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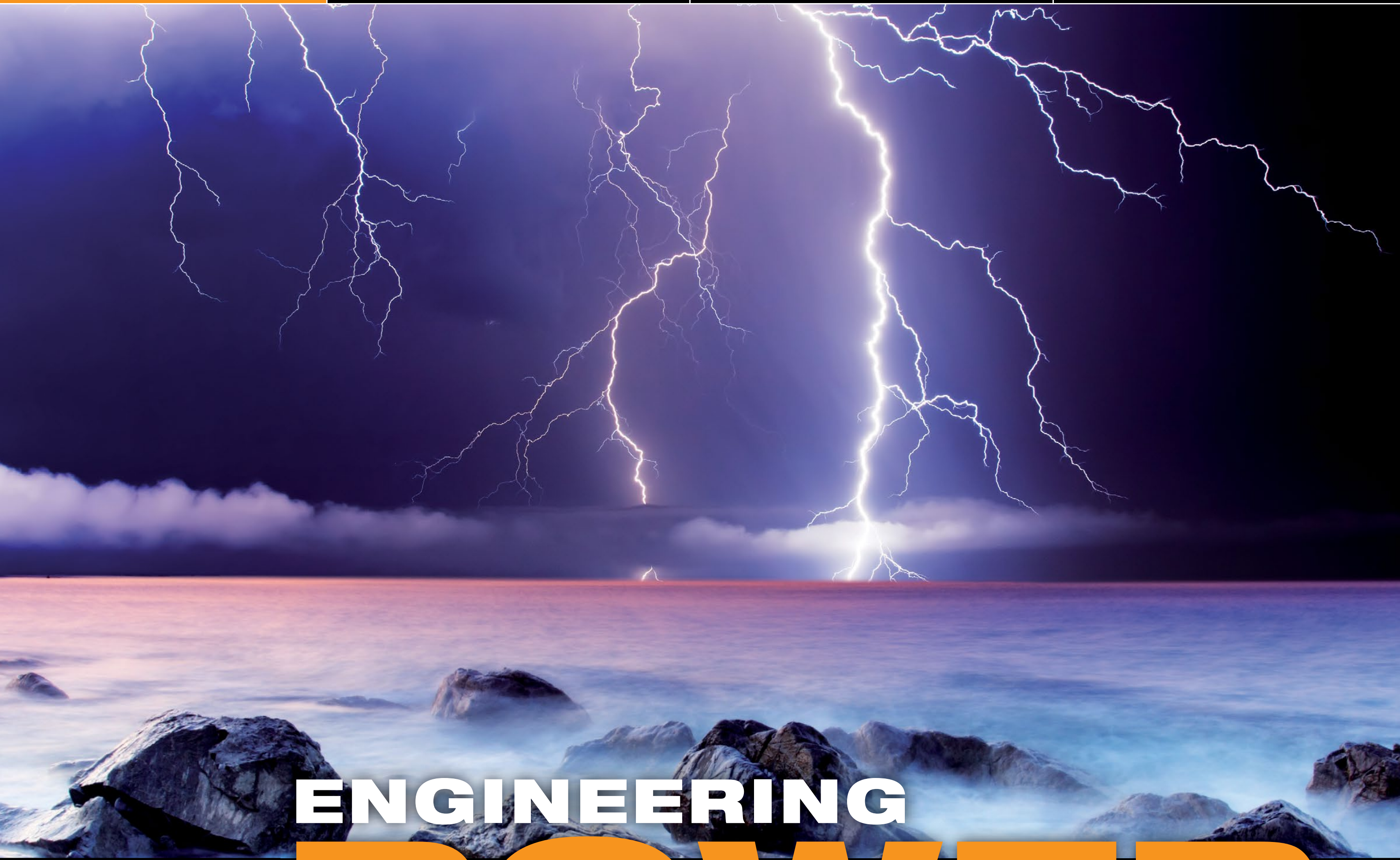
Bodo´s Power Systems®

Electronics in Motion and Conversion

January 2016



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GvA Power Electronics

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The Gallery

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Events

Embedded World 2016,
Nuremberg, Germany, February 23-25
http://www.embedded-world.de

EMC 2016,
Düsseldorf, Germany, February 23-25
http://www.mesago.de/en/EMV/home.htm

CIPS 2016
Nuremberg Germany, March 8-10
https://conference.vde.com/cips/2016/Pages/welcome.aspx

smartsystemsintegration
Munich Germany, March 9-10
http://www.smartsystemsintegration.com

APEC 2016, Long Beach, CA,
March 16-20 http://www.apec-conf.org/

New Energy Husum 2016,
Husum Germany, March 17-20
http://www.new-energy.de/new_energy/de/

battery university 2016,
Aschaffenburg, Germany,
http://www.batteryuniversity.eu

Happy New Year – We Hope for One

I wish a peaceful year for the world, without conflict or terrorism. We must strive to avoid war. Although most of us are too young to have seen it ourselves, we can learn from history all that war means and see the effects in today's news.

Some other disasters are manmade - global warming is well documented by the melting of glaciers in the artic regions. Industrialization must become neutral to the environment. That is a great engineering challenge. Renewable energy is indeed moving forward - wind power, solar power and water power contribute a strong portion of our energy use, particularly in Germany.

Why are some people still pushing for nuclear energy sources? Would they like to live in Fukushima ? When I was a young Engineer I was shocked by Chernobyl. Must we learn the hard way to understand what these events tell us ? The promise of nuclear power was for a safe and non-polluting technology. Two major disasters and a host of contaminated sites show the promise to be false. Still organizations push for nuclear power, and some politicians grasp for the bauble.

What can we do as engineers? What better than technical solutions to reduce consumption of energy and the losses in projects we control. Wide bandgap semiconductors pave the way to higher efficiency, as they progress beyond specialized applications towards all kinds of commercial use. In addition to reduced losses, heat sinks are smaller, and passive components can shrink with operation at higher frequency.

The year will start with important conferences that highlight the technology of the better world we need to pass on to our kids. The first important meeting is APEC in Long

Beach California, in March. In May we all will be back in Nuremberg for the PCIM Europe conference. And in 2016 we have electronica again. There are many events during the year – all learning opportunities. All of these are listed on my web-site. The most important ones for me are in the editorial planner at: http://www.bodospower.com/pdf/bodos_editorialplanner.pdf

This is the first issue for the new year. All technical articles are archived on my website and are also 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.bodoschina.com**

My Green Power Tip for January:
Turn the heat down 1 degree in your house - if you feel cold, get your sweater on.
If you need to cool the house, wear light clothing and put the setting up 1 degree. You yourself can contribute to the world climate change target of less than 2 Degrees.

Let us work hard to have a Happy New Year

Bodo

High Interest in the Training Program and the 16 Presentations

The 9th Developer Forum Battery Technologies – November 3-4, 2015 at Lindner Park-Hotel Hagenbeck in Hamburg, Germany – organized by Batteryuniversity, was fully booked within a very short period of time. The 110 participants showed great interest in the 16 presentations, during which high-caliber experts gave reports, about trends and development potential in the area of lithium-ion batteries, optimal utilization of capacity through intelligent battery management and possibilities to reduce costs with contactless energy transfer. The half-day basic training seminars on the topics of 'lithium-ion battery technologies' and 'charging devices' were also hugely popular.

Dr. Jochen Mähliß expects a similar high level of participation at the 10th Developer Forum Battery Technologies to be held April 5-7, 2016 in Aschaffenburg. In future, it is planned to not only offer events for interested parties from the north of Germany, but also similar local events for neighboring countries such as, for example, Poland. "In recent years, we have noticed a strong and growing interest in innovative storage technologies, especially from developers in Poland. We have therefore, for the first time, decided to also offer this ever increasingly larger number of people a three-day Developer Forum in the Education and Congress Center of the Silesian University of Technology in Gliwice, Poland. This will take place relatively close to the event held in Aschaffenburg," said Dr. Jochen Mähliß. He explained that Batteryuniversity had been able to gain BMZ GmbH – Europe's leading systems supplier of rechargeable batteries, located in Karlstein, Germany – as partner for the planning and organization of the congress and accompanying exhibition to be held June 28-30, 2016. BMZ GmbH's manufacturing facilities in Poland are among the largest and most modern battery facilities in Europe.

www.batteryuniversity.eu

Now with a Design & Application Centre

Würth Elektronik eiSos, manufacturer of electronic and electromechanical components, is increasing its presence on the Spanish market with the opening of the new Design & Application Centre in Barcelona.
The establishment of the new branch in the Catalonian capital will also make it possible to devote more effort to the development of

customer-specific solutions and applications. Competence and resources for personal support in the areas of product management and application development are also being reinforced.
With its excellently equipped laboratory, the centre will not only enhance the current cooperation programme with the University of Valencia, but also further intensify the collaboration projects with cooperation partners and research institutes throughout Catalonia.
With the opening of the Design & Application Centre (on 24 November 2015), Würth Elektronik eiSos is creating a great number of jobs for engineers and software developers in Barcelona. The focus of the activities of the people employed there will lie on the development of software for design tools and cross-platform apps and also of particularly energy-efficient and electromagnetically compatible power inductors, together with innovative areas of application.

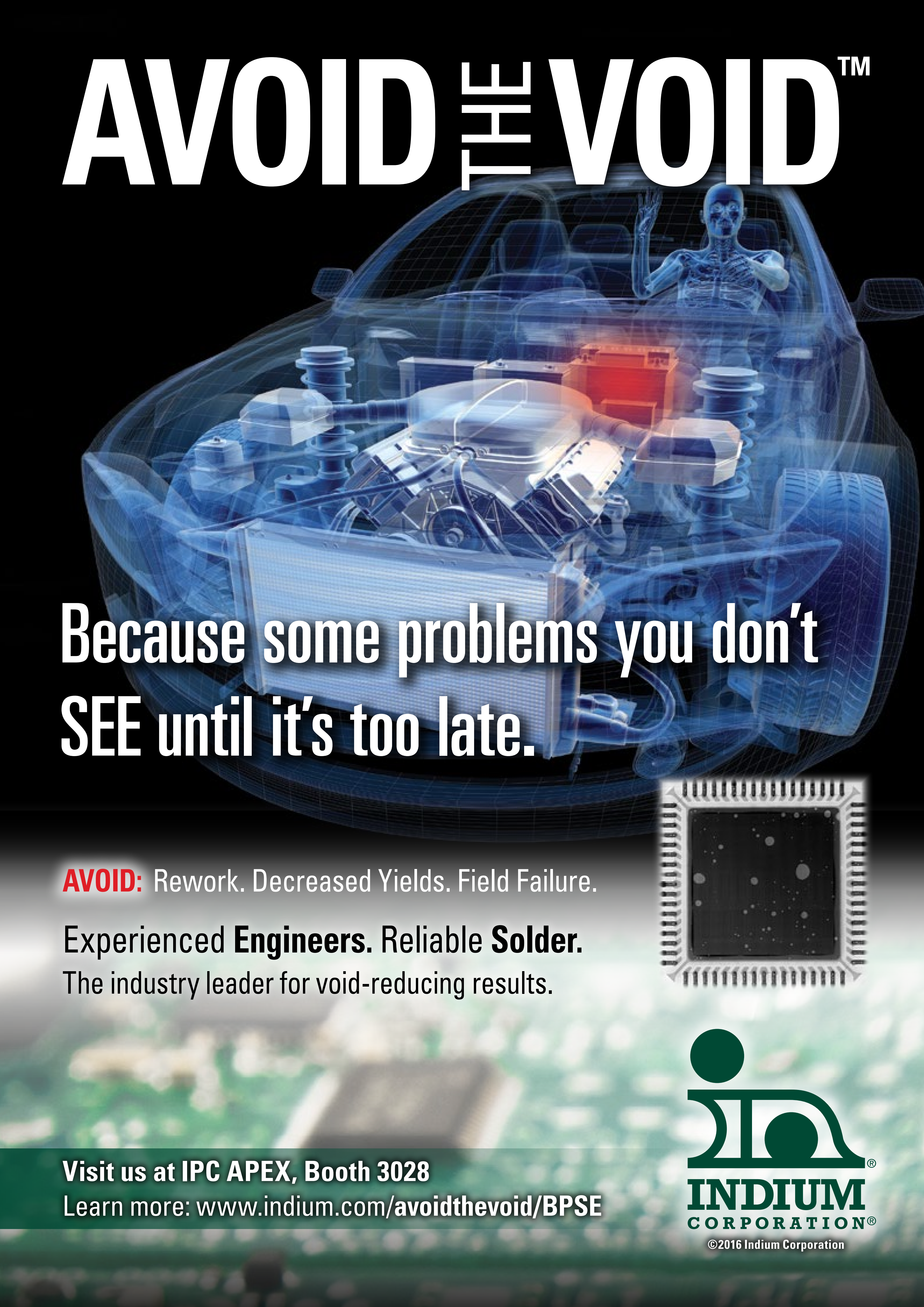
www.we-online.com

Nick Cataldo Joins Efficient Power Conversion as Senior VP of Global Sales and Marketing

To support its accelerating growth, Efficient Power Conversion Corporation (EPC) is proud to announce that Nick Cataldo has joined the EPC leadership team as senior vice president of global sales and marketing. Mr. Cataldo has over 35 years of marketing and sales operation experience within the semiconductor industry. His primary responsibilities at EPC are creating and implementing sales and marketing strategies to achieve the company's global sales objectives.
"Nick Cataldo has extensive experience in leading edge power semiconductors as well as recent experience in new materials that are edging out the incumbent silicon," said Alex Lidow, CEO and co-founder of EPC.

Mr. Cataldo joins EPC from United Silicon Carbide where he was vice president of global sales. Previously Cataldo had senior sales and marketing leadership positions at International Rectifier and Semtech. "I am very excited to have the opportunity to work with the extremely talented EPC technical team that is revolutionizing the power conversion industry with leading edge gallium nitride FETs and integrated circuits. This is the first time in 60 years that there is a technology that is both higher performance and lower cost to manufacture than silicon. It's a dream-come-true for sales and marketing," commented Cataldo.

www.epc-co.com


AVOID THE VOID™
Because some problems you don't SEE until it's too late.
AVOID: Rework. Decreased Yields. Field Failure.
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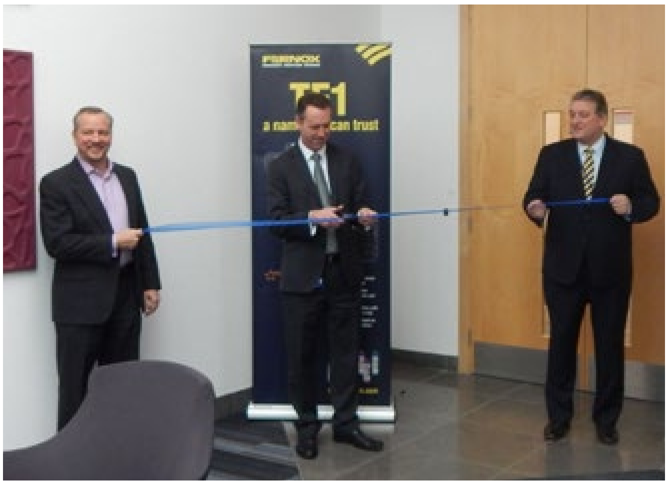
Alpha's European Headquarters Moves to New Woking Office



Alpha Assembly Solutions the world leader in the production of electronic soldering materials opened its new European Headquarters in Woking, United Kingdom on the 16th November. The location is shared with Fernox, a water treatment company and affiliate.
The new Woking office was officially opened at a ribbon cutting ceremony led by Bruce Moloznik, Alpha's Regional Vice President for Alpha and Ernie McDonald, Fernox's Managing Director. Both Fernox and Alpha will continue to operate their European Headquarters from the new Woking site.
"The move signifies an exciting new chapter for Alpha Europe as we move forward into 2016", comments Bruce Moloznik. "The site is a vast improvement to our old office building, providing a modern and exciting new environment for the Alpha team to work in".

www.alpha.alent.com

Leti to Collaborate with Keysight Technologies

CEA-Leti announced it has signed an agreement with Keysight Technologies, the industry-leading device-modeling software supplier, to adapt Leti's UTSOI extraction flow methodology within Keysight's device modeling solutions for high-volume SPICE model generation. The simulation of the Leti-UTSOI compact model, which is the first complete compact model dedicated to Ultra-Thin Body and Box and Independent Double Gate MOSFETs, is currently available in Keysight's modeling and simulation tools. This agreement expands the collaboration to include the extraction flow and will enable device-modeling engineers to efficiently create Leti-UTSOI model cards for use in Process Design Kits (PDKs).

