhard Thal, Koichi Masuda and Eugen Wiesner, Mitsubishi Electric Europe B.V., Ratingen, Germany

The evolution of SiC technology in power modules and its principle loss reduction potential are shown in Figure 1. Mitsubishi has developed two new full SiC module types with 800A and 1200A rated currents and 1200V rated voltage [1]; [2]. This article is describing the 800A module.

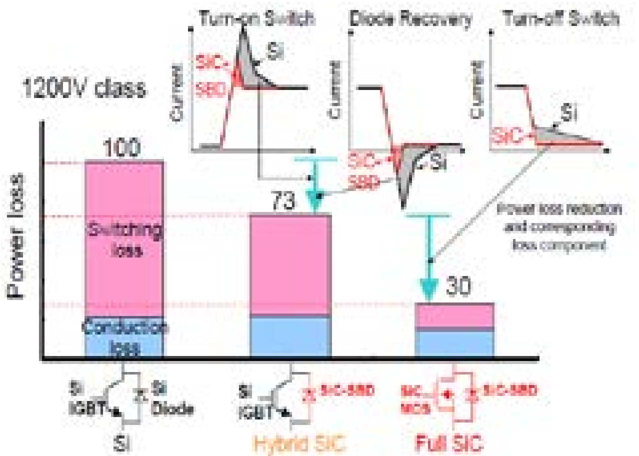

Figure 1: Evolution of SiC technology in power modules

Package outline and circuit diagram

The appearance of new 800A/1200V full SiC module (type name: FMF800DX-24A) and its internal circuit diagram are shown in Figure 2. The module contains 2 x 400A half bridge configurations. By externally paralleling the main P-, N- and AC-terminals an 800A/1200V 2in1 configuration is formed. By this paralleling approach the internal package inductance LS has been decreased to less than 10nH, which is important for limiting the overvoltage spikes at chip level due to high di/dt at switching of SiC-MOSFET.

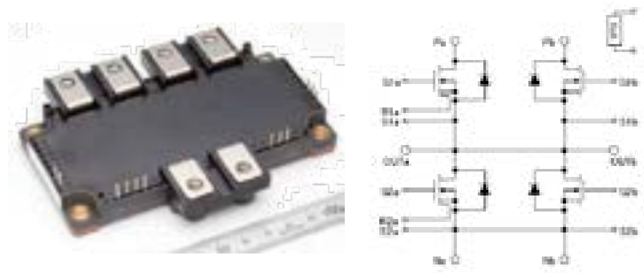

Figure 2: FMF800DX-24A package outline and internal circuit

The baseplate dimension of FMF800DX-24A is 62mm x 121mm. Thus the module size of new 800A/1200V full SiC module is about 1/2 compared with conventional Si-based IGBT modules having the same current rating, see Figure 3.

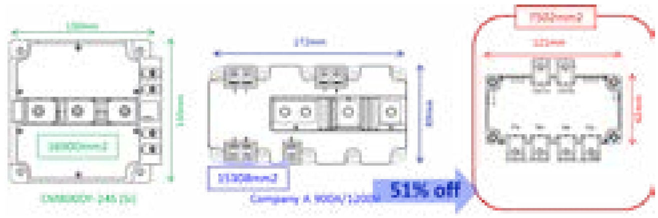

Figure 3: Footprint comparison

For monitoring the baseplate temperature TC a NTC-sensor located close to the MOSFET/FWDi chips is incorporated into the module. For short circuit and overcurrent protection MOSFET-chips with on-chip current sensing are used in one of the half bridge configurations (see Figure 2).

Main module parameters

The main parameters of 800A full SiC module are shown in Table 1. The values of VDS, RDS(on) and VSD are given on chip level.

Symbol	Parameter	FMF800DX-24A
V_{DSX}	Drain-source voltage (at V_{GS}=-15V)	1200V (max)
I_D	Drain current	800A
$I_{D(max)}$	Max. drain current (pulse)	1600A
$T_{J(max)}$	Max. junction temperature	150°C
$V_{DS(on)}$	Drain-source On-voltage @ I_D; T_J=150°C	2,4V (typ)
$R_{DS(on)}$	Drain-source On-resistance @ I_D; T_J=150°C	3,0mΩ (typ)
V_{SD}	Source-drain voltage @ -I_D; T_J=150°C	2,2V (typ)
$V_{GS(+)}$	Gate-source On-voltage	13,5V…16,5V
$V_{GS(-)}$	Gate-source Off-voltage	-9V…-16,5V
$R_{th(j-c)Q}$	MOSFET thermal resistance	42 K/kW
$R_{th(j-c)D}$	FWDi thermal resistance	61 K/kW

Table 1: Main FMF800DX-24A parameters

Switching characteristics

Typical turn-on and turn-off switching waveforms at VCC=800V; TJ=150°C; RG(on)=RG(off)=5Ω are shown in Figure 4 and 5 for different drain currents ID=140A…1400A.

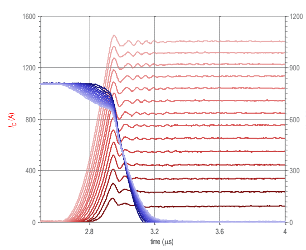

Figure 4: Turn-on waveforms

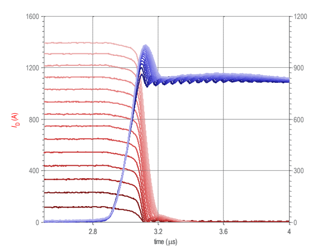

Figure 5: Turn-off waveforms

For limiting the turn-off overvoltage spike a cross-snubber capacitor of CS=6μF was connected between P- an N-terminals. The dependency of switching speed di/dt on drain current ID is shown in Figure 6 and 7

for different junction temperatures TJ=25°C; 75°C; 125°C; 150°C and different DC-link voltages VCC=600V; 800V.

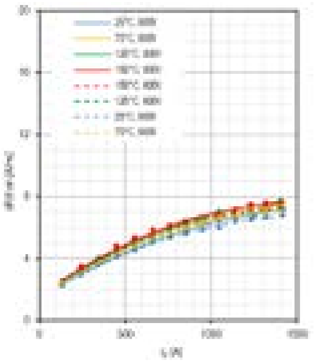

Figure 6: Turn-on di/dt versus I_D

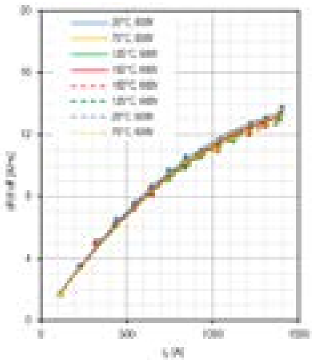

Figure 7: Turn-off di/dt versus I_D

Two comments can be derived from Figure 6 and 7:

a) The current slopes at turn–on and turn-off don't show a strong dependency on chip temperature TJ and DC-link voltage VCC. This behavior differs from today's IGBT-modules.

b) The maximum di/dt at turning-off ID=1400A was about 13A/ns, which is quite similar to the switching speed known from today's high current 1200V IGBT-modules.

Loss comparison with Si-based IGBT modules

The typical forward characteristics of new 800A full SiC module and existing 800A Si-based IGBT module are compared in Figure 8.

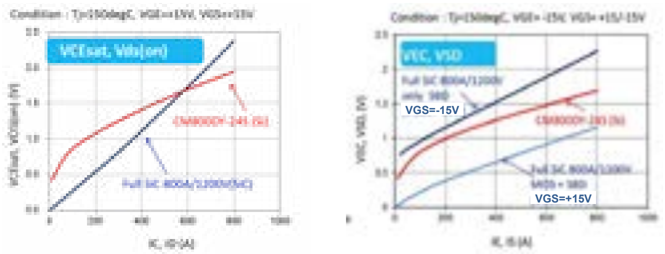

Figure 8: Forward characteristics

The comparison of switching energies in Figure 9 is indicating a key benefit of SiC technology: the switching losses can be drastically reduced compared with Si-based IGBT modules.

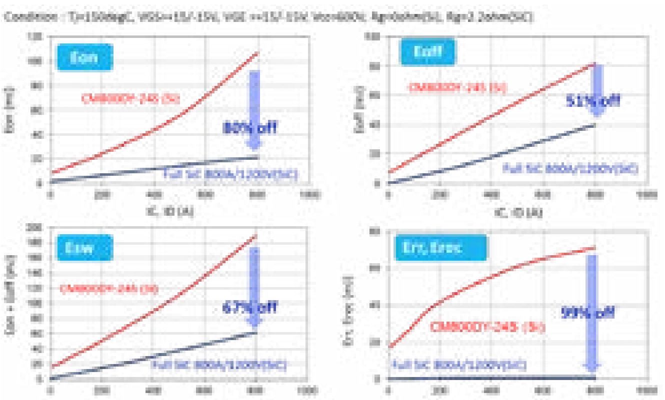

Figure 9: Switching energy comparison

This benefit can be seen in the power loss simulation results per Transistor/FWDi-pair in inverter operation for two different PWM frequencies 15kHz and 30kHz and the corresponding temperature rise ΔT(j-c) in Figure 10 and Figure 11.

The total power loss can be drastically reduced (by 71% for 15kHz and 76% for 30kHz) when full SiC-module is used. This loss reduction is mainly due to reduced switching loss. Conclusion: full SiC modules are very well suited for applications requiring high switching frequencies, where conventional Si-IGBT modules are reaching their thermal limit.

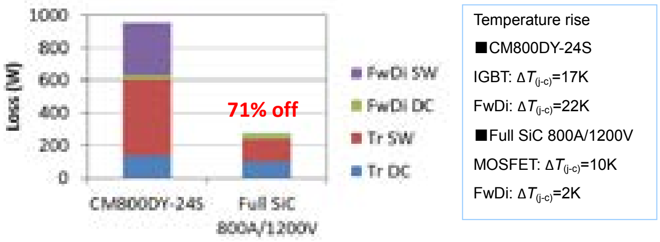

Figure 10: Loss and ΔT(j-c) simulation at fc=15kHz; VCC=600V; IO=400A(peak); PF=0,8; M=1,0

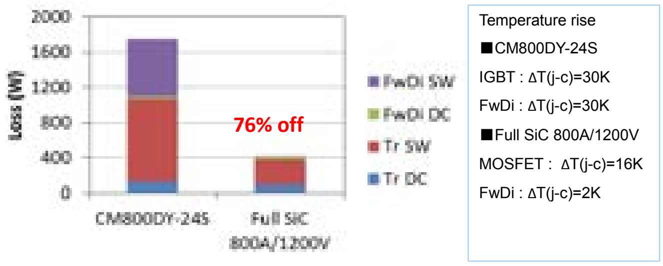

Figure 11: Loss and ΔT(j-c) simulation at fc=30kHz; VCC=600V; IO=400A(peak); PF=0,8; M=1,0

Gate Driver with SC-protection

The new 800A/1200V full SiC-Module can withstand a short circuit current for a limited time of tSC(max)=2,5µs. This limit is given in the SCSOA specification.

For conventional Si-IGBT modules typically a short circuit capability of tSC(max)=10µs is specified. In such conventional IGBT drivers a blanking time between desat-detection and SC-turn-off of typically to=1 3µs is installed, which is sufficient to ensure both: no false SC protection tripping and safe SC-turn-off.

Considering the relatively short tSC(max)=2,5µs specified for the new 800A/1200V full SiC-module another SC-protection method is proposed, known as RTC (Real Time Current Control). For this purpose one p-side and one n-side SiC MOSFET chip are equipped with a current sense electrode (refer to Figure 2). The equivalent circuit and the external view of this SiC MOSFET chip are shown in Figure 12.

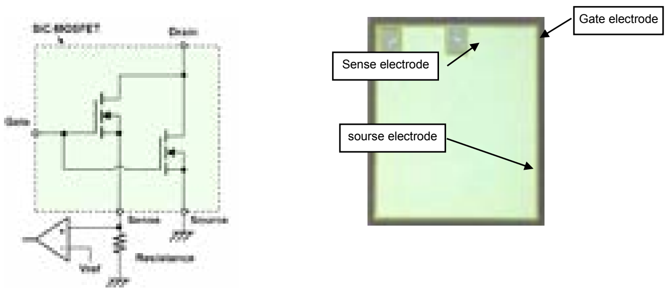

Figure 12: SiC MOSFET chip with current sense terminal

The functional block diagram of a dedicated gate driver for FMF800DX-24A using the proposed RTC protection is given in Figure 13. The measured short circuit waveforms during RTC operation are shown in Figure 14.

