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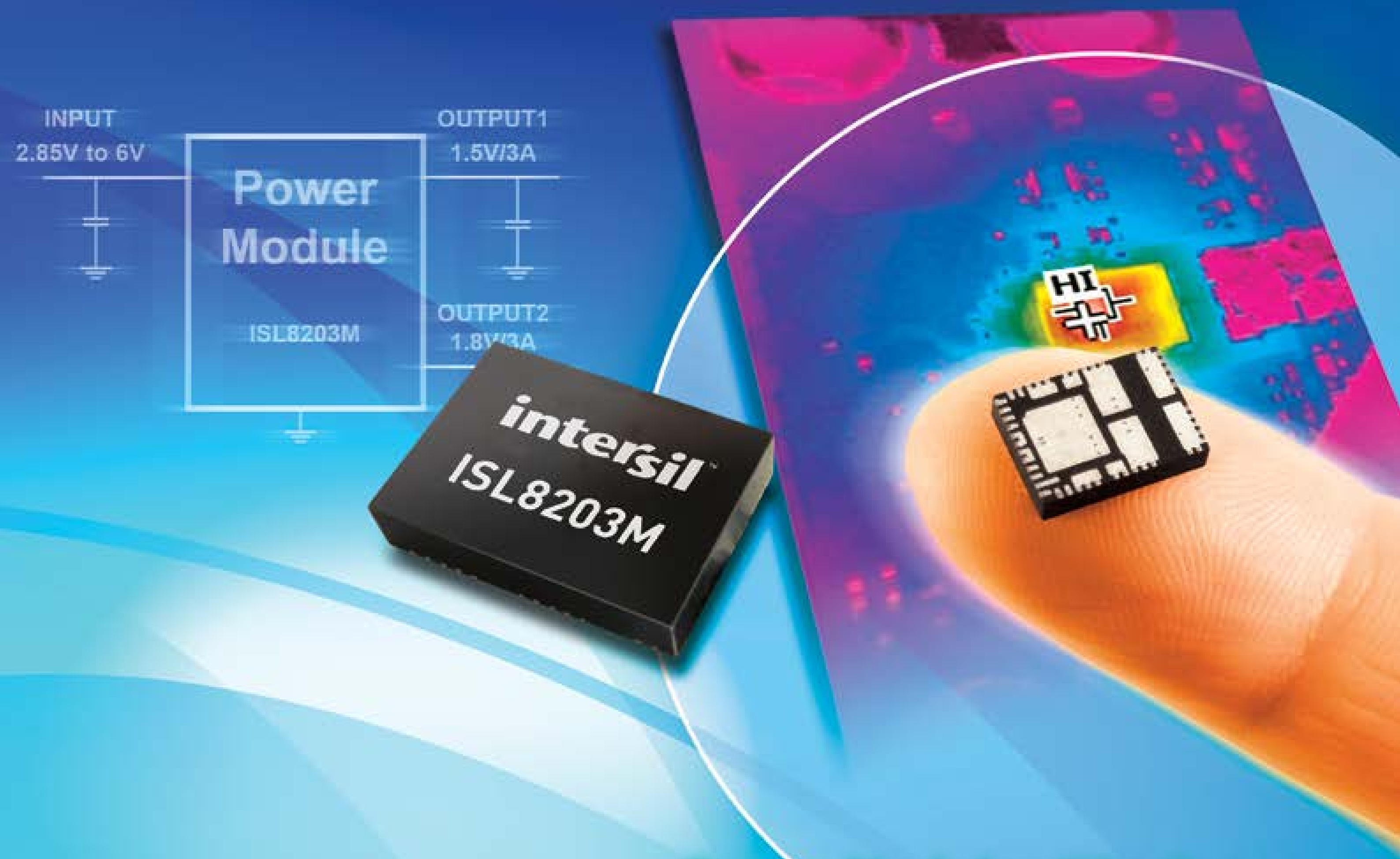
Electronics in Motion and Conversion

March 2015



Power Modules Win Out, but Choose Wisely

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powerguru.org

The Gallery

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Events

ESARS 2015,
Aachen, Germany, March 3-5
www.esars2015.org/

smart systems integration,
Kopenhagen, Denmark, March 11-12
www.mesago.de/de/SSI/

APEC 2015, Charlotte, NC, March 15-19
www.apec-conf.org/

New Energy Husum 2015,
Husum Germany, March 19-22
www.new-energy.de/new_energy/de/

EMC 2015,
Stuttgart, Germany, March 24-26
www.mesago.de/en/EMV/home.htm

The Reality of Power Modules

The term "power modules" refers to a very wide range of products. Our cover story from Intersil, describes DC to DC conversion in the low, below 80 volts, range. The article from APEI covers Power Modules switching 400 amps at 600 volts. Then there is the USCi work, at several thousand volts, which is also referred to as a power module. Historically, I believe the phrase began by referring to a single package of several devices, with a power capability above that of IC's, and since then it's become complex. Simply using "power module" makes understanding just what kind device it is difficult, so today it is helpful to describe the module's functionality as well.

In this issue, a device configuration that has a history and a number of advantages is explained; the Cascode structure for high power switching. The USCi article describes the advantages of a Cascode, and a "Super Cascode" in very high voltage applications. Dr. Seibt from Vienna has done comparisons in switch mode power supply applications of wide band gap devices and the well-known "Coolmos" devices. His findings showed that the Cascode is a major contributor to achieving good efficiency. Coolmos even equaled the performance of wide band gap devices in a Cascode structure.

We look forward to the first big conference of the year, the Advanced Power Electronics Conference (APEC) in Charlotte, North Carolina. The heartbeat of electronic equipment is a stable and reliable power supply. APEC is focused on improvements in power supplies and the reduction of losses in conversion. It is an international event with a long tradition, celebrating its 30th anniversary this year.
A number of other events are taking place including smart systems integration in Copenhagen, Denmark; the Battery University in Aschaffenburg; EMC in Stuttgart; Esars in Aachen; and ExpoElectronica in Moscow. The world of Power Electronics is active everywhere.

PCIM Europe is just around the corner in May, the next very large conference. I look forward to seeing you there at my traditional

Podium discussion at the Fach Forum, Hall 6, Booth 345, on Wednesday May 20th from 11:00 to 12:00. This year the focus is on the practical volume production of new technology devices. The headline is: "Reliable Volume Production of Wide Band Gap Semiconductors"

For several years now, articles in Bodo's Power Systems magazine have explained that we are in a generational change from established silicon to GaN and SiC. Volume production with high yield is mandatory for success in applications.

Communication is the only way to progress. We have delivered three issues this year. My technical articles are archived on my web-site and also are retrievable at Power-Guru. Bodo's Power Systems serves readers across the globe. If you speak the language, or just want to have a look, don't miss our Chinese version: www.bodospowerchina.com.

My Green Power Tip for March:
If you live in the North and face the winter, do like the birds, fly south and stay there until spring. You will save heating your house.

Best Regards

Magna-Power Electronics Sales Office Opens in the United Kingdom

Magna-Power Electronics, a leader in high-power direct current programmable power products, announced the immediate opening of Magna-Power Electronics Limited in the United Kingdom. The new sales office follows significant growth of the Magna-Power Electronics brand in the United Kingdom, Ireland and the rest of Europe. The direct sales office provides local resources for sales and support of the company's broad range of programmable DC power supplies.

Located in Reading, the new office represents a significant commitment in the UK market for the Magna-Power Electronics brand. Bob Collins, with over 25 years of experience in the programmable power industry, is leading Magna-Power Electronics Limited as Managing Director. "I'm very excited to be joining the Magna-Power team by setting up a direct office here to support the installed and future UK customers," states Bob Collins. "With strong industry and application knowledge, we will be able to further promote the Magna-Power brand and its market leading products, while becoming a leading supplier to this important territory."

"With Magna-Power Electronics' strong reputation in its domestic United States market, the company has been focusing on building a sales and service infratructure abroad," explains Adam Pitel, Vice President overseeing worldwide sales and marketing. "Excellent customer feedback, improved brand recognition, and strong year-over-year growth for the 2012 German sales office Magna-Power Electronics GmbH prompted Magna-Power to pursue a similar sales model for the United Kingdom."

With an active research and development team, the breadth of Magna-Power's product offering has increased significantly in recent years. Magna-Power's programmable DC power supply line now spans power ratings 1.5 kW to 2000 kW+ at industry-leading power densities, with voltage ratings up to 10,000 Vdc and current ratings up to 24,000 Adc. The company's vertically integrated manufacturing facility in Flemington, New Jersey has nearly tripled in size within the last three years to 73,500 sq-ft to accommodate increased demand and manufacturing processes.

www.magna-power.com

Illinois Capacitor Inc. Acquired by Cornell Dubilier Marketing, Inc.

It was announced that Illinois Capacitor Inc., and its affiliates have been acquired by Cornell Dubilier Marketing, Inc. This acquisition brings together two of the leading manufacturers of capacitors for the electronics marketplace. For the foreseeable future, Illinois Capacitor will operate as a separate subsidiary of Cornell Dubilier, and will continue to be headquartered in suburban Chicago. Its Asian headquarters will remain in Hong Kong.

The two companies have mostly complementary product lines, with some areas of overlap. Illinois Capacitor and its customers will benefit by an expansion of product sales and distribution resources, as well as enhanced engineering and manufacturing capabilities. Cornell Dubilier will gain product breadth with Illinois Capacitor's extensive board-level product lines, which include aluminum electrolytic, polymer, film and EDLC (super) capacitors and modules.

www.cde.com

Momentum Builds for 19th Annual CWIEME Berlin

This year's CWIEME Berlin will take place across six halls at the Messe Berlin, Germany on the 5-7th May. After 19 years of continuous growth, the show is anticipating record attendance from engineers, designers, buyers and academics in the global automotive, energy, consumer electronics, industrial machinery, military and aerospace sectors with advance registration figures already going strong.

Last year's CWIEME Berlin welcomed more than 6,500 visitors from 78 counties.

In 2015 over 70 new suppliers will be taking part. Newcomers such as Efaflu from Portugal, Schaffroth GmbH from Germany, Raytech GmbH from Switzerland, Winding and More from Italy, plus Zhejiang Innuovo Magnetics Co. from China, and Aichi Steel Corp from Japan will join regulars ABB, Alstom, Elektrisola, Eurotranciatura, Hidria, Ruff, Superior Essex, Voestalpine and Von Roll on the show's 750-strong exhibitor roster.

New for 2015, CWIEME Berlin will also include an MRO zone, dedicated to the maintenance, repair and operation of electrical equipment and components.

CWIEME Berlin 2015 also sees the launch of CWIEME Challenge, a initiative aimed at bringing together the businesses of today with the electrical engineers of tomorrow. Students from academic institutions around the world are invited to present their projects in the CWIEME Challenge Hub, both in poster form and on stage in a live final.

www.coilwindingexpo.com/berlin

Order for Advanced SiC Reactor from Leading European Research Center

Epiluvac AB has received an order for its advanced EPI-1000X SiC reactor from a leading European research center. The reactor type comprises an unprecedented reactor design. Both gas flows and heating system are unique, with a potential to drastically reduce problems with particles and parasitic depositions. The reactor is a single wafer reactor, but due to the very high growth rate, efficient use of the precursors and a minimum of parasitic depositions, it is interesting also for production.

“This is another step in our ambition to supply the best possible CVD tools to R&D labs around the world,” says Bo Hammarlund, managing director of Epiluvac AB. “The reactor design is extremely promising and we are certainly very pleased that we can bring this novel reactor design to the market. There is nothing like this anywhere in the world today.”

The new reactor type, still a hot-wall reactor, has been simulated in all details. The temperature profile inside the reactor can be adjusted during the growth cycle with a number of different heat zones in order to optimize uniformity. The installation and commissioning of the system will be completed during the first quarter of 2015.

www.epiluvac.com

Advancements in Thermal Management

Advancements in Thermal Management 2015 is a symposium highlighting the latest advancements in thermal technology for product design, electronics, system development and process management. It will be held August 5-6, 2014 in Denver, Colorado.

This event features presentations on advancements in thermal management and technology for electronics packaging, temperature sensing and control, thermal materials, systems design and optimizing thermal properties. Topics will include all types of new thermal technology, commercial applications of recent advancements in thermal science, thermal research and development, and the latest market trends in thermal materials, products and systems.

www.thermalnews.com/conferences/

Ismosys as Manufacturers’ Representative

CUI Inc has announced the addition of Ismosys as their manufacturing sales representative in the European market. Ismosys will represent CUI’s diverse portfolio of power products and board level components. Operating from local offices throughout Europe, Ismosys will offer customers unparalleled access to technology, information and service as they promote CUI products throughout the region. The partnership with Ismosys is the latest step in CUI’s commitment to expand its support network in Europe.

“We recognize the great opportunity for growth that the European market provides CUI,” explained Matt McKenzie, President of CUI. “Our new found partnership with a well respected sales organization like Ismosys is an important milestone in that process. We are extremely pleased to be able to utilize their expertise in the EU region to amplify our reach and customer support,” McKenzie concluded.

“Through an unwavering commitment to build collaborative customer partnerships and invest in the latest technologies, CUI has positioned itself a leader in the power and electromechanical space,” stated Ismosys President, Nigel Watts. “Ismosys could not be more excited to begin this business relationship with a first-class organization like CUI.”

www.cui.com

www.Ismosys.com

Conference program of PCIM Europe 2015 published

PCIM Europe 2015 international exhibition and conference takes place from 19 – 21 May 2015 at the exhibition centre Nuremberg. The PCIM Europe conference is one of the most leading conferences, addressing the fields of power electronics and its applications in intelligent motion, renewable energy and energy management.

This years’ conference program is more comprehensive than ever before and presents a high diversity on the latest technological trends and developments in power electronic components and systems.

The highlights include, amongst others, three keynote speeches, five special sessions and in addition 29 oral sessions as well as two poster sessions. Furthermore, on the two days before the conference, well known experts will share their substantial knowledge in nine half day seminars and nine full day tutorials.

View the PCIM Europe 2015 conference program for the detailed information with all sessions, tutorials and seminars.

ECPE Calendar of Events

ECPE Tutorial 'EMC in Power Electronics'
2 – 3 March 2015, Lausanne, Switzerland
Chairmen: Prof. E. Hoene (Fraunhofer IZM),
Prof. J.-L. Schanen (G2ELab)

ECPE Workshop '6th ECPE SiC and GaN User Forum'
20 – 21 April 2015, Warwick, UK
Chairmen: Prof. P. Mawby (Univ. of Warwick), Prof. A. Lindemann (Univ. of Magdeburg), Prof. L. Lorenz (ECPE)
and Technical Committee

ECPE Lab Course 'EMC Optimised Design (Parasitics in Power Electronics)'
27 – 28 April 2015, Berlin, Germany
Course Instructor: Prof. E. Hoene (Fraunhofer IZM)

ECPE Tutorial 'Power Semiconductor Devices & Technologies'
29 - 30 April 2015, Graz, Austria
Chairman: Prof. D. Silber (Univ. of Bremen)

ECPE Workshop 'µPower Electronics/PowerSoC: Powering Low-Power Systems'
16 – 17 June 2015, Munich, Germany
Chairmen: Prof. B. Allard (INSA de Lyon), Prof. J. Cobos (UPM),
Prof. C. O'Mathuna (Tyndall)

ECPE Tutorial 'Power Electronics Packaging'
29 - 30 June 2015, Hamburg, Germany
Chairmen: Prof. U. Scheuermann (Semikron),
Dr. J. Popovic-Gerber (Delft University)

ECPE Tutorial 'Thermal Engineering of Power Electronic Systems - Part I (thermal design and verification)'
21 – 22 July 2015, Erlangen, Germany
Chairmen: Prof. U. Scheuermann (Semikron),
D. Malipaard (Fraunhofer IISB)

On the ECPE website www.ecpe.org you always find the up-to-date information on the ECPE Events as well as the up-to-date ECPE Calendar of Events.

www.ecpe.org

Distribution Deal with Ecomal Europe

GaN Systems Inc. announced it has signed a distribution agreement with Ecomal Europe to promote and distribute its gallium nitride (GaN) high power switching transistors. GaN Systems' gallium nitride power transistors are based on its proprietary Island Technology® and offer significant advantages over traditional silicon MOSFETs and IGBTs to bring smaller, lighter and more efficient power electronics to numerous applications. GaN Systems selected Ecomal Europe for its expertise in power systems and complimentary line card.

GaN Systems is the first company to have developed and brought a comprehensive product range of devices with current ratings from 8A to 250A to the global market – its Island Technology® die design, combined with its extremely low inductance and thermally efficient GaNPX™ packaging and Drive Assist technology means the company's GaN transistors offer a 40-fold improvement in switching and conduction performance over traditional silicon MOSFETs and IGBTs.
Martin Behlke, Managing Director of ECOMAL Europe said "We are delighted to have the opportunity to work with GaN Systems and its exciting products. We feel that this collaboration will offer great things for the industry and keep our customers at the forefront of a fast-paced market."
Girvan Patterson, President, GaN Systems comments: "Gallium nitride devices are recognised to be the future of power electronics, and as our product portfolio is now ready for commercialisation, it's both key and timely for us to continue to build our worldwide distribution network. In Ecomal Europe, we are confident we have found a technically excellent and strong partner for success in Europe."
Tony Astley, Director EMEA Sales Operations, GaN Systems adds: "I am very excited to be partnering with Ecomal Europe and looking forward to working with our mutual customers as they harness the full potential of this industry-changing technology"

www.gansystems.com

Conference Program of PCIM Europe 2015 published

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This years' conference program is more comprehensive than ever before and presents a high diversity on the latest technological trends and developments in power electronic components and systems.
The highlights include, amongst others, three keynote speeches, five special sessions and in addition 29 oral sessions as well as two poster sessions. Furthermore, on the two days before the conference, well known experts will share their substantial knowledge in nine half day seminars and nine full day tutorials.
View the PCIM Europe 2015 conference program for the detailed information with all sessions, tutorials and seminars.

http://www.mesago.de/de/PCIM/home.htm

Evaluate IGBTs from ABB with Web-Based Simulation

ABB Semiconductors introduces SEMIS, a web-based simulation tool which is embedded in ABB's homepage.

SEMIS offers a quick and easy way to evaluate the performance of IGBT modules from ABB under various operating conditions. All you need is a web browser on a computer or mobile device. You can immediately start a simulation without the hassle of installing software or creating a user account.

The first simulation model is a typical voltage-source inverter circuit supplying an RL-load. Nearly all circuit properties such as the load characteristics, the cooling system and the PWM control can be configured to match the values of your specific application.

From a list of semiconductors choose an appropriate IGBT module for the desired DC voltage and load current. By selecting multiple IGBT modules, the device losses and temperatures can be compared directly against each other. The simulation results are displayed as scope waveforms and data tables. In the scopes you can zoom into the transient waveforms of voltages, currents and temperatures. For a quick summary, the average switching and conduction losses as well as the maximum junction temperature are listed in tabular form.

SEMIS is based on PLECS, the leading simulation software for power electronic systems. On the ABB homepage, the semiconductor models used in SEMIS are provided as downloadable files. This allows you to continue the simulation offline on your computer. By using original thermal models developed by ABB you can easily calculate accurate switching and conduction losses. This will help you to design optimum cooling solutions that keep junction temperatures within specification. The offline simulation can be performed with a free demo or trial license of PLECS, or with a fully licensed PLECS installation.

To run SEMIS now, go to www.abb.com/semiconductors.

About ABB

ABB is a leader in power and automation technologies that enable utility and industry customers to improve performance while lowering environmental impact. The ABB Group of companies operates in around 100 countries and employs about 145,000 people.

ABB Switzerland Ltd., Semiconductors, is a leading supplier of power semiconductors with more than 100 years of experience in power electronics. ABB Semiconductors' full range of thyristor and IGBT high-power devices are key components for industrial, traction, power generation & distribution and renewable energy markets.

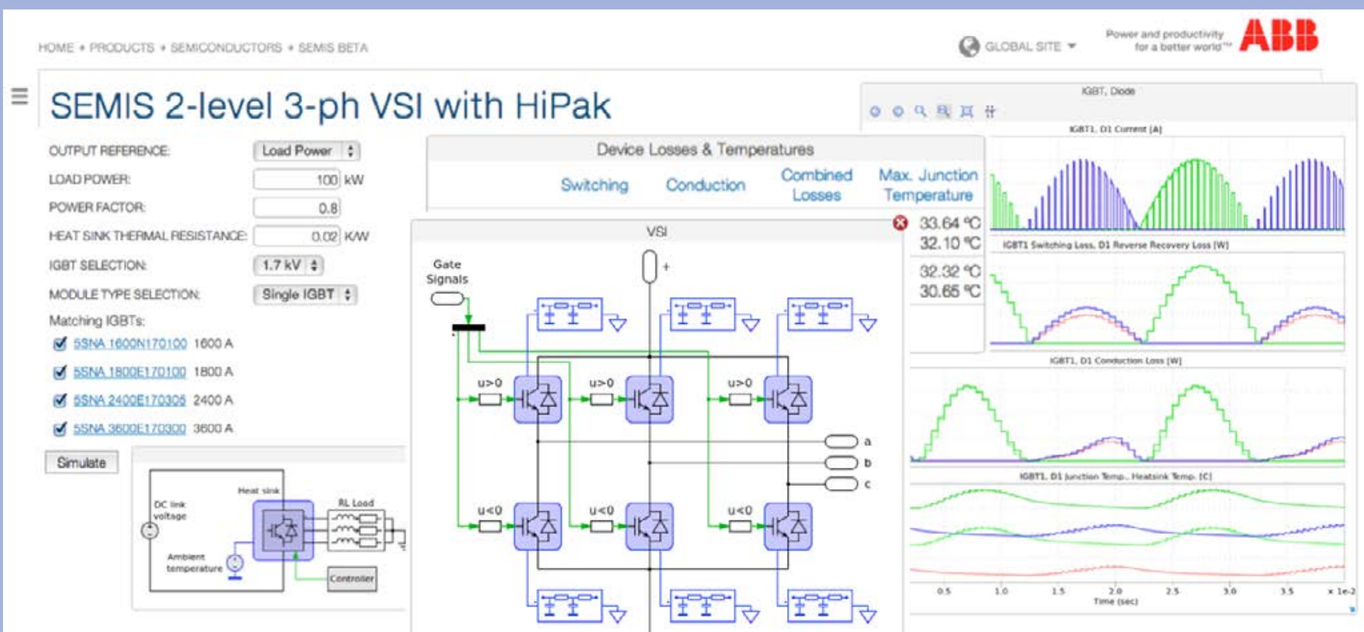
www.abb.com

About Plexim

Plexim is a global leader in simulation software for power electronic systems. Our software enables industry customers to innovate their products at a faster pace by reducing development time and cost. Our products are based on latest software technologies and simulation algorithms combined with innovative modeling concepts. By carefully listening to engineering experts, we offer our customers pioneering solutions for their needs of today and tomorrow.

Since 2002 the simulation software PLECS has become the industry standard for power electronics simulation across various industries. With own offices in Zurich and Boston, and with the support of our local representatives worldwide, we are always close to our customers.

www.plexim.com



Does the Internet of Things mean that analog electronics on the way out?

