POWER ELECTRONICS EUROPE

ISSUE 1 – Jan/Feb 2011 www.power-mag.com

WIND POWER

How to Handle Electricity from µW to MW in Windmill Applications

THE EUROPEAN JOURNAL FOR POWER ELECTRONICS AND TECHNOLOGY

Also inside this issue


PREMIUM SELECTION
PERSONALIZED SERVICE
FREE SHIPPING
ON ORDERS OVER €65!*
Digi-Key
CORPORATION

Editor Achim Scharf
Tel: +49 (0)892865 9794
Fax: +49 (0)892800 132
Email: achimscharf@aol.com

Production Editor Chris Davis
Tel: +44 (0)1732 370340

Financial Clare Jackson
Tel: +44 (0)1732 370340
Fax: +44 (0)1732 360034

Circulation Manager Anne Backers
Tel: +44 (0)208 647 3133
Fax: +44 (0)208 669 8013
Email: anne@abdatalog.co.uk

INTERNATIONAL SALES OFFICES

Mainland Europe:
Victoria Hufmann, Norbert Hufmann
Tel: +49 911 9397 643 Fax: +49 911 9397 6459
Email: pee@hufmann.info

Armin Wezel
Tel: +49 9568 897 097 Fax: +49 9568 897 096
Email: armin@eurokom-media.de

UK
Steve Regnier, Tim Anstee
Tel: +44 (0)1732 366555
email: Sales@starmediaservices.co.uk

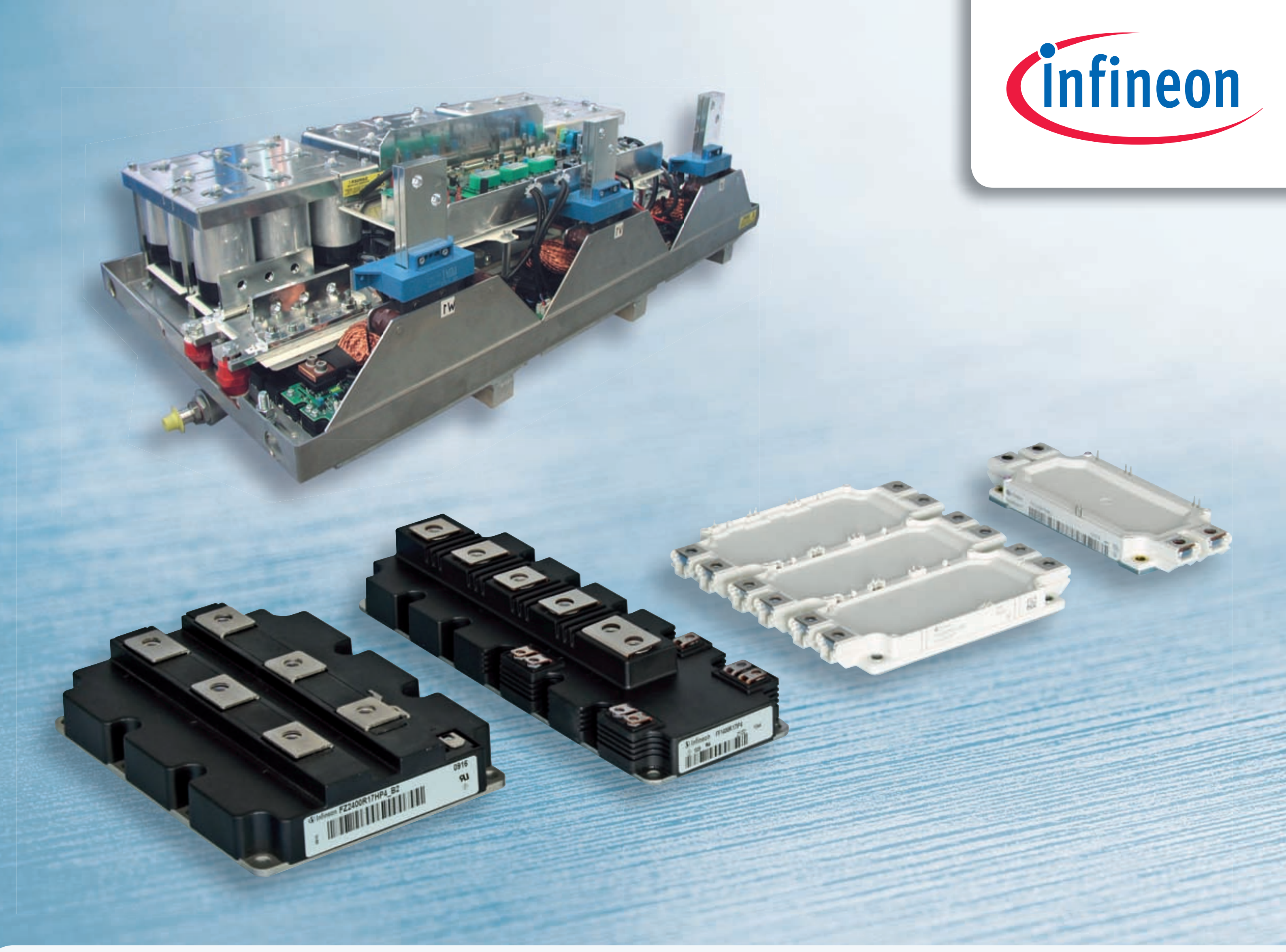
Eastern US
Karen C Smith-Kernc
email: KarenKCS@aol.com
Western US and Canada
Alan A Kernc
Tel: +1 717 397 7100
Fax: +1 717 397 7800
email: AlanKCS@aol.com

Italy
Ferruccio Silvera
Tel: +39 022 846 716 Email: ferruccio@silvera.it
Taiwan
Prisco Ind. Service Corp.
Tel: 886 2 2322 5266 Fax: 886 2 2322 2205

Publisher Ian Atkinson
Tel: +44 (0)1732 370340
Fax: +44 (0)1732 360034
Email: ian@dfamedia.co.uk
www.power-mag.com

Circulation and subscription: **Power Electronics Europe** is available for the following subscription charges. **Power Electronics Europe**: annual charge UK/NI £60, overseas $130, EUR 120; single copies UK/NI £10, overseas US$32, EUR 25. Contact: DFA Media, Cape House, 60a Priory Road, Tonbridge, Kent TN9 2BL Great Britain.
Tel: +44 (0)1732 370340. Fax: +44 (0)1732 360034. Refunds on cancelled subscriptions will only be provided at the Publisher's discretion, unless specifically guaranteed within the terms of subscription offer.
Editorial information should be sent to The Editor, **Power Electronics Europe**, PO Box 340131, 80098 Munich, Germany.

Printed by: Garnett Dickinson.
ISSN 1748-3530



Solutions for windpower systems

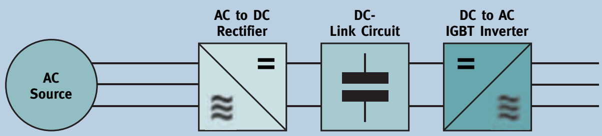
Energy-efficient components for high system reliability

The Infineon product portfolio provides components for the highest energy efficiency in windmill power converter and pitch control solutions.

Our Power Modules with latest 1200V/1700V trench fieldstop IGBT4 and Emitter Controlled diode chip technology offer best in class power density solutions in conjunction with extended lifetime. The modules feature low on state losses, optimized soft switching behavior and a wide operation temperature range up to 150°C maximum junction operation temperature. The newly introduced stack assembly ModSTACK™ HD leads to more than 50 % higher power density at same footprint.

The following benefits are provided to our customers:

- Extended module utilization by 150°C maximum junction operation temperature
- Highest power density
- Supreme power cycling and thermal cycling capability



[www.infineon.com/highpower]

Good Outlook for Power Electronics in 2011

The global semiconductor market has achieved the largest dollar increase in its history in 2010. Worldwide semiconductor revenue amounted to $304 billion in 2010, up from $229.5 billion in 2009. This represents growth of 32.5% for the year. Despite the relatively modest growth of worldwide car sales in 2010, the automotive semiconductor market achieved the highest growth of all major chip application markets with growth of 41%. While growth in electronics revenue is expected to continue in 2011, the multiplying factors that propelled growth in 2010 will lose their potency. As a result, market researchers project a soft landing for the semiconductor industry in 2011 with 5% annual growth. Global power management semiconductor revenue will climb to $36.2 billion in 2011, up 14% from 2010. Among the factors causing the continuing expansion of global revenue in 2011 is the move toward more efficient battery-powered devices. With consumers everywhere looking for longer battery life in their mobile devices-from cell phones to tablets, to notebooks, to portable navigation devices-new design trends will likely emerge in power management integrated circuits (ICs), boosting revenue among suppliers. Also anticipated in 2011 is a move toward greater integration in power ICs; suppliers with the technology to further integrate their chips will reap the greatest benefits in terms of revenue. Another factor driving expansion will be the growth in alternate energy markets, including solar, wind, the electrification of vehicles and the smart grid.