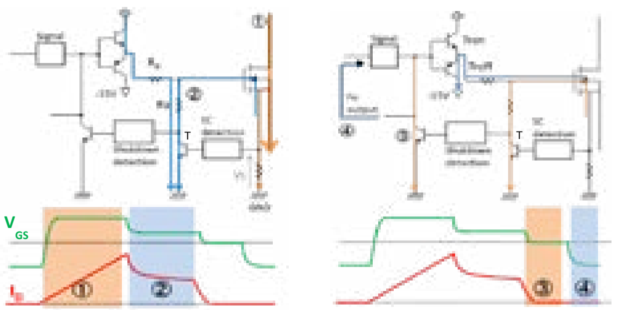

Figure 13: Principle of SC-protection by RTC

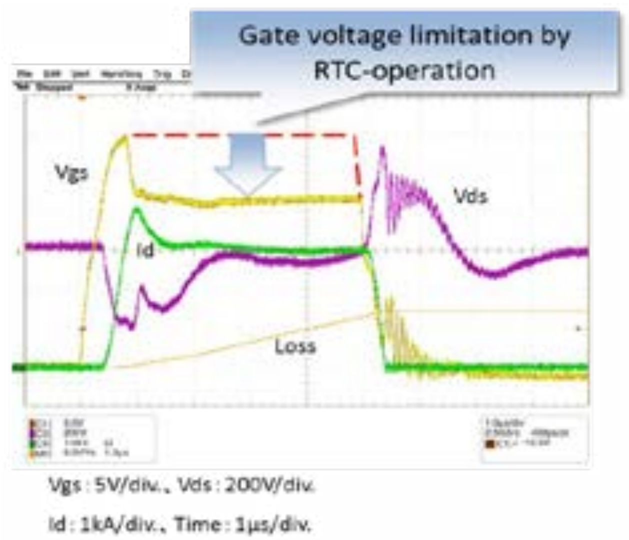

Figure 14: SC-waveforms during RTC-operation

During SC-turn-off operation by RTC four modes can be distinguished. In mode ① the main current ID is increasing until the voltage Vs across the shunt resistance is reaching a defined trip level. After reaching this trip level the mode ② starts: the transistor T is turned on and the Gate-Source voltage is reduced from +15V to about +7V resulting in a decreased SC-saturation current. Due to this SC-current reduction the allowable short circuit time is increased again to the well-known from IGBT drivers tsc(max)=10μs. Means from now on the conventional IGBT gate driver timing can be applied. During phase ③ the gate driver transistor Tron is switched off and VGS becomes Zero thus causing a soft turn-off of the short circuit current. In the final phase ④ the driver transistor Troff is turned on thus applying a negative VGS to the SiC MOSFET in off-state.

Summary and outlook

This paper is describing a new 800A/1200V full SiC dual module. Its type name is FMF800DX-24A. Compared with conventional Si-based IGBT modules the following unique points are confirmed:

- Module size reduced by 50%
- Switching loss (Esw= Eon + Eoff + Err) reduced by 75%
- Reliable SC-protection by RTC

Based on these features the new 800A/1200V full SiC module provides an interesting alternative to conventional IGBT modules in power electronic systems up to several 100kW, especially if one of the following system characteristics is of specific importance:

- Compact equipment size/high power density
- High efficiency
- High switching frequency (beyond the today's limit reachable with IGBT modules)

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[2] Press release No.2733 "Mitsubishi Electric develops Large capacity SiC Power Module Technologies" Tokyo, February 14, 2013

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SiC-Diodes, SiC-MOSFETs and Gate Driver IC

The best use of SiC devices and applications are shown. Uninterruptible Power Supplies (UPS) will be described in more detail. Additional to SiC, a portfolio of very fast, high output current and high common noise immunity Gate Drivers will be introduced. Those devices can drive Si-SJFET and -IGBTs but are especially perfectly suitable for switching SiC Devices.

By Christopher Rocneanu, BDM, ROHM Semiconductor GmbH

Due to the excellent physical and electrical characteristics of wide bandgap material SiC-devices have several well-known advantages e.g. fast-switching, low-losses, high temperature and high frequency operation as well as high breakdown voltages. Next to its 650V and 1200V SiC Diode and –MOSFET portfolio Rohm Semiconductor is developing e.g. a 1700V 1.2 Ohm SiC MOSFET which enables designers to increase performance and reduce cost in Auxiliary Power Supplies. Like in the past Rohm Semiconductor pioneers again by using D3PAK (TO-268 2L) package with only two leads. This package increases the creepage distance and is easy to mount. Compared to Si devices the low gate charge, low input capacitance and only 1/8 of $R_{DS,on}$ value can lead to heat sink removal which has been needed in the past for slow switching high ohmic, high voltage Si-MOSFETs. Thus total system cost can be decreased while increasing total efficiency. At the same time ROHM is also developing 1700V Diodes for 50A and MOSFETs with an R_{DS}, on of 100mOhm and 57mOhm for high power applications. In the coming years it is even possible to get devices with breakdown voltages of 3,3kV and higher in an acceptable price range.

	TO220AC (K A)	TO220FM (K A)	TO247 (A K A)	D2PAK-3L (K; N/C A)	Bare Die
650V	6-20A	6-20A	15-40A	6-20A	6-20A(MP) 30A-100A(DS)
1200V	5-20A		10-40A		5-20A(MP) 30-50A(DS)
1700V					17A-50A(DS)

Figure 1: ROHM Semiconductor SiC Diode portfolio

Diodes: Since 2010 Rohm has a wide portfolio of SiC Diodes with a breakdown voltage of 650V, 1200V and 1700V and a current rating from 5A to 100A as can be seen in figure 1. Standard packages are TO-247, TO-220 and SMD packages. With the industry's lowest forward voltage drop (VF) those SiC Diodes are not only suitable in PFC, Industrial equipment, Welding, SMPS, and (Battery) Charger Applications but especially suitable in those applications where a low voltage drop is necessary to achieve highest efficiency and lowest total system cost e.g. in Solar, Energy storage or UPS. SiC Diodes don't suffer from Reverse Recovery like Si-diodes since the SiC Diode is a unipolar device where only a very small, capacitive and thus temperature independent junction capacitance has to be discharged. Another application is for example automotive. Most on-board chargers are at least including a SiC Diode in as PFC Diode and most manufacturers are either using or considering Rohm as preferred source due to its strength in automotive sector.

Another advantage occurs when using SiC Diodes as Freewheeling diodes together with IGBTs e.g. in Bridge configuration. In those configurations the losses of the Diode will be seen at the Transistors. For a RMS current of 300A you usually use a 900A-1000A rate IGBT module due to the high losses of Si-IGBT and Si-Diode. When using SiC Diodes for free-wheeling the total losses can be reduced and thus the derating of the IGBT can be decreased which will save costs. All major third party module manufacturers have tested and qualified Rohm's SiC diodes. For further information you can either ask your favourite module manufacturer or email the author.

SiC-MOSFET: Since beginning spring of 2012 ROHM started to mass produce its second generation of 1200V, 80mOhm SiC MOSFET. Meanwhile other MOSFETs with $R_{DS,on}$ of 80mOhm, 160mOhm, 280mOhm and 450mOhm have been added to Rohm's portfolio as can be seen in Figure 2.

[illegible]	[illegible]	Package	[illegible]	[illegible]	SBD	Status
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	MP
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	co-packed	MP
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	MP
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	MP
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	MP
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	MP

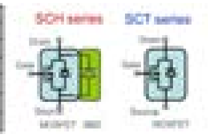

Figure 2: ROHM Semiconductor SiC MOSFET portfolio

Si and SiC-MOSFETs contain a parasitic body diode formed by a p-n-junction. Due to the wide bandgap material SiC body diodes have a high threshold voltage (~3V) and a larger forward voltage drop com-

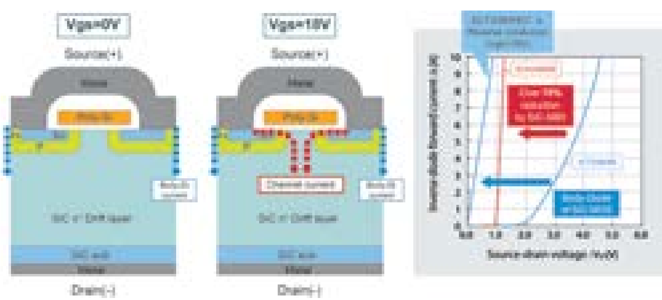

Figure 3: Comparison of VF using SCT2080KEC body diode, SCH-2080KEC and SCT2080KEC in reverse conduction mode

pared to (Ultra-fast) Si-Diodes. The big advantage of a SiC MOSFET is the very good parasitic body diode. Since it is fully qualified one can use the body diode of Rohm's SiC MOSFET for free-wheeling, which can save significant cost.

Rohm's SCT2080KEC body diode has a very good Qrr of 44nC but like all SiC body diodes it suffers from a high VF which is a SiC phenomenon. In most applications the higher VF of the body diode doesn't hurt you compared to the extra cost and space of an additional SiC Diode. For applications where performance but not cost has the highest priority e.g. in the oil and gas industry or for automotive racing Rohm has added an external SiC Diode into the TO-247 package. Now the VF decreases by roughly 70% to 1,4V.

In opposite to other SiC competitors Rohm also introduced SCT2120AF which is a 650V 120mOhm SiC MOSFET in TO-220 package. In the field of 650V competition from Si-devices, especially SJ-FETs are quite strong since they have low $R_{DS,on}$ and are affordable. The advantage of SiC vs Si is the lower $R_{DS,on}$ dependency versus temperature and the higher temperature capability as well as the good body diode reverse recovery performance. Of course it depends on your application and target cost which devices you want to choose but Rohm's portfolio also many attractive Si devices like SJ-FETs, IGBT and a so called Hybrid-MOS. The Hybrid-MOS which is a SJFET with IGBT characteristics has lower conduction losses and higher current capability than a SJFET and lower switching losses and higher frequencies are possible than with an IGBT.

(Bidirectional) Application: Not only but especially for bidirectional application like battery charger, regenerative Drives, power supplies, etc. one can also use the SiC MOSFET in reverse conduction. In most topologies the high and low side MOSFETs are driven with a complementary signal which can be seen in figure 4. After the dead time elapsed the gate at commutation side is turned on. Compared to the body-diode the channel has a lower VF and the currents flow mostly through the MOSFET. Thus the MOSFET operates in reverse conduction mode which increases performance and decreases costs by removing the SBD.

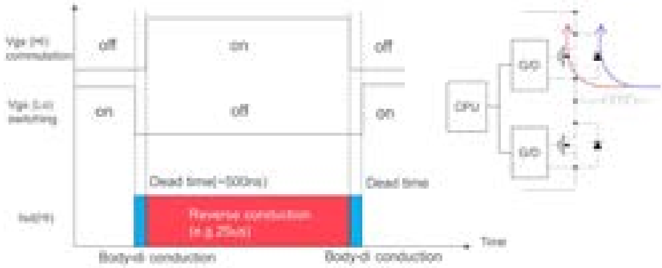

Figure 4: Reverse conduction of SiC MOSFET in half-bridge configuration

With the rising demand of new internet technologies IT centres have to become more energy and cost efficient. Thus one interesting application for SiC is the uninterruptible Power Supply (UPS). There are three types of modern UPS system which are called–on-line, line-interactive and offline or standby topology.

The simplest topology is the Standby UPS which is mostly used in a power range of 0-500VA. Under normal condition a battery charger is used to convert AC to DC and charge the battery while the AC power is bypassed through the UPS to the load. During failure the inverter converts DC to AC to support the load. The offline UPS is normally used in single-phase non critical loads and is called single conversion as the power is converter only once at any point of operation. Thus the efficiency is high. Additionally, the offline UPS is targeting consumer applications e.g. Desktop Computers and can be made very inexpensive but suffers from high and low input voltages due to the lack of power conditioning.