By Steve Roberts, Technical Director RECOM Engineering GmbH

The hype surrounding the Internet of Things (IoT) is now reaching fever pitch. According to a model of modern technology evolution (http://en.wikipedia.org/wiki/Hype_cycle) , it will soon hit the "peak of inflated expectations" before descending into the "trough of disillusionment" and finally levelling out to the "plateau of productivity". We know that we have reached the inflated expectations peak when we read comments like; "The Internet of Things will transform everything - in the future, the next generations will look at us and wonder how we ever survived our "dumb" homes". Considering that millions of people in the world make it through their lives quite satisfactorily without even the benefit of electricity, we can see how rash such comments are. A more level-headed commentator on the recent surge of questionable IoT products - such as plant pots that send SMS messages, feeding bottles that monitor your baby's milk intake and fridges that inform you that they are empty - questions whether people are really that lazy or unobservant to realize that their plants are dry, their baby is full or that they need to buy more beer. The same commentator more realistically suggests that about 4% of the current IoT proposals will actually turn out to be useful. Nevertheless, those few products that do succeed will be very profitable, hence the excitement in the electronics industry over IoT.

The corollary concept to IoT is that everything will be dominated by digitally interconnected devices with local and group intelligence, thus the future will be binary, not analog. Any traditionally analog function will be successively replaced by its digital equivalent; all sensors will transmit their information directly as digital data, any analog signals will be filtered by DSPs and "dumb" analog power supplies will be exchanged for digital power supplies that can intelligently adapt themselves to the load conditions. The expectation is that soon analog electronics will no longer be relevant in the modern world – the end of analog electronics as we know it.

However, analog electronics is not going to go away. We live in the real world, not a digital simulation of it. After all, at the most basic level, all electronics is analog and digital is just fast analog. What is on a sharp growth curve is mixed-signal electronics; microprocessors with on-board operational amplifiers, PWM generators and ADC's, for example. Real world voltages and currents often exceed the 3.3V limits of most digital circuitry and their micro-amp supplies - and as long as there is a need for analog-to-digital and digital-to-analog interfaces, there will always be a need for analog electronics. This is doubly true for power electronics as there is no such thing as a digital switch.

In a recent interview, the CEO of one of the larger power supply manufacturers stated that the future for his company lies in power modules with digital control and digital feed-back and that consequently he was diverting resources away from analog design. This may be a good strategy for higher power units where the expectations for exceptional efficiency, high power factor and a fast response to dynamic loads can hardly be reached using non-digital control systems any more, but all power supplies have performance artefacts that arise from analog interactions – whether it be simply the inductance of the cabling, unwanted cross coupling between components or stray leakage capacitances, not to mention the complex layered EMC interference signals that many digital simulations do not or cannot take into account. As long as the heart of any power supply is the transformer, then analog electronics will still be at the center of power supply design.

There is also a significant trust issue with digital power supplies – many do not feel comfortable working on designs that resist empirical analysis. Electronics engineers need to be able to look at a circuit schematic and, with the help of the performance specifications in the datasheets, be able to figure out how a circuit is supposed to work or troubleshoot why it does not. As soon as there is a digital processing or control stage in the design, the logical link is lost between input and output, hidden in some cryptic part of the coding.

Returning to the theme of the Internet of Things; how will all of these devices be powered? The accepted answer is to use either a single cell battery or energy scavenging from thermal gradients, vibration and solar energy or by tapping into the electro-smog of all of the other RF networks. All of these energy sources generate either very low or very variable voltages, so there is still a need for boost converters/regulators with high efficiency at very low loads. A coin-cell battery may be able to power an IoT processor for many years (after which, presumably, the device will be simply thrown away), but the 1.5V battery output also severely limits the sensor choice. Temperature and visible light measurements are generally OK, but many other sensors require significantly higher voltages and there are very few power supplies in the market that can efficiently generate higher output voltages from single cell supplies or low voltage energy scavenging circuits. For the few that do exist, the severe cost restrictions of a disposable power supply product mean that only simple analog DC/DC converters are suitable. So as the Internet of Things gathers momentum, the requirement for very low power analog power supplies will actually increase. For the few remaining analog power supply designers out there; analog is not on the way out and long live the IoT!

www.recom-power.com

Electronics Industry Digest

By Aubrey Dunford, Europartners

Gartner forecasts that 4.9 billion connected things will be in use in 2015, up 30 percent from 2014, and will reach 25 billion by 2020. This expansion will boost the economic impact of the IoT as consumers, businesses, city authorities, hospitals and many other entities find new ways in which to exploit the technology. IoT will support total services spending of $ 69.5 billion in 2015 and $ 263 billion by 2020. Consumer applications will drive the number of connected things, while enterprise will account for most of the revenue. 2.9 billion connected things will be in use in the consumer sector in 2015 and will reach over 13 billion in 2020. The automotive sector will show the highest growth rate at 96 percent in 2015. From an industry perspective, manufacturing, utilities and transportation will be the top three verticals using IoT in 2015 – all together they will have 736 million connected things in use. By 2020, the ranking will change with utilities in the No. 1 spot, manufacturing will be second and government will be third, totaling 1.7 billion IoT units installed. Government will take the No. 3 spot as it invests in smart street and area lighting for energy saving reasons. Utilities will move to the No. 1 position because of investment in smart meters.

SEMICONDUCTORS

Global semiconductor sales through November have matched the total from all of 2013. Worldwide sales of semiconductors reached $ 29.7 billion in November 2014, an increase of 9.1 percent from November 2013 and a slight decrease of 0.1 percent from October 2014, so the WSTS. Year-to-date sales through November are 10 percent higher than they were at the same point in 2013. Regionally, year-to-year sales increased in the Asia Pacific (12.3 percent), the Americas (11.1 percent), and Europe (3.4 percent at $3.18 billion), but decreased in Japan (-4.5 percent). Sales were up compared to the previous month in the Americas (1.8 percent), but decreased slightly in Asia Pacific (-0.2 percent), Europe (-0.7 percent), and Japan (2.6 percent).

O2Micro International, a supplier of integrated circuits, is refocusing the company's Intelligent Power Management business unit to better align its resources to focus on its new tablet and smartphone power management products. The strategy is aimed to better utilize its proprietary battery management technologies for industrial applications, including its precision battery gas gauge products. As a result of this measure, the company is reducing its current worldwide employee base by approximately 80 employees. The majority of the employees affected by this announcement are based in the company's European and U.S. locations. Founded in April 1995, O2Micro develops and markets power management components for the computer, consumer, industrial, automotive and communications markets.

Renesas Electronics, a Japanese supplier of advanced semiconductor solutions, announced the results of its early retirement program for employees in Japan, announced on October 29, 2014. 1,725 persons will leave the company at the end of the month. Renesas expects to record special loss of approximately 7.9 billion yen for the three months ending December 31, 2014. Renesas anticipates the program will result in reduction of annual personnel cost by approximately 14.8 billion yen ($ 125 M).

Headquartered in Cork, Ireland, Powervation, a developer of digital power ICs, has closed a $ 3 M term debt agreement with Ares Capital Corporation that supplements a $ 4 M private equity financing that closed in the December quarter. The company's integrated digital control and digital power management IC products are based on a proprietary digital control platform which delivers regulation, full auto-tuning, dynamic performance and flexibility. The funding will be used to scale the business in response to adoption of the company's Intelligent Digital Power IC products in the cloud server, high performance computing, communications, and power supply markets.

Koch Industries had acquired Molex in 2013, for a total equity value of approximately $ 7.2 billion.

PASSIVE COMPONENTS

Molex, a global interconnect and cable assembly provider, has acquired SDP Telecom. Headquartered in Montreal, Canada, SDP designs and manufactures RF/microwave solutions for the wireless communications industry. Founded in 1995, SFP has manufacturing facilities in China in addition to its Montreal headquarters. SDP will be managed by the RF/Microwave Business Unit that is part of Molex's Global Integrated Products Division. Molex and SDP will broaden their RF/Microwave product capabilities in the wireless infrastructure market.

OTHER COMPONENTS

Rogers, a global supplier of engineered materials solutions, has signed a definitive agreement to acquire Arlon, a provider of high frequency circuit materials and engineered silicones currently owned by Handy & Harman, for $ 157 M. Revenue and operating income for the Arlon segment of Handy & Harman Ltd. were $ 100.4 M and $ 16.7 M, respectively, for the trailing twelve months ended September 30, 2014.

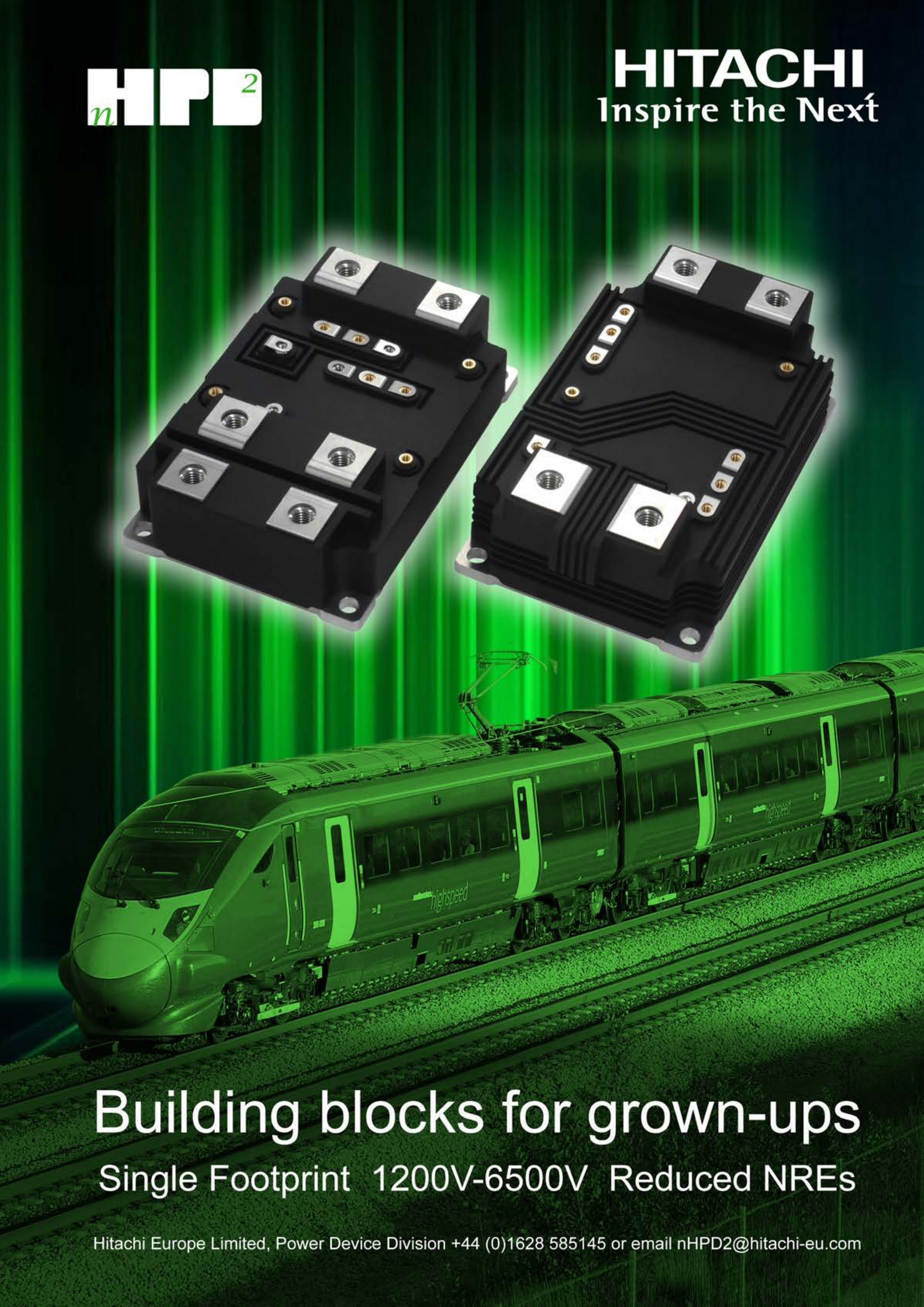
The Alliance for Wireless Power (A4WP) and Power Matters Alliance (PMA) announced the organizations have signed a letter of intent to merge and establish an organization that will accelerate the availability and deployment of wireless charging technology on a global scale. The A4WP and PMA, leaders in wireless charging technology, have agreed in principal to the terms of the merger that is expected to close by mid-2015. The new entity will operate under a to-be-announced new name.

DISTRIBUTION

Mouser Electronics has entered into a global distribution agreement with DB Unlimited, a supplier of audio components ranging from transducers, indicators, and speakers, to the latest MEMS technology used in their microphones.

This is the comprehensive power related extract from the « Electronics Industry Digest », the successor of The Lennox Report. For a full subscription of the report contact: eid@europartners.eu.com or by fax 44/1494 563503.

www.europartners.eu.com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Wireless Power is not a "Done Deal"

By Richard Ruiz, Analyst, Darnell Group

The First Edition analysis of the Wireless Charging market from Darnell Group is an in-depth analysis detailing the latest developments in this important emerging market. The wireless power charging IC market will see tremendous growth over the next five years, with a dollar market increasing from $284.3 million in 2015 to over $2.8 billion in 2020, a compounded annual growth rate (CAGR) of 58.7%. The wireless power charging market covered in this report is made up of both wireless charging receiver ICs and transmitter ICs. But the longer-term market growth is still uncertain.

While wireless charging is rapidly gaining market share, its continued success and the final size of the wireless charging market is still to be determined. There are a number of significant factors that could derail this emerging market including the continued uncertainty of the standards environment, especially the on-going development of a new standard by IEEE and the uncertainty regarding the efficacy of wireless charging relative to energy efficiency standards such as the California Energy Commission (CEC), Level V, that mandates ac adapters meet a minimum efficiency of 85%.

It remains to be seen if wireless charging technology can meet this requirement. For these and other reasons, wireless charging is not a 'done deal'.

Although this report presents the wireless charging market in five categories: Consumer, Computers, Industrial, Medical and Military, it is an emerging technology and there are no traditional applications within these categories to rely on to lead the way. The further growth of wireless charging power is entirely dependent on the growth of wireless charging penetration rates in a number of key applications such as mobile phones and tablets.

The large mobile phone market will continue to dominate the global wireless power charging market throughout the forecast period. Specifically, further wireless charging growth in the rest of the applications covered in this report will depend on the growth of the wireless charging penetration rate within the mobile phone industry. If mobile phone penetration is unable to progress at a rate approaching 30-50% by 2020, the future of ubiquitous wireless charging will be in serious jeopardy

For the purpose of this report, the worldwide market includes four regions: North America, Europe, Asia and the rest of the world (ROW). The Darnell Group expects to see considerable growth for the wireless charging IC unit market over the forecast period in each of these regions. Overall, the worldwide unit wireless charging IC market will grow from 135.2 million units in 2015 to over 1.4 billion units in 2020, a CAGR of 61.7%.

The development of wireless power charging isn't about just reducing the number of external ac-dc power supplies in the world it's about increasing the capability of wirelessly powered devices in everything from cellphones and tablets to automobiles and industrial tools and sensors. The elimination of the need to maintain multiple external power supplies, one for each electronic device, has long been a goal for both the consumers and manufacturers of consumer electronics equipment and over the past several years there have been a number of developments moving the industry towards this goal.

One of the more challenging aspects of wireless charging adoption for both manufacturers and users of electronic applications is the current mix of standards in place. Progress has been limited by the fact that no universally adopted standard is available and this has hindered development. Understandably, device manufacturers want infrastructure in place before they commit to mass production of their products and infrastructure manufacturers want devices in place before they commit to mass production.

Over the past several years there have been three primary organizations working towards the establishment of a working wireless standard. Each of these three bodies has their respective technologies and has the backing of a large number of industry participants. They include the Wireless Power Consortium (WPC), the Power Matters Alliance (PMA) and the Alliance for Wireless Power (A4WP).

The standards that have been developed or are under development by each of these three bodies differ. However they typically define requirements for transmitters designed to deliver power, receivers for mobile phones that will use the power and a specific communications protocol for the devices. In January 2015, the A4WP and the PMA announced that they had signed a Letter of Intent to merge. This development is projected to play an important role in the strengthening of standards and the further development of wireless charging power.

In a development likely to have considerable impact on the drive towards wireless charging, the IEEE (Institute of Electrical and Electronics Engineers) Working Group is attempting to establish the IEEE P2100.1 Standard Specifications for Wireless Power and Charging Systems. It is the first in a series of anticipated standards addressing parallel wireless power and charging technology specifications. The IEEE is seeking to establish an interoperable standard that will allow users to wirelessly power and recharge smartphones and other mobile devices.

Specifically, IEEE P2100.1 will establish parallel specifications for wireless power and charging for both transmitter and receiver devices, with an initial focus on inductive (or tightly) coupled technologies. When completed and approved, IEEE P2100.1 will offer advantages and benefits over a wide range of markets including consumer electronics and appliances, electric vehicles, medical devices, and more. As the interest in loosely coupled systems increases, the working group will adapt to focus on this technology and incorporate this into the standard as well.

One of the biggest challenges wireless power charging has to overcome is the level of efficiency when compared to the traditional use of wired power. Regulatory standards regarding efficiency may prove one of the biggest obstacles to the adoption of wireless charging. The California Energy Commission (CEC), Level V, mandates that ac adapters meet a minimum efficiency of 85%. It remains to be seen if wireless charging technology can meet this requirement.

Additional forecasts in this report include both low and medium power receiver and transmitter ICs for both Wireless Power Consortium Qi technology and A4WP technology. Driven by the large mobile phone market, over the forecast period the receiver IC market is projected to be dominated by Qi technology, while the transmitter IC market will have a higher percentage of A4WP technology. For the purpose of this report, the A4WP and PMA products have been combined.

Among the additional areas to watch are advances in IC technology, in particular advanced semiconductor developments which are moving towards circuits with dual-mode wireless power capability, components and materials, and advances in digital power technology. Also important to observe are a number of long-term alliances and partnerships as well as developments in standards and regulations, efficiency and standby power requirements and the clear long-term shift from first generation (tightly-coupled) to second-generation (flexibly-coupled) wireless power transfer technologies.

This report contains over 45 tables, graphs and illustrations covering the wireless charging market. The focus of this comprehensive analysis will be to provide decision makers and manufacturers and operations with a detailed and insightful look at the current and future opportunities available in the wireless charger IC market, details can be found at:

www.Darnell.com

Biricha Lecture Notes on Analog and Digital Power Supply Design

Part 1.C Foundations: Understanding and Using Transfer Functions

In the last 2 articles we discussed frequency response analysis and loop measurement. We talked about what to look for in a Bode plot and showed what the Bode plot of a nice stable power supply should look like.

By Dr Ali Shirsavar, Biricha Digital Power Ltd

However, we still need to take the Bode plot of the plant of our power supply and with the addition of some extra circuitry change its shape so that the final Bode plot meets the stability criteria. The extra circuitry that allows us to change the shape of the Bode plot to what we desire is our compensator. Typically in analog PSUs this is just an inverting op-amp with a few capacitors and resistors.

The compensator circuit is usually very simple; the hard part is calculating the correct values of the capacitors and the resistors to get the correct shape of the overall Bode Plot. How do we calculate these? Do we randomly pick a bunch of components, solder them on and hope that the power supply magically becomes stable? No, we clearly need a mathematical method of linking our capacitors and resistors to the shape of the Bode plot; this is the job of our transfer function.

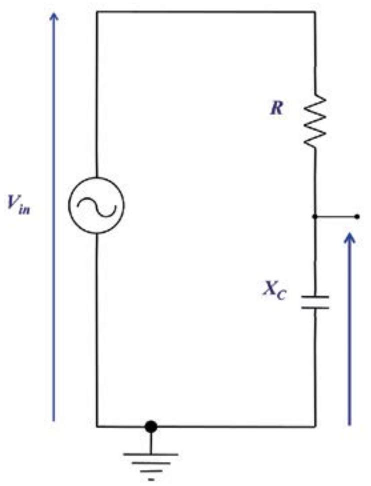

Figure 1: Simple low pass RC-filter circuit.

A transfer function is simply a mathematical model of our circuit that relates its input to its output. It follows therefore that if I have the transfer function of our system and I use a known sine wave as my input (say 1V amplitude at 10Hz), I can then calculate the amplitude and phase of the sine wave that comes out. Et voilà; we have a way of mathematically plotting the Bode plot of our system before building it.

Plotting Bode Plots from Transfer Functions

The transfer function relates the input to the output and by definition it is:

$$H(s) = \frac{Y(s)}{X(s)} = \frac{Output}{Input}$$

Consider the simple low pass filter shown in Figure 1.

Using the potential divider equation we have:

$$V_{out}(s) = V_{in}(s)\frac{X_c}{(X_c + R)}$$

$$Where: X_c = \frac{1}{j\omega C} = \frac{1}{j2\pi f C} = \frac{1}{sC}$$

Please note that we only use the Laplace operate "s" to simplify the algebra. There is nothing to fear about Laplace; it is just another mathematical tool to help us analyse circuits. Substituting Xc and a little bit of algebra results in my transfer function H(s):

$$H(s) = \frac{1}{(1 + sRC)} = \frac{1}{(1 + j2\pi f RC)}$$

You can see from the previous equation that the transfer function is a complex number. This is great news because it means that now as I vary the frequency f, I can plot my gain and my phase; i.e. I have a way of relating the component values R and C to the shape of the Bode plot. I have achieved my objective! Moreover, if I am not happy with the shape of the Bode plot I can influence its shape by changing the values of R and C.

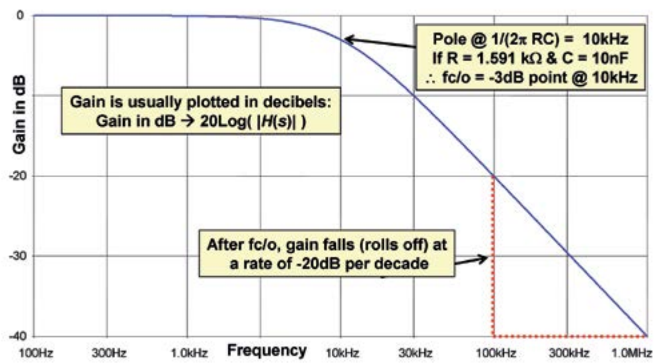

Figure 2: Gain of the low pass filter circuit, with a single pole, displayed on the Bode plot

We know from our mathematics classes how to get the gain of a complex number:

$$Gain = |H(s)| = \sqrt{\mathrm{Re}^2 + \mathrm{Im}^2} = \frac{1}{\sqrt{(1^2 + (2\pi f RC)^2)}}$$

Note that the result is not complex and therefore I can plot my gain vs. frequency which is usually done in decibels as shown in Figure 2. This is my gain plot of my Bode plot.

I can now do the same thing for my phase. I know from school mathematics, how to work out the phase of the complex number. In my case this will be:

$$Phase = \phi \tan^{-1}\left(\frac{\mathrm{Im}}{\mathrm{Re}}\right) = -\tan^{-1}(2\pi f\ RC)$$

Again this equation is not complex and therefore I can plot my phase vs. frequency to get the phase plot of my Bode plot. This is shown in Figure 3.