These opportunities for power electronics in renewable energies are confirmed by other studies. The global PV inverter market i. e. is forecast to reach $8.5 billion by 2014, growing at compound annual growth rate of nearly 25%. More than 7 million inverters will be sold in 2014, up from less than 1 million in 2009. Despite a factory-gate price decline of around 11% in 2010, revenues generated from PV inverters have more than doubled, and exceeded $5 billion for the first time. In the longer term, positive growth is predicted to continue, despite on-going price reductions and architecture changes, and the market will double in size again in the next 5 years. And wind could meet 12% of global power demand by 2020, and up to 22% by 2030. In addition to environmental benefits, wind energy is becoming a substantial factor in economic development, providing more than 600,000 'green collar' jobs today both in direct and indirect employment. By 2030, the number of jobs is projected to increase to over 3 million. In 2010 the workers of the wind industry put up a new wind turbine every 30 minutes. By 2030, the market could be three times bigger than today, leading to a €202 billion investment and a new turbine every seven minutes. The role of power electronics in such turbines are clearly described in our cover story, there are a lot of challenges which have to be mastered. Within the complex entity known as "The Windmill", handling electricity in an extreme wide range of power levels is the omnipresent challenge. Data needs to be gathered, transferred and processed at the lowest power levels. Mechanics and hydraulics need to be controlled to operate the mill. The quality of fulfillment depends on several electric subsystems. These in turn need to be supplied with power magnitudes below the mills output. Channeling the harvested energy to the grid is the most obvious task focusing on megawatts and beyond.

Also new power devices will enter the market in 2011, such as high-voltage Silicon Carbide (SiC) and Gallium Nitride (GaN) switches. On January 17 Cree has introduced the industry's first fully-qualified commercial Silicon Carbide power MOSFET. This establishes a new benchmark for energy efficient power switches and can enable design engineers to develop high voltage circuits with extremely fast switching speeds and low switching losses. The addition of the SiC power MOSFET to Silicon Carbide Schottky diodes already on the market enables power electronics design engineers to develop "all-SiC" implementations of critical high power switching circuits and systems with levels of energy efficiency, size and weight reduction that are not achievable with any commercially available silicon power devices of comparable ratings. According to the manufacturer, compared to the best silicon IGBTs, the 1200V SiC MOSFET improves system efficiency up to 2% and operates at 2-3 times the switching frequencies. Higher component efficiency also results in lower operating temperatures. The SiC MOSFET can be used today for solar inverters, high-voltage power supplies and power conditioning in many industrial power applications. Over the next several years, SiC power switches and diodes could also expand into motor drive control, electric vehicles and wind energy applications. The market for power semiconductors in these applications is estimated at approximately $4 billion today, reaching nearly $6 billion by 2015. In contrast the market for SiC power semiconductors will grow significantly from today's $100 million to $400 million by the year 2013. And with the launch of 600V GaN switches an other alternative to Silicon MOSFETs will enter the market. APEC and PCIM and here in particular PEE's Special Session will be the place to get deeper insights.

I wish all readers an interesting and successful year!

Achim Scharf
PEE Editor

Highest Growth for Semiconductors in 2010

The global semiconductor market has achieved the largest dollar increase in its history in 2010, courtesy of a boom in DRAM and NAND sales that is benefiting memory suppliers, according to a preliminary forecast from the market research firm iSuppli, now part of IHS Inc. Following a 41.6% boom in 2010, revenue growth in the global power management semiconductor market will slow significantly in 2011 but still will manage to increase at a double-digit pace.

Worldwide semiconductor revenue amounted to $304 billion in 2010, up from $229.5 billion in 2009. This represents growth of 32.5% for the year. Percentage growth was higher in 2001 than in 2010, when revenue rose by 36.7%. However, revenue increased by $74.5 billion in 2010, a record increase that shattered the previous benchmark expansion of $59.2 billion in 2001. "While many observers expected the semiconductor industry in 2010 to achieve a solid rebound following the deep drop of 2009, the actual growth far outstripped all expectations", said analyst Dale Ford. "The enormous expansion in semiconductor revenue was based on renewed demand for electronic equipment, such as computers, televisions and cell phones. However, semiconductor sales in 2010 are set to rise at more than three times the rate of electronics equipment revenue. This augmented growth is being driven by a range of multiplying factors, including inventory rebuilding, upward price pressure due to a supply/demand imbalance and an increase in the average semiconductor content of major electronic products".

A deeper examination of the dramatic growth in the semiconductor market in 2010 yields some surprising insights. Despite the relatively modest growth of worldwide car sales in 2010, the automotive semiconductor market is projected to achieve the highest growth of all major chip application markets with growth of 41%. This will vastly exceed the growth of the second-fastest growing segment, the data processing semiconductor market, which expanded by 37% largely because of the DRAM segment. On the other hand, regardless of all the headlines showing the growth of smart phone shipments, the wireless communications segment have seen the lowest overall growth among the major chip application markets, with semiconductor revenue rising by only 24% in 2010.

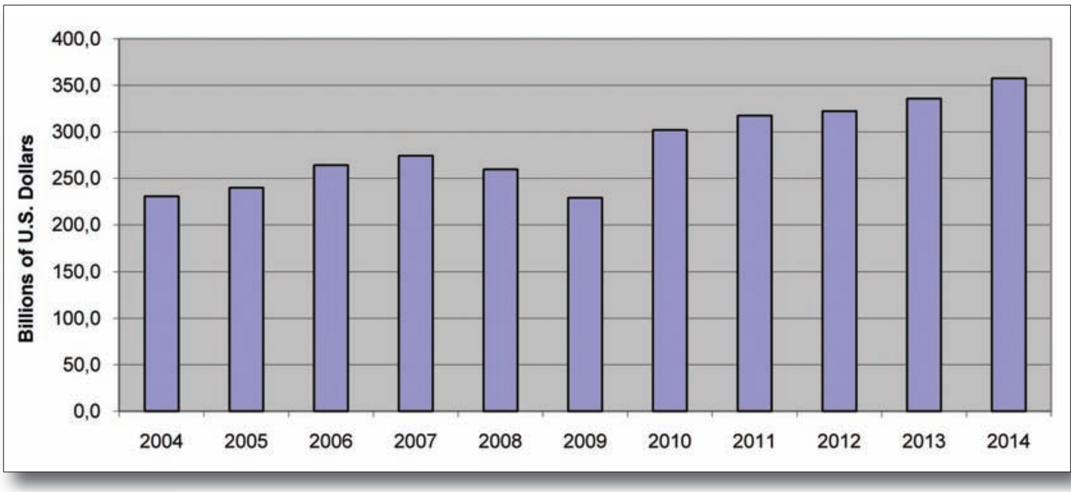
While growth in electronics revenue is expected to continue in 2011, the multiplying factors that propelled growth in 2010 will lose their potency. As a result, Ford is projecting a soft landing for the semiconductor industry in 2011 with 5% annual growth.

Even more growth in power management semiconductors

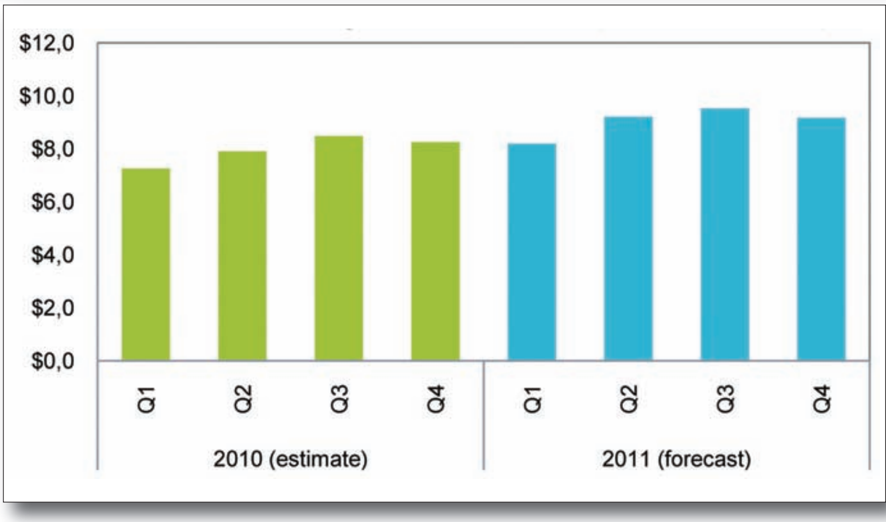
Global power management semiconductor revenue will climb to $36.2 billion in 2011, up 14% from 2010. "The solid rise in 2011 follows a banner year in 2010, when power management semiconductor revenue soared to $31.8 billion," said analyst Marijana Vukicevic. That figure, Vukicevic noted, was up from $22.5 billion in 2009. "But sales in 2011 simply will not be able to keep pace with the rapid expansion of 2010, when revenue rebounded dramatically from the recession year of 2009".

Among the factors causing the continuing expansion of global revenue in 2011 is the move toward more efficient battery-powered devices. With consumers everywhere looking for longer battery life in their mobile devices-from cell phones to tablets, to notebooks, to portable navigation devices-new design trends will likely emerge in power management integrated circuits (ICs), boosting revenue among suppliers. Also anticipated in 2011 is a move toward greater integration in power ICs; suppliers with the technology to further integrate their chips will reap the greatest benefits in terms of revenue. Another factor driving expansion will be the growth in alternate energy markets, including solar, wind, the electrification of vehicles and the smart grid.

www.isuppli.com



ABOVE: Global semiconductor revenue forecast with 2010 breaking the $300 billion barrier



RIGHT: Quarterly global power management semiconductor revenues 2010 and forecast 2011 (in $ billion)1 IHS iSuppli

Endless Possibilities!