www.leti.fr

APEC is Back to Long Beach California

APEC 2016 promises to be the largest APEC event ever. The site of APEC 2016 will be the popular Long Beach Convention Center. Attendance at APEC 2016 in March, 20th to 24th is projected to exceed 4,500 – about a ten percent increase from APEC 2015.
The technical program has been expanded to nine concurrent lecture tracks (up from seven in 2015). A record-breaking 1,211 paper digests were submitted. Of these, about fifty percent were selected for the program (351 lectures and 261 poster sessions). In addition to the traditional tracks (ac-dc, dc-dc converters, motor drives, etc.), there has been a significant increase in coverage of emerging topics including transportation electronics, renewable energy systems, micro-grid and others. The number of Industry Sessions has also increased going from three tracks to four with over 80 presentations.
The Plenary Session is shaping up to be a truly can't miss event. Presentations from Google and Tesla are among the companies in the preliminary line-up.

www.apec

Alpha Shines at LED A.R.T. Symposium in Atlanta

Somerset, NJ – December 1st, 2015 – Alpha, the world leader in the production of electronic soldering and bonding materials, had a strong presence at the first annual LED Assembly, Reliability, Testing Symposium organized by SMTA that was recently held in Atlanta, Georgia. Alpha was an integral part of the program as an organizer, exhibitor and presenter.
Dr. Robert Karlicek, LED industry luminary and Director of RPI's Smart Lighting Engineering Research Center, presented a Keynote address titled "Emerging Trends in LED Packaging, Applications and Systems" in which he reviewed cutting edge trends in the LED industry.
In his keynote address, Kurt-Juergen Lang, LED Key Expert at Osram Opto Semiconductors presented "Reliability for LEDs and LED Lighting Systems," where-in he covered the basics of LED reliability, assembly process impacts on reliability and reliability requirements for key end uses. He also presented the results of a joint study between Osram Opto Semiconductors and Alpha, which studied the impact of solder alloy selection on LED assembly reliability.
Amit Patel, Project Manager, Engineer – LED for Alpha, presented his paper, Characterization and Optimization of Board Warpage for Linear LED Lighting Assemblies. His presentation focused on board warpage issues faced by manufacturers of LED T-8 tubes and ways of overcoming these issues.
"The information provided during the LED A.R.T. Symposium helped to bridge the gap between LED device physics and the architectural design level issues in LED supply chain," said Ravi Bhatkal, Vice President, Energy Technologies at Alpha.

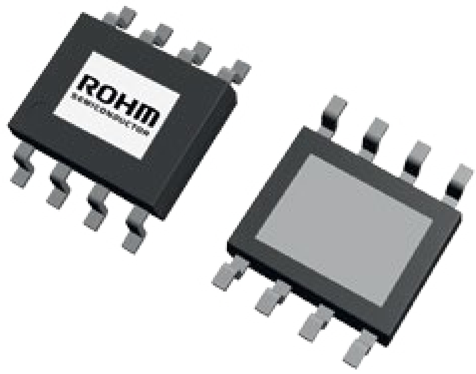
www.alpha.alent.com

80V DC/DC CONVERTER IC

- High Voltage
- High Reliability
- Ultra-High Efficiency

ROHM is announcing the availability of BD9G341, a 12 to 76V input, 3A variable output voltage, DC/DC Buck converter IC with integrated 80V MOSFET.

BD9G341 Benefits



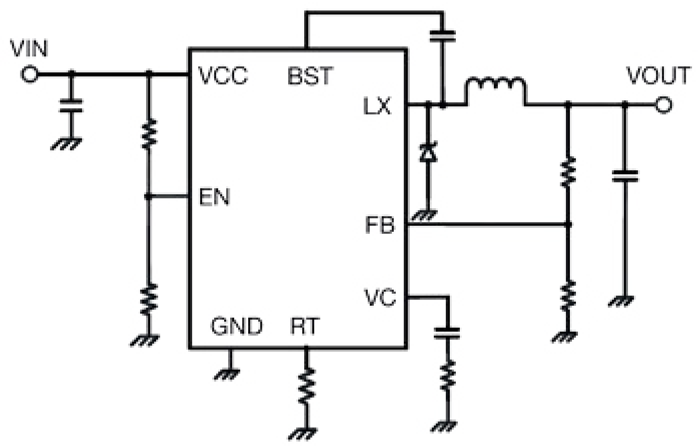
- Wide input voltage range, 12V to 76V (80V max.)
- High efficiency under light and heavy load conditions
- Achieving high response load by optimizing current control
- High-precision EN pin threshold makes possible to set up low voltage lockout and the hysteresis with an external resistor

BD9G341 Features

- Input voltage range: 12V to 76V
- Output voltage range: 1.0V to VCC V
- Reference voltage: 1.0V±1.5%(25°C)
  ±2.0 %(-40°C to 85°C)
- Operating frequency: 50 to 750kHz (typ.)
- Maximum output current: 3.0A
- Operating temperature range: -40°C to 85°C
- EN pin threshold : ±3%
- Soft start function
- Thermal shut down (TSD) function
- Over current protection (OCP) function
- Under voltage low output (UVLO) function

Number of external parts: **12**

IC size: **29.9mm²** (8pin)



IDT Completes Acquisition of ZMDI

Integrated Device Technology, Inc.® completed the acquisition of privately held ZMDI (Zentrum Mikroelektronik Dresden AG) for $307 million. Announced six weeks ago, the acquisition brings to IDT a highly regarded automotive and industrial business, as well as high-performance programmable power devices and signal conditioning solutions.

"IDT has gained an extraordinarily talented team and intellectual property that will help fuel our growth as we continue to outpace the semiconductor industry at large," said IDT President and CEO Greg Waters. "In addition to increasing our technology portfolio, we gain a very complementary customer base that significantly extends our future ability to provide integrated system-level semiconductor solutions."

ZMDI's strength in the automotive and industrial segments provides IDT immediate design-in leverage for wireless charging, power management, and timing and signal conditioning. ZMDI's high-power programmable power devices complement IDT's existing low- and medium-power devices, creating a new industry franchise for high-performance, scalable power management solutions ideal for everything from solid state drives to data centers and 4G/5G base stations.

www.IDT.com

Partnership FTCAP and Richardson Electronics

FTCAP has entered into a global sales partnership with the US company Richardson Electronics, Ltd. As a result, FTCAP capacitors are now available to an even larger range of customers.

The partnership with Richardson Electronics, Ltd., a worldwide leading supplier of electronic devices, power electronics, as well as RF and microwave components, is a major opportunity for FTCAP. "FTCAP is an established and reliable manufacturer of capacitors which among others is characterized by a distinctive innovative spirit.

The partnership will allow us to meet the requirements of our customers even better in the future," says Greg Peloquin, Executive Vice President of Richardson Electronics' Power & Microwave Technologies Group.

Dr. Thomas Ebel, Managing Director of FTCAP, is likewise pleased about the new partnership: "The global network of Richardson Electronics will make our technologies, products and services available to an even larger range of customers."

www.ftcap.de

PEMD 2016 Conference Programme Announced

Join over 400 power electronics, machines and drives specialists at one of the biggest power electronics conferences in the UK– Power Electronics, Machines and Drives. PEMD 2016 will be attended by both industry and academia and attracts some of the most prominent industry names to our conference exhibition.

The programme spans 3 full days with 5 different conference streams. You will hear over 200 oral presentations and over 100 poster presentations – this year's conference programme is bigger and better than ever offering high quality, peer reviewed papers in all aspects of power electronics, machines and drives.

Conference sessions include:

- Aerospace and marine machines
- Converters for grid connection and power distribution
- Electric fuel cell / hybrid vehicles
- HVDC and converters
- Machine drive control
- Multi-level converters
- Permanent magnet machines
- Solar PV, tidal, wave, sea, river and hydro power systems

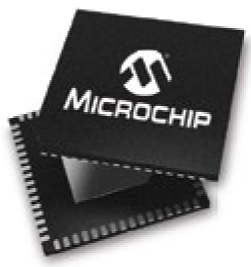
PEMD 2016 takes place in Glasgow on 19-21 April 2016. See the full programme and register your place at

www.theiet.org/pemd

Do you need Digital Power with next-generation capabilities?

New dsPIC® DSCs set benchmarks for size, latency and power consumption

Enabling sophisticated control algorithms operating at higher switching frequencies and Live Update Flash, Microchip's 16-bit dsPIC33EP "GS" Digital Signal Controllers offer next-generation digital-power performance.



These DSCs consume up to 80% less power in any application and provide less than half the latency of the previous generation when used in a three-pole three-zero compensator.

In addition to exceptional performance for non-linear, predictive and adaptive control algorithms, the DSPIC33EP "GS" family offers higher integration and more features in packages which include the industry's smallest digital-power-optimised DSC, 4 x 4 mm UQFN.

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www.microchipdirect.com

MICROCHIP

www.microchip.com/get/eudspic33ep

High Voltage Diodes for Automotive and High Temperature Applications – HVA Series

Dean Technology, Inc. announced the newest addition to is discrete axial lead high voltage diode line, the HVA series. This series of axial lead silicon rectifiers was designed specifically to withstand high operating temperatures, making it ideal for many specialty applications, including automotive uses.

The HVA series currently includes two voltage ratings, 3,000 and 5,000 volts, along with a relatively high maximum forward current for it's very small package size. Both offer a maximum junction temperature of 175 degrees Celsius and standard recovery as well as low maximum forward voltage drops.

"There are not enough manufacturers focusing on improving high voltage parts for higher temperature uses", said Ahmet Kilinc, Managing Partner of HVP High Voltage Products GmbH, a specialty distributer of high voltage components and systems in Europe. "It is a real help for us be closely partnered with Dean Technology, and able to work with them in the design of a new series of parts that meets the immediate needs of an important customer, as well as many potential others. We are excited about these new high temperature diodes."

While the HVA series is currently available in two voltage ratings, Dean Technology is committed to expanding the offerings. Custom high temperature diodes can be offered in short term, and future design work is already planned for adding to the standard HVA series. As the demands of high voltage customers continue to require more demanding features, Dean Technology is committed to working to meet those needs.

The HVA series parts are in stock and immediately available directly from Dean Technology, or through any approved sales partner or distributor.

About Dean Technology, Inc.

Dean Technology, Inc. (www.deantechnology.com) specializes in the manufacture, distribution and support of high voltage components, assemblies and power supplies. Its three main product lines include HV Component Associates (HVCA), CKE, and High Voltage Power Solutions (HVPSI). The HVCA line of products centers on high voltage diodes, rectifiers, bridge rectifiers, ceramic disk capacitors, and custom assemblies for specific applications. CKE products are a leading line of high voltage and high power silicon rectifiers, MOVs, selenium suppressors, silicon carbide varistors, as well as custom assemblies. The HVPSI product line includes high voltage power supplies, multipliers and test equipment. Dean Technology's full family of products provides complete coverage of high voltage and high current solutions for any application. For sales and technical information Dean Technology can be reached at +1.972.248.7691.

www.deantechnology.com

Six for SiC - or is it too soon?

By Roger Kinnear, Wafer Fab Manager, Semiconductors, Raytheon UK

There is much discussion within the industry regarding when is the best time to switch from 4 to 6-inch wafers for the fabrication of Silicon Carbide (SiC) power semiconductor devices. Let me declare upfront that at Raytheon UK's Glenrothes plant we are currently processing 4-inch wafers – Si and SiC - but that is not to say that 6-inch is not on our roadmap.

The production of SiC semiconductors is expected to follow a similar path to Si during the 1970s and 1980s, when demand drove suppliers to continually reduce their per-chip manufacturing costs. Switching from 4- to 6-inch proved a practical means of delivering economy-of-scale, as about twice as many die per wafer can be realised.

However, the drivers for SiC are somewhat different. It is a more enabling semiconductor material; being a wide band gap material, its physical properties allow for high switching speeds, lower losses, high breakdown voltage and an ability to operate at high temperatures. Accordingly, there is an increasing acceptance of the benefits of SiC within a variety of sectors including power transmission, traction and factory automation. Moreover, there are undoubtedly applications – ways of further exploiting SiC's electrical and thermal properties – that no-one has even thought of yet.

Compared to its Si counterparts, SiC power semiconductors are seemingly far more application-specific. For instance, about a year ago Raytheon was selected by a leading automotive manufacturer to fabricate a bespoke ISO/TS 16949 compliant 650V/60A SiC MOSFET for hybrid-electric and plug-in hybrid electric vehicles.

The question therefore is: bar for a few 'generic' power semiconductors, will SiC devices ever need to be made in very high volumes?

Today, in addition to the base material cost of processing being higher for SiC, the cost of a 6-inch wafer including its epitaxial layer is considerably higher than for a 4-inch one. It is generally considered that the wafer price ratio needs to be 2.25:1 (6-inch:4-inch) to make full use of any cost benefits. Currently it is 3.4:1. Granted, the gap will close, but at a rate governed by demand, which itself will be a function of wafer quality, reliability and market adoption.

Also, the quality of the substrate must be significantly improved in order to fully realise the die-per-wafer increase. Leading substrate suppliers are typically quoting 90% usable die for 6-inch SiC wafers versus 98% for 4-inch.

Usable area aside, there's also the issue of the quality of the devices being fabricated. Since most devices tend to be vertically integrated, wafer thickness must be consistent - which presents some additional concerns for the fabrication tools. Any bow or warp in the 6-inch wafer could lead to manufacturing challenges on 6-inch tools; and the doping variation of a 6-inch wafer is double that of a 4-inch wafer - and this parameter is very critical to device performance and therefore yield.
The adoption of SiC devices into systems will not just be governed by die cost and reliability though. Packaging is important too, particularly if one is to take advantage of SiC's high breakdown voltage and its ability to operate at high temperatures. The packaging issues are far more challenging than they ever were for Si.

For prototype work, including multi-project wafers (MPWs) and low to medium volume runs of up to 10,000 wafers, 4-inch is currently the most cost-effective; noting that the semiconductor industry considers most power applications to be low volume compared to Si products. Or, to put it another way, true economy-of-scale will come from runs of 10,000 wafers and above, and at 100s of die per wafer you're looking for markets in need of millions of devices. For high voltage applications - in grid or rail, for example - the demand may never be high enough to realise such economy-of-scale benefits.

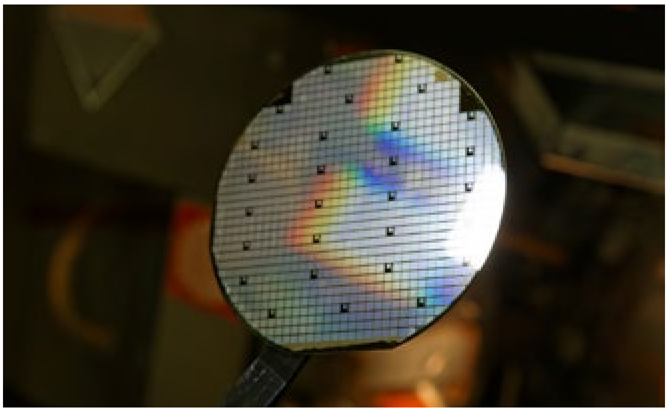

Figure 1: The adoption of SiC devices into systems will be governed by a variety factors, including wafer quality and cost, but demand will be the main driving factor for switching from 4- to 6-inch wafers.

As mentioned, costs will come down. Accordingly, so too will the quantities required to hit true economy-of-scale. That 6-inch wafer processing is on the way is therefore a given, and a number of 6-inch Si fabs are being purchased in readiness for 6-inch SiC processing. Indeed, it's possible that 6-inch Si only processing may all but disappear.

However, foundry qualification is costly and takes a great deal of time, particularly if a facility's processes also need to comply with sector-specific standards (such as the aforementioned ISO/TS 16949 for automotive). Recruiting engineers with the appropriate processing skills and experiences takes time too.

At Raytheon UK in Glenrothes, Scotland, we have over 12 years' experience processing SiC. Moreover, we are the longest established independent full-scale production-qualified facility in Europe - if not the world - capable of 4-inch SiC wafer processing. We also have over 50 years' experience fabricating Si devices.