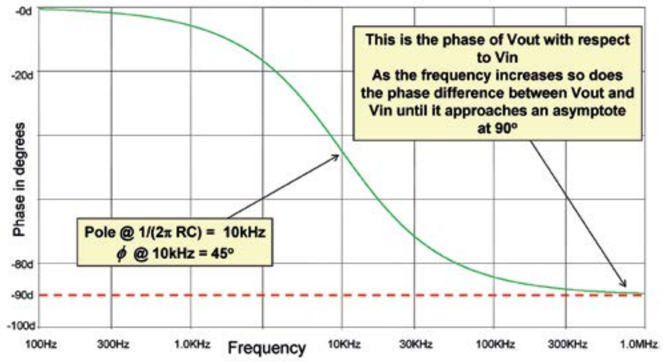

Figure 3: Phase of the low pass filter circuit, with a single pole, displayed on the Bode plot

Poles, Zeros and Their Use

The poles of a transfer function

The transfer function of our simple low pass filter takes the form of

$$\frac{1}{(1 + s\,\alpha)}$$

Where in our case α= 2πRC. If we vary s from –infinity to +infinity as some point s will become equal to -1/2πRC and thus the denominator of our transfer function becomes zero. At this point the "numerical value" of my transfer function will become infinity (even though mathematicians would call this "undefined", for us engineers infinity will suffice). Please note that this does not mean that the output voltage becomes infinity, it only means that the numerical value of the transfer function becomes infinity.

This is called the pole of my system. In other words whenever the numerical value of my transfer function goes to infinity, I have got a pole in my system. And the only the reason I am trying to determine the locations of the poles (and later the zeros) is because they tell me a lot of information about the stability of my power supply. The values of R and C are shown on the gain plot and you can see that we have a pole at 10kHz.

Characteristics of a pole in the transfer function

There are really only 2 things that you need to know about poles:

1 – Every pole in our transfer function (located in the left hand side of the s plane) will result in the gain to fall at a rate of 20dB per decade after the pole frequency. This means that after 10 kHz, every time our frequency goes up by a factor of 10, our gain falls by 20dB i.e. a factor of 10. This is clearly shown on the gain plot. If I had 2 poles in my system then the gain would fall at a rate of 40 dB per decade.

2 - Every pole in our transfer function will result in a phase lag of 90° at frequencies much higher than the pole frequency. You can clearly see from the phase plot that at high frequencies the phase approaches -90° (i.e. a phase lag of 90°). If I had 2 poles in my system then I would expect a total phase lag of 180°.

The zero of a transfer function

Sometimes our transfer function takes the following form:

$$\frac{(1+s\beta)}{(1+s\alpha)}$$

We have already discussed the pole in the denominator, so let us now concentrate on the numerator. Now as we vary s from –infinity to +infinity at some point s will become equal to -1/β. This is called a “zero” of our transfer function as at this point the “numerical value” of the transfer function will become zero. Again this does not mean that the output voltage will become zero and again I am only interested in the position of zeros because they tell me information about the stability of my system.

A zero (on the left hand side of the s plane) is a little bit like an “anti-pole” so every time you have a zero in your system, the gain rises by 20dB per decade and you get a phase lead of 90°. If you had two zeros the gain would rise at 40dB per decade and you would get a phase lead of 180°.

So why am I interested in the position and the number of my poles and zeros? We can see that as the designer, I can place my pole at a certain frequency by choosing the appropriate values of R and C and therefore control the shape of the Bode plot. I can therefore start manipulating the shape of the Bode plot in order to make it fit the stability criteria.

How Well Does the Transfer Function Match with Reality

As mentioned earlier we use transfer functions in order to have a mathematical tool to design our circuits. But how well do Bode plots simulated mathematically using transfer functions match with reality? Well, there is only one way to find out; let us measure one.

Earlier in this article, we simulated a low pass filter with R =1.59kΩ and C = 10nF giving us a pole frequency of 10kHz. We can see from simulated plots earlier that at 10kHz our gain is -3dB, our phase is -45°, our high frequency phase lag is 90° and the slope after 10kHz is -20dB/decade.

We will now measure a real low pass RC filter with R = 1.6kΩ and C = 10nF using a Bode 100 network analyser from OMICRON Lab. If the hypotheses above are valid then we would expect the real mea-

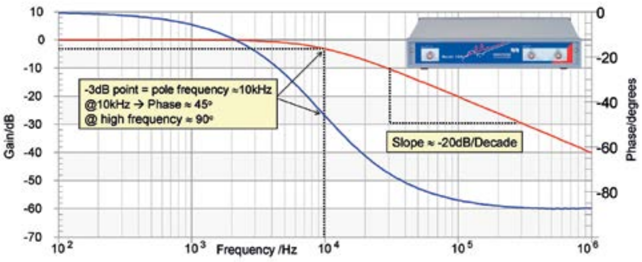

Figure 4: Real measurement of the low pass filter circuit using the Bode 100

surement to be very close to the simulated one.

Figure 4 shows our real measurement. You can see clearly that we have an almost perfect match with simulations.

Concluding Remarks

In this article we discussed transfer functions and their role in helping us design circuits in frequency domain. In essence we can shape the Bode plot of a circuit by appropriate placement of its poles and zeros. Moreover, we can position the poles and zeros by appropriate selection of the circuit components such as the resistors and the capacitors.

Power supply designers use a circuit known as a “compensator” in order to force the power supply to meet the stability criteria as well as other performance targets. In analog power supplies this almost always consists of just an inverting op-amp with poles and zeros which the designer places by correct calculation of Rs and Cs.

In the previous articles we studied Bode plots and stability criteria; here we covered transfer function, poles and zeros and how to place them. We now know all the foundation material needed for stable compensator design.

In the next article we will discuss power supply compensators, their transfer functions, their poles and zeros and how to design them in frequency domain.

Things to Try

1 – Visit OMICRON Lab’s website for more information about Bode 100

Bibliography

[1] Biricha Digital’s Analog Power Supply Design Workshop Manual
[2] OMICRON Lab website

For the PDF version and related videos please visit:

www.biricha.com/bodo1c

Power Modules Win Out, but Choose Wisely

Power modules are the way to go when it comes to leveraging the expertise of power experts and getting your design to market quickly, but choose wisely. Power-module architecture choices can greatly affect your power supply's performance.

By Jian Yin, Intersil Corporation

Whether evaluating step-down switching regulators at the silicon-level (controller with FET), or power modules where the integration, and ease of use of a more complete power supply subsystem may be preferred, system designers everywhere are under enormous pressure. They're being tasked with integrating more power and features in ever-shrinking form factors, and thus adversely affecting the system's electrical and thermal characteristics.

There are various obstacles system designers must overcome on the path to integration nirvana. These include the increased likelihood of noise coupling as components are in closer proximity, as well as heat dissipation, given that the power-handling capabilities continue to increase along with smaller footprint areas.

Fortunately, power module designers continue to innovate to meet these demanding requirements through various architectural and topological design approaches that extract the maximum performance from the smallest package. Yet, these innovations put the burden upon system designers in need of the optimum power module to be careful in their choice of solutions. The techniques used by different power module solutions can greatly affect overall system cost, as well as key performance parameters such as heat dissipation, transient response, ripple voltage, and even ease of use. It's very much a case of 'buyer beware'.

The Case for Modular versus Discrete

For system designers, there are many reasons to opt for a power module versus designing a power converter from the component level, not least of which are ease of use and time-to-market. By adding only input and output capacitors, these power customers can finish their designs relatively easily and quickly, with confidence that their basic performance and space requirements have been met. The power module is a complete power converter system in an encapsulated package that includes a PWM controller, synchronous switching MOSFETs, inductors and passive components, see Figure 1.

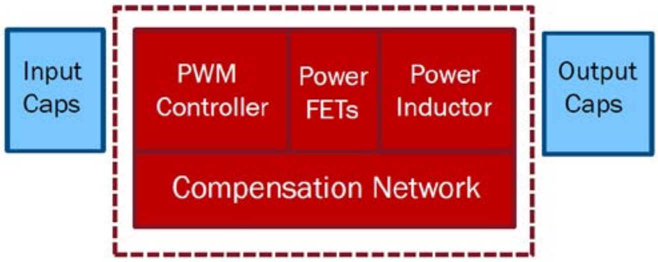

Figure 1: Highly integrated power modules require only input and output capacitors, and maybe a few additional external components to meet a system designer's needs

For example, Intersil's ISL8203M power module has an extremely low profile package at 1.83mm, which is similar to a 1206 capacitor's height. Also, it delivers the excellent electrical and thermal performance to meet all customer requirements. Normally that knowledge would be sufficient, but how that module was designed can greatly affect more nuanced parameters, features and capabilities.

ISL8203M Deep Dive

ISL8203M is a complete DC-DC power module that has been optimized to generate low output voltages ranging from 0.8V to 5V, making it ideal for any low-power, low-voltage applications. The supply voltage input range is from 2.85V to 6V. The two channels are 180° out-of-phase for input RMS current and EMI reductions. Each channel is capable of 3A output current. These channels can be combined to form a single 6A output in current-sharing mode. While in current-sharing mode, the interleaving of the two channels reduces input and output voltage ripple.

ISL8203M is only 1.83mm thick with a footprint of 6.5mm x 9mm, as shown in Figure 2. It has the most compact package profile for a given input and output voltage/current range, see Table 1, and its overall package volume is only 106mm3, which is dramatically smaller than all other power module solutions. Although the ISL8203M package is very compact, it is still delivers very good efficiency, as shown in Figure 3.

Figure 2: The ISL8203M power-module package measures 6.5mm x 9mm x 1.85mm

Parts	Current	Input	Output	Overall size
Competitor 1	Dual 4A/ Single 8A	2.375V to 5.5V	0.8V to 5V	15x15x2.82mm $635mm^3$
Competitor 2	Single 6A	2.375V to 6.6V	0.6V to 5V	11x8x1.85mm $163mm^3$
Competitor 3	Single 6A	2.95V to 6V	0.8V to 3.6V	11x9x2.8mm $277mm^3$
ISL8203M	Dual 3A/ Single 6A	2.8V to 6V	0.8V to 5V	9x6.5x1.85mm $106mm^3$

Table 1: The ISL8203M is the industry's most compact 6A encapsulated power module

Capacitors for Power Electronics

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Small Module Package Offers Excellent Thermal Performance
The ISL8203M uses a QFN (quad-flat, no-leads) copper lead-frame package, where the internal component is soldered directly to the copper lead frame, see Figure 4. Also, the wire bonds can be applied to the top of the internal component for electrical connections to the lead-frame. Then the molding can be filled in to form a complete encapsulated package.

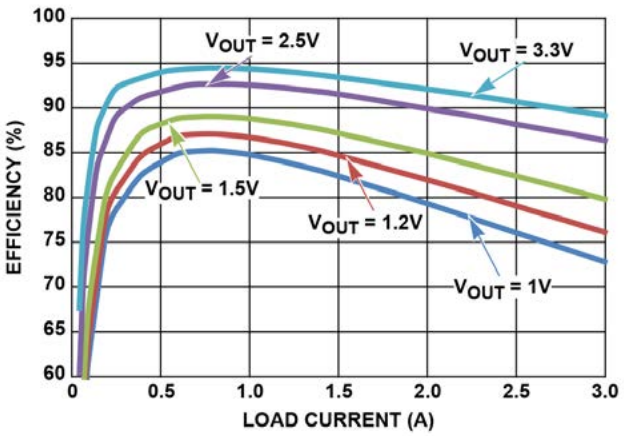

Figure 3 a: Efficiency of ISL8203M (One 3A output at 5Vin) under various output voltage and current conditions

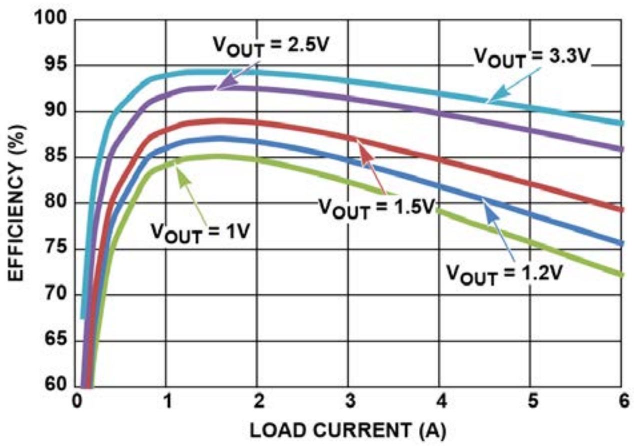

Figure 3 b: Efficiency of ISL8203M (Paralleled 6A output at 5Vin) under various output voltage and current conditions

This structure allows the heat generated by the internal components to be dissipated directly by the copper in the lead frame which has a thermal conductivity of ~385 W/mK. This is about 1000 times the thermal conductivity of the printed circuit board (PCB) which has a typical thermal conductivity of ~0.343 W/mK. As a result, the copper-based lead frame can help the heat dissipate much more efficiently than a PCB-based module. Also, since the copper lead frame can be six times thicker than the 1oz copper on a typical PCB, the module lead frame can help spread the heat over a large area, thus accelerating the effective heat transfer area to the system board.

Figure 4: ISL8203M internal structure

Overall, the module's thermal performance can be better than a discrete solution where the component is soldered directly to the PCB system board.

It's important to note that the molding material in the structure can have a similar heat-spreading effect to the copper lead frame. Although the molding material has a lower thermal conductivity, the heat can still transfer through the molding horizontally and then dissipate into the copper lead frame. The molding also increases the effective heat transfer area from the internal power component, and thus decreases the thermal resistance from the internal part to ambient. This is another important comparison benefit of power modules – the ability to handle high power in a small package versus discrete solutions.

Let's take a closer look at the thermal performance of an ISL8203M mounted on a standard four-layer evaluation board with 2oz. copper on the top and bottom layers, and 1oz. copper in the middle layers, see Figure 5. Running a worst-case scenario of 5Vin to 3.3Vout/6A with no airflow and an ambient temperature of 25°C, the module's maximum temperature is only 66.8°C.

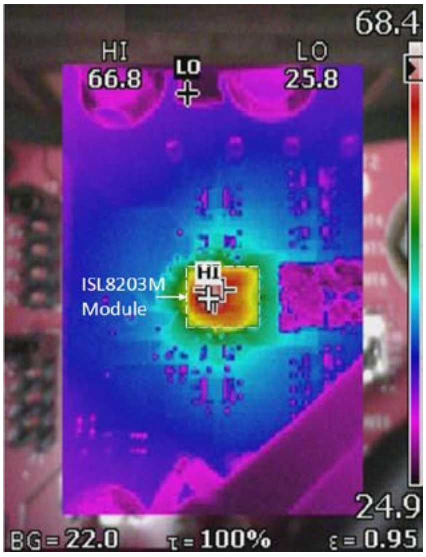

Figure 5: In a worst-case scenario, converting 5Vin to 3.3Vout at 6A -- with no air flow and an ambient temperature of 25°C -- the ISL8203M reached a maximum temperature of only 66.8°C

For Transients, Current-Mode Power Module Achieves Better Performance
There are generally two types of control schemes used in module applications: current-mode and voltage-mode. To ensure a fast transient response under various load conditions, the ISL8203M uses a current-mode control scheme to regulate the output voltage, see Figure 6. The scheme's current-sensing signal is derived from the voltage across the top FET's conducting resistance (Rdson) of the synchronized buck converter. This is then fed into the current amplifier, the output of which undergoes slope compensation before being compared to the output error amplifier to generate what now becomes the pulse-width modulation (PWM) signal. Through the driver, the PWM signal can control the synchronized buck converter to achieve the required voltage regulation. The compensation on the error amplifier is needed to boost the loop gain and phase margin to achieve better performance and stability.

The structure of the voltage-mode control is simpler than current-mode control. It replaces the dashed block area in Figure 6 (a) with a saw-tooth ramp at a fixed frequency shown in (b). This saw-tooth ramp, instead of the current-mode design's current-sensing signal, is then compared with the error amplifier's output to generate the required PWM signal.

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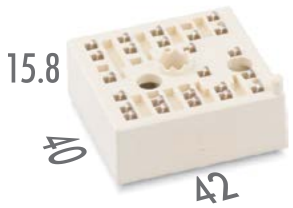
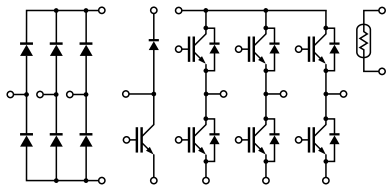
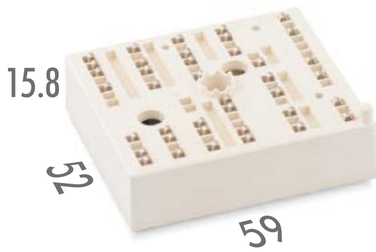
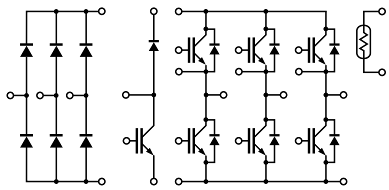




I_C	1200V
8A	●
15A	●

MiniSKiiP® 2

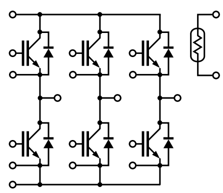




I_C	1200V
25A	●
35A	●

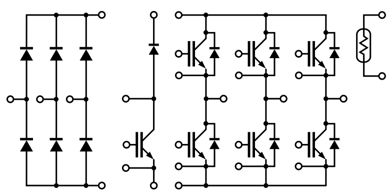
Available also with larger rectifier diodes

MiniSKiiP® 3



I_C	1200V
100A	●
150A	●

Under development



I_C	1200V
50A	●
75A	●
100A	●

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The voltage mode control is also easy to understand. As shown in the figure 7, its open-loop system is a two-order system, with the inductor and output cap forming the complex poles. Clearly, its normalized phase Tv(s), shown in Figure 7 (b) drops very fast by 180° across the 20kHz resonant frequency of the complex poles. This system depends upon the compensation components to improve the phase margin to achieve stability. Otherwise, it only has 10° phase margin with the crossover frequency at 50kHz, as shown in Figure 7 (b). Large phase margin (typically higher than 40°) is a necessity for the loop stability.

If we use this same voltage-mode control system in (a) and modify it to the current loop shown in Figure 6 (a), it becomes a current-mode control system. The system open-loop Bode plot is shown in Figure 7 as Tc(s). This system is close to a single-order system at the low frequency range, so the phase is boosted dramatically from 20kHz to 500KHz, shown in Figure 7 (b). Even without the compensation components, this is still a stable system. If a simple type II compensation is added to improve the low-frequency gain and push the crossover frequency to about 50KHz, the current-mode control phase margin can still be about 80°, which is sufficient for stability. So, for current-mode control, the compensation is relatively simple, versus voltage mode, and can cover a wide range of different output capacitors due to the large phase boost in open loop.

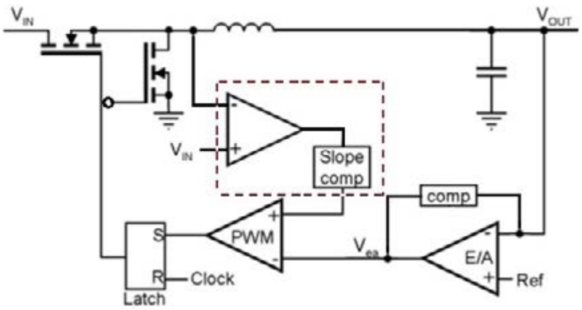

Figure 6a: Current- and voltage-mode control diagram (ISL8203M Simplified current-mode control diagram)

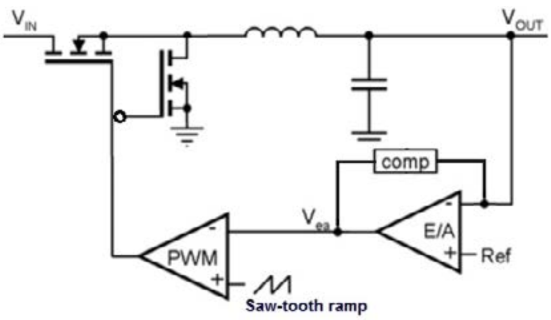

Figure 6b: Current- and voltage-mode control diagram (A typical voltage-mode control diagram)

For power-module applications, the compensation is fixed inside the package, so if the output capacitors are changed with different customers' applications, the complex poles in the voltage-mode control can be shifted significantly. The fixed compensation may not cover the wide range of output-capacitor changes since its open-loop phase is too low once over the LC resonant frequency. So in many cases, it can cause insufficient phase margins if the load conditions are changed. To avoid this, the voltage-mode module must lower the loop bandwidth (cross-over frequency) to ensure enough phase margin for stability at various load conditions compared to current-mode control. The penalty for lowering this bandwidth is poor transient response performance.

To show this critical difference in transient performance, we selected one competitor's 4A power module with voltage-mode control to

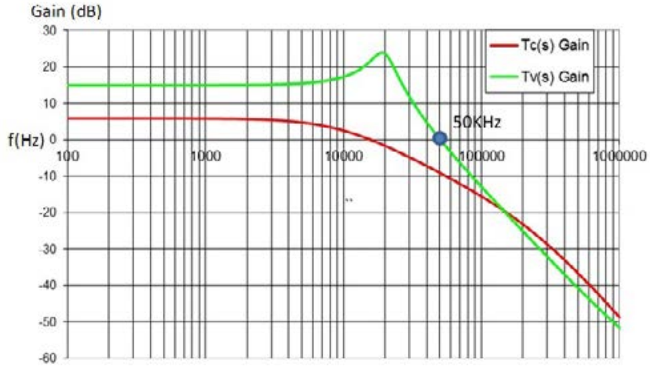

Figure 7a: Open-loop Bode plots of voltage- and current-mode controls (Open-loop gain of voltage and current modes)

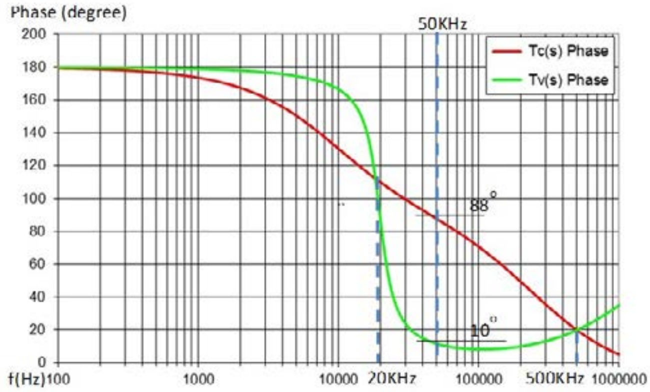

Figure 7b: Open-loop Bode plots of voltage- and current-mode controls (Open-loop phase of voltage and current modes)

compare with ISL8203M. The final loop Bode plots of these two power modules are shown in Figure 8.

If we select the same output capacitors for the test, with the phase margins both at ~60o, the ISL8203M loop bandwidth of one 3A output was much higher than the voltage-mode module, leading to the ISL8203M having much better transient performance, see Figure 9. Under the same testing conditions, the ISL8203M has a peak-to-

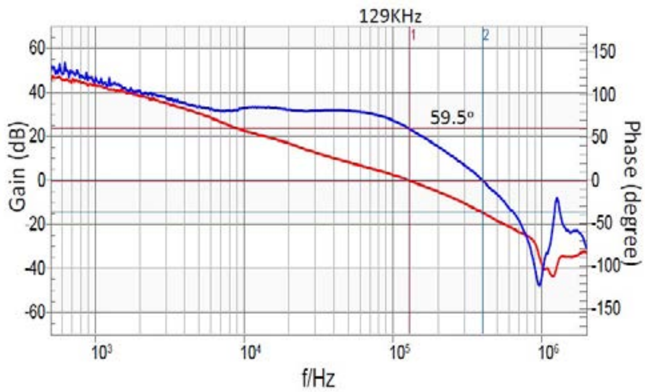

Figure 8a: Closed-loop Bode plots of current-mode and voltage-mode controls on module applications (One 3A output of ISL8203M) (5Vin to 1Vout/3A, with the same COUT=2x10µF ceramic + 47µF tantalum capacitor)

peak variation of 240mV and a recovery time of only 25µS, while the voltage-mode module has a peak-to-peak variation at 275mV and large recovery time of 70µS.