New AR Hybrid Power Module Amplifiers cover an instantaneous bandwidth from 4 – 18 GHz …
with powers that no single technology can match.

We combined new technologies and microelectronics to create small, lightweight, solid-state amplifier modules that deliver up to 5 watts of power across the 4 – 18 GHz range. With excellent gain flatness, 100% mismatch capabilities, and the drive to keep on working in the harshest environments.

Standard Models and Custom Designs Available.

AR's expertise and the resources of our own microelectronics lab enable us to produce hybrid power modules to your specs – up to and exceeding 50 watts, from 500 MHz to 40 GHz. We can even design a module to fit into an existing rack mount. Applications include radar systems, ECM, wireless communications, and more. In fact, the possibilities are endless.

To learn more, visit www. http://goo.gl/S4WuX

Come See Us At EMV 2011, Messe Stuttgart, Stuttgart, Germany
March 3 - 17, 2011

RoHS

ISO 9001:2008 Certified

rf/microwave instrumentation

Other ar divisions: modular rf • receiver systems • ar europe

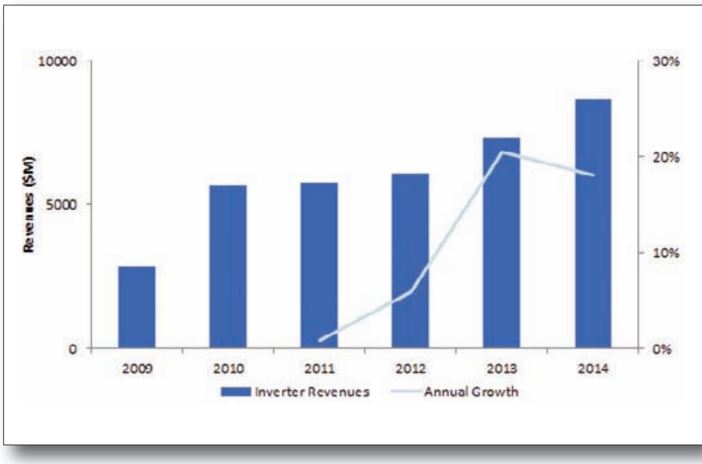
USA 215-723-8181. For an applications engineer, call 800-933-8181.
In Europe, call ar United Kingdom 441-908-282766 • ar France 33-1-47-91-75-30 • emv GmbH 89-614-1710 • ar Benelux 31-172-423-000

PV inverter market to reach $8.5 billion in 2014

The global PV inverter market is forecast to reach $8.5 billion by 2014, growing at compound annual growth rate of nearly 25% according to a newly IMS report which revealed that more than 7 million inverters will be sold in 2014, up from less than one million in 2009. Despite a factory-gate price decline of around 11% in 2010, revenues generated from PV inverters have more than doubled, and exceeded $5 billion for the first time. In the longer term, positive growth is predicted to continue, despite on-going price reductions and architecture changes, and the market will double in size again in the next 5 years.

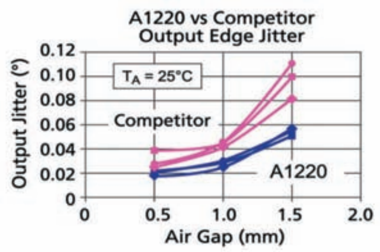
Whilst the development of the PV inverter market is closely linked to PV installations, inverter demand became 'decoupled' from underlying installation growth in 2010 due to shortages, component bottlenecks and double-ordering. "Despite the shortage of inverters at the beginning of 2010, we estimated that more than 2 GW of inverters were produced that were not needed. This has led to high inventory levels, both at suppliers' warehouses, and throughout the supply chain. This came as a direct result of double-orders being fulfilled and has also led to cancellations and push-backs of orders", PV Research Director Ash Sharma commented. This shortage has now abated and the balance has shifted towards a major oversupply of inverters, with high levels of inventory recorded in Q4'10, leaking into Q1'11.

"Inverter suppliers continue to add capacity, most notably in Asia and North America. A further 12-15 GW of additional capacity is planned to be added in 2011 which is somewhat surprising given the uncertain market outlook in 2012 and many suppliers are certainly not being cautious in their expansion plans", Sharma added.

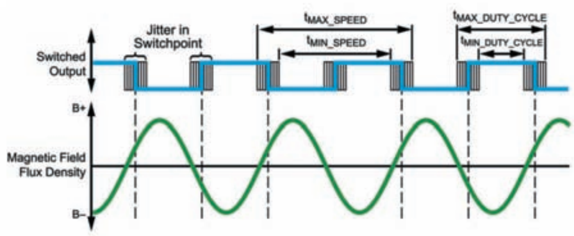


PV inverter market forecast

Allegro's New Family of Robust, Low Output Jitter, Hall-Effect Latches



Switch point jitter over air gap shows substantially less variation compared to a close competitor



Low Jitter Performance = Accurate Speed and Duty Cycle Measurement

Allegro's A1225/7/9 devices are raising the bar on traditionally simple Hall-effect latches, which are commonly used to measure the speed or commutation point of electronic motors.

Enhancements include: on-chip protection against high voltage transients to eliminate the need for additional protection components and a patented chopper stabilization technique to provide low noise and low output jitter switching.

For applications that do not require extremely robust protection against voltage transients, Allegro's A1220/1/2/3 Hall-effect latches provide a suitable alternative, without compromising low jitter performance.

Representatives

ALLREM
94616 Rungis Cedex
FRANCE
Tel: +33 (0) 1 56 70 03 80
E-mail: info@allrem.com

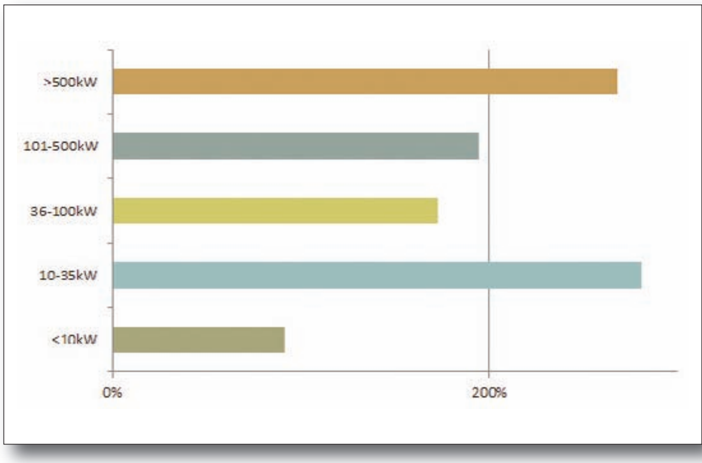
SSG Semiconductor Systems GmbH
D79856 Hinterzarten
GERMANY
Tel: +49 (0) 7652-91060
Website: www.ssg-de.com
E-mail: mail@ssg-de.com

Consystems s.r.l. – Divisione Cefra
I-20144 Milano
ITALY
Tel: +39 02 4241471
Website: www.cefra.com
E-mail: info@cefra.it

MSM Ltd.
Weybridge
Surrey, KT13 0RZ
United Kingdom
Tel: +44 (0) 1932 341106
E-mail: msm@intonet.co.uk

Allegro® MicroSystems Europe Ltd.
High Performance Power and Hall-Effect Sensor ICs

www.allegromicro.com/promo979



Demand increase by inverter power level in 2010 Source: IMS Research

Although announcements from microinverter and power optimizer vendors grabbed the headlines in 2010, the biggest architecture changes came from traditional inverter suppliers with a dramatic shift towards small three-phase products, typically rated below 20kW. These products were in fact the fastest selling in 2010 and gained major share due to installers' preferences for these products in commercial installations up to 100-200kW. Very large inverters above 500kW also experienced high growth in 2010, with shipments increasing by more than 250% due to robust demand from MW-scale PV plants around the world. In the longer-term, IMS Research predicts this will be one of the most promising segments of the market for a number of reasons. "Large central inverters above 500kW or even 1MW will become an increasingly attractive business area for many suppliers as high demand is anticipated from utility-scale projects in several countries, including the USA and India. In addition these products are typically highly engineered, with advanced functionality and design which attract healthy margins and also prevent low-cost competitors from stealing market share", Sharma concluded.

Move to Digital Power Supplies Drive SiC Components

According to an other report from IMS Research, the explosive growth projected for power supplies with digital control and management will increase demand for Silicon Carbide (SiC) diodes, Digital Signal Processors (DSPs) and Microprocessors (MPUs). However, in the long term, this will be at the expense of PFC controller ICs, and analog controllers and regulators.

"Although supplies with digital control and management are predicted to account for less than 10% of the total merchant market for power supplies in 2015, their components will be worth almost $1 billion. There will be a strong growth in demand for all component types. However, digital controllers/converters are predicted to replace their analog counterparts; and with the use of a DSP or MPU, some functions such as power factor correction will be performed without a dedicated IC. This will thus impair the demand for some component types", commented analyst Ryan Sanderson. "But the impact on some analog component markets is somewhat offset by growth in the markets for components which have previously not been used in power supplies. The market for MPUs and DSPs in merchant power supplies is forecast to increase four-fold from 2010 to 2015, and the use of SiC diodes is increasing rapidly, particularly in the PFC stage".