We use most of our processing tools for both Si and SiC device fabrication; where such dual utilisation is recognised as a means of reducing the cost of SiC devices. We have market-leading SiC materials knowledge, practical device processing experience and an approach to sustained production and yield improvement that position us very nicely in the market.

Our thoughts on 6-inch? We have the expertise, resources and knowledge to transition to a larger wafer size at the appropriate time. But we're not rushing. Not when we're able to support our customers capture their markets with reliable devices fabricated on high-yielding 4-inch wafers.

http://www.raytheon.co.uk

About the author

Roger Kinnear is Raytheon UK's Silicon Carbide Wafer Fab Manager. He has more than 30 years' experience in semiconductor manufacturing and for the past five years has been focused on cost management, process development and yield improvement for all of Raytheon's SiC new business developments.

Innovative Building Technologies for the Smart Grid

By Dr. Francisco Gonzalez-Espin, Discipline Leader, Power Electronics United Technologies Research Centre Ireland, Limited

In 1931, Thomas Edison mentioned during a conversation with Henry Ford and Harvey Firestone one of the key issues of modern society lies in facing the depletion of conventional energy sources: "We are like tenant farmers chopping down the fence around our house for fuel when we should be using Nature's inexhaustible sources of energy — sun, wind and tide. I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait until oil and coal run out before we tackle that."

Despite Edison's visionary and inspiring statement and the increasing societal concern with reducing our dependency on coal and gas, the total renewables capacity worldwide reported by the U.S. Energy Information Administration (EIA) was less than 30 percent in 2012, with more than half of that coming from hydroelectric power. Solar, tide, wave and wind represented just seven percent of the energy mix at that time, and the further increase of these renewable – but highly unpredictable and uncontrollable energy sources – still requires innovative thinking and technology breakthroughs to support the design, operation and metering of the electrical power grid of the future.

The 30 percent renewables limit has been recognized as the threshold at which grid operators can assure system stability, even in the presence of the unpredictable nature of wind and sun energy sources. Beyond this limit, meeting the real-time balance between energy generation and consumption is challenging, and often requires significant capital expenditures to offer enough system flexibility to cope with sudden power generation shortfalls or excesses… at least if the conventional generation-follow-demand concept is applied. However, in order to increase the penetration of renewables in the energy grid without losing controllability, grid operators might find it easier to control electricity demand while moving toward a demand-follow-generation approach.

The Smart Grid is intended to facilitate the transition to this new paradigm through the extensive use of communications and ubiquitous real-time acquisition and control signals in the electrical power system. As the largest energy demand-side actor, buildings play a key role as one of the basic building blocks in this complex puzzle. In addition, energy directives related to nearly zero-energy and even net zero-energy buildings require buildings to reduce energy consumption, increase self-sufficiency, improve intelligence (i.e. interacting with the ecosystem), and increase flexibility.

In this scenario, building operators would be required to equip building infrastructure with the technology to communicate automatically and securely with utility suppliers in order to reduce energy demand during critical periods – and offer tenants voluntary and automated reductions and re-scheduling options through time-of-day-pricing or event dispatching.

As the world's largest provider of integrated and intelligent building technologies, United Technologies Corp. offers such technologies today through our elevator, escalator, fire safety, security, building automation, heating, ventilating, air-conditioning and refrigeration systems and services – all designed to promote integrated, high-performance buildings that are safer, smarter and sustainable. These technologies provide innovative building-management solutions for increased building energy demand flexibility.

For example, Automated Logic Corp., a UTC brand specializing in innovative building management solutions, provides an open automated demand response (ADR) add-on for the provision of ADR services for increased flexibility in building energy demand. This application provides a standard way for utility suppliers to automatically and securely communicate with customers' building automation systems to reduce energy demand during critical periods.

Further, new generations of Otis elevators, manufactured by Otis Elevator Company, another UTC company, use regenerative drives in place of conventional non-regenerative drives. In a typical non-regenerative drive, energy is dissipated as heat in a set of resistors when braking occurs, resulting in reduced efficiency and creating additional waste-heat loads in the building. The Otis ReGen™ drive feeds this energy back into the building's internal electrical utility where it can be used by other loads or users connected to the same network. Electrical power is generated when the elevator travels up with a light load, travels down with a heavy load and during the elevator system's deceleration. In this way, building owners can save up to 75 percent of energy consumption compared to conventional systems.

Now, what if those same elevators easily connected to building-based solar power — like the Otis Gen2® Switch elevator released in Europe recently? The result would be 100 percent savings in electricity costs. That technology is also currently available from UTC.

To summarize: the radical revolution in electricity generation, transmission, distribution and consumption is significantly increasing the demand for innovative intelligent buildings technologies able to integrate buildings into the smart grid. With a final goal of transitioning toward a more sustainable energy model, buildings are expected to play a key role by offering the required flexibility, while providing new business opportunities for technology providers and energy consumers.

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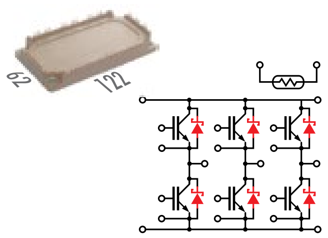
Hybrid IGBT Modules

Si-IGBT with SiC-Schottky diode

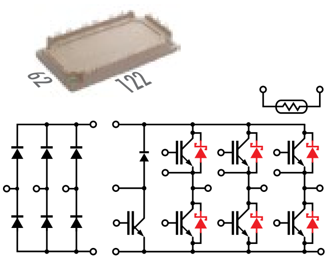
- Higher efficiency
- Higher output current
- Suitable for high switching frequencies
- Significant lower reverse recovery and turn-on losses

6-Pack



I_c	600 V	1200 V
100A		●

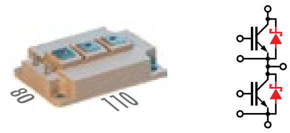
PIM



I_c	600 V	1200 V
35A		●
50A	●	●
75A	●	
100A	●	

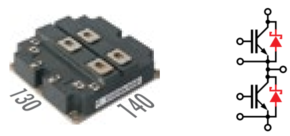
2-Pack

I_c	1200 V	1700 V
200A	●	
300A	●	
450A	●	



I_c	1200 V	1700 V
400A		●

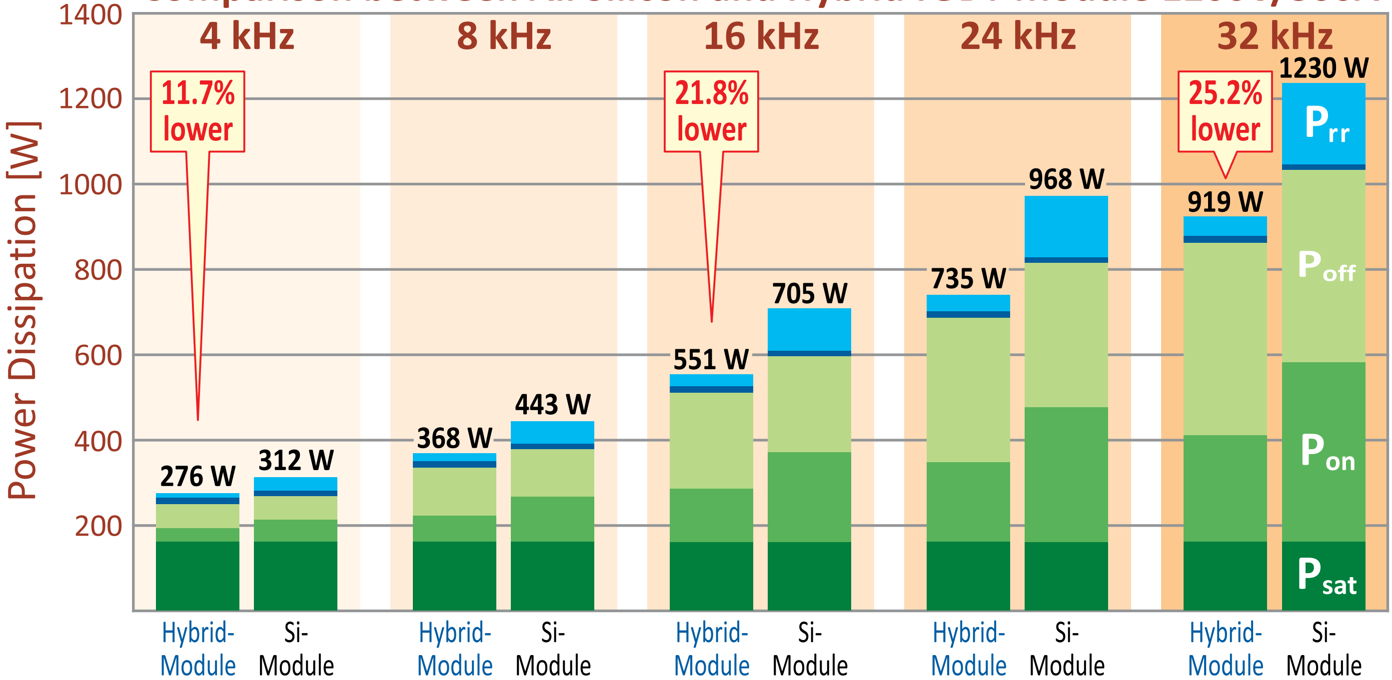
I_c	1200 V	1700 V
550A		●
600A	●	



I_c	1200 V	1700 V
1200A		●

I_c	1200 V	1700 V
1000A		●
1400A	●	●

Comparison between All Silicon and Hybrid IGBT Module 1200V/300A



Conditions: 3 arms PWM • V_{CC} = 600 V • I_O = 212 A_{rms} • f_O = 50 Hz • cosφ = 0.9 • λ = 1.0

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Wireless Charging: Power without Boundaries Becomes Available to the Masses

Wireless charging has been in the wilderness, hidden in a chasm until standardisation, strategic partnerships and technology integration recently gathered pace. The market is predicted to become worth billions of dollars in the next few years - yet it has been the domain of a few Tier-1 companies as the resources and know-how needed to develop and integrate solutions were significant. The latest technology is already out-dating the cumbersome initial solutions and IDT is leading the charge in packaging and democratizing this sophisticated technology so that anyone could develop a solution in hours.

By Graham Robertson, Vice President, Corporate Marketing, Integrated Device Technology (IDT)

Bridging the chasm

Wires are bad. The can fray or fracture, connections can become tarnished or damaged - not to mention man's ability to forget, lose or trip over the ever-important cable. As we try to eradicate wires, we live in an increasingly wireless society - but until now, the focus has been on wireless data, principally driven by wireless Ethernet and Bluetooth.

Despite the substantial and somewhat obvious benefits, history shows that wireless technology takes time to be adopted. Ethernet was invented as a wireless communication technique in 1973 (hence 'Ether') but the early implementations were solely with cable until at least twenty years later.

The chasm in wireless power is far greater. The history of wireless power stretches back to 1831, when Michael Faraday discovered electromagnetic induction. It rose again in the late 1800s, when Nikola Tesla began conducting tests transmitting power by inductive and capacitive coupling.

Then, nothing. For the entire 20th Century. We were all too busy replacing valves with semiconductors, sending men into space and jumping onto the World Wide Web.

In 2006, researchers at the Massachusetts Institute of Technology (MIT) reported that they had discovered an efficient way to transfer power between coils separated by a few meters. The team, led by Marin Soljačić, theorized that they could extend the distance between the coils by adding resonance to the equation.

As the 21st century dawned, mobile computing spiraled. Consumers could carry devices with computing power far beyond what they had on their desk only twenty years before. The Internet became ubiquitous, wireless connectivity matured and consumers could email, surf and communicate on the move - until the power ran out. Without power, our 21st century road-warrior became shackled to a wall outlet by their charging cable before resuming their carefree mobile life.

The market for wireless charging

If cables are not yet dead, they soon could be, at least as far as mobile device charging is concerned. Wireless charging is set to become the preferred means of charging mobile devices such as smartphones, tablets, and the 'hybrid' phone / tablet format referred to as 'phablets.'

The success of wireless charging will be based on a combination of high technology and pragmatism. The challenge of transferring power without wires has been solved and is evolving rapidly - the simplicity, safety, reliability and pure convenience will ensure wide adoption approaching ubiquity once consumers understand the benefits - not least, never having to worry about forgetting their charger and cable.

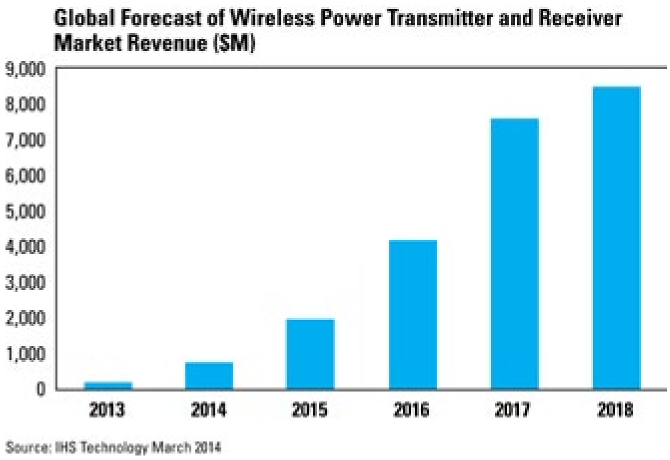

Figure 1: Global Forecast of Wireless Power Transmitter and Receiver Market revenue ($M)

Early wireless charging systems have typically been novelty aftermarket items and really did not offer a viable alternative to conventional adapters and cables. The systems available were cumbersome and bulky, requiring the mobile device to be inserted in a charging sleeve before being placed on the charging mat. Retail prices were high, generally in excess of USD100 for a complete solution and consumers had to carry the charger and cradle with them. Adoption stalled as the wireless charging benefits were not realized and cables were simply easier, lighter and cheaper.

If the technology is to be successful, then elegant and inexpensive technical solutions and market adoption are key pre-requisites. Adoption brings more entrants to the market, increases innovation and ultimately drives costs down to a point where adoption becomes universal. History has shown us that in the early stages of market formation competing solutions and standards - whether formally defined or de-facto - are critical for enabling the necessary adoption. Once coherent standards exist and interoperability between manufacturers and standards is proven the market will accelerate even more rapidly.

IHS Technology, when launching its Wireless Power Report in 2014, forecast that revenue from shipments of wireless power transmitters and receivers would rise from $216 million in 2013 to $8.5 billion in 2018, an almost forty-fold increase.

The changing standards landscape

As with many other emerging markets fragmentation precedes consolidation (remember VHS and Betamax?) and wireless power is no exception - but there are signs that alignment and consolidation are on the horizon.

Leading industry players, including software and component companies, handset manufacturers and network operators, came together to develop the standards needed to allow interoperability between charging systems and mobile devices from different manufacturers.

In the early days, three major groups were vying for supremacy within wireless power, The Wireless Power Consortium (WPC), the Alliance for Wireless Power (A4WP) and the Power Matters Alliance (PMA). In early 2014, A4WP and PMA agreed to join forces and this was approved by a vote of the A4WP and PMA boards on June 1st, 2015. On November 12th, 2015 the new combined entity announced that it would be known as the AirFuelTM Alliance.

The newly-aligned and branded AirFuelTM Alliance is currently 195 members strong and board of directors companies include AT&T, Broadcom, Duracell, Flextronics, Gill Electronics, Integrated Device Technologies, Intel, MediaTek, ON Semiconductor, Powermat Technologies, Qualcomm Inc., Samsung Electronics, Samsung Electro-Mechanics, Semtech, Starbucks and WiTricity.

The Wireless Power Consortium currently has 227 members and their Board of Management / Steering Committee comprises ConvenientPower, Delphi Automotive Systems LLC, DongYang E&P Inc., Freescale Semiconductor, Fulton Innovation, Haier, HTC, Integrated Device Technologies, Leggett & Platt, LG Electronics, Microsoft Corporation, Nokia, Panasonic, Philips, PowerbyProxi Inc., Qualcomm Inc, Rohm Co Ltd, Samsung, Sony Corporation, STMicroelectronics, Texas Instruments, Toshiba and Verizon Wireless.

A quick examination of the board members will show how the industry is split between the two camps with only a handful of organizations taking up a leadership position in both. One of these industry-leading organizations is IDT who hold a board-level position in both organizations and can be considered a significant force in this industry.