Paralleled Operation Provides Low Output Ripple

Finally, the ISL8203M can operate with dual 3A outputs or a single 6A output. When it runs at 6A, the two 3A outputs can be paralleled as shown in Figure 10. With the phase interleaving between two outputs at 180°, the input and output ripples can be reduced dramatically. As shown in Figure 11, the paralleled output ripple is only 11mV, while the competitor's single-phase module ripple goes as high as 36mV,

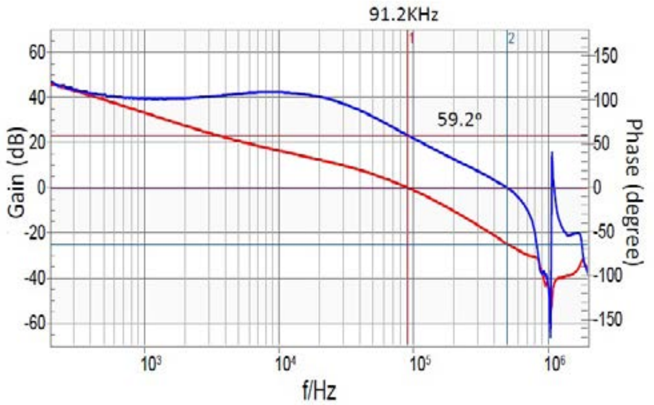

Figure 8b: Closed-loop Bode plots of current-mode and voltage-mode controls on module applications (A competitor's voltage-mode) (5Vin to 1Vout/3A, with the same COUT=2x10µF ceramic + 47µF tantalum capacitor)

under the same test conditions. More importantly, for a given output ripple, the ISL8203M needs less than half of the output capacitors compared to the single-phase module, thus providing significant cost savings.

Conclusion

The ISL8203M comes in a compact package yet still meets customers' electrical and thermal performance requirements. The module's standard evaluation requires no heat sink and no airflow, delivers a total power of 20W to the load, with the module reaching a maximum temperature of only 66.8°C.

Its current-mode control scheme allows the ISL8203M to achieve good transient performance with excellent peak-to-peak variation and a recovery time that is one-third that of competitive power modules. The ISL8203M's special parallel mode also enables it to deliver 6A, with extremely low output ripple, and two outputs interleaved at 180°. This feature also comes with significant component cost savings for a given ripple limit.

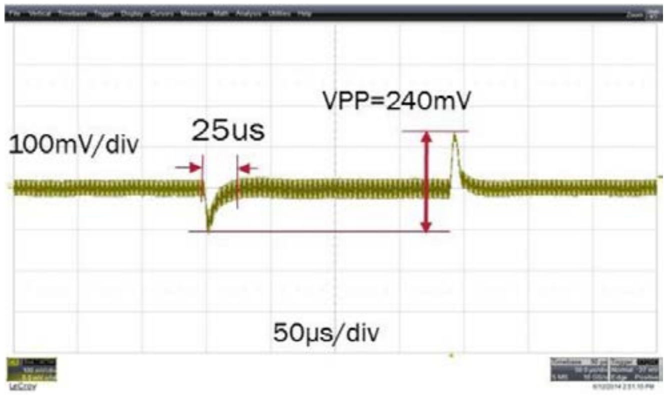

Figure 9a: Output load transient response with the same output capacitors (One 3A output of ISL8203M) (5Vin to 1Vout 0 to 3A, COUT= 2x10µF ceramic + 47µF tantalum capacitor; load-current step slew rate at 1A/µs)

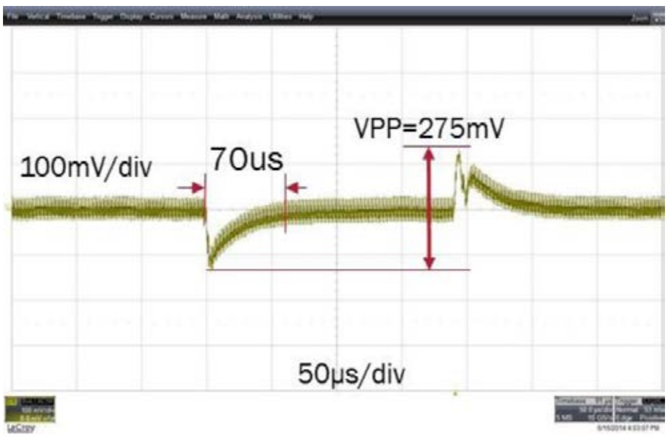

Figure 9b: Output load transient response with the same output capacitors (A competitor's voltage mode control power module) (5Vin to 1Vout 0 to 3A, COUT= 2x10µF ceramic + 47µF tantalum capacitor; load-current step slew rate at 1A/µs)

With all of these superior performance characteristics, the ISL8203M is a good candidate for any low-power, low-voltage application, such as test and measurement, communication infrastructure and industrial control systems, all requiring high density and good performance.

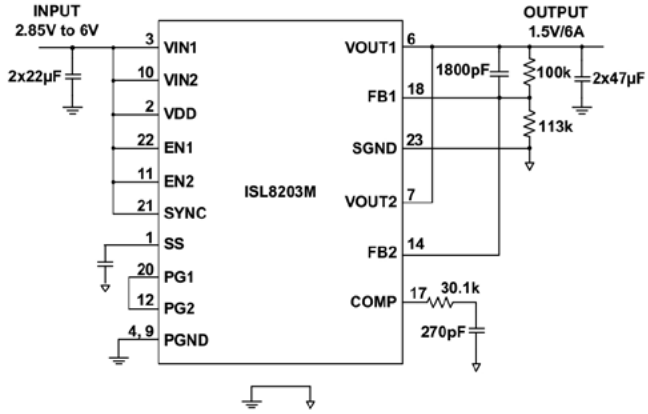

Figure 10: ISL8203M can be quickly and easily programmed to parallel operation.

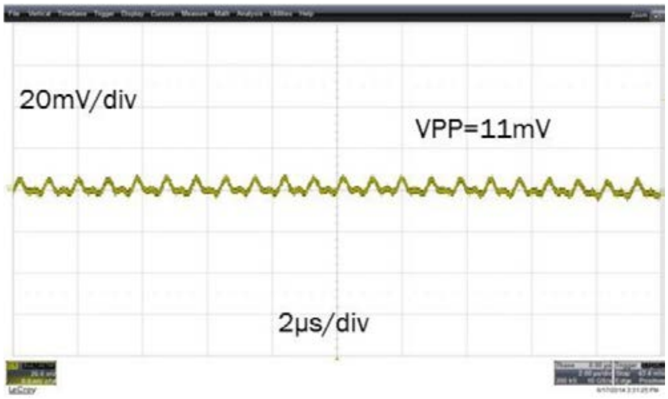

Figure 11a: Output ripple performance with the same output capacitors (ISL8203M ripple at 4A with two outputs in parallel) (5Vin to 1Vout 4A, COUT= 2x4.7µF ceramic + 68µF POSCAP capacitor; load-current step slew rate of 1A/µs)

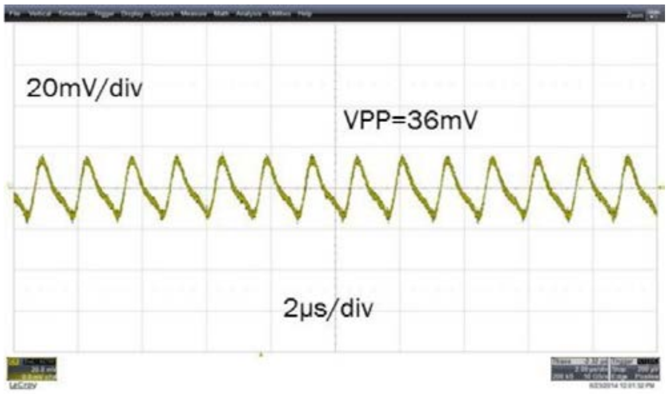

Figure 11b: Output ripple performance with the same output capacitors (Ripple for a competitor's 4A single-output module) (5Vin to 1Vout 4A, COUT= 2x4.7µF ceramic + 68µF POSCAP capacitor; load-current step slew rate of 1A/µs)

To meet the challenges of designing the power subsystem for these systems, many designers are using power modules instead of traditional discrete point-of-load designs, when time-to-market, size constraints, reliability and design capabilities are the motivating factors. Find out more about Intersil's ISL8203M power module at:

www.intersil.com/products/ISL8203M.

A High Current, Low Inductance Wide Bandgap Power Module for High Performance Motor Drive Applications

Over the past decade, substantial effort has been devoted to mature and commercialize wide bandgap power devices [1,2] for discrete and multi-chip power modules (MCPMs) meeting the demands of power electronic systems which include high speed motor drives [3], down-hole drilling [4], hybrid-electric and all-electric vehicle chargers [5], and solar/wind inverters [6] to name a few. As such, the adoption of wide bandgap-based devices, subcomponents, and systems has increased exponentially exhibiting a substantial increase in the power density and efficiency of the system, simplifying cooling requirements, and extending the reliability of the overall system.

By B. Passmore, B. McPherson, R. Shaw, T. Berry, J. Hornberger, P. Killeen, T. McNutt, and A. B. Lostetter, APEI

To address the needs of an array of applications, a high temperature, high performance half bridge power module was developed for industrial, aerospace, and automotive motor drive applications to exploit the superior characteristics of wide bandgap semiconductors. The HT3000 is rated to +1200 V, +400 A, and 3.6 mΩ on-resistance per switch. This high power density power module was designed to house both SiC and GaN power devices in an industry standard footprint. In addition, other configurations, such as common source and common drain, are available as well. Figure 1 shows a CAD image of the HT-3000 with dimensions.

Figure 1: APEI's high current, low inductance industry standard footprint wide bandgap power module – HT-3000

APEI employs a design process that jointly uses SolidWorks®, a design-focused software, and COMSOL Multiphysics®, a modeling-focused software, to interactively design and model a power module or system to achieve optimal performance using the minimum design time. During the design process, a large series of adaptive finite element analysis (FEA) simulations were performed to fully optimize the thermal, mechanical, and electrical characteristics of the power module. Properly identifying the impact of material and geometry changes were crucial in designing an effective and robust power module. An example of a thermal resistance sweep as a function of thermal conductivity and baseplate thickness is shown in Figure 2 (left). Since both parameters impact the thermal resistance of the power module stack-up, it is imperative that a matrix of values from both parameters are modeled to pinpoint the optimal solution. As an additional example, deflection surfaces were extracted in a similar manner as the thermal performance. Surfaces were plotted representing a series of sweeps of the CTE (ranging from Kovar – 5.5 ppm/°C to Aluminum – 23.1 ppm/°C) and thicknesses (ranging from 0.5 mm to 6 mm) as shown in Figure 2 (right). The trade-offs between the design variables analyzed and optimal dimensions and material were selected that maximized performance and minimized cost.

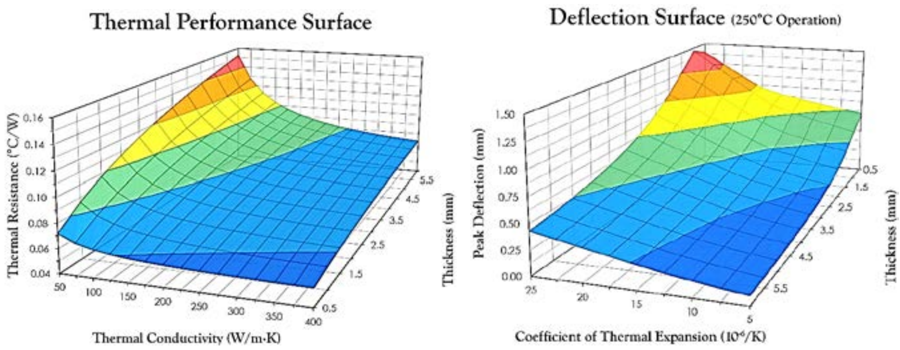

Figure 2. (left) The thermal resistance vs. baseplate thermal conductivity and thickness and (right) baseplate deflection vs baseplate coefficient of thermal expansion and thickness for the HT-3000

To gain a better understanding of how inductance of the HT-3000 compares to various other commercial power modules, the power loop of the HT-3000 was modeled using

COMSOL Multiphysics®. The resulting comparison is presented in Figure 3. Two commercial modules are standard half-bridge "bricks" whereas the other two are thin 6-pack pin style packages. As shown, the HT-3000 has a substantially lower inductance than all other options (while also exhibiting a much higher current carrying capability). This is primarily due to the low profile of the module which shortens the length of the power contacts, wide power contacts since inductance is inversely porportonal to width of the contact, and the layout specifically designed for paralleling many devices. It serves as a salient example of the benefits of designing modules from the ground up to embrace the potential of high frequency wide bandgap power devices.

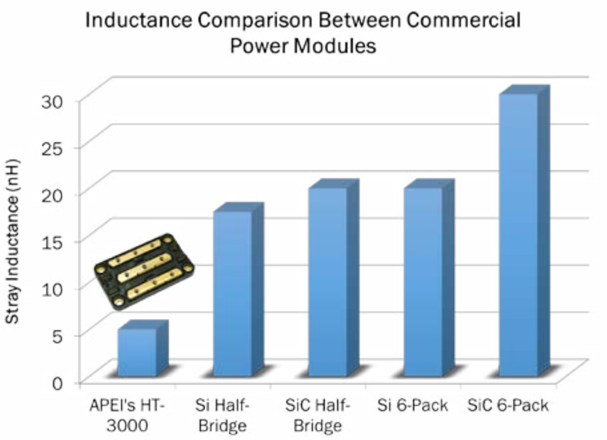

Figure 3: Parasitic inductance comparison between the HT-3000 and other power module types

For power electronics systems, it is not only important to reduce on-state losses but also reduce switching losses. Consequently, the majority of the switching losses is dominated by the device speed and inductance associated with the module and eventually system as a whole. In addition, to reduce the size and complexity of existing systems, the demand for higher switching frequencies continues to increase. Thus, the need for low inductance, high power density power modules with fast transition speeds is an enabling technology that allows efficient, high frequency operation. Figure 4 illustrates switching test results for the HT-3000 power module with two different

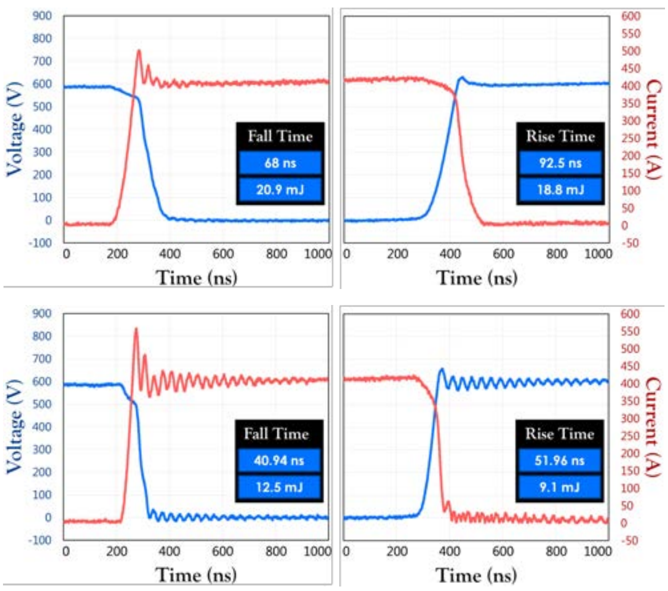

Figure 4: The experimental dynamic switching results with (top) 10 Ω and (bottom) 5 Ω external gate resistors for the HT-3000

gate resistor configurations (10 Ω and 5 Ω, respectively). The 10 Ω gate resistor results in less than 100 ns for a total of 40 mJ of loss for both the turn-on and turn-off events, switching 600 V and 400 A. However, the 5 Ω gate resistor configuration results in very low rise and fall times of 50 ns or less, and on/off switching losses of under 20 mJ total, while maintaining extremely clean switching waveforms of less than a 50 V overshoot under 600 V and 400 A switching conditions.

<< A summary of the switching losses and rise and fall times as compared to other commercially available Si power modules is shown in Figure 5. APEI's HT-3000 has roughly one-fourth the total switching losses compared to both Si IGBT-based power modules (300 A cont.) In addition, the HT-3000 can switch over 2 – 3 × faster than its counterparts. As compared to other commercial SiC power modules, the HT-3000 has the lowest known on-resistance which significantly reduces system on-state losses. The HT-3000's superior dynamic characteristics coupled with extremely low on-resistance set it apart from existing Si and post Si solutions.

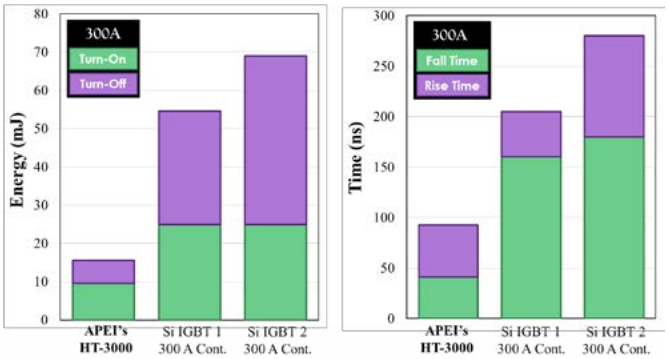

Figure 5: The switching losses and rise and fall times measured experimentally for APEI's HT-3000 power module compared to other commercially available Si power modules.

In this article an advanced high-performance power module (HT-3000) was presented that takes full advantage of the unique benefits of wide bandgap devices including: high current density, high junction temperatures, fast switching speeds, and reduced losses. Implementation of this advanced package and SiC or GaN device technology may result in substantial system level improvements, particularly in applications where size, weight, and efficiency are paramount.References

(Endnotes)

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Boost Your System!

Defining the Future of IGBT High-Power Modules

Continued progress in the performance of power semiconductors drives demand for corresponding improvements in packaging technology. Infineon has contributed to this evolution across more than two decades. With its announcement of "The Answer" in 2014, power system designers now have a path to meet ever tougher application requirements. This article provides insight into the development of this new flexible high-power platform and demonstrates how Infineon's approach from product thinking to system understanding works at its best.

By Thomas Schütze, Georg Borghoff, Matthias Wissen and Alexander Höhn, Infineon Technologies AG

Historical background

Infineon has a long history of setting international standards for IGBT modules. In 1993 the first IGBT High Power Module (IHM) with blocking voltages up to 1.7kV was launched to the market. Subsequent advancements were the development of the IGBT High Voltage Module (IHV) family for voltage classes up to 3.3kV and, with the availability of 6.5kV chips, the launch of the IHV 6.5kV housing in 1999. With the PrimePACK,TM launched in 2006, a flexible module with high-current ratings in dual configuration captured the 1.2 and 1.7kV market.

All designs were available for licensing by other suppliers, contributing to the resounding market acceptance of these high-power product families. The same applies to low- and medium-power modules such as Easy, Smart, Econo and EconoPACKTM +. Across multiple generations of chip technology, the designs initially developed by Infineon and licensed by multiple suppliers have found their way into countless applications and are widely spread across the world.

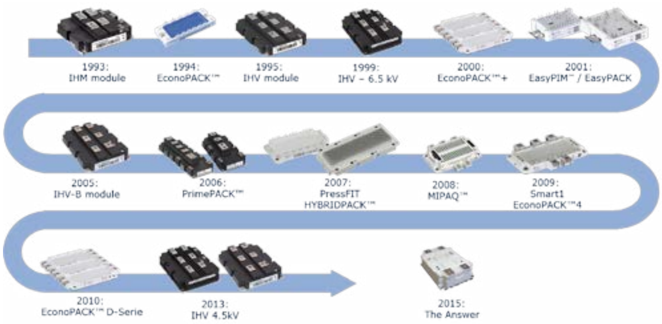


Figure 1: What will happen next?

"System Thinking" is one of the Infineon`s biggest drivers in its search for new innovative technologies that offer maximum benefits to customers. In power modules, new applications lead to new performance requirements in four principal areas; power density, efficiency, lifetime durability and reliability. Flexibility to accommodate the need for "custom" solutions in some industries is increasingly important. In addition, constant improvement in power chip performance and anticipated adoption of innovative new technologies mean that commonly used modules will ultimately fall short of market requirements. New packaging technology and a corresponding change in the form factor will address these new demands while helping end customers control system costs.

Infineon discussed its roadmap for high-power modules at the PCIM Europe 2014 conference. Subsequently, plans for royalty-free licensing of the new packaging and the timetable for launch of the first two platforms to use the design were announced. Now the company presents a deeper insight into the future of flexible high-power modules.

The Scope

The new housing for high-power IGBT modules is designed to cover the full-voltage range of IGBT chips from 1.2 to 6.5kV. Principle applications of the new package are expected in industrial drives, traction, renewable energy and power transmission applications. One key innovation is its scalability, which will greatly simplify system design and manufacturing. Additionally, due to its robust architecture, the new high-power platform will provide long-term reliability in applications with demanding environmental conditions.

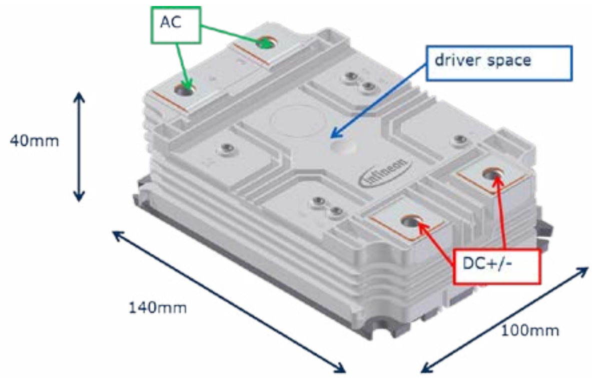


Figure 2: The new high-voltage package

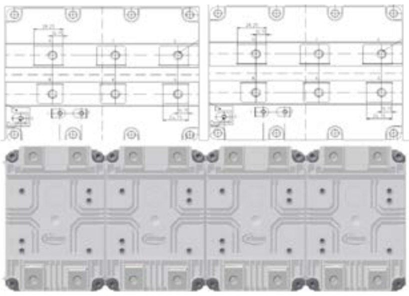
A main focus in development of the new platform was to achieve the flexibility and reliability while assuring optimal integration into customer systems. Features defined to meet this goal include:

- Modular approach, wide scalability with high-current density
- Half bridge switch configuration, resulting in the first half bridge modules for 4.5KV and 6.5KV
- 1.2kV up to 3.3kV in a low-voltage (LV) package, 3.3kV up to 6.5kV in a high-voltage (HV) package, each one is optimized for the specific needs of this voltage range

- Design for lowest stray inductance of internal connections, which enables low inductive external connections at the same time
- Ultrasonic welding connections of highest reliability and quality
- 1.2kV and 1.7kV modules will be first to use new chip and joining technology

2 x FZ1500R33HE3
installed IGBT current: 3000A
(190+10+190)mm x 140mm: 546cm²
power density: 5,49A/cm

+17%



4 x FF450R33T1E3
installed IGBT current: 3600A
400mm x 140mm: 560cm²
power density: 6,43 A/cm²

Figure 3: Package comparison of a phase leg built of two single IHV or four dual modules

The Design

Two housings with different heights are planned. The LV module with up to 6kV insulation and corresponding creepage distances will house 1.2kV and up to 3.3kV chips. Two extra AC terminals will allow for the higher achievable currents of these voltage classes. The HV module, housing 3.3kV, 4.5kV and 6.5kV chips, will offer up to 10.4kV insulation and corresponding creepage distances.