The line-interactive topology is mostly used for server applications and can be found in a typical power range from 500VA-5kVA. This topology is also using a 4-quadrant Converter but compared to standby UPS the DC to AC Inverter is always on and connected to the output of the UPS system. In failure mode the Inverter operates in reverse mode and the battery supplies again to the load. The battery is usually used more than in standby topology which affects the reliability. The use of a tap transformer keeps the energy from dropping abruptly and provides voltage regulation. Additional filtering can be achieved when using an inductance. Thus the line-interactive topology pays a little penalty to the efficiency due to the inductor or transformer losses but on the other hand can increase the range of protection features and power conditioning.

ITEM	STANDARD				FEATURES															Status
	AEQ-100	UL1577 (Basic Ins)	UL1577 (Double Ins)	VDE0884-10 (Reinforced Ins)	PKG (SSOP-)	Isolation [kVrms]	Delay Time [ns] (max)	Negative Power Supply	Miller Clamp	DESAT	Short Current	Temp S/M	Output State Feedback	RDY Output	Flyback Controller	Soft Turn OFF	Advanced Soft Turn OFF	Passive Smart drive	
BM6101FV	✔	✔	–	–	-B20W	2.5	350	✔	E	✔	✔	S	–	–	–	✔	–	–	MP
BM6102FV	✔	✔	–	–	-B20W	2.5	200	–	E	✔	✔	S	–	–	–	✔	–	–	MP
BM6104FV	✔	✔	–	–	-B20W	2.5	150	✔	E	✔	✔	–	✔	–	–	✔	–	–	MP
BM6108FV	–	✔	–	–															
BM6105FW	–	A	–	–	SOP16WM	2.5	95	✔	B	✔	–	–	–	✔	–	–	–	–	CS: Available
BM6106FV	✔	✔	–	–	-B20W	2.5	140	–	B	✔	✔	S	–	–	–	✔	–	✔	ES: Apr/2015 CS: Jun/2015
BM60051FV	✔	✔	–	–	-B28W	2.5	260	–	B	–	✔	M	✔	–	✔	✔	–	–	MP
BM60052FV	✔	✔	–	–	-B28W	2.5	110	✔	B	✔	–	S	✔	✔	✔	✔	–	–	ES: Available CS: Apr/2015
BM60053FV	✔	A	–	–	-B28W	2.5	260	–	B	–	✔	M	✔	–	✔	✔	✔	–	ES: Sep/2015 CS: Jul/2016
BM60054FV	✔	✔	–	–	-B28W	2.5	110	✔	B	✔	✔	S	✔	✔	✔	✔	–	–	ES: Available CS: May/2015

Figure 5a: Complex Gate Driver portfolio, A=Available, B=Build in, E=External, S=Shutdown, M=Monitor, ES=Engineering sample, CS=Commercial Sample, MP=mass production

ITEM	STANDARD				FEATURES						Status
	AEQ-100	UL1577 (Basic Ins)	UL1577 (Double Ins)	VDE0884-10 (Reinforced Ins)	Channel	PKG (SSOP-)	Isolation [kVrms]	Delay Time [ns] (max)	Miller Clamp	Negative Power Supply	
BD6562FV	–	–	–	–	2ch Low side	-B16	Not Isolated	385	–	–	MP
BD6563FV	–	–	–	–	3ch Low side						
BM60014FV	✔	✔	–	–	1ch	-B20W	2.5	120	B	–	MP
BM60015FV	–	–	A	A	1ch	-B10W	3.75	75	B	–	ES: Available CS: Sep/2015
BM60016FV	✔	TBD	TBD	–	1ch	-B10W	TBD	75	B	–	TBD
BM60210FV	✔	–	–	–	Half Bridge	-B20W	High side: 1.2kVDC Low side: Not Isolated	75	B	–	ES: Jun/2015 CS: Dec/2015

Figure 5: Simple Gate Driver portfolio, A=Available, B=Build in, E=External, S=Shutdown, M=Monitor, ES=Engineering sample, CS=Commercial Sample, MP=mass production

The on-line topology is mainly used from 5kVA-1MVA+ and is also called double conversion. Compared to the standby topology the primary power path is now coming from the inverter instead of the AC Mains. Therefore the battery charger and the inverter are converting the complete load power flow. By using a transformer common mode noise immunity and electrical isolation is provided. Advantageous is the increased range of protection and a very good electrical output performance. By using SiC devices the UPS System can be made more efficient, more reliable and more inexpensive.

Driving SiC MOSFETs: To obtain less V_{TH} shift Rohm guarantees for its SiC MOSFETs a Gate Source Voltage of 22V/-6V. This is also the Voltage under which all reliability tests (e.g. HTGB) are performed. For more information on reliability test please contact the author or your responsible Rohm Sales Representative. Other competitors have given max. V_{GS} in their datasheet of 25V/-10V but test their device at the given operating V_{GS} =20V/-5V only. Rohm recommends a V_{GS} of 18V/-3V or-4V in order to switch the MOSFET safe and optimize efficiency. At room temperature and 18V the $R_{DS,on}$ =80mOhm while at 15V the $R_{DS,on}$ =100mOhm. Just by not choosing the right positive Voltage you can lose 25% efficiency. You can switch off the SiC MOSFET at 0V but you have to be careful that ringing doesn't exceed V_{TH} in order to avoid parasitic turn on and failure of your application. At the same time a low negative Voltage gives you a higher margin and decreases switch off time. Rohm's customers have successfully used 0V as well as low negative Voltage to switch off the device. In general you must adapt to your case and application but you shouldn't try to "plug and play" the SiC MOSFET with an IGBT This means you need to consider the optimal V_{GS} and you have to consider your design for SiC in terms of EMI, distance between Gate to driver, stray inductances etc… or you can be wasting a lot of money and time.

To support customer as best as possible ROHM has created a portfolio of industrial and automotive qualified, high performance, simple and complex Gate Driver ICs which are suitable for IGBTs, SJFET, and SiC MOSFETs. Simple means single channel with only a few features like Miller Clamping and complex means 2 channel driver where one channel is used for feedback. The complex drivers have several features the customer can choose like negative power supply, Miller clamping, desaturation, temperature monitor or shutdown and even an integrated flyback controller. All features can be seen in Picture 5. The gate drivers have a magnetic coreless transformer design, featuring an isolation voltage of 2,5kV and a delay time of as low as 90ns. Also they have a peak current of 5A, an ambient temperature -40°C – +125°C and industries best common mode noise immunity of 100kV/us which makes them a perfect suitable to switch fast SiC devices. BM6105FW for example is pin-to-pin compatible to competitors solution.

The drivers are originally designed for high side but since some customers are using negative V_{GS} an isolated gate driver on the low side is useful as well.

Cost, Reliability and Second Sourcing: The main arguments against SiC have been cost, reliability and second sourcing. Reliability issues have been shortly discussed before and all necessary reliability test can be send upon request. While at first there were several manufacturers using different transistor structures like BJT, JFET and

MOSFET. Meanwhile the MOSFET has won the race. Rohm Semiconductor and competitors have been manufacturing SiC MOSFETs since 2010/ 2011 and other major players are following with SiC-MOSFETs. The advantage of the MOSFET is the normally-off behaviour as well as the very fast body-diode. Rohm and competitors portfolio are similar with respect to $R_{DS,on}$ which means there is a second source available.

At the same time there are only two major manufacturers of SiC Wafers. One of them is SiCrystal a 100% owned subsidiary of Rohm Semiconductor. SiCrystal is located in Nuremberg and supplies SiC wafers to Rohm's Japanese factory. SiC is a very hard material (9.6 on the MOHS Scala where diamond has a 10) which requires high cost processing. At the same time while Si wafers are at 8inch, SiC device manufacturers are using 4inch at the moment. An increase in demand will allow ROHM to adapt to 6inch very quickly. Even at 3 and 4 inch wafers the cost of the SiC diodes has been decreased over the years. For 650V diodes the cost per amp is below 0,20USD/Amp at high quantities. For 1200V diode cost is roughly at 0,40USD/Amp. Cost for the MOSFET has come down from roughly 100USD per device in 2011 to below 15USD from online distributor for 1kpcs today for a 1200V 80mOhm MOSFET. The high vertical integration of the supply chain - from wafer to chip to module - allows Rohm semiconductor to control its quality and decrease the time to market as well as the delivery time.

Summary: Rohm's SiC Diode and –MOSFET portfolio has been introduced and several advantages have been shown from SiC MOSFETs and -Diodes versus conventional technologies. Besides a wide portfolio of power products Rohm also offers Gate Driver with a high output current, small delay time and high Common Mode Noise Immunity making them especially suitable for switching SiC devices. Since Rohm also offer Si-IGBT and SJFET there are plenty of options for developers. An introduction to UPS has been given.

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DC-Link Capacitor Technology Comparison

Aluminum Electrolytic vs. Film Capacitors

By Dr. Arne Albertsen, Jianghai Europe Electronic Components GmbH

Introduction
The progress in semiconductor design sets the trend in current and future devices of power electronics: it manifests itself particularly in smaller dimensions, as well as in higher voltages and switching frequencies. Referring to intermediate circuit capacitors, this trend leads to aiming at higher energy densities and larger current loads, and – at the same time – decreasing space.

Under these conditions, especially aluminum electrolytic capacitors and plastic film capacitors offer advantageous solutions. Jianghai has both technologies in the production program and this article gives an overview on the major differences between aluminum electrolytic capacitors and film capacitors.

Applications of intermediate circuit capacitors
The intermediate circuits (DC-link) of converters frequently utilize capacitors. The main tasks of these capacitors are (a) smoothing of the ripple voltage superimposed on the DC-bus voltage and (b) the provision of electrical energy. Figure 1 shows the block diagrams of converters that have a DC link.

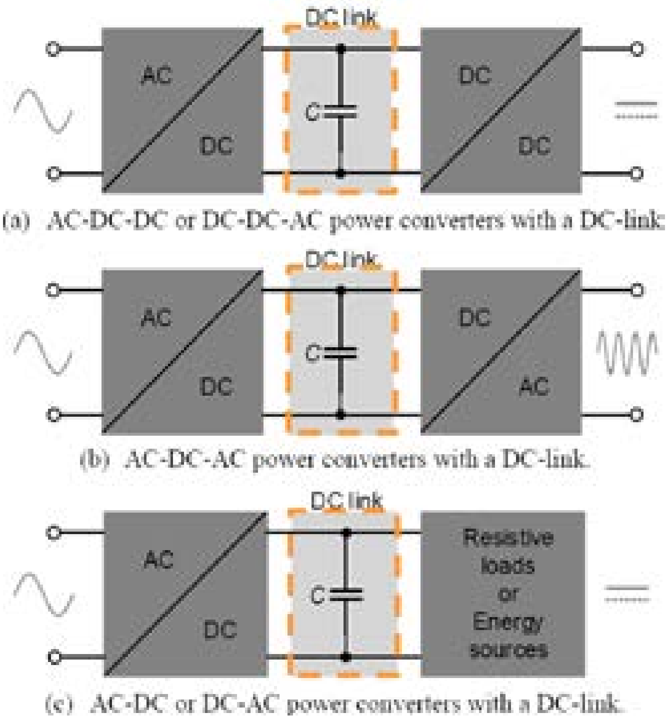

Figure 1: Examples of inverters with a DC link [6]

Application examples for inverter comprise wind turbines, photovoltaic power systems, UPS (uninterruptible power supplies), electric motors, electric vehicles, lighting and welding equipment. Depending on the application, different demands for lifetime, reliability, temperature, dielectric strength, current-carrying capability, and other parameters of the intermediate circuit capacitor may exist. Because there is no universal capacitor solution for all applications, a selection of suitable capacitors on the basis of the specific requirements of the respective application is necessary.

Comparison of electrolytic capacitors and film capacitors
Figure 2 shows the construction and the essential materials of an aluminum electrolytic capacitor (left) and a polypropylene film capacitor (right). While the active part of electrolytic capacitors, the so-called wound cell, consists of aluminum (anode and cathode foil), paper, and electrolyte, the film capacitor is made of metal-coated plastic film that builds its electrodes.

The peculiarity of the electrolytic capacitor is its “liquid cathode”: the total surface of the highly roughened aluminum anode foil, coated with aluminum oxide as dielectric, can be fully contacted through the electrically conductive electrolyte, to realize the high specific capacitance of this technology [1].