The technology behind Magnetic Inductance (MI) charging

Essentially, the principles and technology behind MI charging are very similar to most switch-mode power supplies (SMPS) used by the billion in the world today.

In the simplest form, the AC mains voltage enters the wireless transmitter / charger and is turned into DC via a rectifier. This is then 'chopped' into a high-frequency AC signal (typically between 100-200kHz for MI charging).

In a traditional SMPS this high frequency AC waveform is then passed into a magnetically-coupled transformer that changes the level of the voltage before again rectifying the voltage to supply DC to the load.

Perhaps the easiest way to understand the similarities and differences is that in an SMPS the transformer is a single component with the primary and secondary windings coupled very efficiently by a material such as Iron or Ferrite. In MI, the transformer is split. The primary winding is part of the transmitter / charger and the secondary winding is embedded in the receiver - which is the mobile device being charged.

The obvious difference is that in MI air itself forms the coupling between the primary and secondary and the coupling between the two magnetic fields is much looser. However if certain basic criteria are met (spacing of charger and device, size of coils and distance between coils relative to the size of the coil) then a good coupling can be achieved and power transferred.

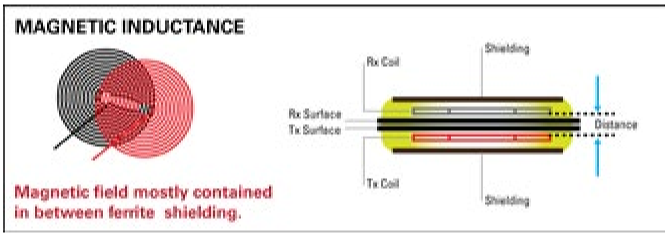

Figure 2: The basic principle of transfer power via Magnetic Inductance charging

MI charging relies on a physical charger (usually in the form of a charging mat). The device to be charged is placed on the mat, the charger detects its presence and charging commences.

The WPC says that operating the transmitting coil of an MI charger at a frequency slightly different from the receiver's resonant frequency ensures the highest power and efficiency. This off-resonant operation requires the transmitting and receiving coils to be in close proximity. Hence, charging can be sensitive to the alignment of the coils, meaning, in practical terms, that the device has to be carefully placed and not knocked during charging. A multi-coil transmitter reduces this sensitivity, and also allows simultaneous charging of multiple mobile devices.

Magnetic Inductance (MI) vs Magnetic Resonance (MR) - how do they stack up?

There are two fundamental technologies emerging within wireless charging, the already described Magnetic Inductance and Magnetic Resonance. Within wireless charging there are two priorities which compete, to an extent, and the ideal solution will depend upon the application.

A simple comparison of the two approaches illustrates the key differences in an application: magnetic inductance requires close coupling and can achieve the highest levels of efficiency when x/y displacement is minimal. Meanwhile, magnetic resonance allows better spatial freedom though it cannot match the peak efficiency of inductance-based approaches. Figure 3 below illustrates this difference, showing the 'focus' of MI against the 'breadth' of MR.

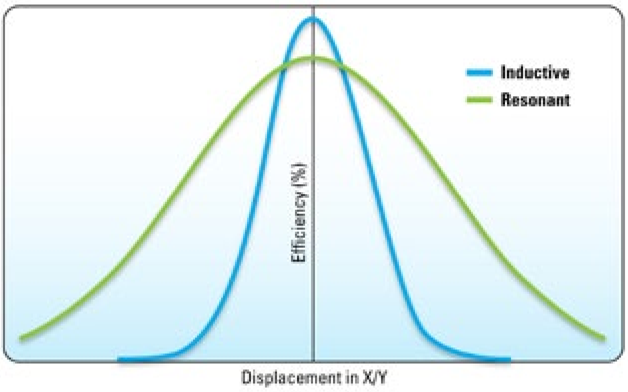

Figure 3: Magnetic inductance technology achieves greater efficiency levels when displacement is minimal. Magnetic resonance cannot achieve the same performance when transmitter and receiver are close together, but efficiency does not drop off as quickly when displacement increases.

Future outlook for wireless power

We have already seen that the market is predicted to grow rapidly. The availability and ease of use of the technology will play a key role in adoption, both with the end consumer (device user) and the original equipment manufacturers (OEM) who will incorporate this technology into furniture, cars, airports, cafes, trains and the like.

While battery technology is improving rapidly, users demands and reliance on their mobile devices increases so the need to charge 'on the move' is set to increase - mobile devices become essential when they become the primary means of paying for goods and services, for example. However, will manufacturers, retailers and service providers make charging stations available until there is a large enough installed base of devices that can take advantage of the technology? Will the device manufacturers include the charging coils in their mobile devices until consumers can easily access charging stations? Both the infrastructure and installed base of devices have to grow together for the value proposition to be realized.

Looking to recent product announcements we can see that investment and adoption is already happening - maybe more than we initially realize. Qi charging was incorporated in the Nokia Lumia 820 and 920 in September 2012. It was also present in the Nexus 4 from Google / LG as well as Motorola Mobility's Droid 3 and 4 and HTC's Droid DNA. The inclusion of wireless charging continued into 2013 with the Samsung Galaxy S4 as well as Google partnering with ASUS on the Nexus 7 and with LG on the Nexus 5.

The Apple watch, set to define a new category of wearable devices also includes wireless charging and earlier this year Samsung announced that their flagship S6, S6 Edge and S6 Edge+ include technology to wirelessly charge from both Qi and PMA compatible chargers - the start of universal compatibility.

On the charging side, Samsung has incorporated a Qi-based wireless charging function into their latest LED monitor. The mobile device rests on the monitor stand and charges while you watch, work or surf.

While the progress is rapid and clearly on a trajectory that will only accelerate, the forecast exponential growth needs support from a large number of OEMs - not just the 'Tier 1' companies. Ideally, access to the technology will be democratized into a multitude of smaller companies and, ultimately, the consumer themselves.

Some of the major players are supporting the democratization process. IKEA is now selling furniture with the technology built-in. More interesting are the kits they are now offering where the consumer can purchase a charging pad - and the appropriate sized hole saw - and fit a charging pad almost anywhere. This fuels the democratization process as consumers are not required to commit to the expense of replacing furniture to take advantage of wireless charging.

However, the easy availability of the modular solutions also allows low-volume furniture suppliers to integrate the technology with no technical expertise - or restaurant owners - or libraries, the list is long and the only limit to the spreading of wireless charging will be people's imagination.

IDT has moved democratization to a truly exciting new level with the announcement of a new range of plug-and-play kits. These pre-configured transmitter and receiver boards are built around proven IDT wireless power semiconductors, and include easy-to-use reference boards and comprehensive support materials. The kits make integrating wireless charging easy, practical and affordable for companies without the need to invest in gaining an in-house understanding of wireless technology.

Figure 4: Plug-and-play kits

In effect, IDT has removed the barriers-to-entry by doing much of the heavy lifting themselves, embedding their know-how, expertise and market-leading technology into simple modules which can be used by almost anyone.

In order to illustrate the point, the first run of the kit prototypes arrived at IDT's offices around 5PM one evening. Within around 200 minutes an engineer had successfully converted a set of headphones that charged through metal prongs in a cradle into a set of headphones that charged wirelessly.

Even in the early stages, it is clear that IDT's approach is driving democratization. "These kits were developed for the mass market, and since introducing them in August, we've had orders and design-ins from a remarkably broad array of companies," said Mario Montana, IDT vice president and chief sales officer.

The IDT kits make creating new applications simpler and quicker through the inclusion of instructional videos, user manuals, foreign object detection (FOD) tuning guides, layout guides, layout instantiation modules, schematics, bill-of-materials (BOM), Gerber files, and more. Beyond this, the high level of integration offered enables system designers to achieve considerable savings in terms of bill-of-materials and engineering costs, compared to earlier commercial wireless charging systems that were typically built using discrete components. Hence the latest highly integrated chipsets from IDT also enable much smaller equipment sizes and greater system reliability, which will have a major influence on widespread market adoption of wireless charging.

Key commentators in the industry are quick to endorse IDT's initiative. David Green, research manager, Power Supplies & Wireless Power at IHS, supported this view by writing: "Integrating wireless power capabilities into existing electronics is a complex process, and one of the factors that has unquestionably slowed its adoption throughout the electronics industry. This approach of providing self-contained, ready-to-go wire- less charging kits has the potential to change the landscape for those not yet equipped."

Clearly, the innovative approach IDT is taking to making their technology available on a plug-and-play basis to everyone will be looked back on as a tipping point on the short journey to ubiquity for wireless power.

About the author

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Reading Between the Lines

Using data sheets correctly when selecting resistors

When selecting a resistor for your application, there is more to bear in mind than you might think. In order to make a preliminary choice using a product data sheet, developers need certain background information and have to calculate some dimensions themselves. An example shows how to correctly use a data sheet.

By Thomas Otto, Isabellenhütte

Basic information
Which resistor is suitable for a current measurement? A quick look in the data sheet is not enough, as there are many factors that influence the precision, temperature dependency and long-term stability. Here, Isabellenhütte gives an introduction to the basic calculation and dimensioning of components.

When measuring current with a resistor, the main parameters that need to be taken into account are the amount of space required, the operating temperature, the dissipation, temperature behaviour, tolerance and the production technology. The data sheet provides important information for perfectly integrating the resistor into the respective application. The construction, material used and the configuration of the layout can, however, lead to greatly varying results in practical operation. Developers can use the calculations and background information to better understand and use the specifics of the individual parameters and the way they interact. A data sheet may not be a replacement for technical consultation, but it can be a valuable aid when dimensioning the component.

The fundamentals of current measurement
Measuring current using a resistor uses the voltage drop as the direct measurement for the current, as per Ohm's law. This is no problem with resistance values above 1 Ω and currents of a few hundred mA. The situation changes completely with currents in the range above 10 to 20 A, as the dissipation $P = I^2 \times R$ generated in the resistor can generally no longer be ignored. Every developer will try to limit the dissipation with lower resistance values. But as the measurement voltage also decreases simultaneously, the resistance value is often limited by the resolution and quality of the evaluation electronics.

The formula $U = R \times I$ generally applies for the voltage measured at the resistor. Factoring in the influences of the component, the material and the construction, however, the formula looks like this:

- $U = R \times I + U_{th} + U_{ind} + U_{iext}$

Key to symbols:
- U_{th} = thermoelectric voltage
- U_{ind} = induced voltage
- U_{iext} = voltage drop at supply wires

The error voltages not caused by a current flow can heavily distort the measurement result. Their influence should therefore be minimised by selecting suitable construction elements and carefully attuning the layout.

Disruptive influences
A resistance value never stands alone, but is always dependent on parameters such as temperature, time, voltage, frequency and others. Table 1 shows the influence of material shape and production process on the resistor's measurement signal. By using optimised amplifier circuits, it is now possible to work with a very low measurement signal. This means that a low-ohm resistance value that leads to a significantly lower dissipation with the same current is sufficient. The component, and therefore the circuit board, are also heated less.

Properties/requirements	Material	Model	Process
Low temperature coefficient	xxx	x	x
High long-term stability	xxx	x	xx
Low thermoelectric voltage	xxx		
Low inductance	x	xxx	
High accuracy			xxx
High capacity	x	xxx	
Small thermal resistance		xxx	x
Four-wire version		xxx	
Low total resistance		xxx	x
High safety	xx	x	x
Low price	x	xx	xxx

xxx = large influence
xx = medium influence
x = small but not negligible influence

Table 1: influence of material shape and production process

In addition to the influence of offset, temperature coefficient and noise from operational amplifiers, the resistance values can be lowered to the milliohm range, so that the dissipation P = I2 x R that arises when measuring with a resistor at high currents falls significantly.

Practical example
Using a practical example, such as one that could arise in the automotive sector or industrial drive technology, we can shine a light on which influential parameters are relevant for choosing the suitable resistor. The following factors apply here:
- A current of 17 A is to be measured with high precision.
- A measurement signal of 170 mV is required.
- The component is to be used as an SMD resistor.

The need to measure a current of 17 A and receive a measurement signal of 170 mV results mathematically in a resistance value of 10mΩ:

• R = U/I = 0.170 V / 17 A = 0.010 Ω

Based on this, we can now calculate the dissipation: P = I^2 x R gives a dissipation of 2.89 W.

Optimum component size

The maximum operating temperature in the application is required for determining the correct component size. Isabellenhütte data sheets refer here to the contact point temperature in operation. This can be easy to check, with infra-red images able to show the temperature difference here between the hotspot and the contact point. In the data sheet, Isabellenhütte indicates the parameter "internal heat resistance" (abb. Rthi), which describes the heat conductivity of the component design. Using this parameter, it is possible to calculate the temperature increase in the component.

Assuming that P = 2.89 W, a VMS resistor from Isabellenhütte's VMx series with a power of 3 W can be the component of choice. In the VMS, we now have a temperature increase of 2.89 W x 25 K/W = 72 K. According to the data sheet, the VMS delivers the 2.89 W even at a contact point temperature of 98 °C, well above the possible operating temperature of competitor products. Eugen Löwen (Fig. 1), Application Management Sales Components at Isabellenhütte, emphasises: "Isabellenhütte is the technological market leader as far as the component size in relation to dissipation is concerned. In the industrial sector in particular, however, an evaluation is usually made at a temperature of 70 °C. The calculated increase of 72 K would lead to the component heating up to just 142 °C. With a specified maximum permitted temperature of 170 °C for all Isabellenhütte components, there is still a lot of leeway here."

Increasing the temperature

In addition to the standard specification P70°C , the Isabellenhütte data sheets also list the temperature at which the component can still perform as specified. In the VMS, for example, this is 3 W at P95°C. These considerations are relevant above all for applications in the automotive sector, where higher temperatures are often involved.

In the case above, a smaller model can also be used. The specification of dissipation P70°C should also be used here. In the VMP (2010), this is given as 3 W. The 2010 model is therefore easily suitable, even when the VMP, with its 2 W, may not be the obvious choice when the calculated dissipation is 2.89 W. Customers must know the maximum operating temperature of the application. Using the power derating curve in the data sheet, they can determine the maximum temperature of the component at the power level.

In general, reducing the resistance value at higher currents is recommended. In certain circumstances, this allows the use of a smaller and cheaper model. The lower dissipation also means that the system heated up less.

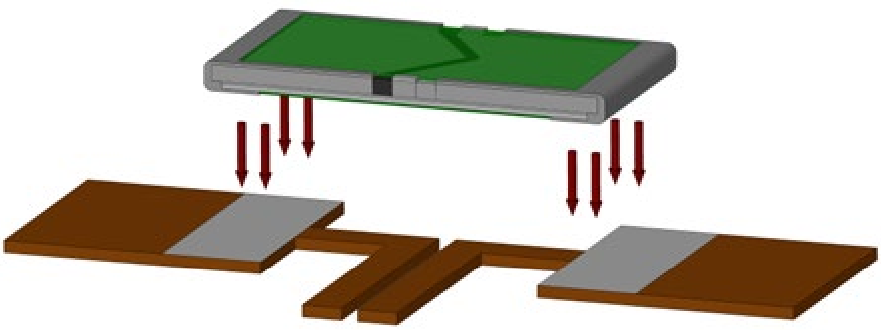

Figure 1: Sensible layout for optimising the temperature coefficient of a measurement resistor.

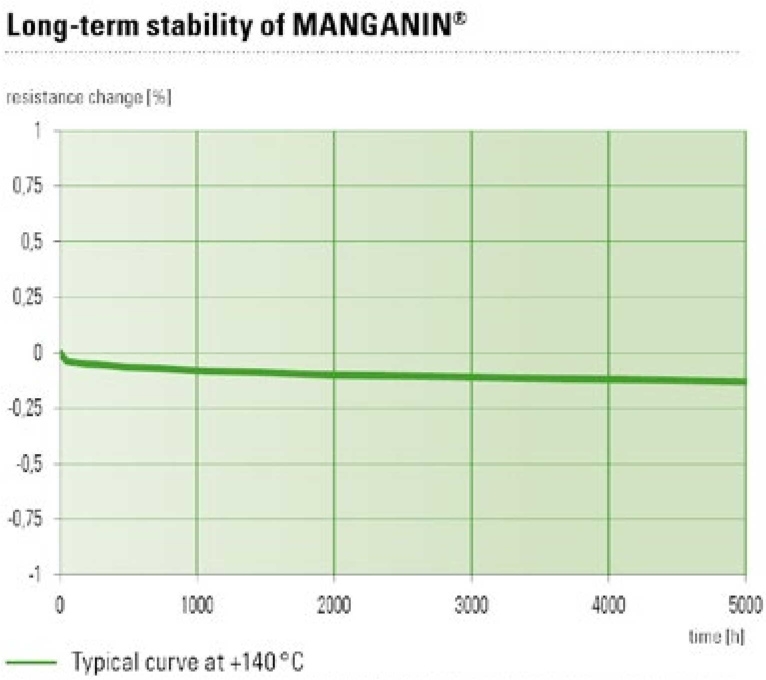

Figure 2: Change in resistance over time in a real SMD resistor operated at 140 °C.