These module dimensions were chosen to deliver a footprint similar to currently used IHV-A and IHV-B modules. Due to the unchanged depth of 140mm, identical extruded heat sink profiles can be used. Four modules with a foot print of 140x100mm, mounted without a gap due to an alignment hook, will fit exactly into the space used today by two 140x190mm IHV modules, with a mounting space, to build one

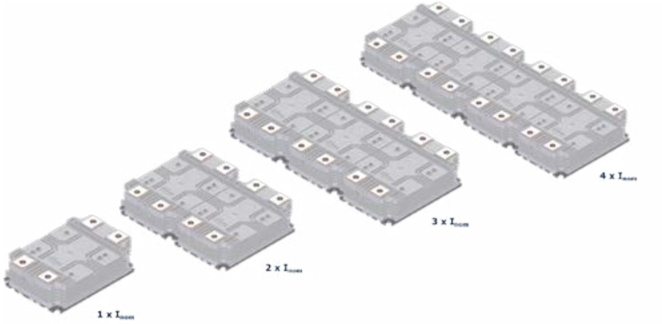


Figure 4: Scalability by simple paralleling

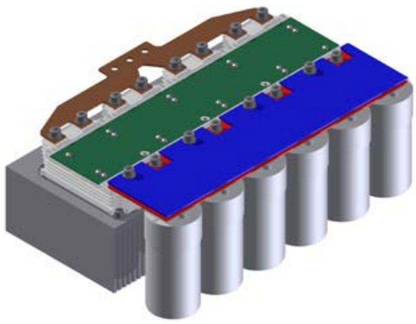


Figure 5: This example shows four modules in parallel with gate PCB, DC-link and phase output busbar.

phase leg. The achieved current density for this configuration of four paralleled devices is 17% greater than a phase leg with the same footprint formed by two IHV modules using the same chip technology.

This example illustrates how, in comparison to existing products, the modular approach of this packaging leads to considerable flexibility. This concept makes it possible to easily parallel the high-power platform for various applications; the single module is simply a building block for units with higher current ratings. Paralleling of up to four devices will not need a derating from user side due to an excellent internal and external current sharing.

The terminal arrangement of Infineon´s flexible high-power platform also allows an easy-to-implement "flow through concept". The DC-link terminals offer a simply structured connection to the capacitor bank and the AC terminals can be paralleled by a single bar. The area in between can be used for an interconnecting PCB carrying driver or the booster stages.

voltage class	3.3kV	4.5kV	6.5kV
technology	IGBT 3	RCDC	RCDC
current rating	2 x 450A	2 x 400A	2 x 275A

Table 1: Device Matrix

Due to a commutation inductance between the upper and lower switch of less than 25nH for the HV module, in combination with the easy-to-implement "flow through concept," the new platform allows for unbeatable low stray inductances of the overall commutation loop.

Product range of the new HV platform

The flexible paralleling concept allows the system builder to replace a multitude of different housings with easily implemented stringed devices, creating savings in purchasing and production efficiency. For example, a high-voltage module portfolio of dual and single switches that is delivered today with modules of 73x140, 130x140 and 140x190mm foot prints can be reduced to one device per voltage class used in multiple parallel configurations.

As noted above, Infineon's announced roadmap to implement the technology includes plans for first products at PCIM 2015. Seen here are switching waveforms for turn-on, turn-off and recovery of the first product, FF450R33TE3.

Summary

Infineon is building on more than two decades of leadership to again provide a standard platform for implementation of high-voltage power systems. "The Answer" we have developed to problems faced by industrial customers provides fundamental benefits that extend from today's state-of-the-art to future new technologies. Users can expect:

1. Scalable product range based on a single platform product for the LV and HV range across flexible frame sizes, delivering reduced system and life cycle costs.
2. Support for the latest chip technologies, such as RCDC and wide-band gap for highest power density.
3. Suitability for the latest joining technologies, delivering highest reliability and long lifetime.

www.infineon.com/power

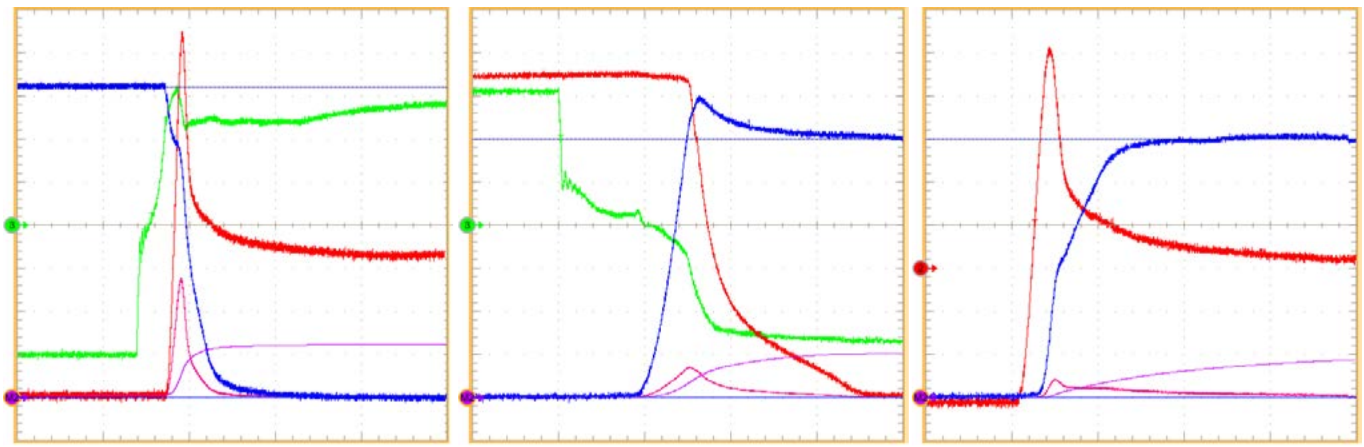


Figure 6: Switching waveforms of FF450R33TE3 at nominal conditions 1800V / 125°C

Get to Market Faster with Digital Power

In our competitive world, being first to market gives your product that slim edge that can mean the difference between success and failure. Everyone knows that companies generate profits by getting their products to the market faster. It's why we have simulation and emulation tools, logic synthesizers, software debuggers and the like. Every facet of equipment design has been digitized and optimized, except for power, until now.

By Ramesh Balasubramaniam, Marketing Director,
International Rectifier, an Infineon Technologies Company

Traditional analog power supply design and verification techniques continue to be laborious and painstakingly slow as you try to work around the limitations of the power supply vendor's chosen feature set. But advanced digital power (digital power 2.0) supply design changes all that, now you are in control of the power, not the other way around – it's like TiVo for your power supply! Here's why:

Figure 1 shows a typical sequence of events required to design, optimize, characterize and validate a power supply in a system.

Figure 1: Typical design sequence

In an analog design environment, step 1 (Design Schematic & Layout) requires careful forethought and planning. Figure 2 compares the circuitry that has to be designed in advance to characterize a power supply in an analog system versus a digital system. It's not enough to just design for the right power delivery and performance, you must also prepare for measurement capability, voltage margining, slew rate adjustments etc. in short, you must prepare for the unforeseen! The analog way is incredibly time-consuming, requires more board space, is prone to mistakes and cannot deliver all of the characterization options and measurements – it's highly custom design. Digital power regulators have all these knobs built in so that you only spend your effort designing the power delivery and performance – International Rectifier's approach is even faster as you only need to choose from a few preset schematics. What can easily take one week in Analog power supply design can be shortened to as little as one day with digital power. Furthermore, all this functionality is already verified by the digital power supply manufacturer so you are not wasting time verifying the characterization circuitry.

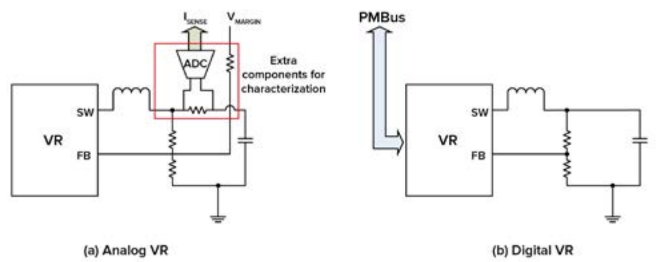


Figure 2: Design of Characterization circuitry

Once the board has been designed and built, the process moves into step 2 (debug VR). One of the greatest frustrations in debugging an analog power supply is trying to determine why it shut down - is it over current, is it over voltage, is it over temperature, or something else? Rarely do analog regulators provide fault diagnostics beyond the Power Good signal, so hours must be spent trying to re-capture the problem whilst using an oscilloscope to monitor several signals in an attempt to determine the shut-down mechanism. Digital power supplies, on the other hand, can immediately stream out the fault mechanism. Furthermore, the fault thresholds can be adjusted based on system characterization. Figure 3 shows the status tab of an International Rectifier PMBus™ enabled regulator indicating the wide variety of fault diagnostics available from a digital power supply.

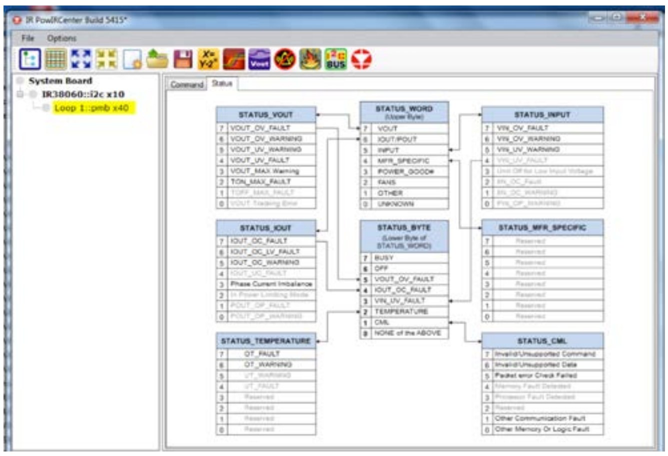


Figure 3: International Rectifier Fault Status Reporting

Once the power supply is up and running, steps 3 and 4 are to optimize and characterize. Optimization the analog way requires soldering and de-soldering components to change parametric values such as switching frequency, output voltage, compensation bandwidth etc., once again, a laborious, time-consuming task. On the other hand, Graphical User Interfaces (GUI) for digital power supplies typically allow the user to change these parameters at the press of a button. Quite often, the parameters can even be changed on the fly without having to shut down the board. Figure 4 shows how easy it is to change the switching frequency of an International Rectifier PMBus voltage regulator.

Characterizing the power supply becomes quick and easy with digital voltage regulators as they can stream out telemetry information such as voltage, current, temperature, efficiency, power and dissipation. In addition, International Rectifier PMBus regulators also store and provide peak current, peak voltage and peak temperature readings to truly understand the environment of the power supply.

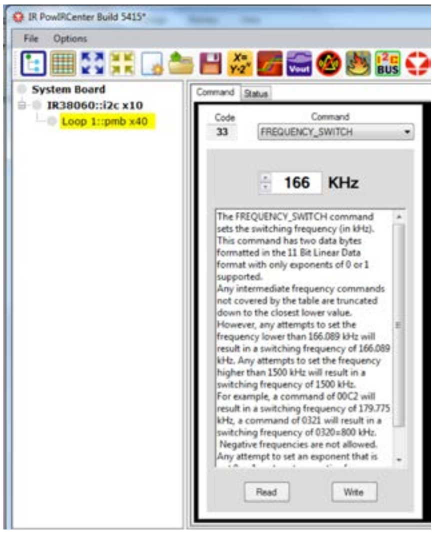


Figure 4: International Rectifier Switching Frequency control

regulators, sequencing is simply controlled by setting the on/off delays and rise and fall times to achieve the desired start-up and shut-down sequences. Margining the power supply rails is childishly easy with digital power components and allows all sorts of combinations to be tested e.g. all rails margin up/down together by the same or different amounts or margin some rails up whilst others are being margined down at the same time. “But margining is easy too in an analog power supply system”, I hear you cry. Looking at Figure 2a, it theoretically only takes one resistor extra into the feedback node to create a marginable supply. However, in practice, you have to be extremely careful to set the margin slew rate and the margin amount very precisely to avoid tripping the regulator’s over/under-voltage detection circuits and powergood flag. All this is automatically taken care of in a digital voltage regulator.

For an analog power supply, we have reached the end of the process. But for the digital power supply there is an added bonus not even possible with analog regulators. Digital power supplies allow the capability for field programmability. As long as a communication link can be established with the system in the field, a digital power supply can

					TOTAL
Analog Power	1 week	1 week	4 weeks	n/a	6 weeks
Digital Power	1 day	1 day	4 days	✓	1 week

Figure 5: Design Cycle Reduction with Digital Power

The last parts of the process (Steps 5 and 6) no longer look at a voltage regulator in isolation but instead focus on the interaction of all the voltage regulators in the system as a whole. After all, it’s the system performance that the end user cares about. What’s important here is ensure the right sequencing between the power supply rails, margin the rails randomly against each other to test for sensitivities and review that the entire system’s power dissipation is to budget.

For analog power supply regulators, most often an FPGA or CPLD is added into the system to control the sequencing and assist with these validation tasks. That’s an added expense, both in terms of system cost and extra design time. With digital power

be monitored and updated from anywhere in the world. One has only to think about wireless base-stations in remote areas to realize the potential for huge time and cost savings that this facility brings.

In conclusion, it is plain to see that all steps in the design process are significantly speeded up by transitioning to digital power regulators. As Figure 5 shows a 6x reduction in the design cycle is easily achievable by transitioning to advanced digital power 2.0 and that means that you can get to market faster!

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Web-based Simulation Tool to Simplify IGBT Selection and Thermal Design in Minutes

By Kristofer Eberle, Plexim and Jiangmin Chunyu and Andrea Gorgerino, International Rectifier, An Infineon Technologies Company

For a given voltage, current rating and package type, there can be many possible IGBT candidates. Additionally, the designer has to ensure that the power stage operates reliably within the thermal constraints. To alleviate these two headaches of power electronics system designers, International Rectifier has added a new web-based simulation feature (IGBT WebSim) to its web site. This helps the engineer quickly select the appropriate IGBT components and obtain the power loss information for their specific application design. The new tool has been developed based on PLECS software, by Plexim, used for the development of power electronic systems. Plexim recently released a version of their offline simulator for running on a web server.

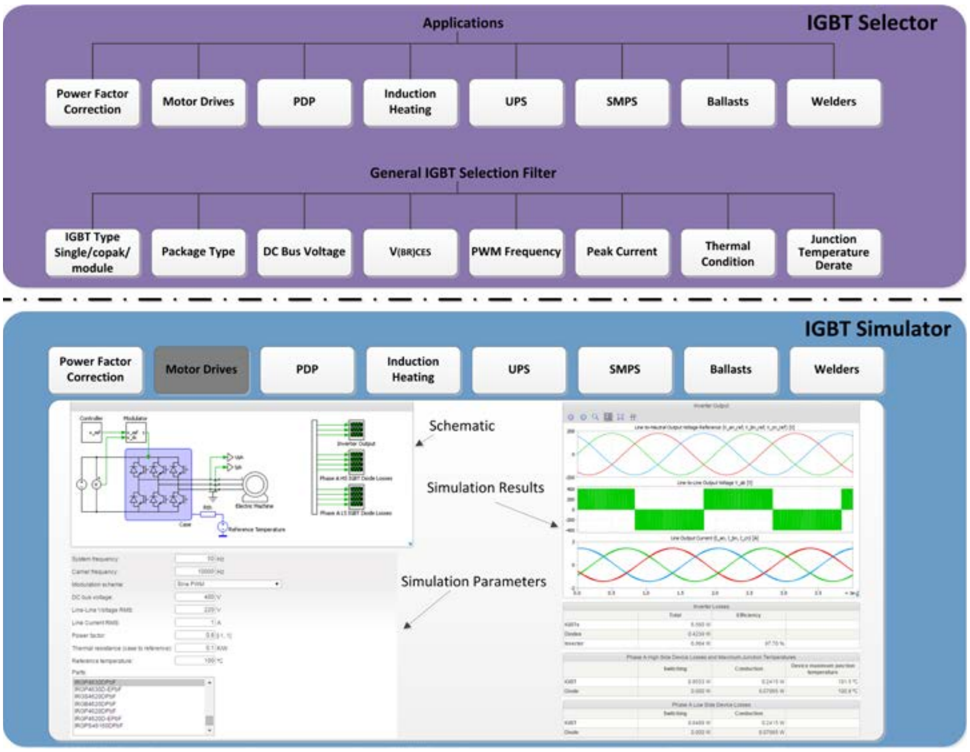


Figure 1: System Block Diagram of IGBT WebSim

IGBT WebSim (Figure 1) consists of two independent tools:

(1) IGBT Selector- Users can select the application type and input general filter parameters (e.g. package type, dc bus voltage, etc.). The tool uses these data to calculate power losses and reduce the list of candidates to devices that would operate at a junction temperature at least 25°C (by default) below maximum junction temperature rating. The short list of potential candidates is shown sorted by power losses; for a more in-depth application-specific analysis, users can be directed to the IGBT Simulator web page once they select the IGBT parts and click the IGBT Simulator button.

(2) IGBT Simulator- Leveraging the fast and robust PLECS simulation engine and its intuitive schematic interface, the IGBT Simulator implements the specific application models listed on the IGBT Selector tool web page. For example, the first iteration of IGBT Simulator includes a three-phase motor drive inverter system with a collection of currently offered IGBT discrete devices. The user can choose various source and load parameters, modulation strategies, and device ratings. Live simulated waveforms can be observed as well as data tables showing calculations for losses in the inverter and junction temperatures of each device. Additionally, the visitor can compare the effect of parameter variations or the operation of different parts directly. Questions such as the efficiency of the power stage of a converter or heat sink or cooling system sizing will be answered at an early stage of the development process.

IGBT WebSim suits engineers of different levels of familiarity with International Rectifier IGBT products. If web page visitors already have made their IGBT selection, they can directly visit the IGBT Simulator web page. In this way one can virtually specify and test a component without downloading a software package or ordering prototypes.

Additionally, the thermal model files can be downloaded to be used in PLECS offline, so International Rectifier parts can be included directly in application-specific designs. PLECS Standalone can be obtained from Plexim's web site and has a free demo mode allowing access to a collection of prebuilt designs. Free PLECS trial licenses can also be requested online for custom model development. Existing PLECS users can also now use International Rectifier's collection of parts.

www.irf.com/design-tools/igbtsim

www.plexim.com/

Using "Normally on" JFETs in Power Systems

A "normally on" device can get short shrift at times due to the negative turn off voltage requirement. Supply Voltage sequencing and single point failures tend to make designers skittish, and thus bypassing the die size/resistivity advantages of "normally on" devices, and the capacitive advantages that go along with using devices with smaller die size.

By John Bendel and Xueqing Li, USCi

The approach to this dilemma is to not only create a "normally off" device by adding additional circuitry, but to do so in order to create advantages over a traditional "off" device. Parity is not enough. A designer needs an incentive. In the context of wide bandgap SiC, this article will highlight several circuit configurations that deliver performance improvements over their corresponding SiC enhancement devices that can give the circuit designer an advantage.

"Normally on" to "Normally off"

The classic way to convert a "normally on" device to "normally off" is the well understood cascode configuration, as shown in Figure 1. A low Voltage device (typically 25 to 30 Volts) is placed in series with a "normally on" high Voltage device (in this example a JFET), and by connecting the Gate – Source and Drain-Source of the two devices, as shown, the JFET VGS is now the inverse of the MOSFET VDS. The JFET will now turn off whenever the MOSFET VDS increases to the |JFET Vth|. The addition of a Low Voltage MOSFET has created a high Voltage normally "off" device.

A MOSFET structure also forms an intrinsic diode, which is critical to switching inductive loads in Bridge configurations. A discrete JFET does not have a drain-source intrinsic diode, so how does the cascode solve this issue? The cascode is a series combination of enhancement (Si MOSFET) and depletion device (SiC JFET). When the cascode MOSFET's intrinsic diode conducts, the JFET is fully "on", and can conduct a current from source to drain, as the JFET VGS is |MOSFET VSD|. The addition of a low Voltage MOSFET creates an electrical path for switching inductive loads.

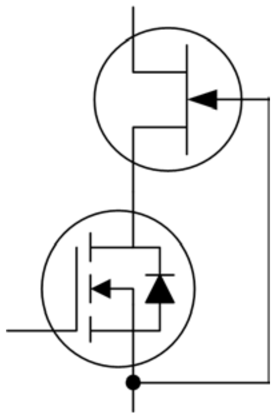


Figure 1: Cascode Circuit

Comparing Cascode and MOSFET in the context of Wide Bandgap

It has been shown that a cascode configuration can reach functional parity with an enhancement mode device, but what of the "ease of use" and "performance"?

Gate Drive

In SiC, Gate drive is a differentiator between cascode and enhancement mode devices. In a cascode configuration, the control device is a low Voltage MOSFET, so the same Voltage levels (0 to 10V) can be used for driving the cascode. Since the JFET is the largest percentage of resistance, the threshold of the MOSFET can be set high to give some relief with respect to threshold decrease with temperature or high dV/dt conditions. The cascode MOSFET's miller capacitor will only see low Voltage excursions (< 30V).

SiC MOSFETs may have low thresholds (2.8V typ.), but to reach advertised RDS, the VGS Voltages must typically reach 18 to 20 Volts. This is outside the range of standard MOSFETs where RDS is rated at 10V VGS, and typical drivers have an absolute maximum rating of 18V. The Gate Drive design of an 1.2kV SiC MOSFET must also take into account that the Miller capacitor will see the full dV/dt of the load Voltage, when put in context of the low VTH may require negative gate drive to insure the device is off during all conditions (-5V to +20V).

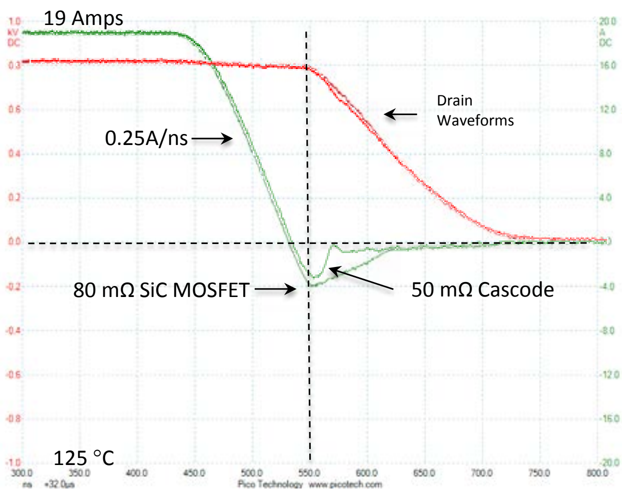


Figure 2: QRR Comparison (SiC MOSFET,381Nc vs. Cascode 155 nC)

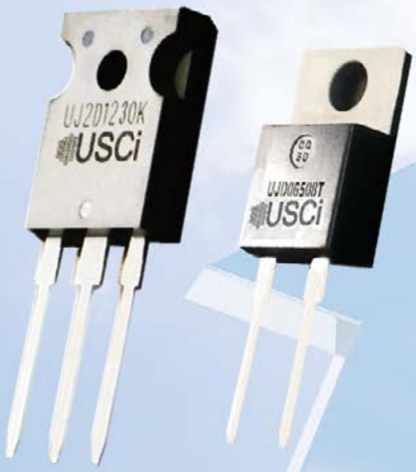
QRR, Reverse Recovery

Switching inductive loads in Bridge configurations requires an intrinsic diode to transition from passing current to blocking Voltage every cycle. This reverse recovery (QRR) generates losses that impact system efficiency. To compare cascode against a single device, the reverse recovery of an 80 mΩ SiC MOSFET is compared against the cascode of a 45 mΩ JFET and 5 mΩ MOSFET at 125 °C (Figure 2). The reverse recovery of the SiC MOSFET is 2.5x that of the cascode, and that is a 50 mOhm cascode solution vs. 80 mOhm MOSFET. Putting QRR in context, a SiC MOSFET's QRR will essentially triple over a 100 °C rise, where a cascode's QRR will increases by only 10%.