Further, the report "The World Market for Semiconductors in Merchant Power Supplies" revealed that the total market for semiconductors and components in merchant power supplies is projected to reach over $7 billion in 2015. AC/DC merchant power supplies will account for over 90%; DC/DC merchant power supplies account for less than 10%.

www.ims-research.com
www.pvmarketresearch.com

High Power IGBTs

We never sell a product alone
It always comes with Quality

- **High reliability**
  by innovative solder material and ultrasonic welding
- **Improved thermal behaviour**
  by reduced thermal cross coupling and uniform temperature distribution
- **Low internal inductance**
  by parallel and closely arranged bus-bars

Package 2-Pack & Chopper	I_C	1200V E-type	1200V P-type Soft turn-off	1700V E-type
 89 x 172 mm	600A	●		
	650A			●
	900A	●	●	
 89 x 250 mm	1000A			●
	1400A		●	●

$T_{j,op}$ = 150°C $T_{j,max}$ = 175°C $V_{iso, 1min}$ = 4.0kv   CTI > 600

FUJI ELECTRIC EUROPE
e-Front runners

Fuji Electric Europe GmbH
Goethering 58 · 63067 Offenbach am Main · Germany
Fon +49 (0)69 - 66 90 29 0 · Fax +49 (0)69 - 66 90 29 56
semi-info@fujielectric.de . www.fujielectric.de

Future European Grid And Markets

The benefit of integrating 265 GW of wind into Europe's grids by 2020 - compared to no further growth in wind power capapcity - would be a saving of €41.7 billion per year in the cost of electricity. This is a 'merit order' effect of €11 for every MWh produced not just those MWh produced by wind turbines. And if our electricity markets are functioning that is a saving that could be passed on to consumers, a recently published report by the European Wind Energy Association (EWEA) outlines.

The electricity grid infrastructure needed to accommodate increasingly large amounts of renewable energy and create effective competition in a single market in electricity includes a new offshore grid in Europe's Northern Seas (North Sea, Irish Sea and Baltic Sea), as well as a number of improved interconnections across continental Europe (especially between Spain and France but also between Germany and its neighbours, across the Alps and in eastern and south eastern Europe). HVDC cables are an attractive new technological option for long-distance electricity superhighways such as the offshore grid that is required in the near future, says the report.

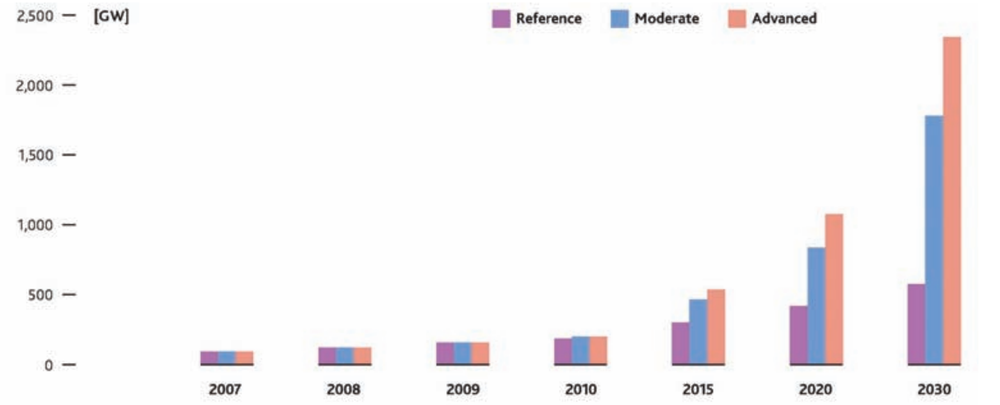
The report also reveals that flexibility will need to be a key feature of European power systems in the future. This means power generation will have to be more flexible to take into account variable sources of power such as wind and solar. Smart grids will be needed to allow management of demand as well as improved management of supply, and largely national grids will have to be better interconnected. EWEA's report shows how Denmark, Germany, Spain, Ireland and the Netherlands have managed their power systems much more flexibly than in the past. "The European Commission recently presented an ambitious and far-sighted vision for a European grid", said Christian Kjaer, EWEA CEO. "Our report shows a vision for a future European power infrastructure to complement the EU governments' and European Parliament's ambition to increase renewable electricity's share from 15% in 2005 to 34% in 2020. It shows how we can continue to expand beyond that short timeframe".

Wind could meet 12% of global power demand by 2020, and up to 22% by 2030, according to a study published in October 2010 by the Global Wind Energy Council (GWEC) and Greenpeace. "Wind power can make a massive contribution to global electricity production and to de-carbonising the power sector, but we need political commitment to make this happen", said Steve Sawyer, GWEC's Secretary General. "Wind power technology provides governments with a viable option for truly tackling the challenges of our time and for being part of the energy revolution our planet needs."

In addition to environmental benefits, wind energy is becoming a substantial factor in economic development, providing more than 600,000 'green collar' jobs today both in direct and indirect employment. By 2030, the number of jobs is projected to increase to over 3 million. "In 2010 the 600,000 workers of the wind industry put up a new wind turbine every 30 minutes," added Sven Teske, Senior Energy Expert from Greenpeace. "By 2030, the market could be three times bigger than today, leading to a €202 billion investment. A new turbine every seven minutes - that's our goal".

Wind energy is already a mainstream power generation source in many countries, and it is now deployed in more than 75 countries around the world. "Interestingly, a great proportion of wind power growth is already happening outside of the industrialised world", said Klaus Rave, GWEC's Chairman. "By 2030, we expect that around half the world's wind farms will be located in developing countries and emerging economies".

www.ewea.org
www.gwec.net



	2007	2008	2009	2010	2015	2020	2030
Reference [MW]	93,864	120,297	158,505	185,258	295,783	415,433	572,733
[TWh]	206	263	347	406	725	1,019	1,405
Moderate [MW]	93,864	120,297	158,505	198,717	460,364	832,251	1,777,550
[TWh]	206	263	347	435	1,129	2,041	4,360
Advanced [MW]	93,864	120,297	158,505	201,657	533,233	1,071,415	2,341,984
[TWh]	206	263	347	442	1,308	2,628	5,429

Global cumulative wind power capacity in three different scenarios: a Reference scenario based on figures from the International Energy Agency (IEA); a Moderate version which assumes that current targets for renewable energy are successfully met; and an Advanced scenario which assumes that all policy options in favour of renewables have been adopted

SEMIKRON Ranked One of the Best Employers

In May 2010 the University of St. Gallen conducted a survey among 1,500 SEMIKRON International employees, scrutinising the company's HR management. The outcome: on 27th January 2011 Semikron was awarded the "top job" seal of quality by mentor Wolfgang Clement in Duisburg, putting the company among the top-ranking employers in Germany.

"What we need is a pact - a pact between universities, businesses, families and government", commented Andreas Dauer, head of corporate development at SEMIKRON. "We are a global leader in the production of diode/thyristor power semiconductor modules. There is a shortage of qualified staff, a fact that is particularly critical in the development of this complex technology. There is an ever increasing need for qualified employees. And it is becoming increasingly difficult to meet this demand".

Prof. Dr. Heike Bruch and her team from the Institute for Management and HR Management of the University of St. Gallen scrutinised the work of 169 HR departments in medium-sized companies from every industry in Germany. The team analysed the chief HR instruments and performed an employee survey, which a minimum of 80% of employees were asked to take part in. The 72 best companies, which included SEMIKRON International, will now bear the "Top Job" quality seal for one year. The 72 top medium-sized employers in Germany have an average of 493 employees. In 2010, each of the "Top Job" firms had an average of 74 new job openings. More than half of the 72 "Top Job" firms in

Andreas Dauer (left), head of corporate development and Heike Rupprecht consultant HR marketing and communication from SEMIKRON are happy to receive the Top Job award from project mentor Wolfgang Clement (right)

2011 are family run businesses. The fact that these include 11 global leaders and 21 national market leaders shows that good employers can be economically successful, too. In keeping with this, more than half of the firms pay their employees salaries that exceed than collective tariff levels. "This award is based on the opinion of our talents, which makes us very proud", Dauer stated. "Additionally, we now know what our employees think of our labour climate. That was important to us, for this is the only way we can become a better employer in the long-term and implement the right measures".

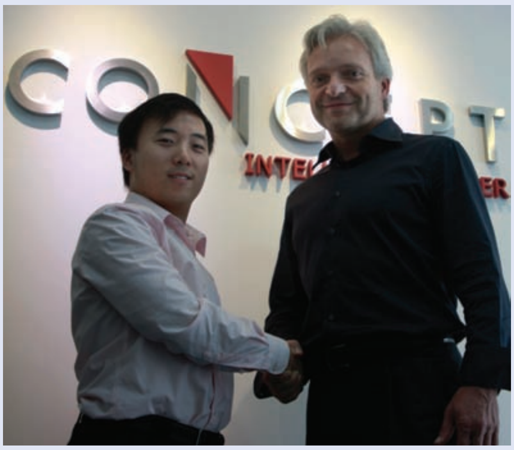
www.semikron.com, www.topjob.de

CT-Concept Goes China

CT-Concept Technologie AG, the Swiss maker of IGBT gate drivers, is strengthening its local presence in one of the main growth markets for power electronics. With effect from January 1st, the CONCEPT office in Shenzhen will start work to support local customers with highly qualified technical support.