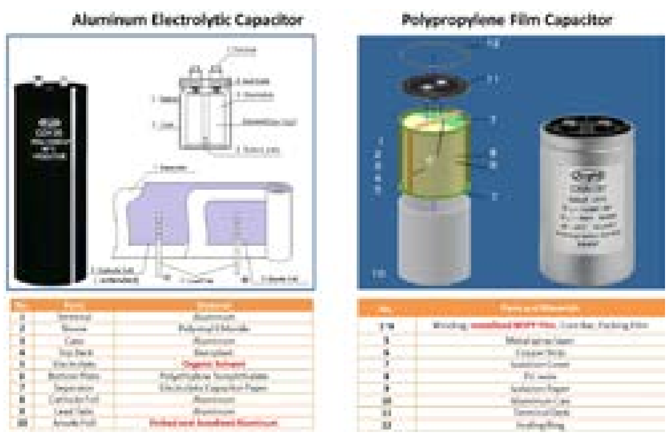

Figure 2: Structure and materials of electrolytic (left) and film capacitor (right) in comparison

The film capacitor is made from dry materials: the capacitor plates consist of metal vapor, which was been deposited on a plastic film that serves as dielectric. Often, the dielectric is polypropylene, consisting of polymer chains that are prefarrably oriented in longitudinal and horizontal direction (also known as BOPP for biaxially oriented polypropylene).

The different electrical properties of the two technologies originate from the different materials used in them. Figure 3 shows the energy densities for some selected dielectrics in comparison. Actual aluminum electrolytic capacitors have up to ten times higher energy density than polypropylene film capacitors.

Because the electrical current flow in aluminum electrolytic capacitors is facilitated by ions flowing through the electrolyte, the viscosity of the electrolyte has a significant influence on the temperature dependence of the ESR values: at low temperatures the electrolyte becomes more viscous and inhibits the free movement of ions, leading to a higher ESR value. At temperatures above 60 °C, the ESR hardly changes [1]. Also the capacitance of aluminum electrolytic capacitors decreases with falling temperatures by a double-digit percentage. However, ESR and capacitance of the film capacitor show themselves largely

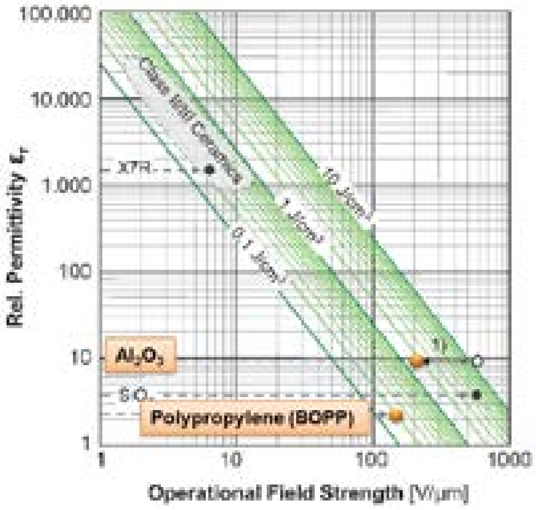

Figure 3: Energy densities of dielectrics compared - aluminum oxide vs. polypropylene [4]

unimpressed by temperature fluctuations: the capacitance over the entire temperature range varies only about 3 ~ 5 %, and ESR values remain nearly constant.

	Aluminum Electrolytic Capacitor	Film Capacitor
Common Failure mode	Parametric failure Open circuit	Parametric failure Open circuit
Common Failure cause	Electrolyte loss („drying out") Electrochemical reactions	Corrosion driven by humidity Loss of dielectric area
Important Stressors	$T_{ambient}$, $V_{operating}$, I_{ripple}	$T_{ambient}$, $V_{operating}$, humidity
„self-healing"	yes	yes

Table 1: Comparison of aging, failure modes, and important stressors (according to [2], [6])

These parameters show a similar performance vs. frequency: for electrolytic capacitors, capacitance and ESR both exhibit a strong frequency dependency [1], while film capacitors show almost constant capacitance and ESR values across the technically interesting frequency range from 100 Hz ~ 200 kHz.

The film capacitor offers higher rated voltages than the e-cap: the voltage proof of a single element can be up to 1500 V, while e-cap rated voltages are limited to 650 V [3]. The voltage (and ripple current) limitations of individual electrolytic capacitors requires multiple capacitors to be connected in series and in parallel to build a "capacitor bank". When connecting electrolytic capacitors in series, an active or passive balancing is beneficial to ensure a uniform distribution of the DC-link circuit voltage on the individual capacitor. This extra effort may prove quite useful, as the relatively new "3-level inverter" topology with lower losses, smaller loads of the intermediate circuit and lower specific costs for inverters with higher output power and switching frequencies impressively demonstrates [5].

Table 1 compares the major stress factors, failure modes and causes. Electrolytic capacitors as well as film capacitors are referred to as "self-healing": defects in the dielectric layer of electrolytic capacitors are repaired by anodic oxidation, consuming oxygen from the electrolyte. Defects in the film capacitor, however, are burnt and thus electrically isolated, but each burnt defect causes a small loss of dielectric film, i.e. a small decrease of capacitance.

Given operating conditions within the specification limits, both technologies show a "graceful" end-of-life behavior that is mainly characterized by parametric rather than by catastrophic failures.

The operating parameters temperature, voltage, and ripple current determine the lifetime of electrolytic capacitors. For film capacitors, temperature, voltage, and humidity limit the lifetime. The influence of ripple current on life doesn't enter into the equation, because the self-heating resulting from the particularly low ESR values in film capacitors is negligible. Typical end-of-life change limits for the ESR are double or triple of the initial ESR values for both technologies. Common capacitance losses at the end of life amount to 3% with film, and to 30% with aluminum electrolytic capacitors.

The cost is an important criterion in the choice of a technology: the specific cost to store a given amount of energy with aluminum electrolytic capacitors is significantly less (approximately by a factor of three) than with film capacitors. On the other hand, the superior current-carrying capability of film capacitors outperforms the electrolytic capacitor in terms of cost per Ampère approximately by a factor of two. These significant differences suggest that both technologies will stay available on the market in the future.

Summary

Modern power electronics designs require compact DC link circuit capacitors with long life spans. Aluminum electrolytic capacitors convince with high specific energy densities and foil capacitors offer great ripple current capability.
Both technologies have physical limits based on their design and the materials used. The selection of a suitable DC link circuit capacitor depends in each case on the respective application requirements. An intensive project support for each application by the capacitor manufacturer is always mandatory.

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Magnetics Design Tool for Power Applications

Predicting the behavior of soft magnetic cores under realistic circuit application conditions allows making an optimum material and core selection. This requires on the one hand, visualizing material data of soft magnetic materials. On the other hand, calculating core parameters such as inductance, core losses, transferable power and EMI suppression as well as associated basic winding design parameters.

By Mauricio Esguerra – Dipl. Phys. Mauricio Esguerra Consulting, Unterhaching, Germany on behalf of Hengdian Group DMEGC Magnetics Co., Ltd, Zhejiang, China

The free app SOFT POWER uses proven simulation methods such as hysteresis modeling for a reliable design, allowing faster time to market while maximizing engineering resources.

Material Parameters – Both soft ferrites and powder core materials are featured based on representative ring cores tested according to IEC 60401-3 and IEC 62044-1/2/3). The software shows graphs of relevant parameters for every material grade:

- Permeability ***μ*** vs. temperature, flux density and DC-Bias
- Complex permeability ***μ´, μ"*** vs. frequency
- Small-signal losses (**tan*δ/μ***) vs. frequency
- Normalized impedance Z_N vs. frequency
- Power losses P_v vs. frequency/flux density/temperature
- Hysteresis loops ***B(H)***

Hysteresis Modeling – In order to accurately simulate high excitation parameters such as power loss and DC-bias at any given condition, hysteresis modeling is necessary. The use of models such as the Steinmetz power equation [1] have limited validity in the frequency, flux density and temperature ranges; extrapolating these limits can result in very large errors due to the exponential nature of the equation. The hysteresis models based on Hodgdon's differential equation [2] naturally overcomes these limitations [3]. By regarding the measured major hysteresis loop as a particular solution to the equation, the upper and lower branches of a minor loop between the end points (H_m, B_m) and (H_M, B_M) can be described as a function of the upper and lower curves of the major loop:

$$H_L^{minor}(B) = H_L^{major}(B) + \frac{H_m - H_L^{major}(B_m)}{C(B_m, B)} \quad (1a)$$

$$H_U^{minor}(B) = H_U^{major}(B) + \frac{H_M - H_L^{major}(B_M)}{C(B, B_M)} \quad (1b)$$

With

$$C(B_1, B_2) = \sqrt{\frac{H_U^{major}(B_2) - \hat{H}(B_2)}{\hat{H}(B_2) - H_L^{major}(B_2)} \cdot \frac{\hat{H}(B_1) - H_L^{major}(B_1)}{H_U^{major}(B_1) - \hat{H}(B_1)}}$$

and the commutation curve

$$\hat{H}\left(\hat{B}\right) = H_L^{major}\left(\hat{B}\right) - H_c\left(1 - \frac{\hat{B}}{B_S}\right)^{\frac{B_S}{\mu_O H_C}\left(\frac{1}{\mu_i} - \frac{1}{\mu_C}\right)} \quad (4)$$

Where Hc is the coercivity, μc its permeability and Bs the saturation flux density. In addition to these parameters the model requires the knowledge of the initial permeability μi, which is also a well-defined quantity.

The measured major loop curves can be parametrized by the following heuristic description introducing the squareness exponents aL and aU for the lower and upper curves respectively:

$$H_L^{major}(B) = \frac{B}{\mu_O \mu_C} \cdot \frac{1}{1 - \left(\frac{B}{B_S}\right)^{a_L}} + H_c \quad (5a)$$

$$H_L^{major}(B) = \frac{B}{\mu_O \mu_C} \cdot \frac{1}{1 - \left(\frac{B}{B_S}\right)^{a_U}} - H_c \quad (5b)$$

Figure 1 shows one example of a major loop and a calculated minor loop.

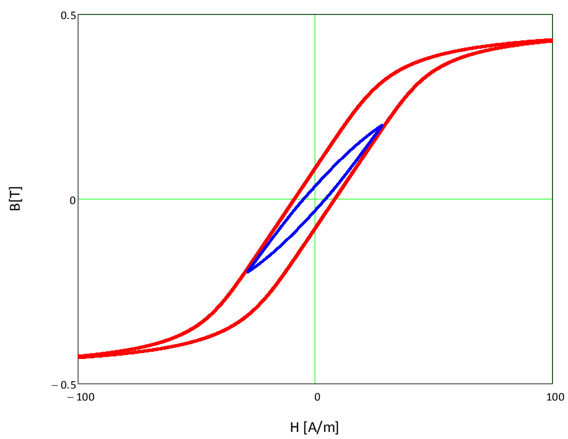
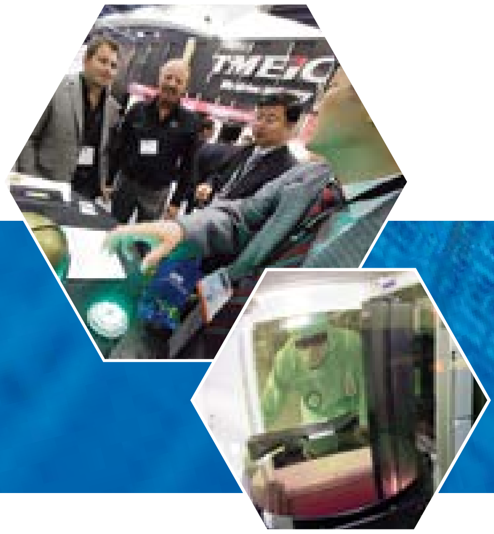


Fig. 1: Major loop for material DMR47 at 80°C. The symmetric minor loop was calculated for -Bm = BM = 200 mT



Derived Parameters – The calculation of application relevant quantities is straight forward:

- Power Loss: the enclosed area of a symmetric minor loop of amplitude BM is obtained by integration:

$$w_s = 2 \cdot \int_0^{B_M} \left(H_U^{minor}(B) - H_L^{minor}(B) \right) dB \qquad (6)$$

  Based on this and considering the frequency dependence, both power losses and the transferable power for a given core and winding can be calculated (Fig. 2a).