"Recover Your Losses"

xR Series 650-1200V JBS Diodes

USCi
United Silicon Carbide, inc.



USCi's silicon carbide xR series junction barrier Schottky diodes have been optimized for minimum Q_C and V_F to meet today's efficiency requirements. Whether targeting an 80 Plus rating in Computing to being paired with IGBTs in a 3 phase solar inverter, the industry leading specifications of these diodes will meet your performance needs.

Part Number	Package	Voltage Rating	Current Rating	Total Capacitive Charge	Typical Forward Voltage
xR Series Schottky Diodes					
UJD6504T	TO-220	650 V	4 A	6 nC	1.5 V
UJD6506T	TO-220	650 V	6 A	9 nC	1.5 V
UJD6508T	TO-220	650 V	8 A	13 nC	1.5 V
UJD6510T	TO-220	650 V	10 A	16 nC	1.5 V
UJD6516K	TO-247	650 V	16 A	26 nC	1.5 V
UJD6520K	TO-247	650 V	20 A	32 nC	1.5 V
UJ2D1205T	TO-220	1200 V	5 A	14 nC	1.5 V
UJ2D1210T	TO-220	1200 V	10 A	35 nC	1.5 V
UJ2D1215T	TO-220	1200 V	15 A	60 nC	1.5 V
UJ2D1220K	TO-247	1200 V	20 A	35* nC	1.5 V
UJ2D1230K	TO-247	1200 V	30 A	60* nC	1.5 V
UJ2D1250Z	Die	1200 V	50 A	158 nC	1.5 V
xJ Series JFETs			I_D max	RDS(on)	
UJN1205K	TO-247	1200 V	38 A	45mO	
UJN1208K	TO-247	1200 V	21 A	80mO	

*denotes single leg

UnitedSiC.com 732-355-0550 or email sales@unitedsic.com

Cascode overview

In short, a designer using cascode will be able to utilize standard Si MOSFET drivers, and have lower reverse recovery losses than using a SiC MOSFET.

Stacking "Normally" On Devices

The above paragraphs went over the advantages one can achieve by implementing a cascode configuration with a "normally on" JFET. This same approach can also be used to create higher Voltage devices. In Figure 3, a super cascode configuration is created by putting a series of low cost silicon avalanche diodes in parallel with a series of "normally on" JFETs.

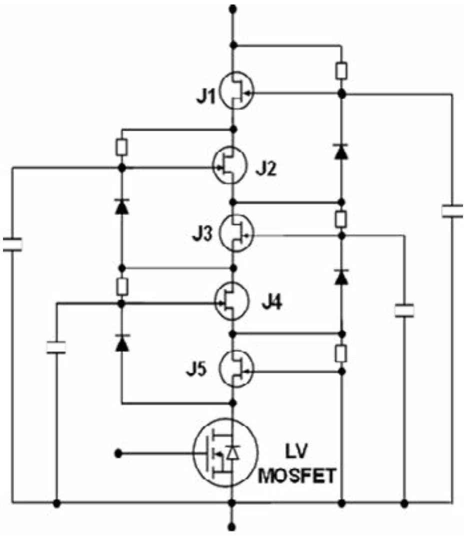


Figure 3: Super Cascode

The operation of the super cascode is similar to the standard cascode, but with the switching happening sequentially. The Low Voltage MOSFET turns "on", which turns "on" its corresponding JFET and this process, moves up the chain until all devices are fully "on".

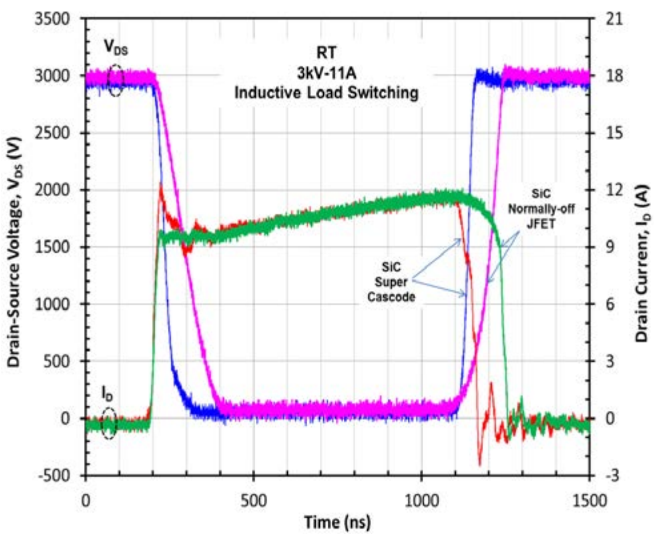


Figure 4: Super Cascode vs. Single device

For turn "off", the silicon diodes' breakdown Voltages fix the maximum Drain-Source Voltage of each JFET. The MOSFET turns "off" and its drain Voltage increases until it reverse bias's the gate of the above JFET. Devices continue to turn "off" up the chain until all the devices are off.

By using a "normally on" device, Voltage is naturally shared and there is no need for complicated gate drive schemes required by "normally off" devices.

The sequencing may sound slow, so how does this compare against a single high Voltage device? In Figure 4, a single 6.5 kV, 300mΩ "normally off" JFET is compared against five stacked 1.2kV, 45 mOhm "normally on" JFETs in a super cascode configuration (~ 230 mOhms) switching 11 Amps.

It is apparent that the switching times of the super cascode are actually faster than the single device. The turn on and turn off energy losses are measured and the super cascode turn "on" loss is less than half of the single device (1.2 mJ vs. 2.7 mJ), and the turn "off" loss of the super cascode is approximately one third of the single device (0.53 mJ vs. 1.54 mJ), even though it has 25% lower on resistance.

The super cascode switches faster and has lower dynamic losses, but it also has an economic advantage. The cost of epi increases with breakdown Voltage to the point that 80% of a 6.5kV device die cost can be in epi. The use of 1.2kV devices gives designers flexibility in tailoring their mid Voltage requirements (breakdown and RDS), but also allows them to take advantage of the higher volume/price curve of 1.2kV.

Summary

There are significantly advantages in gate drive simplicity and reverse recovery performance when using "normally on" JFETs in cascode. Super cascode provides faster switching performance and a lower cost path than traditional single die approaches. It is hoped that designers will give "normally on" devices their due by exploring the trade-offs and advantages in meeting their system requirements.

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Performance Comparisons of SiC Transistors, GaN Cascodes and Si - Coolmos in SMPS

How do available SiC - transistors and GaN cascodes stack up against Si - Coolmos in real-world SMPS? Proven by extensive tests, neither SiC transistors nor GaN cascodes beat Si Coolmos. Alleged advantages of GaN are due to the cascode, not the material.

By Dr. – Ing. Artur Seibt, Vienna

Introduction and Summary

The introduction of 600 V SiC diodes 15 years ago marked the first successful entry of a new material in power electronics. After more than a decade of perpetual announcements of SiC and GaN transistors and the imminent displacement of silicon, only SiC is firmly established.

GaN is heralded only by a wide variety of start-ups claiming fabulous advancements. Investors, notoriously impatient, expect high short-term gains, such statements hence should be pardoned to some extent, also because successful start-ups already failed after investors withdrew. The role and future of GaN is less clear. Unlike Si and SiC, GaN transistors are built on SiC or Si substrates so integration with control and other electronics is possible as is known from Si bipolars and MOSFET's; this is an advantage, as this is not possible with Si Coolmos nor with SiC. GaN will probably find its niche in low and medium power applications, predominantly in lv buck ic's and in bridge circuits. Displacement of Si will remain a fata morgana.

While single hv SiC JFET's were on the market in 2011, no single hv GaN JFET's are available. Enhancement GaN MOSFET's up to 200 V are listed, 600 V types announced, but both are unavailable. Only 600 V Si MOSFET/GaN JFET cascodes in TO-247 and TO-220 are in stock. Eva boards, claiming "efficiencies of up to 99.3%" are offered. As a rule, App Notes and evaluation boards of semiconductor companies seldomly bear any resemblance to saleable products. Independent performance comparisons are not available. Scrutiny of the descriptions of those evaluation boards reveals, e.g., that the circuits are incomplete, and that the losses of all passive components, including the cables, as well as the auxiliary power are excluded, rendering them meaningless. Looking closer at the claims how much smaller a SMPS could be made with GaN cascodes, reveals that the SMPS used for the comparison is a ridiculously obsolete 50 KHz unit.

Knowing cascodes from wideband amplifier design and using them already since 1982 as superior switches in SMPS, the author suspected that the cascode and not the new material was the cause of the alleged better performance. This was supported by the fact that the GaN cascode manufacturers absolutely avoid the term "cascode", trying to convey the impression of single transistors. Their comparisons of the cascodes with single Si Coolmos transistors are blatantly wrong. Users are easily led astray, because if one exchanges a single Si Coolmos for a GaN cascode, with 3 pins looking innocently like a single transistor, in many cases, shorter switching times and lower losses will result, misleading the user to believe in the superiority claims of GaN! Fallen victim!

Subsequent to SiC JFET tests in 2011, the author felt it was high time to again subject current SiC and GaN components to real-world tests in an offline SMPS. Result: The alleged advantages of GaN cascodes are due the cascode circuit, not to the material; with Si Coolmos in cascode better or identical results are obtained. SiC JFET's as singles or in cascodes as well as MOSFET's were at best as good as Si Coolmos. If engineers want to boost the efficiency of their designs, the author highly recommends to add a small lv Si MOSFET to the existing Si Coolmos and construct a cascode.

This statement applies to offline SMPS up to several hundred watts which is the majority. For higher power SMPS SiC MOSFET's or Si MOSFET/SiC JFET cascodes will probably be the best solution. When the author confronted one GaN manufacturer with these results, he neither met with surprise nor contradiction.

Some GaN Claims

- "...usher in a new era in power electronics..."
- "... cost-effective revolutionary performance..."
- "... transforming the future ... changing entire industries..."
- "... GaN -based power technology stimulates revolution..."
- "Redefining power conversion"
- "... the advent of hv GaN-based power devices provides unprecedented opportunities to reduce both conduction and switching losses..."
- "... wireless charging using GaN will eliminate wall sockets altogether
- "... the company's GaN transistors offer a 40-fold improvement in switching and conduction performance over traditional Si MOSFET's and IGBTs..."
- "... GaN FETs perfom 40 times better..."
- "... promises to deliver performance FOM's ten times better than state-of-the-art silicon..."
- "... performance now 5 to 10 times better than the best commercial silicon...GaN will increase this gap to 1,000 times better..."
- "..reducing the conduction losses by orders of magnitude..."
- "... the specific on-resistance of GaN is orders of magnitude smaller than for Si or SiC..."
- "... in the 600 to 1200 V range, GaN-based devices have the potential of improving Rdson by a factor of 1000 over Si MOSFET's..."
- "99.5% efficiency at 100 KHz in a booster with GaN"
- "GaN reduces energy loss by 50 %."
- "... enables power conversion to > 50 MHz to 100 MHz without compromising power conversion efficiency..."

This list of hysterical hype could be extended. This certainly is a big mouthful; the language resembles advertisements for toothpaste rather than for electronic components. The announcements for SiC never used such language. Example: Regarding “... Rdson orders of magnitude lower...”: No SiC or GaN product with < 25 mOhms is available, but 19 mOhms Si Coolmos. Where are the 600 V 19 microOhms GaN’s?

What the propaganda doesn’t mention.

1. The wrong comparisons of GaN cascodes to single Si Coolmos transistors constitute probably the worst misleading information! Cascodes must only be compared to cascodes. Even with bipolar transistors as upper transistors nanosecond hv cascode switches were realized decades ago.

2. SiC and GaN components are not avalanche-proof! This is not mentioned in the documentation or in data sheets. JFET’s, by nature, cannot achieve avalanche-proofness. There are announcements for SiC MOSFET’s, promising a rating. These components can only be used in such circuits like PFC’s in which no over-voltages occur. In practice this means that either the breakdown rating must be far higher than that of an avalanche-rated Coolmos (1200 V equals 650 V) or protective components must be added, raising cost and deteriorating efficiency. In any SMPS there are also start-up, overload, short-circuit and input overvoltages to be reckoned with.
Sincere statements are rarities: J. Roberts of GaN Systems, Canada, Bodo’s Power, July 2013:
“It is necessary for you to recognize that our GaN transistors are similar to ceramic capacitors. That means that, at breakdown, they are destroyed. GaN devices have no avalanche specification. GaN devices have no repeatable, exercisable breakdown voltage capability.” He mentions that his audience was completely stunned which shows that this vital fact had not been communicated by the manufacturers!

3. Most GaN’s are built on Si, some on SiC substrates, this means heat transfer is impeded compared to Si or SiC parts, also thermal conductivity is ¼ of SiC. GaN will thus never reach into the high power realm of SiC. The smaller chip size of SiC and GaN spells higher Rth and, due to the smaller volume, also a much lower overload withstanding capability.

4. The low input capacitance of the GaN cascodes is a property of the cascode and not of GaN. The input is to the Si MOSFET gate, not to the GaN gate.

5. The faster switching speed, compared to that of a single transistor, is a property of the cascode and determined by the Si MOSFET, not the GaN JFET!

6. There are some failure mechanisms like “dynamic on-resistance” which manufacturers claim they have eliminated, only time will show whether this was true.

7. Theoretical definitions like that of a “figure of merit” = Rdson x QG have no practical meaning in SMPS applications. The importance of Rdson is highly exaggerated, at SMPS frequencies, i.e. 100 to 250 KHz, the switching losses predominate. Example: In the tests decribed later, a 200 mOhm Si Coolmos cascode had the same losses as a 50 mOhm GaN cascode! Also, in a Si MOSFET/GaN JFET cascode, it is the gate charge of the lower transistor which is effective (no Miller effect); the gate of the upper(GaN) transistor is charged via the Rdson of the lower one plus the impedance of the resistance in the gate circuit.

Theory meets real world

Eating is the proof of the pudding is an old English proverb. What is the purpose, the measuring stick? It is efficiency, and, precisely speaking, overall lower losses, because the properties of a switching transistor or cascode also influence the losses in other components. Example: the introduction of SiC Schottky diodes in hard switching circuits like PFC's not only decreased the diode losses but even more the switching transistor losses, because it turns on into an ac short as long as the diode does not switch off; with a SiC diode, the transistor can shrink by two sizes.

1. The manufacturers argue as if their transistor or cascode was the only component in a SMPS. At least two components are connected to the drain of any switching transistor. Taking a PFC as example, a choke good for some hundred watts will have a substantial capacitance, even if a low capacitance winding is used (rare). The SiC diode is a Schottky and those suffer from high capacitance, e.g. a 600 V/6 A type will contribute from 300 to 30 pF from 0 to 400 V. The capacitances of the e.c. board conductors have to be added, they are capacitors with the e.c. board material as (lossy) dielectric. Consequently, the transistor's output capacitance contributes only part of the whole capacitance, any reduction will be watered down. What counts is the performance in the circuit.

2. The cascode is the fastest circuit, almost "too hot to handle"; installing one in place of a single transistor can lead to serious malfunctions because wiring and component placement on the e.c. board may not be commensurate with the increased speed! Erratic or chaotic performance may not even be noticed because regulation loops try to uphold the output voltage. It requires solid hf knowledge to fence the cascode in. It is irresponsible to offer cascodes without identifying those as such and warning customers!

Concise review of JFET's and cascodes

Power JFETs, cascodes, the internal structures of power semiconductors, and how to handle them, the difficulties of precise efficiency measurements etc will be treated in detail, for the benefit of young engineers, in a later article.

JFETs

FET's were invented in the 1930's, commercialized from the 1950's as JFET's and MOSFET's, initially only for amplifier and analog switching purposes. Whereas MOS ic's appeared shortly after bipolar ic's, there are no JFET ic's, however, they were integrated early in bipolar ic's, e.g. in operational amplifiers and analog switches. Si power JFET's were manufactured by 4 Japanese firms. JFETs consist of a channel and a pn diode between gate and channel which is normally off; at zero volts the channel is fully conducting, if a voltage higher than the pinch-off voltage is applied, the channel will be cut off. If a positive voltage > 0.6 V is applied, the diode will conduct and connect the gate to the channel. JFET's are unipolar devices and hence, depending on transconductance and capacitances, useful into the GHz region. By nature, a JFET cannot take overstress, overvoltage will cause a drain-to gate diode breakdown.

Cascode circuit

In 1939 F.V. Hunt und R.W. Hickman described the function of a cascode and it was commonly used in all tv sets' and fm radios' input stages from the 1950's. The cascode is also an ideal extremely fast and efficient power switch which merits due recognition by SMPS designers.

The term "cascode" was coined from "pentode" and "cascade", any two (or more) active devices can be hooked up as a cascode. If two devices of dissimilar polarity are used, a socalled "folded" cascode can be constructed which allows, e.g., that input and output are on the same level. It combines a grounded emitter or source transistor with a grounded base or gate transistor in ac, not necessarily also dc, series connection. This way an "ideal" compound transistor is created.

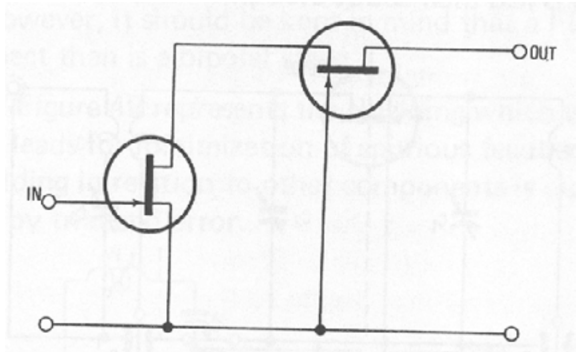

Figure 1: Basic cascode connection combines a grounded source transistor with a grounded gate one, creating an ideal compound transistor.

1. The lower transistor operates into an ac short which is the source input impedance (1/S) of the upper one, hence there is no ac voltage at its drain and consequently no Miller effect. The input capacitance is the lowest possible for a grounded source stage and consists only of the sum of the gate-to-source plus gate-to-drain capacitances, it is easier and faster driven. Due to the high transconductance of Si power MOSFET's the Miller effect is severe in the basic grounded source circuit which slowes the switching down and requires high current, low-impedance drivers. If logic level MOSFET's are used, the transconductance will be still higher. With the drain effectively grounded, the transistor achieves its highest speed. Please note: the properties of any cascode are determined by the lower active element.

2. The upper grounded gate transistor does nothing else but to pass the ac current of the lower one along to the output, its drain, and to establish a shield between the output and the input. As far as speed is concerned, It is fairly immaterial which kind of transistor sits there. This is best understood if one assumes there is a bipolar transistor: in grounded base its alpha = 1 and its alpha or fT - cut-off frequency are effective. Si bipolar power transistors with fT 's of several GHz are common. FET's as unipolar devices know no cut-off frequency, their limit is given by transconductance and capacitances, eventually by transit time limitations. This way amplifiers with GHz bandwidths are realized. A switching circuit is nothing else but an overdriven amplifier, and, remembering the basic formula: rise time = 0.35/bandwidth, a bandwidth of e.g. 1 GHz equals a rise time of 0.35 ns.
Consequently, also the properties of a Si MOSFET/GaN JFET cascode are determined by the Si MOSFET and have almost nothing to do with the GaN JFET! The speed one sees is the speed of the Si MOSFET and not that of the GaN JFET! The speed of Si MOSFET's is often misrepresented and far underestimated.

3. The only contribution of the GaN JFET is its perhaps lower output capacitance; if that is lower than that of any other type of transistor in its place, the total node capacitance will be a little lower and thus the speed a bit higher.

4. The impedance in the source of the upper transistor is equal to the drain output impedance of the lower one which causes strong feedback; the output impedance of the upper one approaches hence infinity. In amplifiers extremely high stage gain can be achieved.

It is mandatory to minimize the capacitance between output and input, otherwise serious Miller effect will spoil the performance. This is easy to accomplish in cascodes made of individual transistors by setting them apart; the connection carries only a current signal, so its capacitance is of lesser importance. If both are in one package the inductance is minimized, but the distance between input and output closest.

5. The fast switching is the cause of the lower losses. In general, the fall time will be the shortest in most circuits, it is typically 10 to 5 ns. The rise time is mostly determined by the circuit. Example: a simple PFC: Assuming the SiC diode and the cascode switch in zero time, the node capacitance can only be charged up to the input voltage through the choke which is a constant-current generator

Si MOSFET/Si Coolmos cascodes are superior, they retain the avalanche-proofness and profit from decades of design and manufacturing knowhow as well as low price, abundant supply, second-sources, established reliability etc. More than a perhaps slightly lower output capacitance these GaN cascodes can not bring to bear, this is at best neglegible, compared to an impressive list of disadvantages: The life expectancy of start-ups is at best questionable, supply is by no means guaranteed, there are no second-sources and hence no competition which spells high prices. The quality and reliability of GaN are at best questionable and will take years to establish. In most companies design in of such unproven single-source components with shaky supply is not allowed; the risks of incorporating such parts in series products are too high. The author recommends to Si Coolmos resp. superjunction manufacturers to bring 4-pin cascodes to market which would be superior to and much less expensive than GaN cascodes. The 4th pin is necessary because power MOSFET's are enhancement types, the gate of the upper one has to be tied to + 12 to 15 V.

If the alleged advantages of GaN were real, the logical step would be to use an enhancement GaN MOSFET as the lower transistor and a Si Coolmos as the upper one in order to combine the best of both worlds. Considering that lv enhancement GaN's are said to be available for some years, it is hard to understand why such cascodes aren't offered, or GaN eMOSFET/GaN JFET cascodes.

Bipolar bridge circuits

In many bridge circuits current must also flow in reverse direction which is a problem for Si MOSFET's because they suffer from the parasitic antiparallel diode which is the CB diode of the parasitic npn. JFET's conduct equally well in both directions and are free from parasitic elements. JFET's were used from the beginning also as switches, this property is independent of the material. SiC power JFET's are available since years. Any enhancement MOSFET/JFET cascode is eligible as a bipolar switch: Reverse current will flow through the antiparallel diode of the MOSFET, this is a low voltage type, so the diode is very fast. What then is the difference between Si and SiC JFET's and GaN JFET's, if any? Si and SiC JFET's use a pn diode between gate and channel which is always reverse-biased unless the gate is overdriven in positive direction; in such case, there will be a connection between gate and channel.

With GaN JFET's, the gate is dielectrically isolated from the channel, similar to MOSFET's. How much bias is safely applicable in both directions is not disclosed and can not be measured in the available cascodes. Hence there is no connection between gate and channel even if overdriven in positive direction. This seems to be the only difference. Why that should be an advantage in practice over Si and SiC is hard to see, because it is only a matter of the gate drive circuit to prevent positive overdrive, also in many cases this will not harm. Because SiC also provides low Rdson and fast switching and is far better suited to such service it is to be expected that Si MOSFET/SiC

JFET cascodes will become available and compete with those GaN cascodes.