"Within the scope of CONCEPT's growth strategy, our presence in China is an important step toward realising our ambitious sales targets. It not only does justice to our most important existing market, but also to the fact that China continues to record the fastest growth rates in the power conversion sector. The Chinese government's new five year plan forms a stable framework for growth in this segment and encourages us to invest consistently in China", notes CEO Wolfgang Ademmer. Winson Wei, 28, has been appointed as Managing Director of its technical office in Shenzhen. He is completely familiar with the high-performance electronics scene in China, and was previously responsible for technical support and training of the sales team at one of main distributors of power electronics. His experience extends across the whole range of power electronics systems, all the way from microcontrollers, via IGBT drivers up to IGBT modules.

www.igbt-driver.com



Winson Wei (left) and CT-Concept CEO Wolfgang Ademmer at the opening of the new China office

Step-Down DC/DC Controller with Digital Power System Management

Linear Technology announces the LTC3880/-1, a dual output synchronous step-down DC/DC controller with I²C-based PMBus interface for digital power system management. The device combines analog switching regulator performance with mixed signal data conversion, supported by a software development system with graphical user interface (GUI). According to Don Paulus, General Manager, Power Management Products at Linear Technology, the well-known analog feedback still has several advantages over so-called digital power, whereas digital power management offers comprehensive monitoring functionality.

Systems in datacom, telecom or storage can have as many as 17 rails and need a simple way to manage these rails with regards to their output voltage, sequencing and maximum allowable current. Thus designers need to easily make changes to these parameters to optimize system performance and to store a particular configuration for each DC/DC converter in order to simplify the design effort. Furthermore, there is a growing need to monitor and report on the health of these DC/DC converters remotely, in order to identify problems and take corrective action.

"The well-known analog feedback still has several advantages over so-called digital power", states Linear's General Manager Power Management Products Don Paulus

Analog feedback and digital monitoring

The LTC3880 is a constant frequency, current mode step-down controller containing two channels operating with various user-defined relative phasing. During normal operation each top MOSFET is turned on when the clock for that channel sets the RS latch, and turned off when the main current comparator, I_{CMP} , resets the RS latch. The peak inductor current at which I_{CMP} resets the RS latch is controlled by the voltage on the I_{TH} pin which is the output of each error amplifier, EA. The EA negative terminal is equal to the V_{SENSE} voltage divided by 5.5 (2.75 if range = 1). The positive terminal of the EA is connected to the output of a 12-bit DAC with values ranging from 0V to 1.024V. The output voltage, through feedback of the EA, will be regulated to 5.5 times the DAC output (2.75 times if range = 1). The DAC value is calculated by the part to synthesize the users desired output voltage. The output voltage is programmed by the user either with the resistor configuration pins or by the V_{OUT} command (either from NVM or by PMBus command).

The current mode controller will turn off the top gate when the peak current is reached. If the load current increases, V_{SENSE} will slightly droop with respect to the DAC reference.

This causes the I_{TH} voltage to increase until the average inductor current matches the new load current. After the top MOSFET has turned off, the bottom MOSFET is turned on. In continuous conduction mode, the bottom MOSFET stays on until the end of the switching cycle.

The LTC3880/-1 allows for digital programming and read back for real-time control and monitoring of critical point-of-load converter functions. Programmable control parameters include output voltage, margining and current limits, input and output supervisory limits, power-up sequencing and tracking, switching frequency and identification and traceability data. On-chip precision data converters and EEPROM allow for the capture and non-volatile storage of regulator configuration settings and telemetry variables, including input and output voltages and currents, duty cycle, temperature and fault logging.

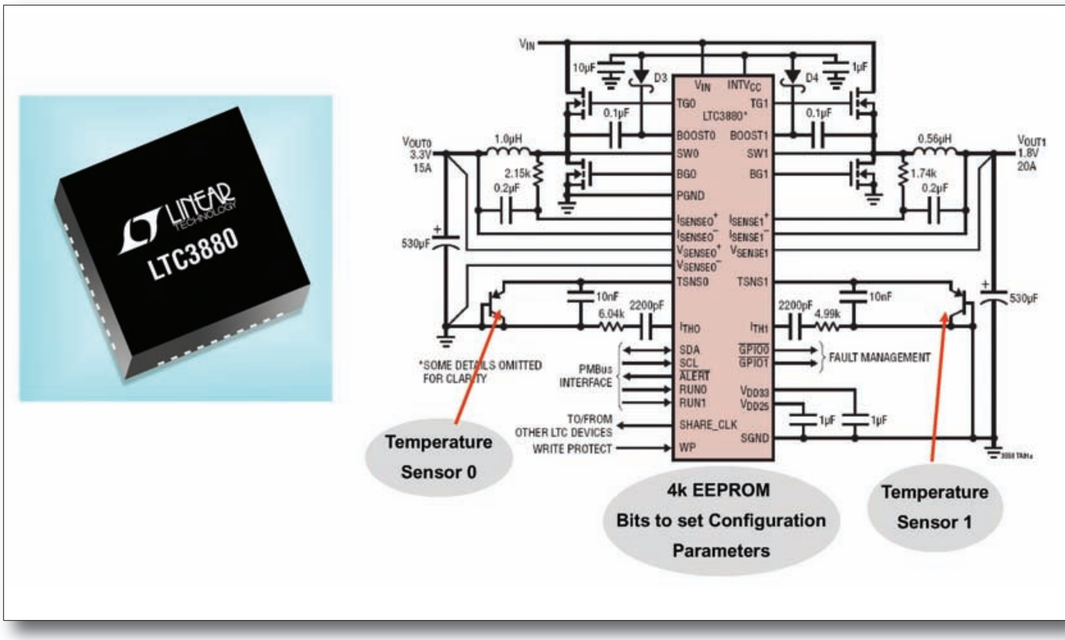
The device can regulate two independent outputs or be configured for a two-phase single output. Up to 6 phases can be interleaved and paralleled for accurate sharing among multiple ICs, minimizing input and output filtering requirements for high current and/or multiple output applications. An integrated amplifier provides true differential remote output voltage sensing, enabling high accuracy regulation, independent of board IR voltage drops. Applications include high current ASIC, FPGA and processor supplies in telecom, datacom, computing and storage applications.

Up to 30A output

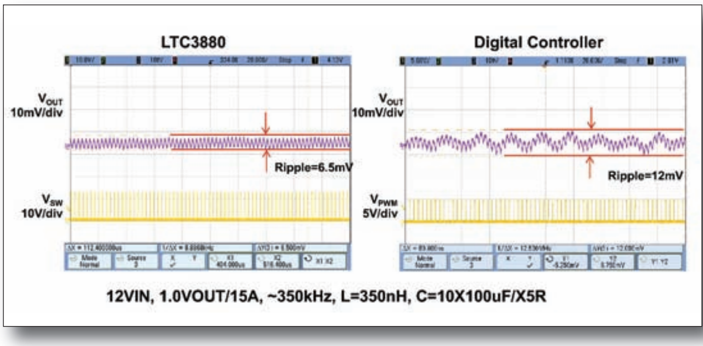
The LTC3880 features high-current integrated gate drivers to drive all N-channel power MOSFETs from input voltages ranging from 4.5V to 24V, and it can produce ±0.50% accurate output voltages from 0.5V to 5.5V with output currents up to 30A per phase over the full operating temperature range.

Here two external power MOSFETs must be selected for each controller in the LTC3880: one N-channel MOSFET for the top (main) switch, and one N-channel MOSFET for the bottom (synchronous) switch.

The peak-to-peak drive levels are set by the INTVCC voltage, typically 5V. Consequently, logic-level threshold MOSFETs must be used in



RIGHT: I²C/PMBus Dual Synchronous Step-Down DC/DC Controller



LEFT: According to Linear, digital control loop quantization effects add incremental steady state voltage ripple that cannot be reduced by increasing load capacitance or adjusting loop compensation

most applications. The only exception is if low input voltage is expected ($V_{IN} < 5V$); then, sub-logic level threshold MOSFETs ($V_{GS(TH)} <$ 3V) should be used. Pay close attention to the BVDSS specification for the MOSFETs as well; most of the logic-level MOSFETs are limited to 30V or less.

Selection criteria for the power MOSFETs include the on-resistance $R_{DS(ON)}$, Miller capacitance C_{MILLER}, input voltage and maximum output current. Miller capacitance can be approximated from the gate charge curve usually provided on the MOSFET manufacturers' data sheet.

Both MOSFETs have I^2R losses while the topside N-channel equation includes an additional term for transition losses, which are highest at high input voltages. For V_{IN} <20V the high current efficiency generally improves with larger MOSFETs, while for V_{IN} >20V the transition losses rapidly increase to the point that the use of a higher $R_{DS(ON)}$ device with lower C_{MILLER} actually provides higher efficiency. The synchronous MOSFET losses are greatest at high input voltage when the top switch duty factor is low or during a short-circuit when the synchronous switch is on close to 100% of the period.