- **DC-bias:** the reversible permeability μ_{rev} is given by the following expression:

$$\mu_{rev}(B_{dc}) = \left(\underbrace{\frac{1}{\left(1-\frac{B_{dc}}{B_s}\right)\cdot\left[2-\left(1-\frac{B_{dc}}{B_s}\right)^{\frac{B_s}{\mu_o H_c}\left(\frac{1}{\mu_i}-\frac{1}{\mu_c}\right)}\right]}\cdot\left(\frac{1}{\mu_i}-\frac{1}{\mu_c}\right)}_{\text{lossrelated term}} + \underbrace{\frac{1+(a-1)\cdot\left(\frac{B_{dc}}{B_s}\right)^a}{\left[1-\left(\frac{B_{dc}}{B_s}\right)^a\right]^2}\cdot\frac{1}{\mu_c}}_{\text{squarenessrelated term}} \right)^{-1} \qquad (7)$$

  The dc bias inductance is calculated from μrev and the dc-bias current Idc from the dc flux density Bdc (Fig. 3).

Temperature Dependence – The hysteresis parameters are determined for major loops tested at different temperatures. In order to allow the software to calculate related quantities at a given temperature, the five hysteresis model parameters are fitted as a function of temperature.

Core and Winding Parameters – Every core type is characterized by three geometrical parameters according to IEC 60205:

- l_e: effective magnetic length
- A_e: effective cross-sectional area
- A_{min}: smallest cross section

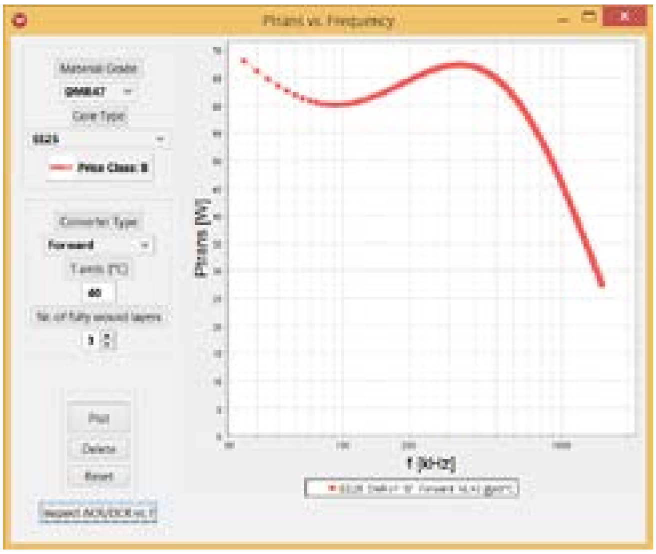
In addition to this, a typical one-chamber bobbin is described by

- l_N: mean turn path
- A_N: winding area

Based on these parameters it is possible to calculate transformer and inductor parameters for a given choice of core shape and material grade. Especially the frequency increase of the winding resistance (ACR/DCR) depends on its arrangement in the bobbin and the core surrounding it through the skin and proximity effects depending on both the number of turns and layers [4] (Fig. 2b).

But also the **winding capacitance** is an important consideration for the high frequency behavior of e.g. an EMC filter inductor [5]. The program calculates it so as to provide the effect of the number of turns on the height and position of the impedance vs. frequency curve. This allows for example to fine tune the inductor design to mitigate electromagnetic interference (EMI) in switch-mode power supplies (Fig. 4).

The effect of larger air gaps on the inductance needs to consider the fringing flux effect [6]. The software considers this in order to accurately calculate the inductance as a function of temperature and DC-bias.



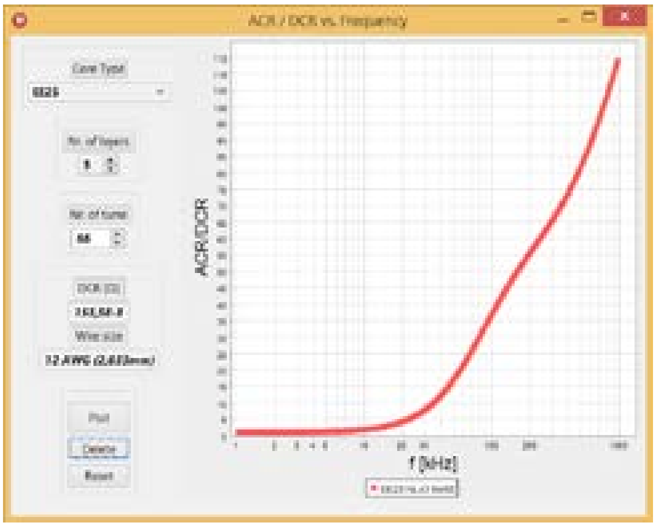


Fig. 2: (a) Transferable power for EE25 core in material DMR47 used in a forward converter topology at an ambient temperature of Tamb=40°C.
(b) Corresponding ACR/DCR vs. frequency for the winding with three full wound layers and N=66 turns (AWG 12).

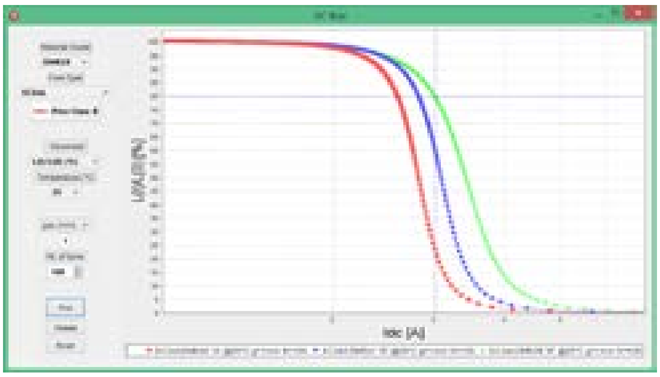


Fig. 3: Inductance vs. dc bias current for a choke built with an EC34A (ETD34) core with an air gap of g=1mm and N=100 turns in materials DMR40, DMR47 and DMR28 at T=25°C.

The free-air convection thermal resistance of a wound component depends from the core volume and is needed to calculate the temperature increase in a power transformer. This is needed to calculate the transferable power (Fig. 2a).

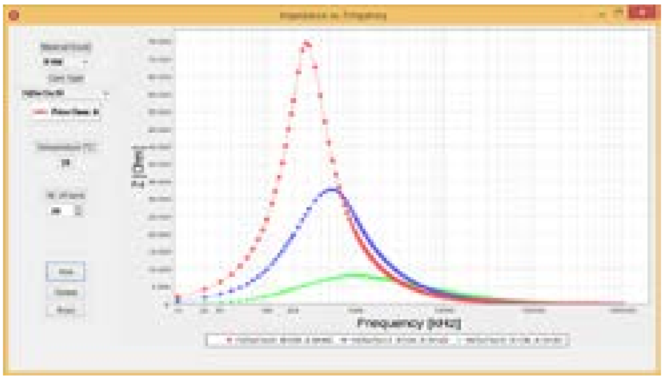


Fig. 4: Impedance vs. frequency for a toroid H25x15x10 in material R10K wound with N=20, 40 and 60 turns. Due to the winding capacitance which increases with the number of turns, the frequency of the impedance maximum decreases.

Material Menus – The front page provides an overview of material grades (MnZn ferrites, NiZn ferrites, powder core materials) core shapes and reference cost. With the help of these tables the user makes then a selection of materials to compare its properties to one another in the following menus:

- Permeability vs. Temperature: from -60°C up to Curie temperature
- Complex Permeability vs. Frequency: from 10 kHz up to 1 GHz. User can select between serial or parallel, real and imaginary permeability as well as normalized impedance.
- Incremental Permeability vs. Magnetic Field: up to saturation between 25°C and 140°C.
- Hysteresis Loop B(H): up to saturation between 25°C and 140°C.
- Amplitude Permeability vs. Flux Density: up to saturation between 25°C and 140°C
- Power Loss vs. Temperature/Frequency/Flux Density: displays losses as a function of temperature (between 25°C and 140°C), flux density (up to saturation) or frequency (from 10 kHz up to 3.5 MHz) with the two other parameters fixed.

Core Menus – Once the user has selected the material grade for his application, he can then select a suitable core shape and calculate for it the following parameters related to his application:

- Gapped AL | µe vs. Temperature: calculation of AL-value including fringing flux effect, effective permeability, and relative permeability variation with temperature. The surface quality for non-toroidal cores (grinding vs. polishing depending on the material grade) is also taken into account.
- DC-Bias: inductance, inductance variation, magnetic energy vs. DC-current or incremental permeability vs. DC-field strength.
- Transferable Power: maximum power output vs. frequency for given ambient temperature and converter topology, limited either by temperature increase or saturation. The number of fully wound layers can be selected and the corresponding frequency increase of the winding resistance (menu R) further limiting transferable power inspected.
- EMI Suppression: high-frequency impedance calculated at room temperature based on material properties and estimated capacitance for an evenly wound core. The surface quality for non-toroidal cores (grinding vs. polishing depending on the material grade) is also taken into account.
- DCR |ACR/DCR vs. Frequency: calculation for a given core shape and its typical bobbin, number of layers and turns of the DC resistance (DCR) and frequency increase due to skin and proximity effects (ACR/DCR). The closest wire gauge to achieve fully wound layers is provided.

Price Class – The software classifies the selected core shape/material grade combination according to an increasing relative price class from A to D. This allows users to make not only the best technical selection but to make relative cost comparisons between different alternatives.

Functionality – All menus deliver both numerical and graphical results. The graph points can be read and the graphs stored for later reference either as a graphics (.png) or as a text (.csv) file. A context menu to adapt the graph can be accessed by right-clicking on the chart.

For more information please contact the author at me@dmegc.de

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Wireless Power Transmission with High Efficiency and Wide Dynamic Range for Extensive Applications

Wireless power transmission has been known for many years, with inductive near field proximity coupling being the most commonly used technology.

By Markus Rehm, Ingenieurbuero Rehm, Villingen-Schwenningen, Germany

The demand for wireless power supplies is huge: Mobile devices, charged without wire or contact, are robust, splash proof, reliable, simple to protect against humidity, sea water, dust, vibrations and explosion and are easy to sterilize. Mobile robots or operation terminals, medical equipment, implanted sensors, amplifiers, pumps and transceivers and e-mobility are some of the predestined applications.

After an enthusiastic start the industry has realized that there are some technical challenges regarding loose coupling, efficiency and EMI.

The „universal Wireless Power“ („uniWP“) presented here represents a new solution to overcome the existing technology barriers.

Traditionally, wireless power transmission uses coupled resonance circuits, where the power transmission reaches its maximum, when the resonance frequency of the two circuits are identical and the transmitter operates at this resonance frequency. Unfortunately the resonance frequency of this coupled arrangement changes due to variations or drifts in the components (tolerances, aging and temperature) and in the coupling (mispositioning- or geometric changes between transmitter and receiver). Even load changes on the receiver side cause the resonance frequency to change as well.

The solution adopted by WPC´s QI [1] and others senses the resulting resonance frequency, when a receiver becomes coupled with a transmitter. Power can be transmitted only, if the system works in resonance. That means transmitter frequency and resonance frequency have to be equal. The resonance frequency depends on several factors, such as the load, the rectification, components in the primary and secondary resonance circuits and of course the coupling. If one of these factors change, for example the load, the distance or a capacitor gets a bit warmer, the resonance frequency changes as well. In normal applications some of these factors change permanently, so the resonance frequency is dynamic, it changes continuously. There is no power transfer at all, if the transmitter frequency does not correspond exactly to the resonance frequency. Additionally, the tight standardization down to circuitry- and component level severely limits adaptability to future evolutions.

Unfortunately, there is no possibility to determine the resonance frequency actively. In fact, the generator is the slave of the various parameters of the resonant circuit.

Can coupled resonant circuits be equivalent to a wired connection?

Wireless power supplies operate with inductive near field transmission. You can imagine that like a transformer. Primary and secondary winding are close together, there is almost no leakage inductance and the coupling factor is almost equal to 1. Conventional wireless power supplies work similarly. They need constant and tight coupling like in the electric toothbrush. But that´s not what the user wants! Normal applications have some distance between transmitter and receiver, perhaps a shifted position, maybe vibrations. So in reality we have a coupling factor much smaller than one, and a leakage inductance much larger than zero, which is even dynamic.