The layout is decisive

The temperature coefficient is determined by the resistance material used. It is possible to manufacture resistors with very high reproducibility. As the measurement has a certain influence on the "2-wire resistance", however, this can distort the temperature coefficient. The standard practice in data sheets is to indicate the temperature coefficient of the resistance material used. According to Eugen Löwen, this does not tell us very much: "In our data sheets, we always use the temperature coefficient once soldered in. In our example of the VMS, we can take a very good temperature coefficient of < 20 ppm/K as a basis for the measurement, provided that the customer sticks to the recommended layout. By comparison, the competition can only offer much higher values here."

Figure 1 shows an example of a sensible layout for improving the temperature coefficient. For calculations using the data sheet, it is vital that the customer uses the specified layout. This is the only way to check the maximum tolerance within the measurement circuit. The temperature behaviour of the component also has an influence on this maximum tolerance. The very good temperature coefficient of < 20 ppm/K can only be achieved when the user complies with the specifications.

The layout also plays an important role in the induction of the component, which is also given in the data sheet. In order to keep this as low as possible, developers should follow the layout in Fig. 3, keeping the two tracks as close to each other on the circuit board as possible so as to avoid loops. This is the best layout for both a small temperature coefficient and for keeping induction as low as possible.

High stability

Another important piece of information in the data sheet is the long-term stability, which is specified dependent on operating temperature. Generally here the lower the temperature, the lower the drift in the resistance value. The information in the data sheet shows the temperature at the contact point. Inside the component, the temperature caused by dissipation is much higher.

Figure 2 shows the change in resistance in a real SMD resistor as a percentage when the component is operated at 140 °C for 5,000 hours. The low drift of around -0.2 % is caused by resolving the last lattice defects in the resistance material and shows that the components continue to stabilise, i.e. continue to improve.

As the drifts are heavily dependent on the temperature level, this effect almost disappears at 100 °C. In the example given at the beginning, however, users must weigh up the long-term stability in relation to the overall tolerance when selecting a resistor. In the VMS, which heats up less at the same power, the long-term stability is better than in the VMP, which becomes warmer. “At the end of the day, we often have to find a compromise together with the customer between the size of the component in relation to the right resistor, heating, maximum tolerance and the resulting price”, explains Eugen Löwen: “As all parameters are linked to each other, it is up to the customer to decide which requirements are most important. This helps us find the right component.”

http://www.isabellenhuette.de/

High Power Digital Inrush Current Controller

Inrush current creates limitations in power supplies and affects reliability due to overstress caused by the huge surge in initial current at power up. Known solutions to limit inrush current [1], [2] require resistors or conventional NTC thermistors which cause significant power loss and decrease efficiency.

By Anatoliy Tsyrganovich, Leonid Neyman, and Abdus Sattar, IXYS Corporation

Our approach [3] illustrates the advantages of digital power control that overcome many of the disadvantages of the existing technology and boosts interest in the digital control of high power converters, thereby stimulating development of the next generation of these devices. IXYS' High Power Digital Inrush Current Controller (HPDICC), which is the second step in developing this new approach, is tested for load currents up to 10A. Industrial AC-DC, DC-AC power supplies such as battery chargers, motor drives, and solar inverters with ratings ≤5 kW can implement this design to control large inrush current.

IXYS High Power Digital Inrush Current Control technology extends to high current levels while also introducing high current Power MOSFET (MMIX1T132N50P3) with monolithically integrated current sense mirror and two temperature sense diodes. This design utilizes Zilog's 8-bit Z8F3281 MCU and other IXYS components such as rectifier and driver ICs.

Key Advantages

The High Power Digital Inrush Current Controller offers the following advantages:

- High efficiency solution with a few components that can be reused for other goals after pre-charge is complete; for example, in PFC/boost converters, where the same inductor, output capacitors, and MCU will be utilized.
- Scalable design that can be adjusted to the desired inrush current by replacing a few critical components and making minor software corrections
- Easy-to- replicate design that does not require any adjustment from one sample to another to obtain the expected result and maximum efficiency.

This inrush controller is tested for a load current up to 10A. The load current may be substantially increased since the power MOSFET used in the design is rated at 120A and a serial current sense resistor for a main current is not present. In order to increase the load current beyond 10A, the designer is required to change the current mirror sensor resistor, a bridge rectifier, and an inductor to be compatible with the increased current rating.

Figure 1 illustrates a circuit schematic in which the key idea is to provide charge to the bulk capacitor in equal increments. The Capacitor (C) is charged by a power MOSFET (SW1) driven according to a time-dependent pulse train. The pulse sequence is designed to provide equal voltage increments at the capacitor and maintains a peak of charging current at about the same value at each cycle. The number of cycles depends on the capacitor's value, which is selected based on the desired amplitude of the ripple voltage at the output. The charge current is a function of the number of pulses and the timing position with respect to the rectified sine wave.

Figure 2 shows a typical pulse train for SW1. If we consider N cycles for inrush control, then we can split the normalized amplitude of the half-rectified sine wave into N segments with 1/N increment. During Cycle 1, SW1 is ON (conducting) from the time stamp t1 to T, allowing the capacitor C charge to the voltage proportional to normalized value 1/N. The charging current does not rise instantly, because it is a current in serial LC resonant circuit. That shapes the current waveform to the resonant one. The current is rising until the capacitor voltage reaches the input voltage.

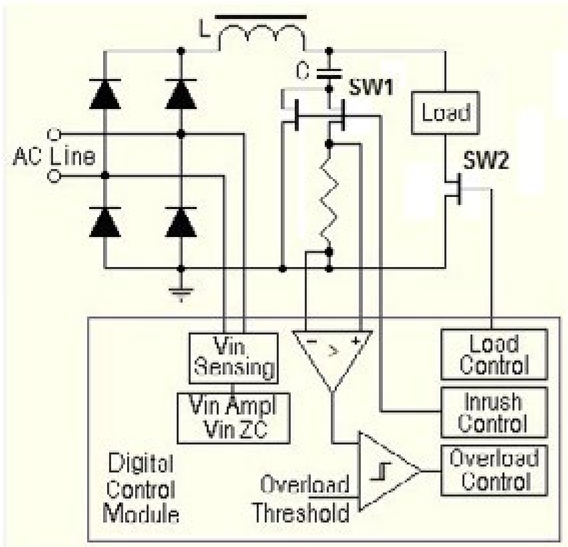

Figure 1: Circuit Schematic for Digital Inrush Controller

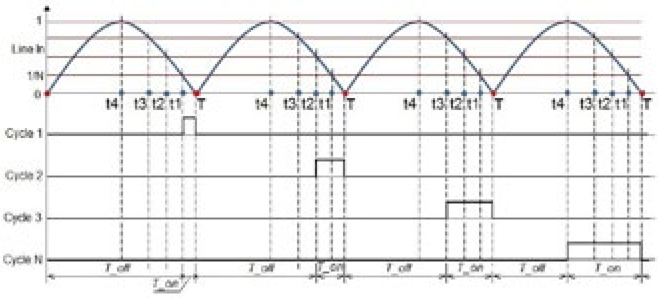

Figure 2: Digital Inrush Control Timing

The current then continues its resonant behavior because SW1 is still conducting. No further oscillation occurs because input voltage drops below the voltage on the capacitor, and then SW1 is OFF (not conducting). The capacitor remains pre-charged to the voltage proportional to 1/N. In Cycle 2, capacitor C is pre-charged by another voltage increment 1/N in a process similar to Cycle 1. Capacitor C is charged N cycles to the voltage value proportional to the input line voltage.

Principle of Operation

This inrush controller utilizes the basic principle of operation described in [3]. The primary differentiation of this reference design is in the use of components with higher power ratings and an appropriate change in the pulse train controlling the pre-charge of load capacitors. The pulse train is designed to limit pre-charge current to a level acceptable to ratings of used components. In this particular design, the limiting component is the inductor AGP4233-223ME, rated to 35.4 A at 20% inductance drop.

The timing position for each pre-charging pulse is given by the following equation:

$$T\_on(i) = T/(\pi/2)\ \mathrm{asin}(i/N), \quad \text{where } i = 1\ldots N \quad (1)$$

Increment in timing position of adjacent pulses defines the amplitude of charging voltage applied to the bulk capacitor. Increasing the number of pulses N reduces the increment, which reduces the steps in the charging voltage. In this example, N= 255, resulting in current limitation to 34 A with a capacitor value of 3000 µF.

The capacitor's voltage and charging current graphs are shown in Figure 3. Amplitude of the pre-charge current drops to the end of the charging cycle, while the capacitor's voltage rises linearly. It is determined by the timing position of current pulses in respect to half sine waveform of the rectified voltage. At the end of the charging cycle, the duration of the pre-charging pulse is longer, with lesser current amplitude, which created the same charge at the bulk capacitor as at the start, and it results in identical capacitor's voltage steps during the entire cycle.

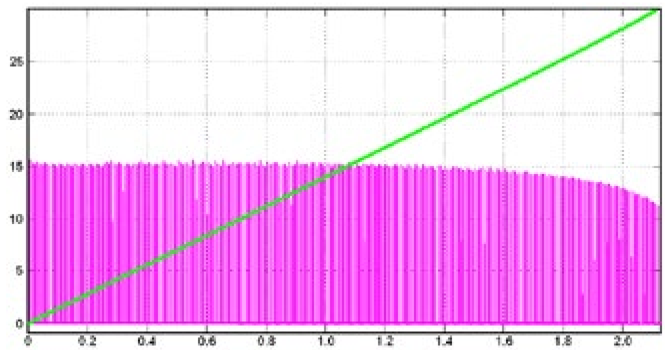

Figure 3: Voltage on the Capacitor and the Pre-charging Current.
Legend: Green – voltage on the capacitor (50V/div),
Magenta – pre-charging current (5A/div), x-axis: Time(s)

Overload Protection

To display the capability of IXYS power components, this design includes a Load ON/OFF switch U3 (see Figure 6), Overload Protection functionality, and Power Good status output. Load switch activation is programmable, and is enabled after the capacitor C pre-charge is completed. In the current reference design, Load Switch is activated with Power Good status signal.

Overload Protection is a key feature that protects a device from being destroyed during overload. The overload threshold is programmable, and is set to 12A in the current reference design.

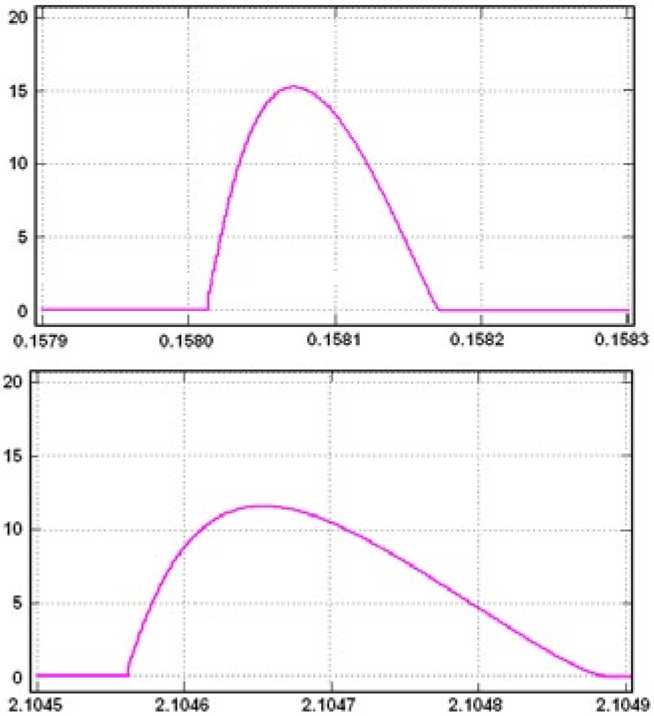

Figure 4: (a) Pre-charge Current at the Beginning of the Charging Train and Figure 4 (b) Pre-charge current at the End of the Charging Cycle.
Legend: Green – voltage on the capacitor (50V/div), Magenta – pre-charging current (5A/div), x-axis: 500ms/div.

If overload is detected by a comparator, the MCU disconnects the load by turning the U2 and U3 switches off.

Overload protection can be programmed for two modes of operation:

- Immediately shut down the device and wait for user action
- Allow the device to restart after the short circuit is removed for a predetermined number of short circuit occurrences if the short circuit occurrences repeat

In the second mode of operation, the delay between restart and the number of restarts is programmable. The delay time is set to 1.5 seconds and the number of restarts is set to 4 in this reference design.

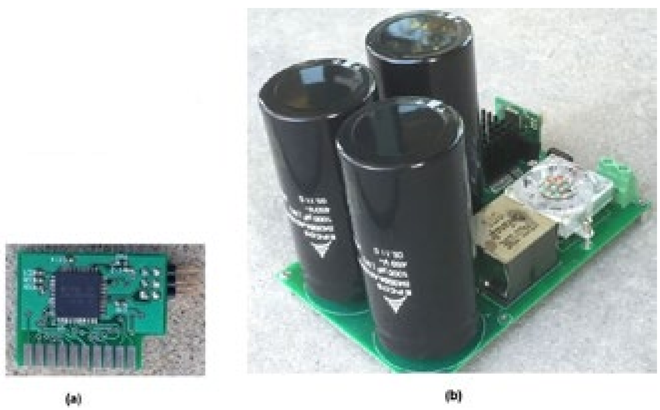

Figure 5: (a) MCU Module and Figure 5 (b) Main Power Board with MCU Module

Power Good status activation is programmable. In this reference design, it is delayed by 2 cycles after the capacitor's pre-charge is completed. The Power Good status is not set if an overload condition is detected.

Hardware Implementation

This Inrush Current Controller consists of an MCU Module and a Main Power Board, as shown in Figure 5. The detailed circuit schematics are shown in Figure 6. The MCU Module is implemented as an add-on device with a connector for MCU programming. The MCU should be programmed before powering the entire system. The MCU Module is powered by an auxiliary power supply: +3.3V for the MCU and 12V for the gate driver applied to connector J4 on the Main Power Board.

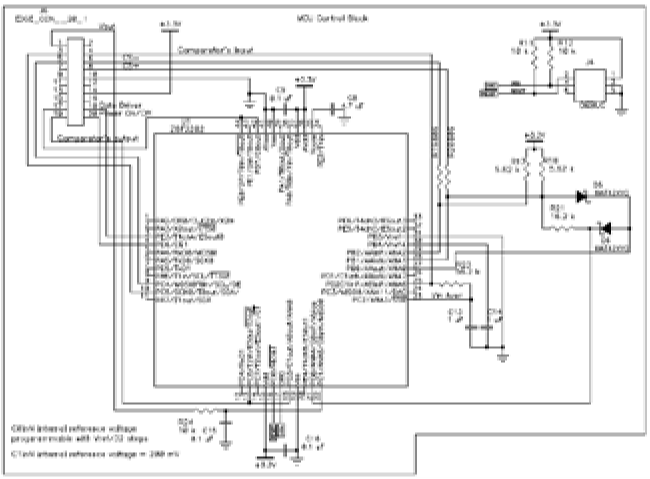

Figure 6 (a): Schematic Diagrams MCU Module

The main Power Board consists of several components including Diode Bridge BR1, power MOSFETs U2, and U3 shown in Figure 6 (b). The MOSFET U2 current mirror is used as a signal source for a capacitor's charging/discharging current measurement, so there is no current sense resistor in a major current path, leading to improved system efficiency. Power dissipation on these MOSFETs is less than 5 W at a 3000 W output power. This board may be powered from a 50 Hz or 60 Hz 120V or 240V AC source.