An optional Schottky diodes conduct during the dead time between the conduction of the two power MOSFETs. These prevent the body diodes of the bottom MOSFETs from turning on, storing charge during the dead time and requiring a reverse recovery period that could cost as much as 3% in efficiency at high V_{IN}. A 1A to 3A Schottky is generally a good compromise for both regions of operation due to the relatively small average current. Larger diodes result in additional transition losses due to their larger junction capacitance.

Highest efficiency is achieved by sensing the voltage drop across the output inductor (DCR) to sense current, or an external sense resistor can optionally be used. This means the ohmic value of the inductor will be used! Programmable DCR temperature compensation cancels the TC of the copper inductor to maintain an accurate and constant current limit over a broad temperature range.

The device's minimum on-time of just 90ns allows for compact high frequency/high step-down ratio applications. Accurate timing across multiple chips and event-based sequencing allow the optimization of power-up and power-down of complex, multiple rail systems. Additional features include constant frequency current mode control with cycle-by-cycle current limit, adjustable soft start, a synchronizable switching frequency, and programmable GPIO pins to indicate part status and to provide autonomous recovery from faults.

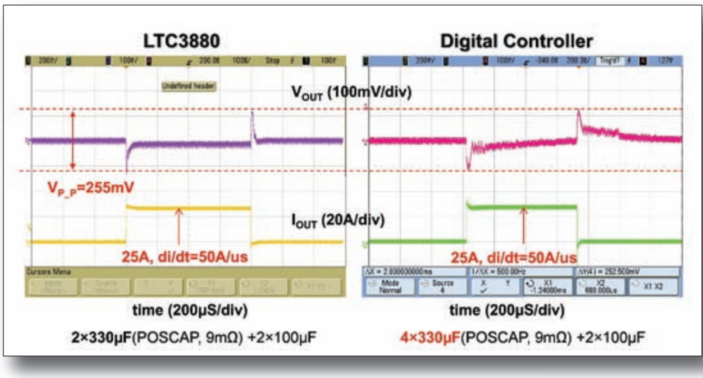
The LTC3880 features also an on-board LDO for controller and gate drive power and the LTC3880-1 allows for an external bias voltage for highest efficiency. Both parts are available in a thermally enhanced 6mm x 6mm QFN-40 package. The extended temperature range grade is specified over a -40°C to 85°C operating junction temperature range. The industrial grade part is specified over a -40°C to 125°C operating junction temperature range.

With configurations stored on-chip, the controller can power up autonomously without burdening the host processor. Default settings can be optionally configured by external resistor dividers for output voltage, switching frequency, phase and device address. Multiple designs can be calibrated and configured in firmware to optimize a single hardware design for a range of applications. The converter loop gain does not change as the power supply parameters are modified, so compensation remains for multiple configurations.

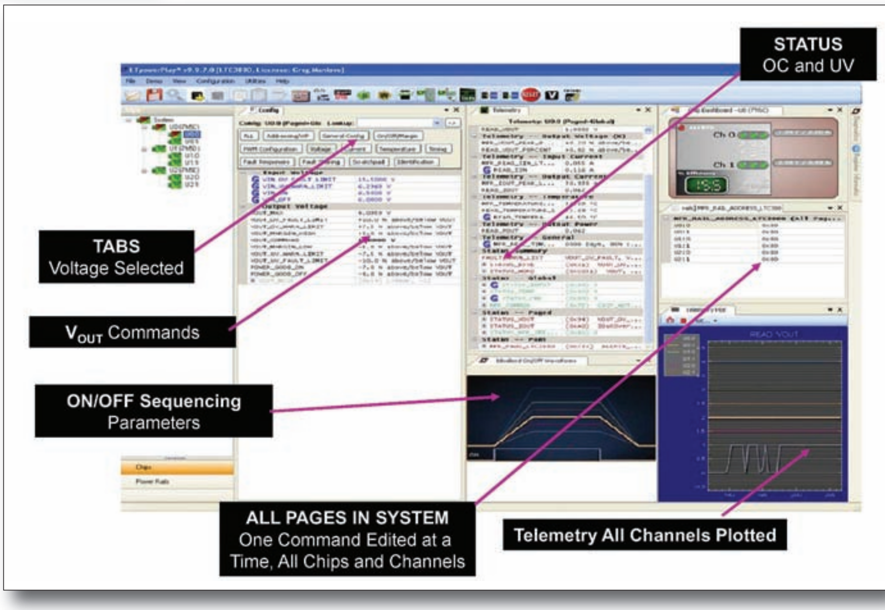
GUI for digital power

Configurations for the LTC3880/-1 are easily saved to internal EEPROM over the I^2C serial interface using LTpowerPlay GUI-based development software. LTpowerPlay is a powerful Windows-based development environment that supports Linear's digital power ICs including the LTC3880. The software supports a variety of different tasks. LTpowerPlay can be used to evaluate ICs by connecting to a demo board or the user application, it can also be used in an offline mode (with no hardware present) in order to build multiple IC configuration files that can be saved and reloaded at a later time.

LTpowerPlay provides diagnostic and debug features. It becomes a valuable diagnostic tool during board bring-up to program or tweak the power system or to diagnose power issues when bring up rails. The software also provides an automatic update feature to keep the revisions current with the latest set of device drivers and documentation. A great deal of context sensitive help is available along with several tutorial demos. Complete information is available at **www.Ltpowerplay.com**



ABOVE: According to Linear, in load step LTC3880 can save 50% POSCAP maintaining same peak-to-peak voltage, with better stability and shorter settling time



RIGHT: Configuration and monitoring of three LTC3880 switchers via LTpowerPlay GUI

Configurable Sensor AFE ICs Simplify Design

National Semiconductor introduced two configurable sensor analog front-end (AFE) integrated circuits (ICs) that work together with Webench to fast-track signal path designs for a variety of sensors from major global manufacturers.

The configurable sensor AFE ICs and Webench® Sensor AFE Designer enable the design engineer to select a sensor, design and configure the solution and download configuration data to the sensor AFE. A typical sensing application that today may require up to several boards and up to 25 components is reduced to just one IC. Sensor systems today are used in every major industry for critical monitoring and control applications, also in power electronics i.e. for temperature sensing (power modules, heat sinks). These sensor systems are shrinking in size, must consume less power and have higher reliability.

The first two configurable sensor AFE products are each customized to a specific sensor application and have a variety of features, including programmable current sources, voltage reference options and adjustable sample rates. The LMP91000 is a configurable, low-power potentiostat that provides an integrated signal path between a sensor and analog-to-digital converter (ADC). The programmable AFE is well-suited for use in micro-power chemical and gas sensing applications such as three-electrode single gas and two-terminal oxygen sensors. The LMP91000 measures current in a potentiostat that is proportional to the gas concentration. LMP90100 is a multi-channel, low power, 24-bit sensor AFE with true continuous background calibration and diagnostics for high performance transmitter and transducer applications.

Two sets of independent external reference voltage pins allow multiple ratiometric measurements. In addition, two matched programmable current sources are available to excite external sensors such as resistive temperature detectors and bridge sensors. Seven GPIO pins are provided for interfacing to external LEDs and switches to simplify control across an isolation barrier. Collectively, these features make the LMP90100 a complete analog front-end for low power, precision sensor applications such as temperature, pressure, strain gauge, and industrial process control.

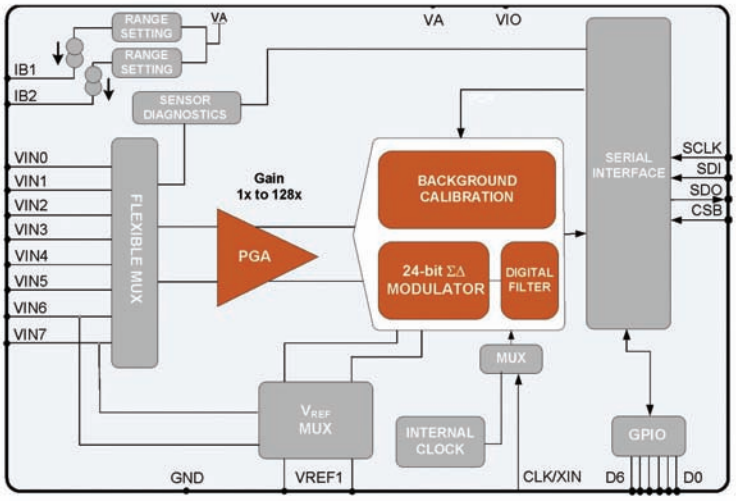
"Our LMP90100 is the industry's first multi-channel, low power, 24-bit sensor AFE with true continuous background calibration and diagnostics for high performance transmitter and transducer applications", commented National's Anita Ganti

Continuous background calibration eliminates offset and gain error over time and temperature. Offset and gain error are determined without disturbing the measured signal.