Actually, the large leakage inductance is not a problem, because it can be compensated with a resonance network via its quality factor Q. A low coupling factor k can be compensated with a high quality factor Q

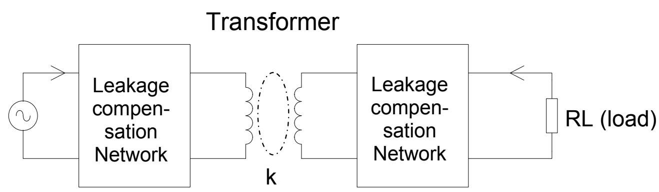

Figure 1: Inductively coupled wireless power transmission link using leakage compensation networks

One defines: Undercritical coupling, critical coupling and overcritical coupling (see Figure 2).

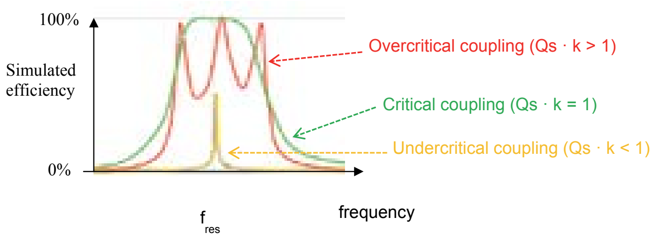

Figure 2: Theoretical efficiency in different coupling conditions

The critical coupling (green curve) is the equivalent of a wired connection. A further increase in Qs moves the system into an over coupled

condition state (bifurcation), wherein there is no stable resonance frequency any longer (red). Over coupling must be avoided, because it increases losses and the semiconductor break down due to overstress. To avoid overcritical operation, common systems work in under critical coupling condition (yellow), which results in very low efficiency and very small bandwidth.

Summary: Conventional wireless power supply fail because of the dynamic resonance frequency, the low efficiency and the high electromagnetic emissions.

The new technology „uniWP“ has two main innovations. One is a large signal VCO, which guarantees independent, fast and stable resonance tracking. Thus, the system is not dependent on the given resonance frequency, because it can determine it itself. The new system uniWP has the ability to adjust the resonance frequency. Second innovation is the guaranteed linear operation with limitation to its physical limit, by avoiding over critical coupling. uniWP detects over coupling condition and takes measures against it. The system can work in critical coupling state, (green curve) which means 100% efficiency in theory.

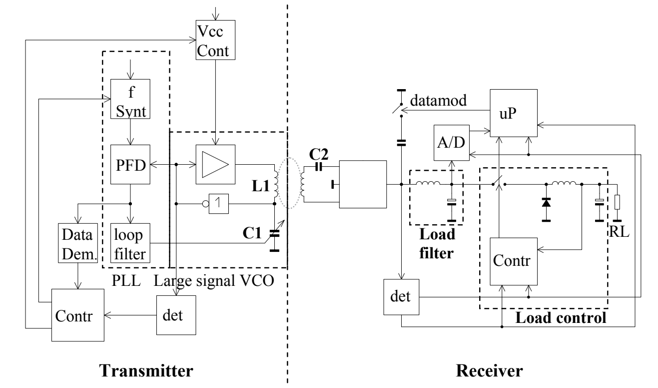

Figure 3: Block diagram of a wireless „uniWP“- transmission link example

New solution „uniWP“ with high efficiency
If the resonant circuit is driven precisely at its resonance frequency, the wireless transmission link behaves like a real transformer. This automatically results in the optimum matched condition since the real load is directly transformed to the transmitter side. This is exactly what occurs in „uniWP“ technology.

The maximum efficiency is achieved under the critical coupling condition as explained above.

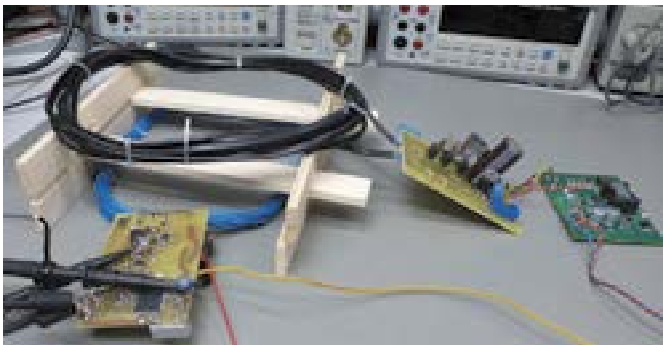

Figure 4: One example of „uniWP“: Transmitter with blue loop antenna, receiver with black loop antenna, synchronous rectification board and buck-boost-converter for a controlled output, here 24 Volt.

The „uniWP“ concept was verified with a regulated output voltage on the secondary side.

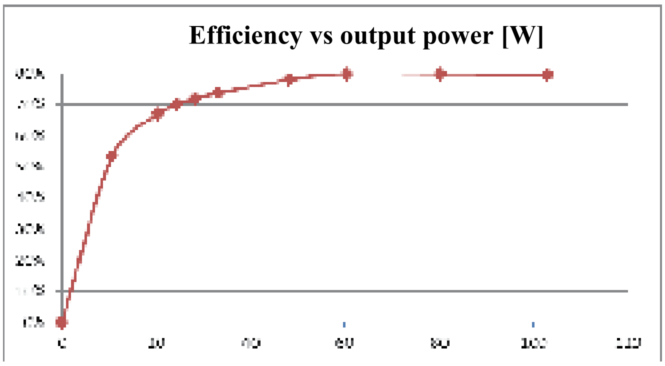

Figure 5: Efficiency of the example as shown in figure 4. There is no auxiliary supply! The distance between transmitter and receiver is approx. 4cm. The output voltage is a controlled 24 Volt.

New solution „uniWP“ improves EMI
Thanks to the high dynamic in the new „uniWP“ large signal resonance frequency control loop, arbitrary frequency spectrums can be generated through software (frequency synthesizer).

Figure 6a depicts a discrete output transmission frequency peak (134 kHz) and Figure 6b shows sweep operation (120 … 134 kHz).

The „uniWP“ frequency spreading feature allows a reduction in the spectral density of 10 dB for the same transmitted power!

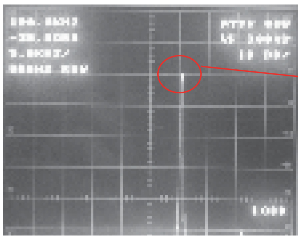

Figure 6a): Transmitter output spectrum in discrete frequency operation

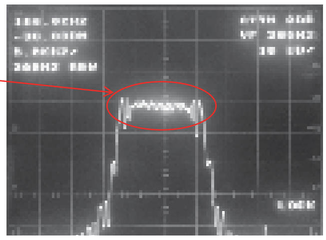

Figure 6b): Transmitter output spectrum in sweep frequency operation

In this manner federal frequency standard EN300330 (Figure 7) can easier be achieved by software without any hardware change (synthesizer frequency data). Thus, frequency notches can be generated at excluded frequencies in the swept frequency hopping mechanism in order to comply with additional national regulations.

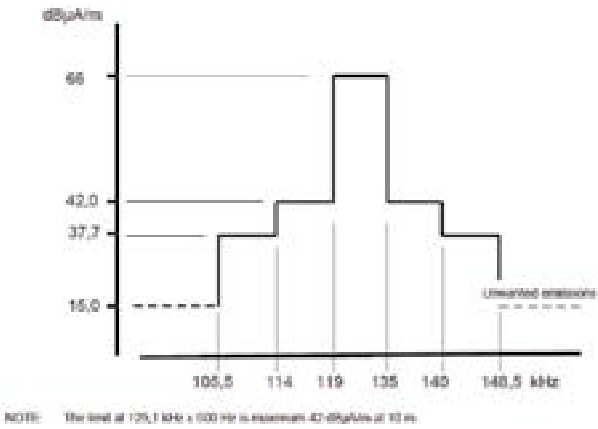

Figure 7: Excerpt from EN300330

EN300330 and others specify the maximum levels in the specific frequency range. Consequently, thanks to the frequency spreading feature, „uniWP“ can transmit higher power levels than all other wireless transmission solutions.

	Known arts	*uniWP*
Resonant frequency is not inside the allowed band	No power transfer	maximum power transfer, because of large signal VCO
Dynamic load and coupling condition	No power transfer	maximum power transfer, due to fast resonance tracking
Efficiency	Low	High, due to critical coupling
Power	A few watts	Up to 200W (1kW planned)
Area of application	Different for each region	Wordwide (frequency management sw.)
Range	Small range	Long range due to high quality factor
Number of receiver	One	Several
Coupling	Tight	Tight or loose
EMI performance	Low	High
Flexibility	No (standard)	High
Data transfer included	Yes	Yes
Cost	High, small tolerance components	Low, only standard components

Table 1: Comparison

Summary

The concept to transmit power over a wireless link according to „uniWP“ allows multiple new applications and features. The advantageously insensitive operation even in harsh and dynamic coupling environments allows the system to be operated at the maximum physical limit. The simple power scalability far outperforms existing solutions. The research activities driven by cost, reliability and practical constraints demonstrate uniWP is a good solution for future product implementations and is well suited for future evolution.

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www.uniwp.de

www.ib-rehm.de

MADMIX: The Standard for Measuring SMPS Inductors

Power inductors are the beating heart of Switched-Mode Power Supplies (SMPS). Accordingly, they are in charge of the actual power conversion. They have a major impact on the performance parameters of the SMPS, such as the efficiency, dynamic behavior, power density, form factor and EMC.

By Mike Wens and Jef Thone, MindCet

Despite their crucial role, inductors historically are poorly understood components. Lacking accurate models for commercial inductors and previously no available equipment to do the modeling, the SMPS designer was left in the dark. On the other side of the table, the inductor manufacturers were not able to easily and consistently measure their products under real-life operating conditions. Sporadic, and often painstaking, measurements in the customer's application brought some answers to performance questions, but not in a consistent and repeatable fashion.

Figure 1: Complete setup

The MADMIX Accurate Inductor Measurement System provides the power electronics industry the solution for these questions and issues. Real-life, hard-switched operating conditions are applied to the Inductor-Under-Test (IUT), whilst simultaneous performance measurements are done: AC-losses, Inductance, Saturation... Figure 1 shows the complete setup, fully controlled by software and with an optional thermostreamer to facilitate ambient temperature variation.

Power Inductor Measurement: HOW NOT TO DO IT

In a typical SMPS circuit, such as a buck, boost and class-D converter, the typical hard-switched voltage over the inductor and the resulting triangular current through the inductor determine the power losses and transient behavior, see figure 2. Needless to say these waveforms greatly determine and affect the overall SMPS efficiency and performance.

In contrast to these large-signal waveforms, conventional commercial inductor measurement equipment uses a small-signal approach. This is based on applying sinusoidal voltages and currents to the IUT to measure the inductance and to determine the equivalent winding resistance and capacitance. By applying a small-signal sinusoidal AC-voltage over the inductor, possibly combined with a DC-current offset, the core-losses are not measured to the right extent. The resulting small-signal model is not representative for use in the SMPS. Indeed, the SMPS designer using this model will end up with significantly larger power losses, resulting in reduced overall efficiency and performance, likely overheating the SMPS and potentially causing instability problems.

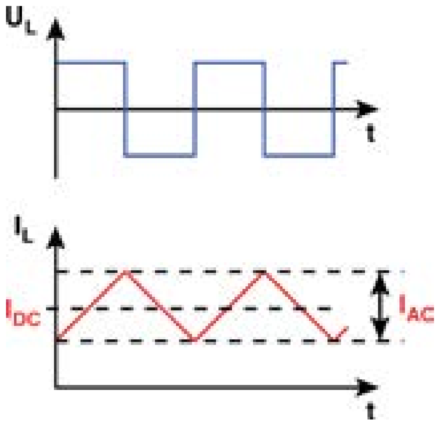

Figure 2: Hard-switched voltage over the inductor and the resulting triangular current

On the side of the estabished inductor manufacturers analytical models have been extensively used for many years. The modified Steinmetz equation (MSE), shown below, is probably the most known and used one for calculating core-loss.

$$P_v = K_0 \times f_e^{K_f-1} \times B_{pk}^{K_b} \times f_0$$

The inherent limitations of MSE are: the need for experimental measurement data of the core material, necessary knowledge on the unique geometry of the inductor and the fact that core saturation is not taken into account.