Samples and Test Vehicle

Only products available from distributors were eligible. In 2011 SiC JFET 1200 V samples in TO-247 of various sizes were tested, in 2014 600 V GaN cascode samples in TO-247 and TO-220 with 50, 160 and 320 mOhms and SiC MOSFET 1200 V TO-247 samples with 75, 85, 50 mOhms and 600 V/0.13 ohms in TO-220.

A 200 W offline wide-range SMPS with 6 output voltages, PFC and FB converters was chosen. Both converters are driven by a low-cost bipolar combo ic at 125 KHz for emi reasons. This SMPS originally uses an Infineon Coolmos 600 V/0.38 ohm 11N60C3 in the PFC and a 650 V/0.38 ohm 11N65C3 in the FB. The PFC uses a SiC 6 A diode, the 6 outputs 6 and 2 A SiC diodes. As described in the author's paper in Bodo's Power, Nov. 09, SiC Schottky diodes excel also as secondary diodes down to appr. 25 V.

The GaN cascodes and single SiCs were first tested against the original C3's, then against the most recent CP and C7 with 600/ 650 V and 200,125 and 100 mOhms. Because these already turned out to be superior, the lower Rdson Coolmos types were not even tested.

All samples were tested in the PFC at 365 V, only the 1200 V SiC and the 650V Si Coolmos could be tested in the FB with a peak voltage of 740 Vp. Each transistor resp. cascode was tested with 3 different drive circuits: 1. direct drive out of the rather slow bipolar outputs of the combo ic (1 to 11 V at 13 V Ucc) - 2. via an intermediate Harris 7667 CMOS gate driver ic with 7 ohms - 3. operated in cascode. The SiC MOSFET's asked for 18 V signals, for these an IR 2110 CMOS gate driver was used. Cascode connection is - as regards losses - practically equivalent to a very fast low-impedance direct drive. With each test, time for thermal equilibrium was allowed. Please note: Input power figures may only be compared within the same test series. No attempt was made to test for an optimum lower Si MOSFET in the cascodes. These tests took an enormous amount of time anyway.

Comparisons with Si Coolmos C3

2011 tests of SiC - JFETs 1200 V, 85 and 45 mOhms

Considering the claims of much lower capacitances first a simple direct drive circuit with an external - 12 V supply was used. In the first test series, only the PFC was operated into a dummy load, With fairly slow rise and fall times at the gate the losses were identical to the single Coolmos' at ¼ load, slightly higher at ½ load and 1.2 load.

A faster direct drive would have been more complicated than a cascode, so this was installed in the continuous-conduction mode FB because there were the higher stresses and losses. For the lower transistor a 80 V/16 mohm Si - MOSFET in TO-263 was chosen. The drive signal was identical to that of the original Coolmos. The higher input power at 115 V line was chosen for the comparisons:

Coolmos C3 0,38 ohms, directly driven:	222.7 W
SiC 85 mohm JFET in cascode	220,4 W
SiC 45 mohm JFET in cascode	222 W
BUT: Coolmos C3, also in cascode	220,9 W

Rise time 30 ns to 700 Vp, fall time 12 ns.

If both SiC JFET and Si Coolmos are operated in cascode, the losses are almost identical. This is no surprise, because the same lower Si MOSFET was used. Please note that the Coolmos is 380 mOhms and obsolete by 3 generations while the SiC's are 85 resp. 45 mOhms! The 45 mOhm chip is too large for 200 W. These SiC JFET's have lower capacitances than the SiC MOSFET's tested in 2014.

Tests of GaN - JFET - cascodes 600 V/0.32, 0.16 ohms in the PFC

All following tests were performed from Sept. to Dec. 2014. Again the PFC with 365.2 V output voltage was operated into a precision dummy load of 200 W. The power at 115 V line was used for comparison. (The figures include an auxiliary SMPS.) Due to the 600 V spec and the missing avalanche-proofness a test in the FB was impossible. The direct drive signal comes again from a bipolar combo and is fairly slow from 1 to 11 V.

1. Coolmos 11N60C3, 0,38 ohms, driven directly:
   217.2 W, 12 ns, 35 ns.
2. Same, driven via Harris 7667 CMOS high current driver:
   213.7 W, 12 ns, 8 ns.
3. Same, cascode: 213.6 W, 10 ns, 8 ns.
4. Larger chip 20N60C3, directly driven:
   216.8 W, 18 ns, 42 ns.
5. Same, in cascode: 214.3 W, 18 ns, 8 ns.
6. GaN - cascode 600 V/0.16 ohms, directly driven:
   213.9 W, 16 ns, 16 ns.
7. Same, driven via 7667: 213 W, 16 ns, 8 ns.
8. GaN - cascode 600 V/0.32 ohms, directly driven: 213.8 W
9. Same, driven via 7667: 212.6 W, 10 ns, 7.5 ns.

Result: Compared to the 0.38 ohms Coolmos C3, also in cascode, with 213.6 W the 0.32 ohms GaN cascode, with the identical direct drive, shows 213.8 W, if driven extremely fast by an additional 7667 CMOS high current driver 212.6 W can be achieved, i.e. 1 W less than with the Coolmos. However, no test was made with the Coolmos C3 in cascode and also driven fast, The 0.32 and 0.16 ohm GaN's had almost identical losses, proving again the minor importance of Rdson in SMPS. The lower Rdson was offset by the higher capacitances of the larger chip.

Tests SiC - MOSFETs 1200 V/85 mohm and 600 V/0.13 ohm in the PFC

Available samples required a 18 to 22 V gate drive, not available from standard SMPS ic's. An IR 2110 20 V CMOS or a Harris 7667 7 ohm CMOS high current driver was inserted between the slow bipolar output and the test object.

1. SiC - MOSFET 1200 V/85 mohms, with a gate resistor
   of 2.2 ohm in parallel with a 4150 diode:
   214.8 W, 25 ns, 25 ns.
2. SiC - MOSFET 600 V/0.13 ohms, directly driven (only 1 to 12 V):
   220 W.
3. Same, driven via IR 2110, 15 V, gate resistor 50 ohms//4150:
   216.4 W, 30 ns, 70 ns.
4. Same, 15 V, 7667 driver, 7 ohms: 214.2 W, 35 ns, 30 ns
5. Same, 18 V, 2110 driver: 213.4 W
6. Same, 18 V, appr. zero gate resistor: 212.8 W, 10 ns, 18 ns.
7. Same, cascode, 15 V, via a 25 ohm resistor: 214.6 W, 18 V: 214.4 W.

This measurement was performed very quickly. Without a S to G diode the source rose to 80 Vp.

8. Same, but a diode S to G added, 10 ohm gate resistor: spike reduced to 35 V, after a few seconds smoke, destruction. The maximum permissible gate voltage is - 6 to + 22 V. MOSFETs normally take equal voltages on the gate like +- 20 V. If the source goes up to 80 or 35 V, this means - 62 resp. - 17 V negative gate voltage. Obviously, these parts can not be used in a cascode connection. As the drain spike is clamped at 740 Vp, gate oxyde breakdown is the probable cause.

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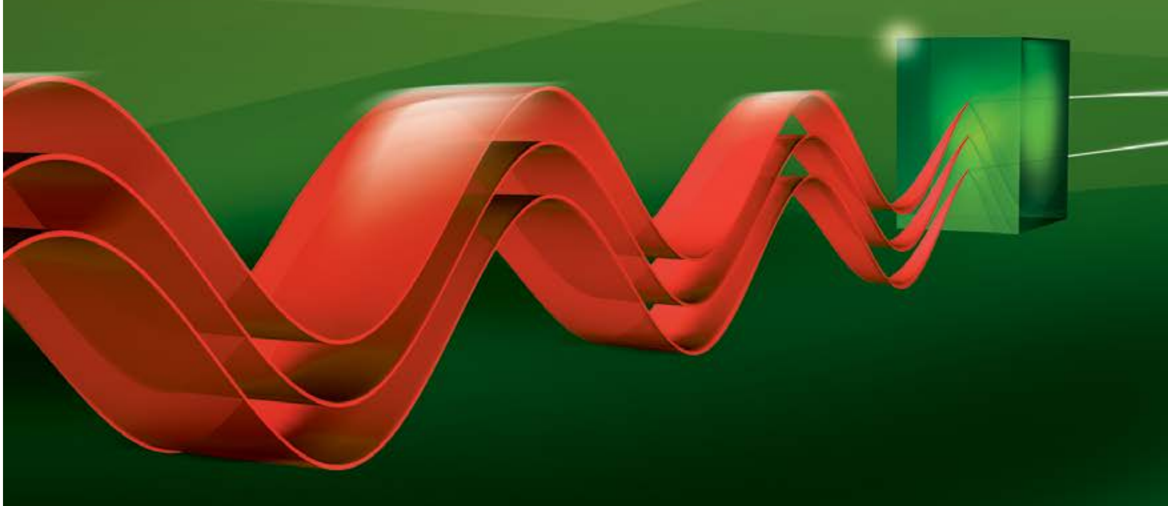

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Test SiC - MOSFET 1200 V/0.3 ohm in the FB
The transistor was tested in the FB in place of the 11N65C3, however via the high current IR 2110 driver at 18 V.

PIn (115 V) = 216.8 W vs. 218 W with the original Coolmos. Rise time 35 ns to 720 Vp, fall time 35 ns. Gain, at first sight: 1.2 W. But the Coolmos, in the original circuit, is driven by the fairly slow signal out of the bipolar combo ic; if operated in cascode its losses drop by 1.8 W.

Result: For a fair comparison the Coolmos must also be driven fast, then its losses are indeed 0.6 W lower than those of the SiC in cascode.

Circuit changed to cascode with a 80 V/16 mohm Si - MOSFET, the gate at 18 V: at turn-on loud noises, smoke and smell: the SiC, the Si - MOSFET, gate resistor and the T 2.5 A input fuse destroyed, the contact of a relay, bridging a 10 ohm current limiting resistor in the line input welded. Again proof that these parts must not be operated in cascode.

Comparisons with state-of-the-art Si Coolmos CP and C7
The CP and C7 series are designed for fastest switching and improved efficiency, the high Rth of 2 degr./W points to chips of half the size of the former series

Comparisons in the PFC
As before P_{IN} (115 V) figures, 365 V, PFC into dummy load 200 W, auxiliary SMPS included.

60R199CP, 200 mOhms, direct, 22 ohms//4150:	213,8 W 12 ns, 20 ns
Same, via 7667 driver, 22 ohms//4150:	212,1 W 12 ns, 9 ns
Same, cascode, 10 ohms in gate, 47 ohms//4150:	212,8 W 10 ns, 12 ns
Same, cascode, driven by 7667	212,5 W 13 ns, 11 ns

GaN cascode 50 mOhms, direct, 22 ohms//4150	212,0 W 20 ns, 14 ns
Same, 47 ohms//4150	212,2 W
Same, appr, zero ohms	211,7 W 20 ns, 12 ns.
Same via 7667 driver, 22 ohms//4150	211,5 W 20 ns, 5 ns
Because of too much 140 MHz ringing 35 ohms	211,7 W 20 ns, 6,5 ns

SiC MOSFET 1200 V80 mOhms, direct 47 ohms//4150	
(direct = 1 to 11 V only)	218,2 W 50 ns, 130ns
Same 10 ohms	215,2 W fall time 50 ns
Same, appr. zero ohms	213,7 W, 30 ns.

60R099CP, 100 mOhms, 7667, 47 ohms//4150	213,0 W
Same 22 ohms	212,5 W 18 ns, 12 ns
Same 10 ohms	212,2 W
Same, direct, 47 ohms//4150	213,6 W 22 ns 22 ns
Same, cascode, 47 ohms	213,2 W 17 ns 10 ns

65R190C7, 190 mOhms, direct 47 ohms//4150	213,4 W
Same 10 ohms	213,2 W 15 ns 23 ns
Same via 7667, 47 ohms//4150	212,0 W
Same 9 ohms	211,7 W 20 ns 7 ns
Same, appr. zero ohms	211,7 W 20 ns 6 ns

65R125C7, 125 mOhms, via 7667, 47 ohms//4150	212,3 W
Same, 10 ohms	211,7 W 20 ns 7 ns
Same, direct, 47 ohms//4150	213,2 W 20 ns 24 ns

Results: These comparisons show how much the results are dependent on the drive, the damping resistor in the gate and whether single or in cascode. Also, in cascode, the protection diode resp. zener influences the losses. The GaN cascode with the lowest Rdson available (50 mOhms) has losses identical to those of the Si Coolmos 190 mOhms and 125 mOhms, if also operated in cascode!

9.2 Comparisons in the FB

The lower PIN (230 V) figures were taken for comparison. In the cascodes, a 80 V/16 mOhm Si MOSFET was used. The tests showed that the new Coolmos types have been drastically improved with respect to their capacitances, the Rdson's are half of C3, because, even with the slow drive, their losses are lower than those of the C3. They show, on the other hand, the low influence of the upper transistor in a cascode.

11N65C3 for reference, direct, 15 ohms//4150: 212,7 W
Same, cascode, 15 ohms //4150: 210,7 W, 28 ns, 45 ns.
65R125C7, 125 mOhms, direct, via 15 ohms//4150:
210,5 W, 37 ns, 75 ns.
65R190C7, 190 mOhms, direct, 15 ohms//4150:
210,5 W, 30 ns, 80 ns.
Same, cascode, 210,0 W, 25 ns, 18 ns.
Same, via 7667 driver: 209,6 W
SiC MOSFET 1200 V/80 mOhms, direct, only 1 to 11 V,
15 ohms//4150. The higher output capacitance was visible:
214,4 W, 90 ns, 80 ns.

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Ensuring System Efficiency

Four Key Features to look for in a GaN-Ready Magnetics Supplier

The dramatic rise in the popularity of Galium Nitride (GaN) switching technology is due to the very significant benefits it provides. Highly efficient GaN devices offer high dielectric strength, high operating temperatures, high current density, high-speed switching and exceptional carrier mobility.

By Welly Chou, Design Engineering Manager, Precision Inc.

GaN switches provide an impressive number of key benefits to design engineers including:

- significant reductions in system volume, weight and size
- higher operating temperatures / reduced heat sink requirements
- lower switching losses / increased power output (up to 95% peak efficiency)
- high breakdown strength, high maximum current and high oscillation frequency

Several of these benefits - most notably high switching frequencies and high operating temperatures - can have a significant impact on the performance of a system´s magnetic components. To ensure optimal performance of magnetic elements, it is essential to locate a supplier that specializes in GaN-ready magnetics. Failure to do so can result in the magnetics becoming a bottleneck for system efficiency.

There are four key features to look for in a quality GaN-ready magnetics supplier:

Core Materials Selection

The high switching frequencies and high operating temperatures made possible by GaN technology bring key benefits to design engineers. They also provide a significant challenge in core material selection for magnetic components as the performance of these components varies significantly based on both factors.

Be sure to choose a magnetics component supplier who understands how to select the optimal core material for your unique GaN-based technology. To do this, make sure that a potential supplier has:

-Expertise In A Wide Range of Core Materials-

A quality supplier will have in-depth knowledge of the performance characteristics of at least 50 different core materials including how they perform at varying operating temperatures and switching frequencies.

-Expertise in Core Material Performance and Switching Frequency-

Ask specific questions about how the performance of any selected core material is impacted by switching frequency. The same material will perform very differently at different frequencies. Figure 1 shows that Material A exhibits five times more core loss when operating at 300kHz compared to 100kHz switching frequencies (assuming a common 0.1T peak flux density). Another way to interpret such difference is that in order to achieve the same core loss (100mW/cm3) at both 100kHz and 300kHz, the 300kHz operating peak flux density must be de-rated by 44% from that at 100kHz. (peak flux density of 0.053T @ 300kHz vs. 0.095T @ 100kHz).

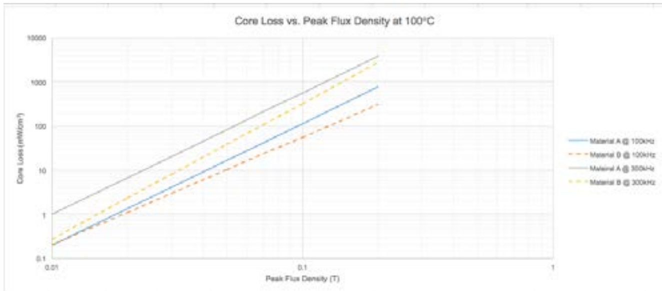


Figure 1 demonstrates that Material B is a better choice for 300kHz switching frequencies as the required peak flux density is 0.07T in order to achieve the same 100mW/cm3 core loss. Being able to operate at a higher peak flux density allows turns to be reduced 2.21 X - a 32% improvement when compared to Material A.

A common misconception is that as operating frequency increases (3X in this case from 100kHz to 300kHz), the number of turns can be reduced by the same ratio (3X). However, the gain in turns reduction is not directly proportional to the increase in switching frequency. Taking the above peak flux density de-rating into consideration, in order to achieve the same core loss, the turns reduction is 1.7X instead of 3X.

Better core material selection can reduce loss variability with switching frequencies. As demonstrated in Figure 1, Material B is a better choice for 300kHz switching frequencies as the required peak flux density is 0.07T in order to achieve the same 100mW/cm3 core loss. Being able to operate at a higher peak flux density allows the turns reduction to be 2.21X. This is a 32% improvement when compared to Material A (1.7 X turn reduction). This will help to further reduce conduction loss and winding capacitance.

- Expertise in Core Material Performance and Operating Temperature -

A quality supplier will also be able to provide precise information about the best core material selection for your application's unique performance environment. Losses vary by as much as 50% at various temperatures with a given core material.

Figure 2 shows the core loss variance versus temperature for Materials A and B (at 100kHz and 0.1T). Material A exhibits its lowest core loss around 100°C. However, core loss can vary greatly with operating temperature. For example, with Material A, core loss is 50%

higher at 40°C and 10% higher at 120°C than was the case at 100°C. On the other hand, the core loss of Material B remains a lot more stable over temperature with loss variance between 40°C and 100°C within 10% from its minima.

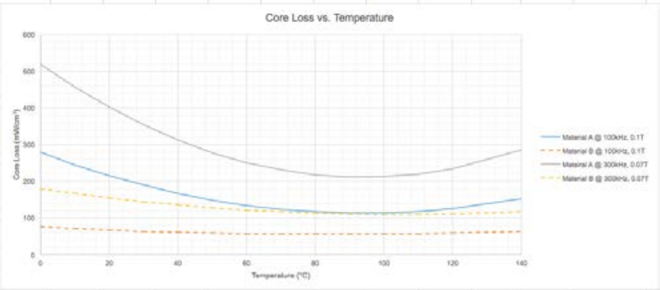


Figure 2: demonstrates that core loss can vary greatly with operating temperature. For example, for Material A, core loss is 50% higher at 40°C and 10% higher at 120°C than was the case at 100°C. On the other hand, the core loss of material B remains a lot more stable over temperature with loss variance between 40°C and 100°C within 10% from its minima.

The important role of operating temperature is often overlooked in an industry where it is common practice to chart core loss curves at a fixed temperature (most often the minima). Selecting the proper core material for your application´s operating temperature can have a significant impact on efficiency. In this instance- selecting Material B over Material A might make the difference between an 80 Plus Platinum and 80 Plus Titanium efficiency certification.

Parasitic Management

Both leakage inductance and capacitance contribute to switching losses. Leakage inductance has been known to create voltage spikes during switching. Depending on their unique application, design engineers will want to minimize or maintain leakage inductance. In nearly all cases design engineers will be looking to minimize capacitance. To achieve precise parasitic management, identify a GaN-ready magnetics supplier who uses both finite element analysis and a variety of winding configurations.

-3D Finite Element Analysis-

Three Dimensional Finite Element Analysis is used to analyze magnetic flux distribution and leakage inductance by analyzing losses due to skin and proximity effects. Electromagnetic properties are modeled and investigated with advanced Maxwell 3D simulation software from Ansys. In addition to ensuring optimal performance, finite element analysis speeds time to market by ensuring performance is optimized from the beginning, eliminating the need for design reiterations.

Figure 3: The same magnetic component with the same bobbin, number of turns and package style can have significantly different capacitance dependent on the winding configuration. As you can see, capacitance can vary as much as 75% dependent solely on winding configuration.

-Advanced Winding Configurations-

Quality GaN-ready magnetic suppliers will also have advanced winding configuration capabilities. The same magnetic component with the same bobbin, number of turns and package style can have significantly different capacitance dependent on the winding configuration. As you can see in Figure 3, capacitance can vary as much as 75% dependant solely on winding configuration.

Be sure any potential GaN-ready magnetic supplier has the advanced winding (both bobbin wound and toroid wound) expertise to minimize parasitics in each unique application.

-Parasitic Management Results-

Using a combination of Finite Element Analysis and advanced winding configurations, quality GaN-ready magnetic suppliers can precisely manage both leakage inductance and capacitance parasitics.
For design engineers looking to maintain leakage inductance, single section bobbins can be created that provide three to five times more leakage inductance than a traditional bobbin. This is done using a single section bobbin where the primary and secondary windings are concentrically wound.
For those looking to minimize leakage inductance, quality suppliers should be able to design a solution where inductance accounts for less than one percent of total part inductance.
Additionally, the combination of Finite Element Analysis and advanced winding configurations will allow GaN-ready magnetic experts to provide as much as five times lower capacitance than traditional magnetic designs.
It is important to ensure that your GaN-ready magnetics supplier goes beyond "theoretical" simulated Finite Element Analysis results to create validated DOE (Design of Experiment) with physically constructed tests.

Extensive Litz Wire Selection

Different switching frequencies require different strand sizes of Litz wire for optimal performance. This is due to both Skin and Proximity Effects.

-Skin Effect-

As switching frequency increases, current tends to travel on the outside of the conductor, increasing its AC resistance. This phenomenon is called Skin Effect. The skin depth of a conductor at a given frequency is defined as the penetration distance from the surface

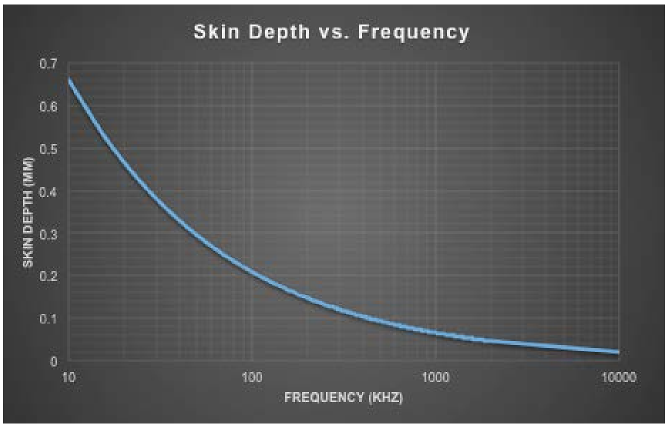


Figure 4: Demonstrates skin depth vs. frequency. Single-stranded wire can be chosen based on skin depth performance to optimize its AC/DC resistance ratio. The goal is to reach the unity condition wherein the conductor is fully utilized for carrying high frequency current without any wasted non-current carrying space in the center.

towards the center of the conductor. Figure 4 demonstrates skin depth vs. frequency. Single-stranded wire can be chosen based on skin depth performance to optimize its AC/DC resistance ratio. The goal is to reach the unity condition wherein the conductor is fully utilized for carrying high frequency current without any wasted non-current carrying space in the center. It has been proven that such unity condition is achieved by selecting wire with twice the diameter of the skin depth. Figure 5 shows the skin depth vs. single strand wire AWG, achieving the unity AC/DC ratio.