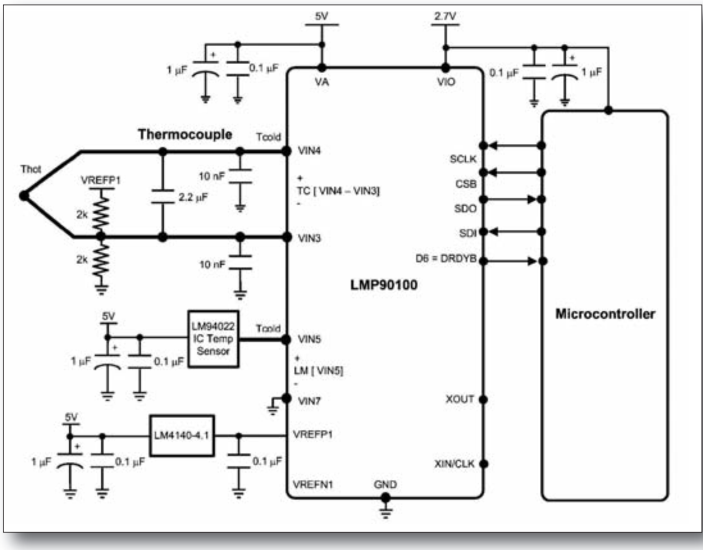
It is a process of continuously determining and applying the offset and gain calibration coefficients to the output codes to minimize the IC's offset and gain errors and is automatically done by the hardware without interrupting the input signal.

The LMP90100 features a 24-bit sigma-delta ADC with a flexible input (mux) configuration to interface with any combination of differential or single-ended inputs. Signal gains (1, 2, 4, 8, 16, 32, 64 and 128), sample rate and diagnostics are programmable for each sensor and two matched current drives are available to drive sensors. The IC draws less than 0.7mA on average and is guaranteed over the entire -40°C to 125°C temperature range, making it suited for temperature transmitter or 4 mA to 20 mA applications. Offered in a 28-pin TSSOP package, the LMP90100 is also available as bare die and priced at $4.95 in 1,000-unit quantities. For more information or to order samples and an evaluation board, visit **http://bit.ly/LMP90100.**

"The LMP90100 is the industry's first multi-channel, low power, 24-bit sensor AFE with true continuous background calibration and diagnostics for high performance transmitter and transducer applications. And our Webench Sensor AFE Designer includes technical specifications for hundreds of temperature, pressure and chemical sensors", commented Anita Ganti, Business Unit Director at National. The new Webench Sensor AFE Designer joins National's portfolio of online tools used also for designing power supplies. A bench-top evaluation tool with a hardware interface is available to minimize engineering design time and facilitate prototype evaluation. This system allows the user to download configuration data from their design to the sensor AFE, attach sensors and



RIGHT: Sensor AFE ICs and LMP90100 block diagram



LEFT: Thermocouple mesurement using cold junction compensation

start their evaluation. "Sensor-based system designs are time-consuming and complicated to develop, requiring an optimal design for each system. Until now, designers have developed customized analog solutions that took weeks or even months to develop, but we can now help them get their design more quickly", Ganti confirmed.

Thermocouple application

Thermocouples have several advantages that make them popular in many industrial and medical applications. Compare to RTDs, thermistors, and IC sensors, thermocouples are the most rugged, least expensive, and can operate over the largest temperature range.

Its junction generates a differential voltage V_{IN}, that is relative to the temperature difference (T_{hot} - T_{cold}). T_{hot} is also known as the measuring junction or "hot" junction, which is placed at the measured environment. T_{cold} is also known as the reference or "cold" junction. Because a thermocouple can only measure a temperature difference, it does not have the ability to measure absolute temperature. To determine the absolute temperature of the measured environment, a technique known as cold junction compensation (CJC) must be used.

In a CJC technique, the "cold" junction temperature is sensed by an IC temperature sensor, such as the LM94022. The temperature sensor should be placed within close proximity of the reference junction and should have an isothermal connection to the board to minimize any potential temperature gradients.

Once T_{cold} is obtained, a standard thermocouple lookup-table should be used to find its equivalent voltage. Next, the differential thermocouple voltage and add the equivalent cold junction voltage needs to be measured. Lastly, the resulting voltage to temperature using a standard thermocouple look-up-table has to be converted. For example, T_{cold}=20°C. The equivalent voltage from a type K thermocouple look-up-table is 0.798mV. Next, the measured differential thermocouple voltage to the Tcold equivalent voltage needs to be added. For example, if the thermocouple voltage is 4.096mV, the total would be 0.798mV + 4.096mV = 4.894mV. Referring to the type K thermocouple table gives a temperature of 119.37°C for 4.894mV.

iPower Event Announces A "Call-For-Papers"

The UK Microelectronics Packaging Society (IMAPS-UK) has announced a call for papers and abstracts for their forthcoming "iPower" event which is intended to 'Showcase UK Power Electronics'. The event will be held on 30 November & 1 December 2011 at the University of Warwick's prestigious IDL Conference Centre.

"iPower", being held in conjunction with the University's Electronics, Power and Microsystems Research Group, will bring together leading experts in the field of power electronics from Science, Academia, Supply and Industry, providing a unique insight into the fields latest developments and technologies.

The two day event and accompanying exhibition will offer delegates the chance to discover technical information on a wide range of topics, including: Applications, Trends & Emerging Markets, Packaging, Test and Reliability, Assembly Materials & Technologies, Integrated Processes (micro-machining, micro-moulding), Thermal Management & Efficiency, Product Design Development & Modeling, Interconnection Integration & Systems, Solutions For Harsh Environments, High Reliability & Temperature, Novel Designs & Future Concepts.

Researchers and innovators in industry, supply and academia who would like to take part and consider that they can offer original and exciting technical presentations or poster displays on any of the topics listed above, should contact the Society with their abstract or proposal for consideration prior to the closing date of 30 March 2011.

Further information on the two day Seminar can be found on the Society's website www.imaps.org.uk or by emailing the events organising committee events@imaps.org.uk

30 Nov - 1 Dec 2011
iPower
Showcasing UK Power Electronics

New ICs for High-Power Applications

Regulatory moves in mandate high power factor for many electronic products with power requirements over 75W and for lighting products over 5W. These rules are combined with numerous application-specific standards that require high power supply efficiency across the entire load range, from full load to as low as 10% load. High efficiency at light load is a challenge for traditional PFC approaches in which fixed MOSFET switching frequencies cause fixed switching losses on each cycle, even at light loads.

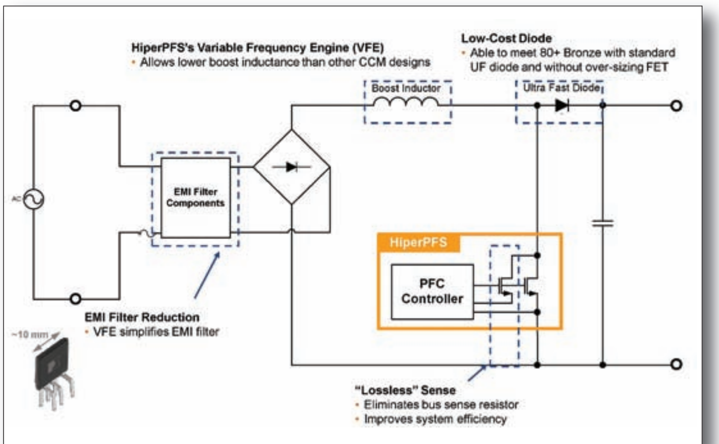
Power Integrations' new IC HiperPFS simplifies compliance with new and emerging energy-efficiency standards over a broad market space in applications such as PCs, LCD TVs, notebooks, appliances, pumps, motors, fans, printers, and LED lighting. "HiperPFS's innovative variable-frequency continuous conduction mode of operation minimizes switching losses by maintaining a low average switching frequency, while also varying the switching frequency in order to suppress EMI, the traditional challenge with continuous-conduction-mode solutions. Systems using HiperPFS typically reduce the total X and Y capacitance requirements of the converter, the inductance of both the boost choke and EMI noise suppression chokes, reducing overall system size and cost", commented VP Marketing Doug Bailey. "Additionally, compared with designs that use discrete MOSFETs and controllers, HiperPFS devices dramatically reduce component count and board footprint while simplifying system design and enhancing reliability. The variable-frequency, continuous conduction mode controller enables the HiperPFS to realize all of the benefits of continuous-conduction mode operation while leveraging low-cost, small, simple EMI filters".