Testing the Digital Inrush Controller

This design was programmed and its performance verified on a test bench. The AC line input was fed through a 2 kW isolation transformer to protect the operator and the test equipment. The load was set to 10A during normal operation. To test overload conditions, an additional load was added to increase the load current to 12A. An instantaneous connection of additional load was enough to trigger overload protection. Continuous overload resulted in multiple attempts to restart the device, with immediate interruption after load current met the 12A threshold. Actual waveforms taken from a scope at normal operation are depicted in Figure 7.

The Inrush current (red line) is limited to 16A. The blue line shows the signal at the U2 gate. After the inrush process is completed, the gate is set to high level to keep U2 conducting. The load is then connected to the pre-charged capacitor. After the load is connected, a drop in the rectified voltage occurs due to the impedance of the isolation transformer and the power grid.

The normal operation starts with pre-charging of the bulk capacitor. When an overload condition is detected by the MCU, the normal operation is interrupted and the U2 and U3 switches are shut down. An attempt to restart the device is initiated at 1.5 second intervals. If

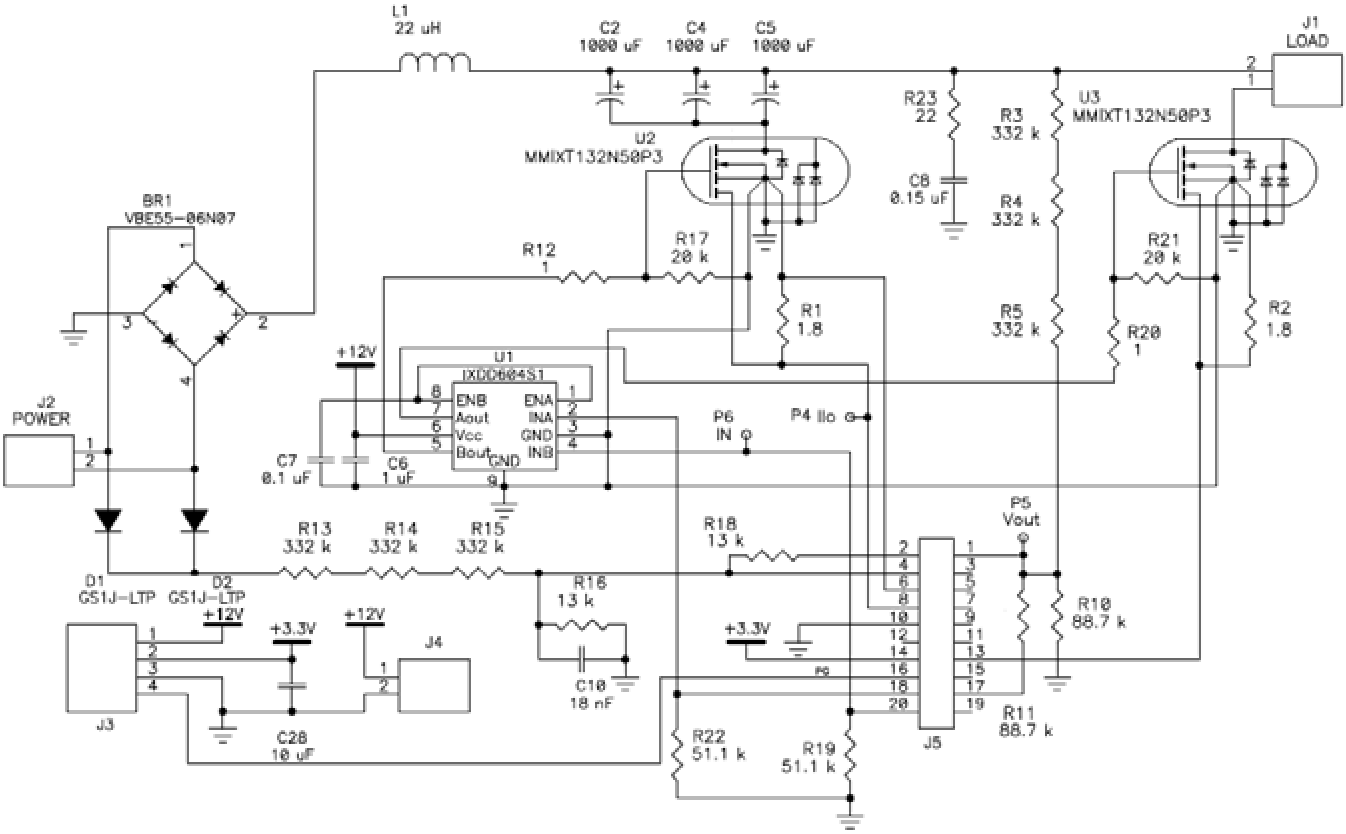

Figure 6 (b): Main Power Board

the overload condition continues, the device is shut down again. The number of attempts is programmable and is set to 4 attempts in this design.

The efficiency of HPDICC is determined to be 99.4% with a load power of 1kW, and the power loss is 6W. Power loss is calculated from the diode rectifier to the load.

Applications

This inrush controller can be used to develop a number of applications, ranging from AC-DC Rectifiers for heavy brushless motors, Auto-Transformer Rectifiers (ATRUs) and Transformer Rectifier Units (TRUs) used in aerospace applications, high power motor drives, AC-DC power supplies for data centers, and battery charging power supplies. It can also be integrated in high capacitive loads like AC-DC power supplies running in parallel operation mode.

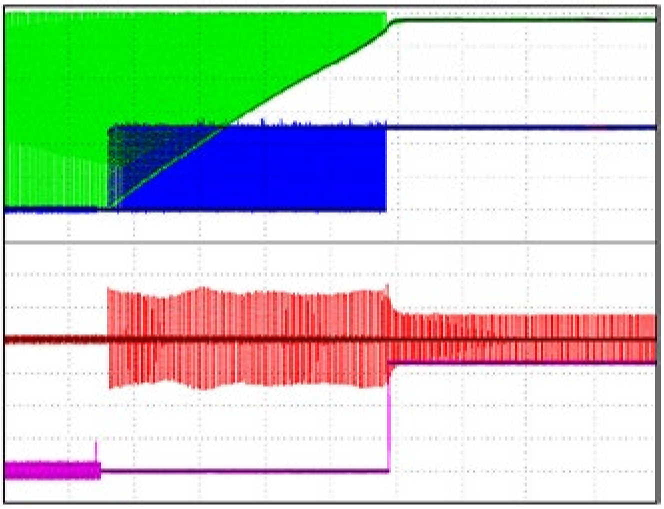

Figure 7: Scope Snapshot of the Digital Inrush Current Control. Legend: Red – power line current (10A/div), Green – Load voltage (50V/div), Magenta– Power Good status signal (1V/div), Blue – U2 control signal (5V/div), x-axis: 500ms/div.

Conclusion

IXYS' HPDICC offers flexibility in implementing a unique control algorithm that aids in the development of an efficient power system. It achieves, increased stability, a high level of efficiency, and reliable performance across a wide range of loads. Because of an innovative current measurement algorithm, it allows common input and load grounds. Users can optimize the device for a wide range of input voltages and frequencies. This design provides instant over-current protection, followed by an intervention by the MCU for corrective actions.

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Temperature Limits for Power Modules

Part 1 Maximum Junction Temperature

To estimate the junction temperature of a power semiconductor chip, calculations are typically made using the power loss in the chip and the thermal resistance value of the chip listed in the device data sheet. This thermal resistance value is provided at a single fixed operating condition. To improve the accuracy of the temperature estimation, it is useful to understand the effect that changing operating conditions and application parameters can have on this value of chip thermal resistance.

By Jeremy Howes and Greg Shendel, Parker Hannifin Automation Group NC. USA and David Levett, Tim Frank, Infineon Technologies North America

Introduction

Accurately calculating the temperature of a power semiconductor die is a key design criterion for any power converter. With the pressure on reducing costs, it is important to maximize the use of any given semiconductor and not leave large margin "on the table". The counterpoint to low cost is reliability, and it is equally critical that the semiconductors are not exceeding data sheet maximum design limits over the full range of the converter operating conditions. Design engineers have to walk this increasingly narrow ridgeline.

Measuring the actual chip temperature is not trivial. The chips are encapsulated in plastic and/or gel, are often buried under PCB's and bus bars, and are operating at high voltage and dv/dt levels. Several manufacturers have produced chips with on-chip temperature sensing and several methods have been proposed for "in situ" measurement of the chip temperature (1) (2). However, these methods are either not practical for larger multi-chip modules or are difficult to implement. Some power modules have an internal temperature sensor, often an NTC device, but for voltage isolation reasons, this is physically separated from the chips on the Direct Copper Bonded (DCB) ceramic, and so does not directly reflect the actual chip temperature (3). This leaves an analytical junction temperature estimator as the protection method of choice.

In the simplest terms, the chip temperature is power loss in Watts multiplied by thermal resistance junction-to-ambient in °C/W plus the ambient temperature. This value of thermal resistance is often divided into three parts (see Figure 1) : Junction to Case (Rthj-case), Case to Heat Sink (Rthcase-sink) and Heat Sink to Ambient (Rthsink-ambient).

The latter can be easily measured by using thermocouples embedded in the heat sink and by generating the operating power loss using power resistors or semiconductor modules operating from a low-voltage, high-current DC supply. The heat sink can also be simulated by using readily available online tools, for example, R-Tools from Mersen.

Thermal resistance values Rthj-case and Rthcase-sink are typically provided in the device data sheet for active switches and diodes. It is easy to assume that these values are immutable. However, from study of the cross section shown in Figure 1 and the plane view of a typical module shown in Figure 2, it can be seen that each die is part of a complex, multi-source, three dimensional, non-linear thermal system making it indubitable that in fact these values are not fixed. Different operating conditions and application factors can, and will, affect the individual chip thermal resistance values making it impossible to specify a single definitive value for Rth.

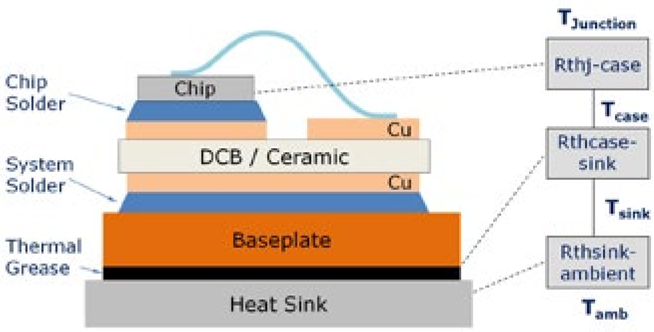

Figure 1: Cross section of a typical module showing the different thermal resistance values

Figure 2: Top view of a dual 600A IGBT module, without cover, showing the internal chip layout.

Parameters Affecting Thermal Resistance Values

We will simulate how three parameters can affect the value of thermal resistance for a typical IGBT module. These are:

- Heat sink type
- Power loss in adjacent chips or cross coupling
- I2R losses in the top DCB copper layer

Two IGBT modules were selected for analysis, a 450A and a 600A 1200V part, both manufactured by Infineon Technologies in the industry standard EconoDUAL™ 3 package. The method of analysis used was to generate a Finite Element Analysis (FEA) model for the module. The material properties, chip dimensions and placement were provided by Infineon. Figure 3 shows the FEA model with a typical thermal map for the 450A module.

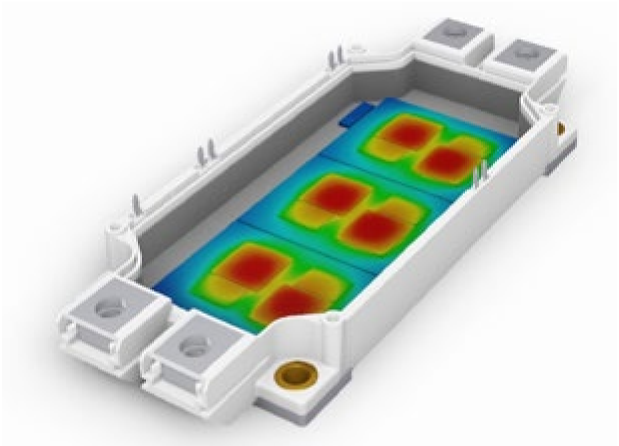

Figure 3: Example of FEA model of 450A module showing die layout and temperature map.

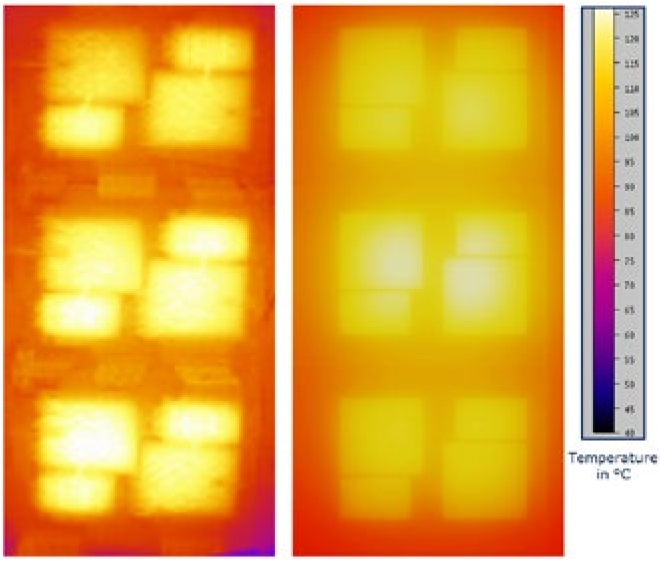

Figure 4: 450A module. Left thermal image with IR camera, right FEA model image.

The model was verified by powering an open module that was painted black, “Cajun style”, with a low-voltage, high-current power supply and imaging the surface temperature with an IR camera. Figure 4 shows the IR and simulation results side by side for the 450A module.

Effect of Different Heat Sink Technology

The FEA model was used to compare the Rthj-case and Rthcase-sink values for the same module and thermal load conditions but mounted on three different heat sinks. The heat sinks selected were a simple Aluminum extrusion, Aluminum based water-cooled chill plate and a copper and brass phase- change based cooling plate (4). With 100W load applied to all the IGBT chips and no load to the diode chips, the FEA model was used to calculate the Rthj-case and Rthcase-sink values, using the average temperature of the hottest chip, for all three heat sinks. The results are shown in Table 1. This shows that the thermal resistance increases as the performance of the heat sink improves. Initially this can seem counterintuitive but can be explained by considering that a higher performance heat sink draws heat more effectively vertically through the system, and so the actual area normal to the direction of the heat flux is reduced. Note the absolute junction temperature is still much lower with the higher performance heat sinks as their lower Rthsink-ambient far outweighs any increase in the Rthj-sink value.

Values Normalized to Air Cooled Heat Sink at 100%	Air Cooled Heat Sink	Water Cooled Heat Sink	Phase Change Chill Plate
Rthj-case	100%	108% (+8%)	114% (+14%)
Rthcase-sink	100%	116% (+16%)	133% (+33%)

Table 1. Changes in thermal resistance due to different heat sink technology. 100W per IGBT die.

Effect of Cross Coupling of Adjacent Die.

The FEA model was also used to compare the thermal resistance of the IGBT when different levels of power loss were applied to the adjacent diode chips. Again 100W was applied to each IGBT chip and then successively 0, 20, 40 and 60W applied to the diode chips with the module mounted on an air cooled heat sink. Thermal maps are shown in Figure 5 comparing the two operating conditions. The variation in Rthj-sink values of the hottest IGBT chip are shown in Table 2. As expected, increasing power loss in the diode, with the inherent thermal cross coupling, produced additional heating of the IGBT, resulting in an effective increase in thermal resistance, in one case more than 20%.