Power Inductor Measurement: HOW TO DO IT RIGHT

MinDCet has come up with a revolutionary way to mimic the typical SMPS inductor waveforms called MADMIX: "Method for Advanced DC-DC Convertor Design based on Macro-model Inductor Parameter Extraction". This patented approach essentially allows for applying real-life, hard-switched operation conditions. An in-house developed power amplifier using state-of-the-art GaN power stages and in-house developed high-speed pre-driver ICs (see figure 3) allow applying: variable frequencies (10kHz-10MHz), duty-cycles (10%-90%), voltages (1V-70V), current-ripples (0-60A) and DC-currents (0-50A) on the IUT in a software-controlled, fully-automated fashion.

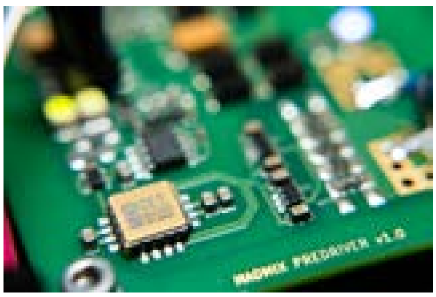

Figure 3: In-house developed power amplifier using state-of-the-art GaN power stages and in-house developed high-speed pre-driver ICs allow applying: variable frequencies

HOW DOES IT WORK?
In each measurement point, featuring the specified frequency, duty-cycle, voltage swing and DC-bias, the current and voltage through and over the IUT are measured in real-time. This key data allows for the calculation of the average inductance:

$$L = \frac{R_{LS} \cdot t_{on}}{ln\left[\frac{I_{min} \cdot R_{LS} - (U_{in} - U_{out})}{I_{max} \cdot R_{LS} - (U_{in} - U_{out})}\right]}$$

And the AC losses, which are distinguished from the DC losses, are calculated by means of:

$$P_{loss} = \frac{I_{max} - I_{min}}{2} \cdot f_{sw}\left[(U_{in} - U_{out}) \cdot t_{on} - U_{out} \cdot t_{off}\right]$$

Powerful Digital Signal Processing (DSP) in the MADMIX's software is used to post-process the raw measurement data. This effectively eliminates switching artefacts and other non-idealities that do not contribute to the actual power transfer in the IUT. To further improve accuracy, the actual AC losses are calculated by integrating IUT voltage and current over time. In certain operating conditions this leads to a maximal resolution of 1mW in the AC power loss measurement. The AC losses incorporate both winding and core losses, which are separated analytically using Fourier transformation. An example of the AC losses as a function of frequency and at fixed ripple current is shown in figure 4.

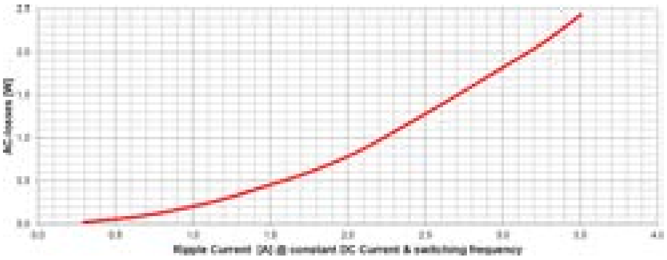

Figure 4: AC losses as a function of frequency and at fixed ripple current

All the losses and the inductance can be measured and explored in the entire operating region of the inductor (and even beyond that!). The result is a large-signal and full-inclusive model, which can be used in the simulation environment of choice.

THE FUNCTIONALITY
Fully-Automated Software: MADMIX loads the inductor-under-test with a combined DC-offset and triangular AC current, having variable amplitude, frequency and duty-cycle. The powerful software with graphical user interface, depicted in figure 5, behind the fully-automated measurement setup allows to automatically sweep one or more parameters for maximal user comfort.

Figure 5: graphical user interface

Saturation Detection and Measurement: The software automatically detects and flags even the slightest amount of core saturation. When it does the mean value of the “knee point” in the inductor current is given. In addition to the overall average inductance, two more values are displayed: the average inductance before and after saturation. Hence, a piecewise linear model can be derived that takes magnetic saturation into account.

Saturation curves: As shown in figure 6, the more common saturation curves vs DC-current bias can also be measured. The big difference with LCR-based measurements is the fact that the ripple added to the DC-bias is not a small-signal sine wave. The resulting curve will tend to show lower overall inductance and saturation kicking in faster. But in the end this is also what will happen in the application.

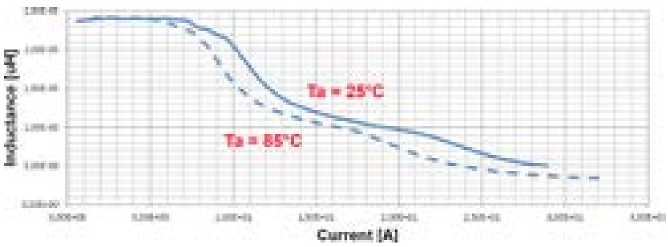

Figure 6: Common saturation curves vs DC-current bias

Coupled inductors measurement: The software features the measurement of coupled inductors by means of an open-short measurement of the secondary winding. As a result the large-signal coupling factor and the AC losses can be effectively measured. By doing so fly-back, forward, SEPIC… type converters and even wireless powering converters are supported.

Temperature Prediction: Seconds suffice to measure the core and DC losses in a certain operating point, with prediction of the steady-state temperature of the IUT. Even operating points that would normally destroy the DUT in steady-state operation can be measured, without being destructive. Definitely, with a maximal input power of 1600W destructive test are possible. This way the user immediately gets a feel if the part is still in a safe operating conditions and would not overheat during continuous use.

Temperature Control: Real-life operating conditions imply varying ambient temperatures, having an impact on the electrical parameters of the inductor, including the overall inductance, saturation and losses. To accommodate these measurements a thermo-streamer unit is used to vary the ambient temperature of the IUT in a matter of seconds.

THE ADDED VALUE

The MADMIX setup allows performing an accurate prediction of the efficiency and overall performance of SMPS designs, even before drawing a single transistor in an IC lay-out or before routing the SMPS PCB. This way the performance of various commercial inductors, and new inductor designs, can be determined beforehand. MADMIX provides a clear insight into the important trade-offs in SMPS design: cost-size-efficiency-performance. Furthermore, in some niche applications the right off-the-shelf inductor does not exist. In such case MADMIX allows to prototype inductors with specific form-factors, temperature ranges (eg. until 225°C!)…

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www.mindcet.com

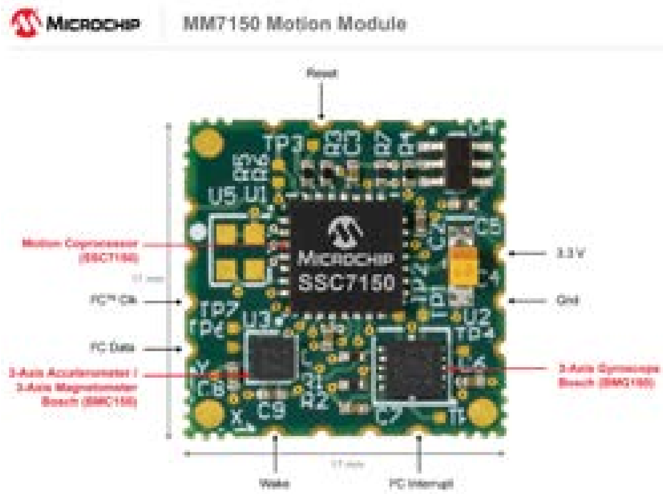
Next-Generation 8-Bit Microcontrollers for the IoT Age

Silicon Labs introduced the company's next-generation 8-bit MCU portfolio designed for today's ultra-low-power, small-footprint IoT applications. Silicon Labs' new EFM8 MCU family includes three lines of highly integrated, peripheral-rich MCUs optimized for exceptional price/performance value, ultra-low-power capacitive touch control and streamlined USB connectivity. The EFM8 MCUs bring industry-leading simplicity, power efficiency, performance and cost-saving integration to every 8-bit application that embedded developers can imagine including home and building automation, wearables, consumer electronics, toys, motor control and industrial IoT.
The EFM8 MCU family meets IoT developer needs with an unparalleled combination of features and capabilities including a high-speed pipelined 8051 core, ultra-low power, precision analog and enhanced communication peripherals, integrated oscillators, small-footprint packages, and an advanced crossbar architecture that enables flexible digital and analog multiplexing to simplify printed circuit board (PCB) design and I/O pin routing.
EFM8 Sleepy Bee: EFM8SB Sleepy Bee MCUs are Silicon Labs' most energy-friendly 8-bit devices offering industry-leading sleep mode power (50 nA with full memory retention and brown-out detection) and ultra-fast 2 µs wake-up time. Core speeds scale up to 25 MHz, and flash sizes range from 2-64 kB. The MCUs integrate a best-in-class capacitive sense controller offering an ultra-low-power < 1 µA wake-on-touch capability, eliminating the need for on/off switches in some products. These power-saving MCUs are ideal for touch-based, battery-powered IoT and industrial applications that require long battery lifetimes and energy-efficient human interfaces.

www.silabs.com

Motion Module Makes Motion Monitoring Easy

Microchip announces from the Embedded World 2015 Exhibition & conference in Germany the MM7150 Motion Module which combines Microchip's SSC7150 motion co-processor with 9-axis sensors, including accelerometer, magnetometer and gyroscope in a small, easy-to-use form factor. With a simple I2C™ connection to most MCUs/MPUs, embedded/IoT applications can easily tap into the module's advanced motion and position data.



The motion module contains Microchip's SSC7150 motion co-processor which is pre-programmed with sophisticated sensor fusion algorithms which intelligently filter, compensate and combine the raw sensor data to provide highly accurate position and orientation information. The small form factor module is self-calibrating during operation utilising data from the pre-populated sensors: the Bosch BMC150 6-axis digital compass; and the BMG160 3-axis gyroscope.
The MM7150 motion module is single-sided to be easily soldered down during the manufacturing process. Microchip makes it easy to develop motion applications for a variety of products using their MM7150 PICtail™ Plus Daughter Board. The MM7150 Motion Module is well suited for a wide range of embedded applications such as portable devices and robotics; industrial applications such as commercial trucks, industrial automation, patient tracking and smart farming; and consumer electronics such as the Internet of Things (IoT), remote controls, gaming devices, toys and wearable devices; among other applications.
The MM7150 is supported by the MM7150 PICtail™ Plus Daughter Board (AC243007) priced at $50.00, which plugs directly into Microchip's Explorer 16 Development Board (DM240001) priced at $129.99, to enable quick and easy prototyping utilising Microchip's extensive installed base of PIC® microcontrollers.
Microchip's MM7150 is available now in a 17 mm x 17 mm body.

http://www.microchip.com/MM7150-Page-022415a.

USB Type-C Implementation in Consumer and Industrial Devices

Lattice Semiconductor Corporation announced three, freely-downloadable reference designs that enable designers working in consumer, industrial and other sectors to quickly implement the cable detect and power delivery functions required to unlock the new capabilities of Type-C including 100W power, 20Gbps bandwidth, reversibility and flexibility.

"Leaders in this market will launch USB Type-C products by the middle of this year," said Gordon Hands, Director New Initiatives at Lattice. "We are providing ready-to-use, low power, miniature, cost-effective solutions that slash time-to-market and mitigate development risk."

The three solutions offered by Lattice address both Cable Detect (CD) and Power Delivery (PD) functions and deliver:

- CD/PD targeting chargers
- CD/PD for devices such as laptops, docks, dongles hand-held industrial
- CD/PD-Phy for devices such as smart phones and tablets

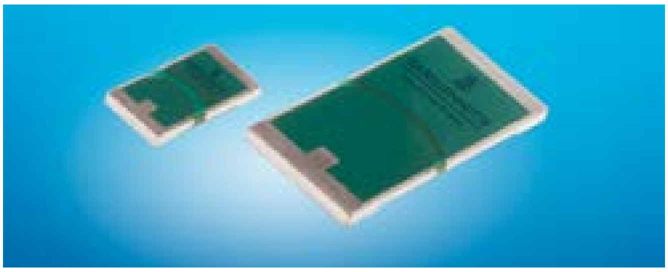
The downloadable reference designs include: Schematic; BOM; Pin-list; Bitstream; and Code to allow Policy Engine customization. The designs are based on Lattice's iCE40™ ultra-low power, miniature and low cost FPGA families.