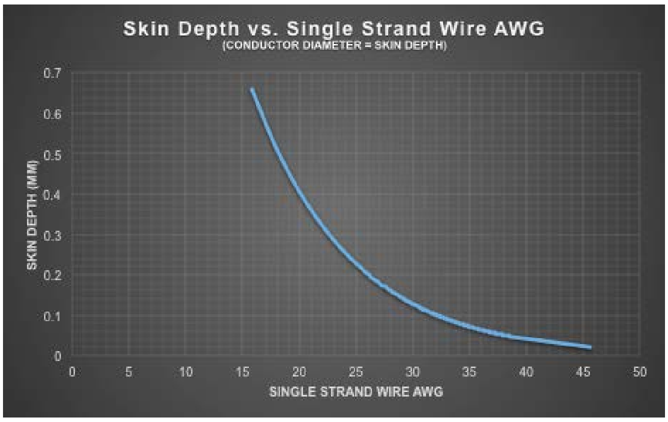


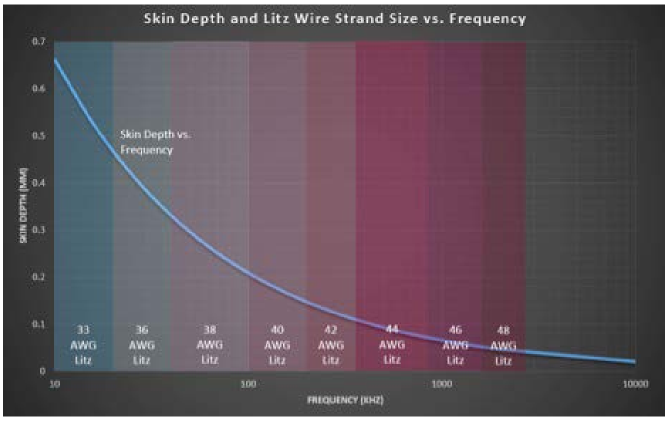
Figure 5: Shows the skin depth vs. single strand wire AWG, achieving the unity AC/DC ratio.

-Proximity Effect-

Skin Effect, however, is only a part of AC resistance that hinders overall efficiency. Another critical contributor to AC resistance is the Proximity Effect which is the current redistribution within a conductor caused by the current flowing in an adjacent conductor. Depending on the design, Proximity Effect can increase the AC resistance of a transformer or inductor by 10 to100 times more than Skin Effect can.

-Litz Wire For Optimal Performance-

Litz wire has traditionally been used to combat both Skin and Proximity Effects. Litz wire is made with a bundle of smaller strand size wire. Figure 6 illustrates commonly used Litz wire strand sizes vs. switching frequency. It is worthwhile to note that, for the same frequency, the strand size in Figure 6 is significantly smaller than the single strand wire AWG in Figure 5 due to Proximity Effect. Such difference further outlines the significance of proper Litz wire selection. Selecting wire strand size incorrectly can prove to be costly to your system efficiency and component temperature.



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Leading GaN Technology Partners

Finally, a quality GaN-ready magnetics supplier will be able to provide demonstrated results of their partnerships with leading GaN technology suppliers like International Rectifier and Transphorm. They will be able to provide firm performance data, based on full demo boards built with industry-leading GaN switch suppliers.

In summary, GaN switches provide an exciting number of key benefits for design engineers. These same benefits can also create challenges in the design of magnetic components. Be sure that any potential magnetic component supplier has advanced expertise in core material selection, parasitic management and an extensive selection of Litz wire options as well as proven partnerships with industry-leading GaN technology suppliers in order to ensure that your magnetics are optimized and helping you achieve a highly efficient system.

www.precision-inc.com

1U SL Series DC Power Supply Line Expands to 6 kW with 17 New Models

Magna-Power Electronics announced the immediate expansion of its popular 1U SL Series product line to 6 kW. The SL Series product line now spans 70 models at power levels 1.5 kW, 2.6 kW, 4 kW, and 6 kW all in a 1U, 1.75” high rack-mount form-factor.

With programmable DC output voltage ranges from 0-5 Vdc to 0-1000 Vdc and programmable DC output current ranges from 0-1.5 Adc to 0-250 Adc, the product line satisfies requirements in a variety of industries including: automated test equipment (ATE) system integration, automotive testing, oil and gas, remotely operated underwater vehicles, and aerospace systems testing.

Magna-Power introduced the SL Series product line–the company’s first 1U power supply–in early 2013 in response to overwhelming demand from customers. “The expansion to 6 kW in 1U continues Magna-Power’s long-standing commitment to offering industry-leading programmable power densities,” explained Adam Pitel, Vice President overseeing worldwide sales and marketing. “This latest innovation is the result of continuous research and development work in power electronics and heat management, along with further advances in the company’s internal manufacturing processes.”

All SL Series models come standard with monitoring and control from a variety of sources, including: front panel, computer interface and an isolated analog-digital I/O connector. A Standard Commands for Programmable Instrumentation (SCPI) command set is supported, allowing easy ASCII text programming over a computer interface. In addition, an IVI driver is included for the Visual Studio programming environment along with a dedicated National Instruments LabVIEW™ and LabWindows™ driver. Additional computer interface options include LXI TCP/IP Ethernet (+LXI), IEEE-488 GPIB (+GPIB), USB and RS-485.

www.magna-power.com

EZ-GaNTM 600V Power Modules Enable Smallest, Fan-Free 4.5kW Residential PV Inverters

Transphorm Inc. announced that Yaskawa Electric Corporation is launching the mass production of world’s smallest power conditioner in its class – and the first to use a GaN power module. Based on Transphorm’s EZ-GaN™ IP-protected platform, Yaskawa’s Enewell-SOL V1 series 4.5kW indoor PV inverter will be distributed in Japan, with a targeted annual production of 34,000 systems.

The new 98%+ peak efficiency, GaN-based power conditioner operates at three times higher frequencies than silicon-based modules. The unit is half the size of competitive solutions thanks to its smaller magnetics and heat sinks. And its exceptional efficiency allows for fan-free, low noise operation. Powered by Transphorm™, the Yaskawa PV inverter’s TPD3215M module utilizes the only qualified, high-voltage (600V) GaN-based solution on the market today. Yaskawa fully exploited the system value proposition of Transphorm GaN by making its record-breaking performance possibilities a commercial reality. This level of mass production for the rapidly growing residential PV inverter segment is one more step toward establishing GaN as the new power conversion platform.

www.transphormusa.com

Power Analyzer with Touch-Driven Oscilloscope Visualization Capability

Keysight introduced the first power analyzer that combines accurate power measurements and touch-driven oscilloscope visualization capability in a single instrument. The IntegraVision power analyzer makes it easy for R&D engineers who are designing and testing electronic power conversion systems to access dynamic views of current, voltage and power so they can see, measure and prove the performance of their designs. IntegraVision power analyzers are suited for

With the touch screen of the IntegraVision, power measurements are no longer time consuming and tedious

R&D engineers who want to quickly and interactively measure AC and DC power consumption, power conversion efficiency, operational response to stimulus and common AC power parameters such as frequency, phase and harmonics – all with 0.05 percent basic accuracy and 16-bit resolution. The power analyzer enables engineers to characterize power consumption under highly dynamic conditions with 5 MSps digitizing speed and 2 MHz bandwidth. It allows engineers to address multiple test scenarios with the flexibility of wide-ranging, isolated inputs up to 1,000 Vrms (Cat II). The instruments offer external sensor inputs and 2Arms and 50Arms direct current inputs, standard on all channels. The external sensor input supports current probes and transducers up to 10V full scale.

The IntegraVision power analyzer features a space-efficient footprint and allows engineers to: Visualize transients, in-rush current and state changes with a high-speed digitizer that captures voltage, current and power in real time, analyze power losses in the time and frequency domains, using full Nyquist-based computations, and Gain new insights by viewing parameters on the large, high-resolution, touch-screen display. The user interface is based on technology from Keysight's InfiniiVision 6000 X-Series oscilloscope, including its 12.1-inch multitouch capacitive touchscreen with pinch, zoom and scroll capabilities. The development of the user interface was guided by extensive feedback from engineers. The result is an intuitive user experience that enables engineers to gain measurement insight with the power analyzer within minutes.

The two-channel Keysight IntegraVision PA2201A power analyzer is suitable for single-phase AC measurements and can be ordered today. Shipments are expected to begin in May. Pricing is available upon request. The IntegraVision PA2203A power analyzer with four channels for three-phase power analysis is scheduled to be introduced in the fourth quarter of 2015.

www.keysight.com

Digital Controller Family with VR12/12.5 Compliant Interface

Powervation Ltd. (www.powervation.com), the Intelligent Digital Power™ company, today announced its latest series of digital DC/DC controllers for servers, high-end desktop, and embedded computing systems. The PV3103, PV3104, and PV3202 devices feature single and dual phase outputs and support both PMBus and Intel's VR12.5 Serial VID (SVID) bus. The highly flexible, fully programmable digital controllers provide precision regulation and telemetry to support the latest high efficiency computing system designs.

The PV3202 is Powervation's latest full-featured VR12.5 dual phase digital controller with Auto-Control®, which provides superior transient performance and real-time adaptive loop compensation. The PV3104 is a single phase controller offered in the standard 5 mm x 5 mm QFN package and is footprint compatible with the PV3202. Completing the family of SVID controllers is Powervation's PV3103, an ultra-small, digital synchronous buck controller in the 4 mm x 4 mm QFN package – PV3103 is ideally suited to high density or compact design needs.
The series features Powervation's unique Auto-Control® adaptive compensation, which is a mode of Powervation's leading xTune™ auto-tuning architecture, which delivers faster transient performance and greatly simplifies the design process and time-to-market. The unique NV memory and RAM architecture allows designers to flexibly configure and store regulator parameters.
"We are very pleased by the strong adoption of our VR12.5 controllers to date in the high performance computing space," commented David New, Powervation's Vice President of Product Marketing. "This new series of digital SVID controllers provides higher performance and new features, and extends our portfolio of auto-tuning digital controller solutions for low- and mid-power SVID and PMBus applications."

www.powervation.com

SiC-MOSFET Ideal for Ultra-High Voltage Pulse Generators

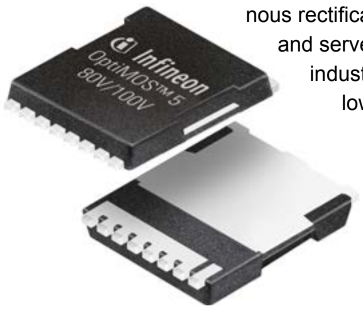
ROHM has recently announced the adoption of its SCT2080KE SiC MOSFET in Fukushima SiC Applied Engineering Inc.'s new ultra-high voltage pulse generators (SiC-Pulser Series) launched in November 2014.
Pulse generators are used is a variety of applications, including high voltage accelerators, plasma generators, and laser processing machines. Conventional systems utilize silicon devices or vacuum tubes as switching elements. However, this often entails a large number of system components, resulting in enormous construction and installation costs. In contrast, leveraging the characteristics of SiC switching elements that combine high breakdown voltage with low ON resistance and high-speed switching performance by adopting ROHM's SiC device in the switch module makes it possible to develop a pulse generator that is considerably smaller and provides a level of performance which cannot be achieved through conventional solutions using vacuum tubes or silicon devices.

ROHM is ramping up production of SiC products, particularly for the power sector. The SCT2080KE SiC MOSFET reduces switching loss by more than 70% compared with Si IGBTs used in general inverters. And support for higher switching frequencies allows the use of smaller peripheral components, contributing to end-product miniaturization.

www.rohm.com

OptiMOS™ 5 80V and 100V Power MOSFETs offers the Industry's Lowest On-State Resistance

Infineon Technologies AG extends its OptiMOS™ 5 portfolio with 80V and 100V variants. This latest generation of Power MOSFETs is optimized for high switching frequencies especially used in synchronous rectification applications for telecom and server power supplies as well as in industrial applications such as solar, low voltage drives and power adapter. The OptiMOS 5 MOSFETs offer the industry's lowest on-state resistance (R DS(on)) – up to 45% reduction for 80V and up to 24% reduction for 100V compared to the previous generation. Due to the lower resistance there is significantly less need to parallel parts resulting in reduced material cost. The newly introduced generation offers the highest levels of power density and energy efficiency.



OptiMOS5 80V and 100V are offered in seven different packages: SuperSO8, S308, TO-Leadless, TO-220, TO-220 FullPAK, D²PAK and D²PAK 7Pin with R DS(on) ranging from 1-4 mΩ, 4-8 mΩ and 8-2 mΩ for 80V and 1-4 mΩ, 4-8 mΩ and 8-10 mΩ for 100V. Samples are available in both voltage classes and all packages. Products are in volume production. Further information on the new Infineon OptiMOS 5 80V and 100V portfolio is available at:

www.infineon.com/optimos5-80v100v

Professional Quality Sound with 96% Power Efficiency

Efficient Power Conversion Corporation (EPC) introduces the EPC9106, a reference design for a 150 W, 8 ohm Class-D audio amplifier. This demonstration board uses a Bridge-Tied-Load (BTL) design, composed of four ground-referenced half-bridge output stages, which allows scalability and expandability of the design. All elements that can impact the sonic performance of Class-D Audio systems are minimized or eliminated in an eGaN FET-based system.

According to Dr. Skip Taylor, co-founder and former CTO of Intersil's D2 Audio, "An eGaN FET power stage provides a precise high-power reproduction of the Class-D PWM signal with extremely high linearity. This high linearity reduces the need for large amounts of feedback, ultimately allowing for the best possible audio quality providing clean, crisp middle and high frequencies and a tight, solid reproduction of the low frequencies."

The EPC9106 features the EPC2016 eGaN FET in conjunction with the LM5113 eGaN FET gate driver from Texas Instruments. This board demonstrates that high quality sound can be achieved in a small size due to the performance capabilities of high frequency switching eGaN FETs. With this high efficiency, the EPC9106 design allows for the complete removal of any heat sink requirement, which also reduces the potential contribution to radiated EMI/EMC emissions and overall system cost.

The power block of the EPC9106 including eGaN FETs, driver, inductor and input/output caps is an ultra compact 2.1 mm x 1.6 mm layout. Despite its small size, the EPC9106 reference design achieves 96% efficiency at 150 W, 8 ohms, and 92% efficiency at 250 W, 4 ohms.

www.epc-co.com

AlphaDFN™ Family Enhances Mobile Battery Protection

Alpha and Omega Semiconductor Limited announced the release of two new MOSFETs optimized for battery protection applications. The AOC2804 and AOC2806 are the latest additions to the AlphaDFN™ package portfolio which takes chip scale packaging to the next level. These devices are specifically targeting one and two cells portable battery pack applications such as those found in the latest smart phones, tablets, media players and wearable devices.

In mobile battery pack applications the protection MOSFET controls charging and discharging of the battery, and is critical to battery life and battery safety. The new generation of devices is optimized with AOS's proprietary power trench technology, which minimizes RSS (source- to-source resistance) in a common-drain MOSFET configuration. For the same dimensions, these new devices can deliver 20% lower resistance, which makes them ideal for conserving battery life. AOC2804, 1.5mm x 1.5mm, is aimed at 22 mΩ max RSS level applications such as feature phones and wearable devices. AOC2806, with slightly larger dimension at 1.7mm x 1.7mm, is a 18 mΩ max RSS device that is best-suited for smart phones. When used in parallel, either device can significantly reduce conduction loss by offering <10 mΩ RSS.

www.aosmd.com

Monolithic Gallium Nitride Power Transistor Half Bridge

EPC announces the EPC2102, 60 V and the EPC2103, 80 V enhancement-mode monolithic GaN transistor half bridges. By integrating two eGaN® power FETs into a single device, interconnect inductances and the interstitial space needed on the PCB are eliminated, resulting in a 50% reduction in board area occupied by the transistors. This increases both efficiency (especially at higher frequencies) and power density, while reducing assembly costs to the end user's power conversion system. The half bridges are ideal for high frequency DC-DC conversion.

Using an EPC2103 in a typical buck converter, system efficiency is greater than 97% at 20 A, when switching at 500 kHz and converting from 48 V to 12 V. A second device, the EPC2102 60 V half bridge is also being added to the portfolio. This device achieves 98% system efficiency at 18 A, when switching at 500 kHz and converting from 42 V to 14 V.

Both products come in a chip-scale package for improved switching speed and thermal performance and are only 6.05 mm x 2.3 mm for increased power density.

The EPC9038 and EPC9039 are 2" x 2" (50.8 mm x 50.8 mm) Development Boards and each contains one EPC2102 or EPC2103 integrated half-bridge component, respectively. Both boards use the Texas Instruments LM5113 gate driver and have onboard supply and bypass capacitors. The boards have been laid out for optimal switching performance and include various probe points to facilitate simple waveform measurement and efficiency calculation.

www.epc-co.com

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17th European Conference on Power Electronics and Applications

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What attendees say

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José Alberto Vite Frías, R&D engineer, GPtech, Spain

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Domenico Cavaiuolo, PhD Student, University of Naples, Italy

»Top conference in the field of power conversion with the reference exhibition in the topic.«
Enrique J. Dede, Professor, University Valencia, Spain

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Vittorio Crisafulli, Principal Application Engineer, ON Semiconductor, Germany

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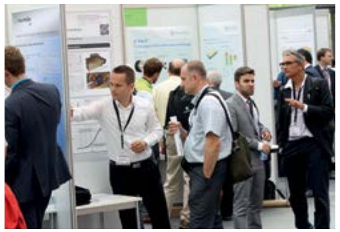

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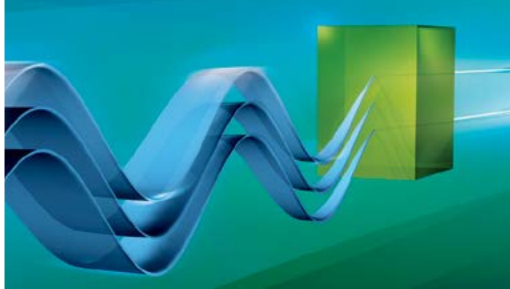

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Tutorials

Monday, 18 May 2015 from 9.00 – 17.00 hrs

99 % Efficiency for AC-DC and DC-DC Converters
Ionel Dan Jitaru, Rompower, USA

Power-Factor Correction – from the Basics to the latest Developments
Richard Redl, Redl Consulting, Switzerland

Electromagnetic Design of High Frequency Converters and Drives
Jacques Laeuffer, Dtalents, France

High Performance Control of Power Converters
Christian P. Dick, Jens Onno Krah, Cologne University of Applied Sciences, Germany

Power Electronics and Control of Renewable Energy Systems
Frede Blaabjerg, Aalborg University, Denmark

Advanced Design with MOSFET and IGBT Power Modules
Tobias Reimann, ISLE Steuerungstechnik und Leistungselektronik GmbH, Germany
Thomas Basler, Infineon Technologies, Germany

Switchmode Design and Layout Techniques for low EMI
Bruce Carsten, Bruce Carsten Associates, USA

Reliability of IGBT Power Modules
Josef Lutz, Chemnitz University of Technology, Germany

IGBT Gate Control – Principles, Optimization and Protection
Reinhard Herzer, Arendt Wintrich, Semikron Elektronik, Germany

Conference

Registration information and full program with all lectures, posters and speakers on **www.pcim-europe.com/program**

Tuesday, 19 May 2015

Conference Opening and Award Ceremony

KEYNOTE »The State-of-The-Art and Future Trend of Power Semiconductor Devices«

Materials	SiC High Power	Control and Drive Strategies in Power Converters	Special Session Solar Inverter Topologies	Special Session Passive Components
High Power Low Inductive	Reliability Monitoring	New and Renewable Energy Systems	Control Techniques in Intelligent Motion Systems	Special Session Digital Control Power – the Future of Power Electronics

Poster/Dialogue Session

Wednesday, 20 May 2015

KEYNOTE »Packaging and Reliability of Power Modules – Principles, Achievements and Future Challenges«

Special Session Power GaN for Automotive Applications	HV-IGBT	DC/DC Converter	Advanced Packaging	Control and Drive Strategies in Power Converters
GaN	Robustness	Power Electronics in Transmission Systems	Applications for Drives & Motion Control	Passive Components and New Materials

Poster/Dialogue Session

Thursday, 21 May 2015

KEYNOTE »Electrochemical Battery Managements and Applications«

SiC Low Power	DC/AC Converter	Power Quality Solutions	Special Session E-Mobility	Motors
Power Module	Low Power Converters	Sensors	Power Electronics in Automotive, Traction and Aerospace	

Automotive N-ch MOSFETs with Low Resistance TO-220SM(W) Package

Toshiba Electronics Europe (TEE) has expanded its line-up of automotive N-channel power MOSFETs with the launch of two devices: TK160F10N1, a 100 V, 160 A product and TK200F04N1L, a 40 V, 200 A class product. Target applications include EPS, DC-DC converters and load switches.

Each device features a chip using the U-MOSVIII-H process in a TO-220SM(W) package that has had its package resistance reduced to its limit with a new internal copper connector. In this way, the products have achieved industry leading low on-resistance characteristics measured @ VGS = 10V.

RDS(ON) = 0.78mΩ (typical) for the TK200F04N1L
RDS(ON) = 2.0mΩ (typical) for the TK160F10N1.

Both devices feature low thermal resistance of Rth(ch-c) = 0.4˚C/W (max) and 175˚C max channel temperature rating.

The MOSFETs realize higher efficiency and lower heat generation. In addition, the U-MOSVIII-H has a better switching ripple suppression capability than the previous generation. It can contribute to EMI noise reduction in applications.

TK160F10N1 and TK200F04N1L will conform with AEC-Q101 automotive level qualification requirements.

www.toshiba.semicon-storage.com

Advertising Index

StrongIRFET™ Rugged, Reliable MOSFETs

Specifications

Package	B_{VDSS} (V)	ID @25°C (A)	$R_{DS(on)}$ max @Vgs = 10V (mΩ)	Qg@ Vgs = 10V (nC)	Part Number
PQFN 5x6	25	100	0.95	56	IRFH8201TRPbF
	25	100	1.05	52	IRFH8202TRPbF
	30	100	1.1	58	IRFH8303TRPbF
	30	100	1.3	50	IRFH8307TRPbF
	40	100	1.4	134	IRFH7004TRPbF
	40	85	2.4	92	IRFH7440TRPbF
	40	85	3.3	65	IRFH7446TRPbF
DirectFET Med.Can	30	192	1.3	51	IRF8301MTRPbF
	40	90	1.4	141	IRF7946TRPbF
	60	114	3.6	120	IRF7580MTRPBF
D²-Pak	40	195	1.8	150	IRFS7437TRLPbF
	40	120	2.8	90	IRFS7440TRLPbF
	60	120	5.34	86	IRFS7540TRLPbF
D²-Pak 7pin	40	195	1.5	150	IRFS7437TRL7PP
	60	240	1.4	236	IRFS7530-7PP
D-Pak	40	90	2.5	89	IRFR7440TRPbF
	60	90	4	86	IRFR7540TRPbF
TO-220AB	40	195	1.3	300	IRFB7430PbF
	40	195	1.6	216	IRFB7434PbF
	40	195	2	150	IRFB7437PbF
	40	120	2.5	90	IRFB7440PbF
	40	118	3.3	62	IRFB7446PbF
	60	195	2.0	274	IRFB7530PbF
TO-247	40	195	1.3	300	IRFP7430PbF

Features:

- Ultra low $R_{DS(on)}$
- High current capability
- Industrial qualified
- Broad portfolio offering

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- Inverters
- UPS
- Solar Inverter
- ORing or Hotswap
- Battery Packs

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