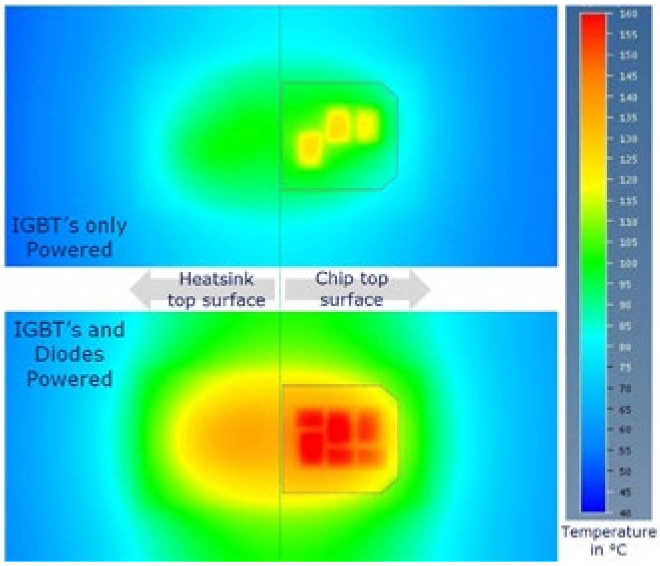

Figure 5: FEA model of 600A module. Above 100W IGBT die and 0W in Didoe die, below 100W in IGBT die and an additional 60W loss in Diode die.

Effect of Module Internal Copper Losses

Finally the model was used to simulate the effect of power loss in the top side DCB copper layer that carries the current to and from the chips. This power loss not only heats the chips but adds to the overall module power loss and will increase the heat sink temperature. The simulation for the 600A module is shown in Figure 6 with the DCB area outlined. The simulation was run with the I2R losses of approx. 17W applied to each DCB, which equated to a load current of 400Arms. This had little effect on the value of Rthj-sink, less than a 1% increase, but it did increase the temperature of the air-cooled heat sink surface directly under the chips by 3°C which resulted in a 3°C increase in the absolute junction temperature.

100W loss applied to IGBT die. Varying power loss in diode die	Diode loss 0W	Diode loss 20W	Diode Loss 40W	Diode Loss 60W
IGBT Rthj-sink	100%	108% (+8%)	115% (+15%)	121% (+21%)

Table 2. Table showing variation in the value of IGBT Rthj-sink for varying loss applied to the Diode die.

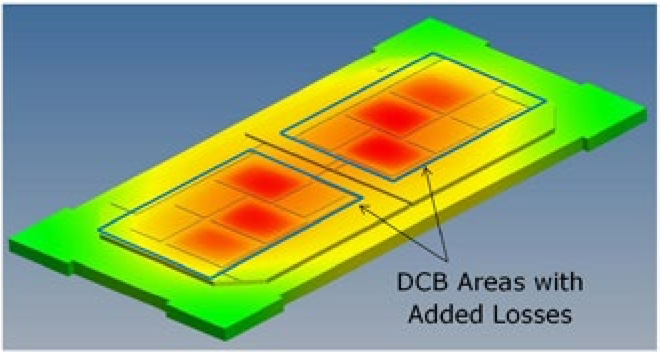

Figure 6: Layout showing area for additional loss on top copper surface layer of DCB

Conclusion.

It is difficult for device manufactures to provide a definitive value for thermal resistance as there are several external parameters, not under the manufacturer's control, which will affect the Rthj-case and Rth case-sink values. Margin can be built into the data sheet number, but it cannot account for all variations in system design and operating conditions. For the designer wishing to squeeze every last electron, (and hole to be inclusive), out a given semiconductor, the data sheet value is a good starting point, but to fine tune the design, an accurate model is required to compensate for the variables that influence the value of thermal resistance.

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Transfer Mold IPM Family "SLIMDIP" with 5A/15A 600V RC (Reverse Conducting) – IGBT in a Compact Package

A very compact Dual-In-line Package Intelligent Power Module SLIMDIP with ratings of 5A and 15A /600V has been developed employing Reverse Conducting (RC) IGBT chip technology. This technology integrates the required freewheeling function for inductive loads into the developed RC-IGBT chip and, hence, makes the Diode that usually is connected antiparallelly to a conventional IGBT redundant.

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Teruaki Nagahara, Power Device Works, Mitsubishi Electric Corporation Japan

As a consequence the employment of reverse conducting IGBT chips save space and that resulted in the new package of the SLIMDIP being designed very compact. The SLIMDIP provides protection functions for under voltage, short circuit and over temperature as well as a linear output signal for the case temperature. The interface circuit of the SLIMDIP is 3,3V to 5V compliant and the pin terminal assignment simplifies the printed circuit board layout design.

Variable speed Inverters are increasingly used to drive small motors aiming to increase the efficiency of motor control systems. This development has become visible also in the white goods and small fan and pump application field that are driven by small motor drives with a rating of up to about 2,2kW. Responding to this demand the continuously further developed Super Mini DIPIPM has been developed in 2004 already and has set package standards in this specific market segment. Now a further technology step has been realized and a new smaller transfer mold IPM has been developed, actually mainly addressing the white goods application market segment such as washing machines and air-conditioner. This new SLIMDIP significantly improves compactness, power density, efficiency and controllability of systems. Today two devices have been developed for the two main existing application segments: A SLIMDIP "small" ("S") with a typical collector current rating of 5A is mainly addressing the power requirements of typical European household washing machines, e.g. driven by a motor of around 750W of shaft power or smaller applications and the SLIMDIP "large" ("L") with a typical Collector current rating of 15A focuses on the higher power demand of air conditioners or drives for professional heavy duty washing machines. Since these applications usually do not use an isolated interface between the IGBT driver stage and the microprocessor the SLIMDIP family is equipped like all transfer mold IPMs with the latest generation of High Voltage Integrated Circuits (HVIC) to drive and to protect the power stage. Simplifying the peripheral circuit the SLIM DIP has got robust bootstrap diodes and corresponding current limiting resistors for the bootstrap operation integrated into the package.

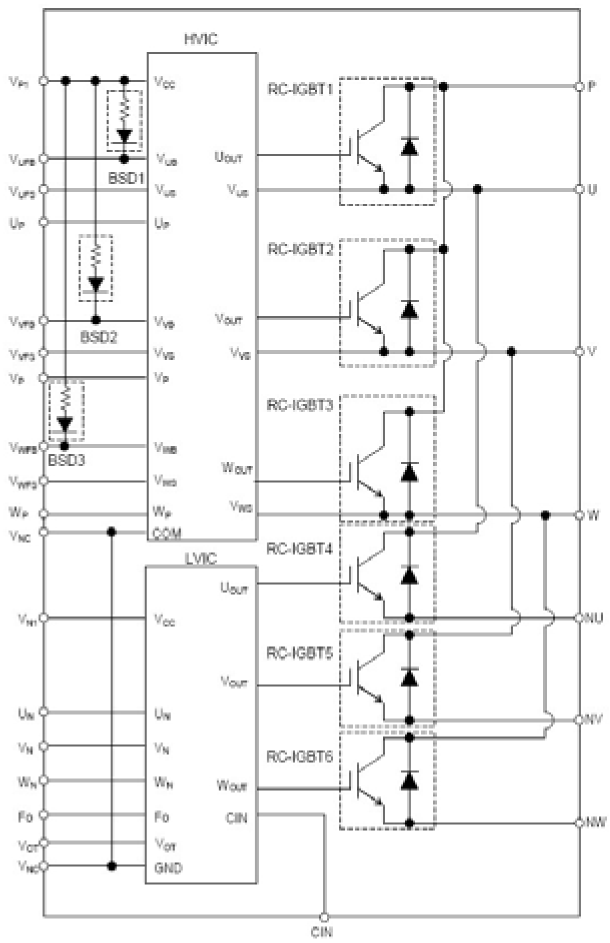

Figure 1: Shows the internal block diagram with RC-IGBT, the LVIC and HVIC and the integrated bootstrap circuitry.

RC-IGBT merits

The RC-IGBT technology provides merits in the fabrication process of the SLIMDIP mainly in the assembling process since it is simpler with a half power-chip-die bonding and without Al wire-bonding from IGBT to the Diode. The availability of a free-wheeling function of the RC-IGBT chip itself, e.g. without an externally connected dedicated diode is saving module space and provides cost efficient and compact package design.

Package design

This new SLIMDIP package is following the DUAL INLINE concept known from the version 6 Super Mini DIPIPM but with a further development of the lead frame and integrated functions. The compact package of only 18,8mm x 32,8mm has got control terminals arranged in zig-zag shape providing sufficient clearance between the holes, the outer annular ring avoiding expensive printed circuit board fabrication processes like fine pattern structures with the utilized pitch etc. The control and power terminal structure and arrangements are indicated in Figure 2.

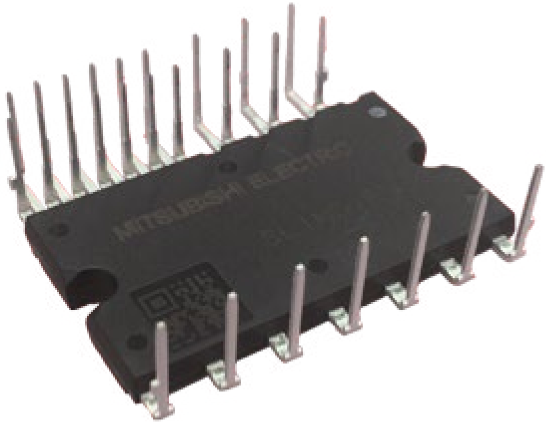

Figure 2: Photo of the SLIMDIP

The arrangement of the terminals has been further improved versus the Super Mini DIPIPM version construction since the bootstrap capacitors have dedicated terminals assigned and a crossing of PCB traces under the footprint of the SLIMDIP to the corresponding output terminal is not required anymore.

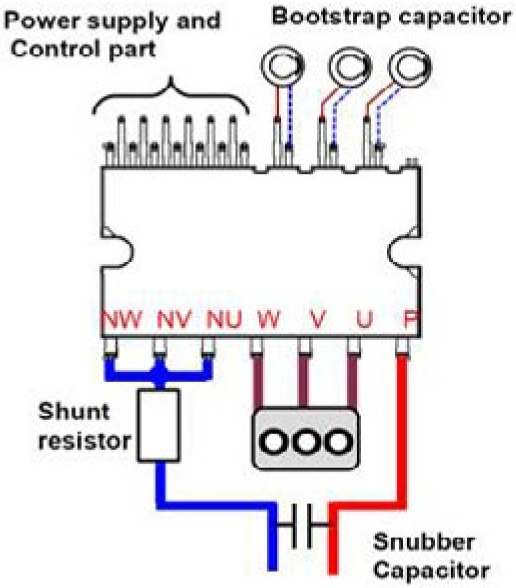

Figure 3: Shows the improved pin terminal layout

Hence, the improved lead frame pin terminal assignment simplifies the design of a printed circuit board and total cost optimized designs targeting the realization of the complete motor drive on only a single sided printed circuit board become possible easier. As shown in this figure the SLIMDIP provides an open Emitter structure that permits the acquisition of phase currents when all low side IGBTs are turned on, e.g. during the lower zero vector of the Pulse Width Modulation (PWM). These shunt resistors if selected as surface mounted device ideally fit under the footprint of the SLIMDIP and would reduce the stray inductance of the complete DC-link construction accordingly.

Figure 4: Evaluation board

Performance comparison
Besides the improvement of the construction of the new SLIMDIP housing a set of performance extensions have been reached with this new developed device. Indeed the maximum case temperature has been specified higher: While previously the Super Mini DIPIPM package has been specified for a maximum of 100°C of case temperature, the new SLIMDIP's maximum case temperature has been extended to 115°C. As a consequence of this extended specification the internal over temperature (OT) threshold has been adjusted accordingly now starting at 115°C. Concerning the isolation voltage the specification has been increased by over 500Vrms from the 1500Vrms that have been specified for the Super Mini DIPIM to the level of 2000Vrms for the SLIMDIP. Along with the more compact dimensions of the case these improvements have been summarized in table 1 showing the extended specification of the SLIMDIP.

Protection functions:
The protection of the power stage is an essential task of an IPM and a dedicated circuitry is employed in the control part or both the Low Voltage Integrated Circuit (LVIC) and the High Voltage Integrated Circuit (HVIC) that contains the level shifting function, too. Under voltage protection, Short Circuit protection are the standard protection functions integrated in the transfer mold IPMs, but as innovation the newly developed SLIMDIP contains a thermal protection function "over temperature protection" and issues at the same time an accurate temperature proportional signal "VOT" that allows to take action when the thermal limit, e.g. the over temperature threshold is close in order to avoid a sudden interrupt of the drive operation.

Tc max	115deg C	+15deg C	100deg C
Package	SLIM 18.8x32.8x3.6	-30%	Super mini 24x38x3.5
V_{ISO}	2000Vrms	+500V	1500Vrms

Table 1: Extended specification of the SLIMDIP

Evaluation platform:
The features and the new extended functionality of the SLIMDIP can be verified by the developed evaluation board. The photo shows the evaluation platform employing the input rectification circuit the bulk DC-link capacitors a 15V/5V DC-DC converter stage and an isolated input circuitry for a safe connection to a microprocessor board.

The board uses clamp connectors for the power connections like AC in, 3~ motor connector etc. which provide a quick connection of cabling to this evaluation board. On the control terminal side a standard self-locking JST connector type is foreseen to connect control signals safely to the evaluation board.

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4th Generation Field Stop IGBT with Enhanced Latch up Immunity

Thanks to their low conduction and switching energy loss, IGBTs are widely used in high power applications such as power supplies, motor driving inverters, electrical vehicles, etc.

By Kyuhyun Lee, Sungmin Yang, Sekyeong Lee, Jiyong Lim and Youngchul Choi, Fairchild Semiconductor

The requirement for more state of the art power devices for power applications has triggered efforts around novel silicon based development, as well as wide band gap material development, to achieve characteristics that stretch the ideal limit of silicon. The theoretical silicon limit for IGBTs was investigated by A. Nakagawa, [1] and in order to realize optimal silicon characteristics, various injection methods to enhance IGBT structures were proposed, such as CSTBT, IEGT, and narrow mesa IGBT [2-4].

In order to push IGBT silicon to the limit, extremely high electron injection efficiency from the MOS gate is required, while the hole carrier injection should be restricted to the level of contribution only for the conductivity modulation. [1] For Fairchild's 4th generation FS IGBTs, electron injection was enhanced by a very fine cell pitch design and hole carrier injection was restricted by a new buffer structure, achieving remarkably better trade off performance as well as strong latch up immunity. To realize the narrow mesa or high-density cathode design of the trench IGBT, a self-aligned contact process was applied. This proved to be very effective in optimizing the critical dimension of active cell design for the enhanced on-state performance, as well as to maximize the latch up current capability. In addition, multiple buffer layers were adopted for the anode side of the IGBT in order to not only effectively control the minority carrier injection during the on state, but also to completely block the electric field during the off state [5].

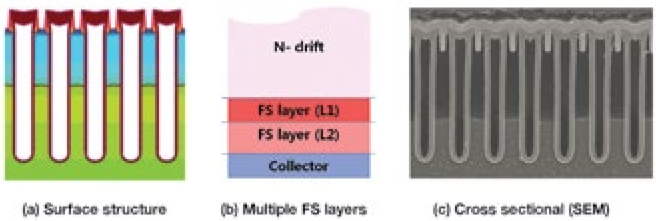

Figure 1: Proposed structure

The vertical structures of the proposed IGBT are illustrated in Figure 1 for the cathode and anode side. Figures 1(a) and 1(c) show that the high density cell design with submicron narrow mesa width is successfully realized by employing a self-aligned contact process, without any photo misalignment. The higher density active pattern shown in this figure is beneficial for extremely enhanced electron injection from the cathode side and, as a result, the higher electron current density. The new buffer structure with multiple layers, as shown in Figure 1(b), is very helpful for the ideal carrier distribution during IGBT operation. Generally, a single buffer layer with 1~5e15cm–3 is used for both hole injection control and electric field blocking efficiently. In this experiment, a thin buffer layer with a much higher doping concentration was additionally embedded for better trade-off performance. In other words, the higher doping concentration in the double buffer layer is even more effective for the electric field blocking and hole carrier injection control by the first FS layer (L1). The lower doping concentration for the second buffer layer (L2) is preferred for forming a lightly doped p-type collector for high-speed switching performance without any lifetime killing process. In addition, the device switching waveform can be effectively improved by varying the doping concentration and thickness of the double buffer layers, due to proper carrier distribution control during switching ON/OFF operation.