The three USB Type C solutions can be freely-downloaded at: www.latticesemi.com/en/Solutions/Solutions/SolutionsDetails02/USBTypeCPowerDeliverySolution.aspx

www.latticesemi.com

High Stability CMx SMD Resistor Series

Isabellenhütte now also offers resistors for medium and lower performance requirements in the SMD-mountable precision and power resistor segment, closing a gap in its range. The existing SMx and VMx SMD series include resistors for high-end applications. The CMx series meets the market demand for reduced technical performance and is available in the standard sizes 2512, 2010 and 1206. The new resistors work in the temperature range from -65 to 170 °Celsius, making them suitable for both industrial applications and as components in vehicle applications. In the automotive sector, they comply with the AEC-Q200 specifications and fulfil the criteria of RoHS 2011/65/EU.



Low TCR across the entire range of temperatures

Despite their reduced resistance, the CMx resistors offer the same quality features as other Isabellenhütte resistors, such as high long-term stability, optimum temperature coefficients and high load capacity. The TCR of the entire range is below 75 ppm/K. "Unlike many other resistors in the lower performance range, our low temperature coefficient applies to the whole resistance range and load capacity is guaranteed, even when the temperature of the contact points is high," confirms Eugen Löwen, Application Management Sales Components at Isabellenhütte. Users also benefit from the long-term stability of Isabellenhütte's technology. Long-term stability after 2,000 hours of operation is excellent, with deviation of less than 1.0 per cent from the original values for all sizes. All three versions have a very high load capacity. The CMS has resistance of 10 to 500 mOhm at a nominal capacity of 2 watts. The CMP also has resistance of 10 to 500 mOhm with load capacity of 1 watt. The CMK offers resistance of 10 to 100 mOhm and a load capacity of 0.5 watts.

www.isabellenhuette.de

Motor Run Capacitors with Locking Terminals Speed Install

QPC Series AC Motor Run Capacitors are quicker to install and offer more durability and reliability. Exclusive locking push-wire contacts speed installation, eliminate soldering and save significant installation time, when compared to conventionally terminated devices. Just push and lock wire in place. Slide a probe tip into a release port to unlock. Metal mounting bracket also speeds assembly, as it can be mounted first. Standard values: 0.4 to 10µF; 250 to 450 VAC, 50/60Hz. The QPC also features small size, high available voltage and capacitance density.

QPC Series capacitors are recommended for original equipment manufacturer (OEM) AC motor applications. Several features help to reduce assembly time and cost. The exclusive locking push-wire contacts eliminate the need to solder connections and available multiple contacts eliminate the need for terminal strips. Removable slide-lock mounting brackets also speed assembly time, as the bracket can be mounted first.

Operating temperature range is from -25°C to +85°C. Very rugged, flame-retardant (UL94V-O) case. UL810, IEC 566-1982, CNS4327, JIS C4908 listed.

www.illcap.com

IXZ631 Series Integrated High Speed Gate Driver/MOSFET RF Modules

IXYS Corporation announced the introduction of its IXZ631 Series CMOS high-speed, high-current integrated gate driver and MOSFET modules by its IXYS Colorado division. The modules are specifically designed for Class D, E, HF and RF applications at up to 27 MHz, as well as other applications requiring high-speed, high-power switching.

The IXZ631 modules feature the IXRFD630 high speed gate driver paired with an RF power MOSFET, packaged in IXYSRF's DE-Series low-inductance surface mount RF package incorporating layout techniques to minimize stray lead inductance for optimum switching performance. Designed with small internal delays, the modules are suitable for high power operation where combiners are used. Their features and wide safety margin in operating voltage and power make the modules unmatched in performance and value.

Two devices are available, the IXZ631DF12N100 1,000 volt 12 ampere device and the 500 volt 18 ampere IXZ631DF18N50. Both modules produce voltage rise and fall times of less than 5 nanoseconds, and minimum pulse widths of 8 nanoseconds. In pulsed mode the 500 volt module provides up to 95 amperes of peak current; the 1,000 volt module provides 72 amperes.

http://www.ixyscolorado.com

125 °C, High Density, Stacked Polyester Capacitors

Cornell Dubilier announces availability of its Type RA multilayered polymer capacitors for 125°C operation. Type RA capacitors are constructed using stacked metallized polyester protected with an impregnated sealant, which eliminates the need for an external case. This package style offers the highest energy density technology available for switching power supplies, DC to DC converters and other high ripple current applications.

“These are excellent high performance filter capacitors in a very small size” says Bill Haddad, Product Manager at Cornell Dubilier Electronics. Type RA capacitors are impregnated with a microcrystalline polymer sealant and exterior tape wrap that protects the capacitor element from moisture, allowing it meet 85 °C/ 85% RH requirements for demanding applications in military vehicles and aerospace.

Available in capacitance values ranging from 0.1 µF to 10.0 µF, voltage ratings of 100, 250, 400 and 500 Vdc, Type RA capacitors are terminated with radial leads to cover a broad range of applications in power electronics where high density capacitors are needed for board-level DC filtering.

Cornell Dubilier RA capacitors series are available through our key franchised distributor sites for quick turnaround on prototype and preproduction quantities.

Since its founding in 1909, Cornell Dubilier has been dedicated to advancing capacitor technology for new applications. The company combines innovative products with engineering expertise to provide reliable solutions for inverters, wind and solar power, electric vehicles, power supplies, motor drives, HVAC, motors, welding, aerospace, medical equipment, telecom and UPS systems.

www.cde.com

PowerStor XL60 Series Supercapacitors Offer Long Life Storage

Eaton unveiled the PowerStor® XL60 Series supercapacitors with large format, high capacity cells to provide a wide operating range and one of the industry’s highest power densities compared to most products in the market. For kilowatt- and megawatt-size systems, the XL60 series is designed specifically to provide long life energy storage for applications in backup power, engine starting, energy capture and re-use, peak power shaving and pulse power.

Supercapacitors are gaining design momentum in transportation, heavy vehicles, uninterruptible power supply (UPS), grid storage, engine starting, lighting applications and other industrial applications for their high energy density, high reliability and long life.

The XL60 Series can be used in conjunction with batteries or as replacements for batteries to offload constant charge/discharge cycles, thereby extending life, increasing reliability and lowering replacement costs. With a low equivalent series resistance of 0.23 mohm for high power and a wide effective voltage range, the XL60 Series provides industry-leading aging characteristics and an industrial temperature range.

With a high capacitance of 3,000 farads (F), Eaton’s PowerStor XL60 Series is designed for high power, high energy applications such as hybrid busses, traction, construction,

mining and material handling. The extended operation temperature range of minus 40 degrees Celsius (C) to 85 degrees for the XL60 series meets industry safety requirements for systems in extreme climate conditions. Additionally, an operating life up to 20 years further enhances system reliability.

www.eaton.com


The perfect place
to do business

High-Isolation Linear Current Sensor IC with 850 Micro-Ohms Current Conductor

Allegro MicroSystems Europe has two current sensor ICs that offer economical high-isolation solutions for AC or DC current sensing in industrial, commercial and communications systems.

The ACS717 and ACS718 devices are offered in a small surface mount package that is ideal for space-constrained applications, although the width of the body provides the creepage and clearance distances needed to provide the high isolation.

Each device consists of a low-offset linear Hall sensor circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field which is sensed by the integrated Hall IC and converted into a proportional voltage. Device accuracy is optimised through the close proximity of the magnetic field to the Hall transducer.

A proportional voltage is provided by the low-offset chopper-stabilised BiCMOS Hall IC, which is programmed for optimum accuracy after packaging. The output of the device has a positive slope when an increasing current flows through the primary copper conduction path, which is the path used for current sensing. The internal resistance of this conductive path is typically 850 micro-ohms, providing a low power loss.

The terminals of the conductive path are electrically isolated from the sensor leads, allowing the ACS717 and ACS718 current sensor ICs to be used in high-side current sense applications without the use of isolated operational amplifiers or other costly isolation techniques.

Typical applications include motor control, load detection and management, switched-mode power supplies, and overcurrent fault protection.

Both devices are offered in a small low-profile surface mount SOICW16 package (suffix MA). The devices are lead (Pb) free with 100% matt tin leadframe plating, and are fully calibrated prior to shipment from the factory.

www.allegromicro.com

Technology to Protect Aircraft against Lightning Strikes

Raytheon UK is partnering on a project that would provide aircraft electronics and wiring with a more efficient device to protect against lightning strikes, which can damage sensitive equipment.

During electrical storms, lightning paths travel cloud-to-ground or cloud-to-cloud; sometimes aircraft in flight can form part of the path.

The outer skin of the aircraft, which is traditionally aluminium, does much to accommodate the lightning's path, and voltage 'surge suppression' devices are used to protect aircraft electronics.

The project - led by Controls and Data Services (part of the Rolls-Royce Group) and which also includes Newcastle University in the role of design authority and TT Electronics Semelab - is exploring the use of Raytheon's and Newcastle University's high temperature Silicon Carbide technology to make CLDs; a new kind of lightning protection device which stands to reduce the amount of electrical energy traditional suppressors have to deal with during a lightning strike.

Currently in phase one, Newcastle University is conducting electrical characterisation tests while TT Electronics Semelab develops the CLD packaging.

www.raytheon.co.uk/semiconductors

Advertising Index

Ultra-Low $R_{DS(on)}$ Automotive COOLiRFET™

Package	Voltage (V)	$R_{DS(on)}$ Max@ 10Vgs (mΩ)	Q_G Typ (nc)	I_D Max (A)	RthjC Max	Part Number
D²PAK-7P	40	0.75	305	240	0.40°C/W	AUIRFS8409-7P
		1.0	210	240	0.51°C/W	AUIRFS8408-7P
		1.3	150	240	0.65°C/W	AUIRFS8407-7P
D²PAK	40	1.2	300	195	0.40°C/W	AUIRFS8409
		1.6	216	195	0.51°C/W	AUIRFS8408
		1.8	150	195	0.65°C/W	AUIRFS8407
		2.3	107	120	0.92°C/W	AUIRFS8405
		3.3	62	120	1.52°C/W	AUIRFS8403
TO-262	40	1.2	300	195	0.40°C/W	AUIRFSL8409
		1.6	216	195	0.51°C/W	AUIRFSL8408
		1.8	150	195	0.65°C/W	AUIRFSL8407
		2.3	107	120	0.92°C/W	AUIRFSL8405
		3.3	62	120	1.52°C/W	AUIRFSL8403
TO-220	40	1.3	300	195	0.40 °C/W	AUIRFB8409
		2.0	150	195	0.65 °C/W	AUIRFB8407
		2.5	107	120	0.92 °C/W	AUIRFB8405
DPAK	40	1.98	103	100	0.92 °C/W	AUIRFR8405
		3.1	66	100	1.52 °C/W	AUIRFR8403
		4.25	42	100	1.90 °C/W	AUIRFR8401
IPAK	40	1.98	103	100	0.92 °C/W	AUIRFU8405
		3.1	66	100	1.52 °C/W	AUIRFU8403
		4.25	42	100	1.90 °C/W	AUIRFU8401
5x6 PQFN	40	3.3	65	95	1.60 °C/W	AUIRFN8403
		4.6	44	84	2.40 °C/W	AUIRFN8401
5x6 PQFN Dual	40	5.9	40	50	3.00 °C/W	AUIRFN8459
		10.0	22	43	4.40 °C/W	AUIRFN8458

The new International Rectifier AEC-Q101 qualified COOLiRFET™ technology sets a new benchmark with its ultra-low $R_{DS(on)}$. The advanced silicon trench technology has been developed specifically for the needs of automotive heavy load applications offering system level benefits as a result of superior $R_{DS(on)}$, robust avalanche performance and a wide range of packaging options.

The COOLiRFET™ Advantage:

- Benchmark $R_{DS(on)}$
- AEC Q101 qualified
- High current capability
- Robust avalanche capability

Key Applications:

- Electric power steering
- Battery switch
- Pumps
- Actuators
- Fans
- Heavy load applications

For more information call +49 (0) 6102 884 311
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