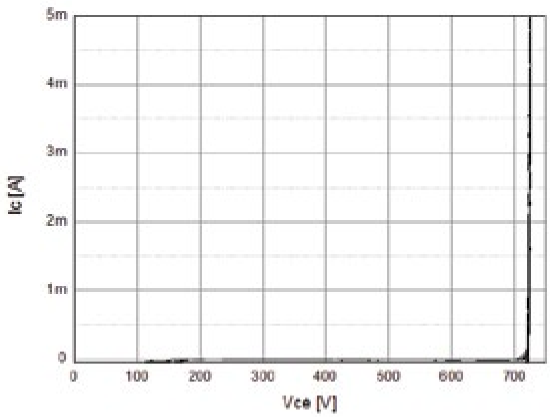

Figure 2: Measured breakdown voltage

As is illustrated in Figure 2, the measured static breakdown voltage is about 720V with hard waveform. It means that the double buffer layer is sufficiently blocking the electric field in the off state. In this work, 650V-50A-rated 4th generation FS IGBT was developed and

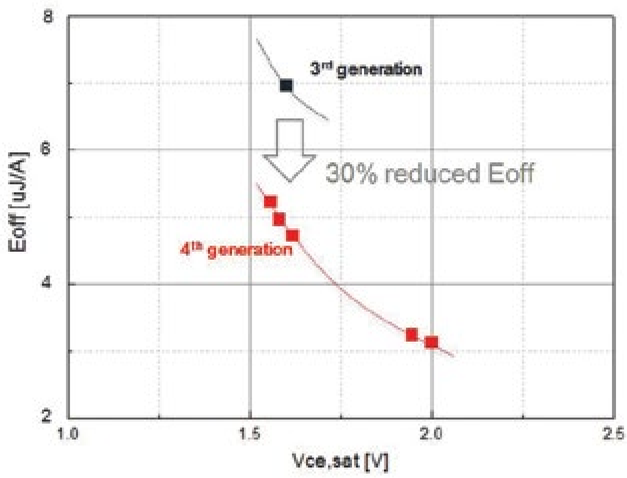

Figure 3: Trade-off performance comparison

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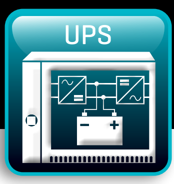

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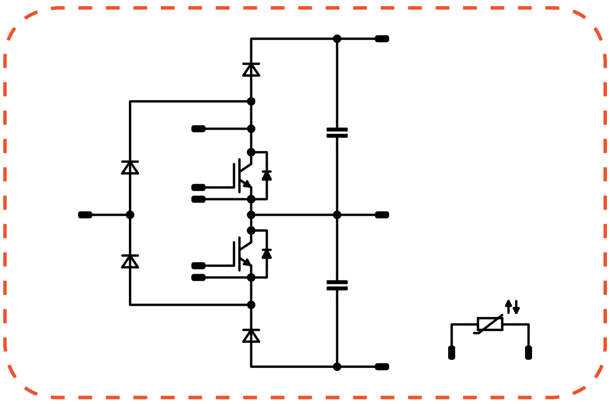

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evaluated. The trade-off performance was also compared with the 3rd generation FS IGBT, as shown in Figure 3, under a current density of 470A/cm2 for on-state voltage drop and turn-off hard switching. The proposed 4th generation FS IGBT shows better trade-off performance, compared with previous generation IGBT technology. (About 30% turn-off energy loss (Eoff) reduction at the same on-state voltage)

The latch up immunity is evaluated under static and dynamic conditions, as shown in Figures 4 and 5 respectively. Figure 4 shows that the maximum static saturation current is around 4000A/cm2 with no latch up phenomenon. In particular, for the dynamic latch up characteristics shown in Figure 5, the proposed FS IGBT shows a very strong ruggedness and also safely operates over 3000A/cm2 current density without failure under the severe hard switching condition (T=150C, Rg=0ohm, Vge=+-15V to induce very high voltage slop (dv/dt) between collector and emitter). This is because the self-aligned process removes possible local weak points from the contact photo misalignment so that the injected minority carrier can evenly flow without crowding into any specific area.

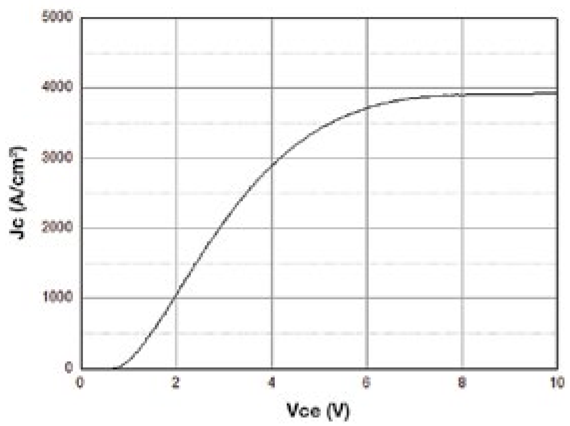

Figure 4: Static latch up characteristics

In summary, 4th generation FS IGBT technology was successfully developed based on the injection enhanced carrier profile that was optimized with an effort to approach the limits of IGBT silicon. This new generation of FS IGBTs with a high-density cell structure and well-designed double buffer layer shows superior device performance under static and dynamic states as well as strong latch up ruggedness. We've confirmed that the self-aligned process is a very effective method for the embodiment of submicron trench and mesa active design, as well as for realizing strong latch up immunity. For the following generation of IGBT development, the mesa width will be narrowed further using the self-aligned process. This will further maximize the injection enhancement and accordingly the buffer structure for the minority carrier injection control should be optimized.

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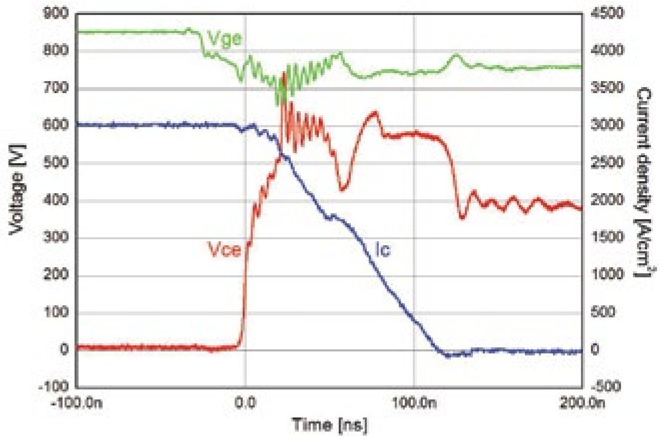

Figure 5: Dynamic lath up characteristics

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Infineon Technologies AG expands its µHVIC ™ family of integrated circuits for high and low voltage: the new single channel low-side drivers IR44252L, IR44272L, and IR44273L enable robust and cost effective design solutions. The device family utilizes Infineon's proven, robust high voltage junction isolation (HVJI) technology to realize multiple functions and integrate robust protection features. The driver ICs are packaged in a small 5-lead SOT23 and are complementary with other µHVIC parts. The devices offer a cost effective and easy-to-implement solution for flexible PCB layouts across many platforms and applications.

In addition to the tiny SOT23 packages, the single channel low-side drivers feature a wide V cc range of 5 V to 20 V, an enable input (IR44272L), and dual output pins (IR44252L, IR44273L). The typical source current and sink current of the IR44252L is specified with 300 mA and 550 mA, 1.7 A/1.5 A for the IR44272L and IR44273L,respectively. The low-side drivers offer V CC Under Voltage Lock Out (UVLO) protection and fast switching. Typical turn-on and turn-off propagation delay is 50 ns and typical turn-on rise time and turn-off fall time down to 10 ns (IR44273L, IR44272L). The devices are 3.3 V logic compatible and provide CMOS Schmitt-triggered inputs.

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Expands Lineup of J1-Series High-power Semiconductor Modules

Mitsubishi Electric Corporation announced the J1-Series high-power semiconductor modules featuring compact 6-in-1 packages mainly for use in electric and hybrid vehicles.

Power modules for automobiles must deliver higher reliability than industrial-use modules due to the extremely high standards for vehicle safety. Mitsubishi Electric pioneered the mass production of power modules for hybrid vehicles in 1997. Since then the demand for these modules has grown in parallel with the expanding global market for electric and hybrid vehicles. The new high-power J1-Series modules feature compact packages with small footprints, low power loss and high reliability for use in the inverters of electric and hybrid vehicles. The 6-in-1 package design shrinks the inverter footprint to about 60% of inverters based on six 2-in-1 J-Series T-PM (CT300DJH120) modules, it provides an extra-compact package for automotive inverters. Low power loss and high reliability for automotive power trains is achieved with the seventh generation CSTBTTM chip technology that enables a reduction of the collector-emitter saturation voltage by about 10% compared to 2-in-1 J-Series T-PM (CT300DJH120). In addition, the direct cooling package with cooling fin improves heat radiation by about 30% compared to 2-in-1 J-Series T-PM (CT300DJH120) mounting power modules on Al fin by way of thermal grease. Surge voltage suppression through internal inductance reduction makes the new module's low-inductance package suitable for high-frequency switching applications. Internal inductance is reduced by about 30% compared to 2-in-1 J-Series T-PM (CT300DJH120). First samples of the new 650V/1000A and 1200V/600A modules will be available

from October respectively December 2015. J1-Series power modules are compliant with the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) directive 2011/65/EU.

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Low Voltage Optically Isolated Error Amplifiers

IXYS Integrated Circuits Division (ICD), Inc., a wholly owned subsidiary of IXYS Corporation, announced the availability of the LIA135 and LIA136 low voltage optically isolated error amplifiers each with an integrated programmable precision shunt reference incorporated into a single 8-pin package. Unique to this pair of devices is the capability of the error amplifier and shunt reference to operate down to 1.6V, the industry's lowest level, enabling higher efficiency, isolated low voltage power supply designs. The LIA135 and LIA136 offers a 1.299V internal precision voltage reference with a very low 0.5% tolerance for improved power supply accuracy.

Optically isolated error amplifiers are important integrated devices for secondary to primary side feedback in AC-to-DC power supplies and DC-to-DC converters. These optical devices save board space and replace bulky transformer secondary feedback circuits. The LIA135 and LIA136 combination of features are optimal for use in isolated power supply design as the bias current for the shunt regulators does not pass through the LED. This eliminates bias-related optical current, providing the user with the industry's largest dynamic range (1000:1).

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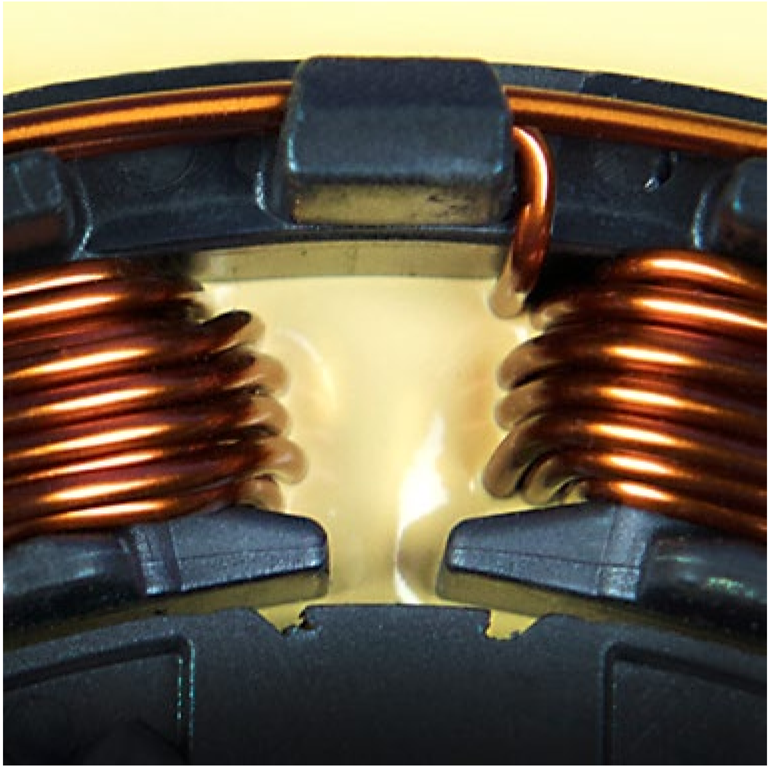

Henkel Adhesive Technologies continues to expand its thermal materials portfolio and today announced the development and commercialization of GAP FILLER 1400SL. An evolution in thermal interface materials, GAP FILLER 1400SL combines the properties of low viscosity and, relative to conventional self-leveling products, comparatively high thermal conductivity in a unique formula designed to accommodate challenging architectures.

A two-part, silicone-based, liquid gap filling material, GAP FILLER 1400SL has extremely low viscosity which allows the material to flow in and around tight, uniquely shaped structures to fill small voids and provide excellent thermal transfer. With a thermal conductivity of 1.4W/m-K, GAP FILLER 1400SL unites high thermal conductivity and exceptional flow – characteristics that have traditionally been mutually exclusive – to allow new levels of design latitude. “Previously, electronics professionals relied on conductive potting compounds with comparatively low thermal conductivity,” explains Lonnie Helgeson, Henkel Product Manager for GAP FILLER materials. “Manufacturers no longer have to sacrifice viscosity or thermal conductivity. With GAP FILLER 1400SL, these properties are united in a novel material that is self-leveling and also delivers shock and vibration dampening.”

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Small and Fast 2A Multifunction LDO Regulators with Adjustable Output

Torex Semiconductor Ltd. has launched the XC6230 series of 2A high-speed multifunction LDO regulators with adjustable output. The XC6230 series are small and fast multifunction LDO regulators with a maximum output current of 2A and an adjustable output voltage and current limit value. An internal 0.17Ω low ON resistance P-ch Tr.

and a stable output voltage with small dropout voltage make these products ideal for post regulators (DC/DC rear-stage ripple removal), various types of microcontrollers, regulators for logic applications, and secondary power supplies. The XC6230 series can also be used in consumer electronics, industrial equipment, communication modules, and electricity smart meters.

In addition to a function that enables the output voltage and current limit value to be set externally and a function that prevents a reverse current higher than the input pin (VIN) from flowing into the output pin (VOUT), a rich variety of protective circuits such as overheating protection (TSD) and startup rush current prevention can be added. The small USP-6C package (1.8 x 2.0 x h0.6mm) or SOP-8FD package (currently under development) can be selected as appropriate for the application.

The output voltage and over-current limit value can be set using a total of only five chip capacitors and chip resistors, and as such these products make a significant contribution to space-saving design even while being multi-functional.

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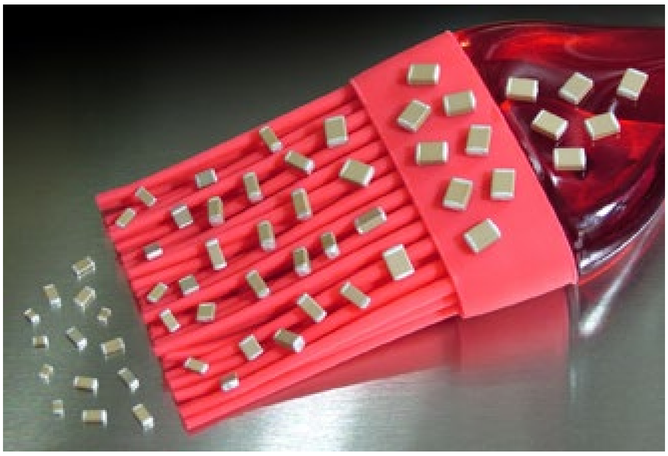
Design engineers looking for capacitors to have a more defined change of capacitance with applied voltage can now specify the VC1 range from Knowles Capacitors brand, Syfer Technology. This



residual capacitance range of X7R MLCCs are designed to not drop more than 50% of their cap value from the 1Vrms 1kHz value, all the way up to full rated DC voltage at room temperature.

In ceramic capacitors, generally speaking, the more stable the dielectric the lower the available capacitance value. There is often a trade-off to be made with the most stable, lowest loss, zero ageing Class 1 dielectric materials only producing low capacitance values. However, developments in materials and processing technology, plus an increased understanding of capacitor design and failure modes over time, has led to Syfer making vast improvements in MLC volumetric efficiency. The ceiling of, say, 56nF for a 1kV 1812 case size part 10 years ago has increased to 180nF today.

The VC1 range can be operated continuously at full rated voltage, but if de-rated will maintain a larger percentage of their original capacitance value. For example, if operated at 80% of the rated voltage the capacitance value will reduce to something near 60%.

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