"With HiperPFS and HiperTFS we are introducing the first ICs for high-power applications at reasonable pricing compared to discrete designs", said Power Integrations' Doug Bailey

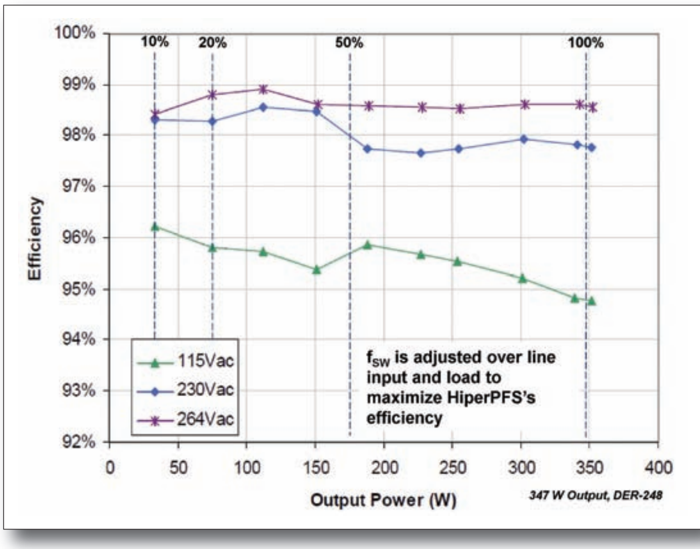
Innovative power factor correction

HiperPFS incorporate a continuous condition mode (CCM) boost PFC controller, gate driver, and power MOSFET in a single, low-profile eSIP™ power package that is able to provide near unity input power factor. The HiperPFS devices eliminate the PFC converter's need for external current sense resistors, the power loss associated with those components, and leverages a control technique that adjusts the switching frequency over output load, input line voltage, and even input line cycle. This control technique is designed to maximize efficiency over the entire load range of the converter, particularly at light loads. This control technique significantly minimizes the EMI filtering requirements due to its wide-bandwidth spread spectrum effect. HiperPFS includes comprehensive protection features, such as integrated soft-start, UV, OV, brown-in/out, and hysteretic thermal shutdown. It also provides cycle-by-cycle current limit for the power MOSFET, power limiting of the output for over-load protection, and pin-to-pin short-circuit protection.

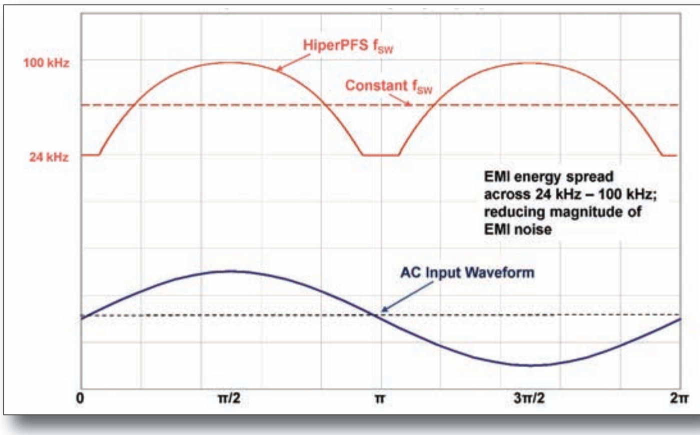
HiperPFS employs a constant amp-second on-time and constant volt-second off-time control algorithm. This algorithm is used to regulate the output voltage and shape the input current to comply with regulatory harmonic current limits (high power factor). Integrating the switch current and controlling it to have a constant amp-sec product over the on-time of the switch allows the average input current to follow the input voltage. Integrating the difference between the output and input voltage maintains a constant volt-second balance dictated by the electro-magnetic properties of the boost inductor and thus regulates the output voltage and power.



HiperPFS ICs are suitable for PFC applications from 75W to 1kW



Frequency sliding technique maximizes light-load efficiency

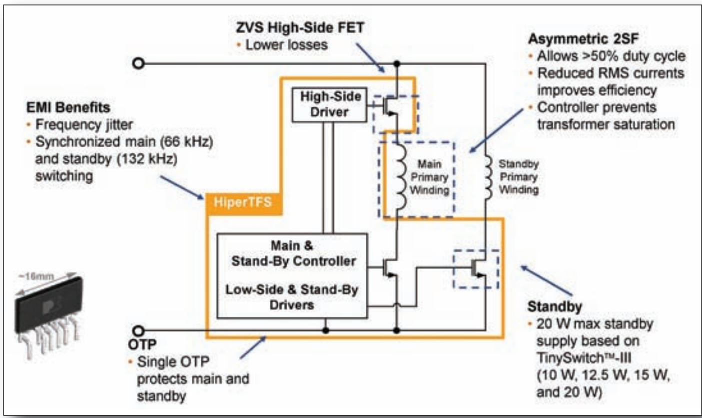


Variable frequency reduces EMI filter size

Power supply in a chip

The new HiperTFS is a highly integrated power supply IC family for high-power applications incorporating both a two-switch-forward converter and a flyback standby power converter into a single, low-profile eSIP power

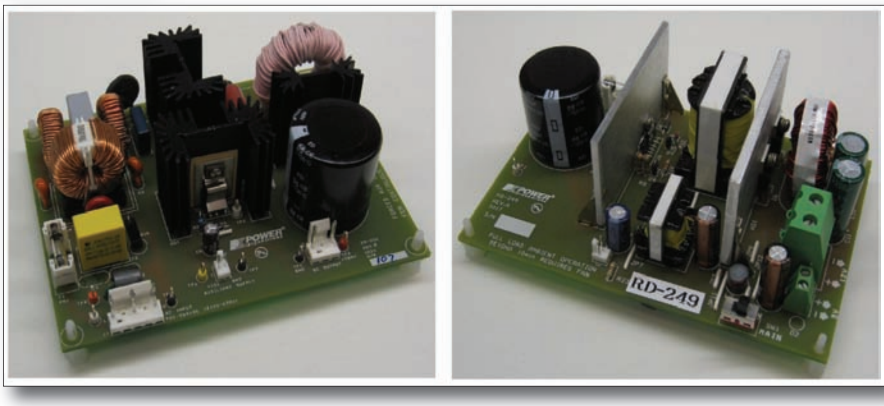
package. As well as the two controllers, the devices include high-



and low-side drivers and all of the high-voltage power MOSFETs for the main and standby power converters and thus well suited for consumer, computer, and industrial power supply designs requiring main power from 120W to 415W and a standby converter capable of up to 20W.

Two-switch-forward power converters are often selected for applications demanding cost-effective efficiency, fast transient response, and accurate tolerance to line voltage fluctuation. The two-switch-forward controller incorporated into HiperTFS devices improves on the classic topology by allowing operation considerably above 60% duty cycle. This improvement reduces RMS currents - and therefore conduction losses - and also minimizes the size and cost of the bulk capacitor. The design also includes transformer flux reset control and charge-recovery switching of the high-side MOSFET, which reduces switching losses. This combination yields an efficient power supply with smaller MOSFETs, fewer passives and discrete components, and a lower-cost transformer. "HiperTFS enables engineers to build power supplies that cost-effectively meet current and emerging power efficiency standards, such as 80+ Bronze for PCs and the new mandatory California Energy Commission efficiency regulations for televisions. With its high level of integration, supported by comprehensive design software, HiperTFS simplifies design efforts and enables engineers to quickly develop high-power power converters. We have brought the advantages of integration to applications below about 50W for many years; now, high-power products can also benefit from the simplicity of a single-chip approach", Bailey stated.

ABOVE: HiperTFS IC integrates 2-switch forward, standby and power FETs



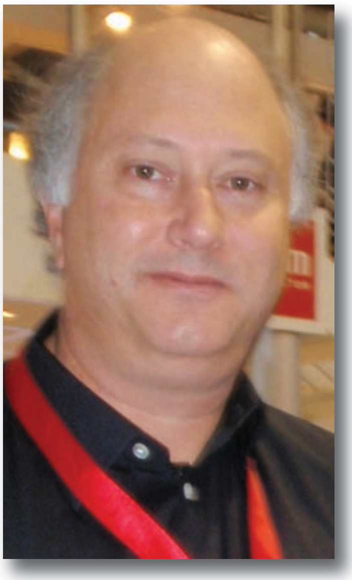
HiperPFS 347W demo board (right) and HiperTFS 315W demo board (far right)

First Commercial Silicon Carbide Power MOSFET Launched by Cree

On January 17 Cree has introduced the industry's first fully-qualified commercial Silicon Carbide power MOSFET. This establishes a new benchmark for energy efficient power switches and can enable design engineers to develop high voltage circuits with extremely fast switching speeds and low switching losses.

The addition of the SiC power MOSFET to Cree's Silicon Carbide Schottky diode family enables power electronics design engineers to develop "all-SiC" implementations of critical high power switching circuits and systems with levels of energy efficiency, size and weight reduction that are not achievable with any commercially available silicon power devices of comparable ratings. "This introduction represents many years of materials research, process development and device design", commented John Palmour, Cree co-founder and CTO, Power and RF. "But the end result is that the industry's first 'ideal' high voltage switching device is no longer a future technology - it is commercially available and ready for design-in today. Together with our 600V, 650V, 1200V and 1700V SiC Schottky diodes, we have established a new class of SiC power components that eventually replace Silicon devices in the majority of critical power electronics applications with breakdown voltage requirements of 1200V or higher".

The new SiC MOSFET, designated CMF20120D , provides blocking voltages up to 1200V with an on-state resistance (R_{DSon}) of 80mΩ at 25°C and this remains below 100mΩ across its entire operating temperature range. Compared to commercially available Silicon MOSFET or IGBT devices of similar ratings, in tests conducted by Cree the CMF20120D had the lowest gate drive energy (Q_G <100nC) across the recommended input voltage range. Conduction losses were minimized with forward drop (V_F) of <2V at a current of 20A. "Compared to the best silicon IGBTs, the SiC device improves system efficiency up to 2% and operates at 2-3 times the switching frequencies. Higher component efficiency also results in lower operating temperatures. Combining these lower operating temperatures with the CMF20120D's ultra-low leakage current (<1µA) adds significantly to system reliability", Palmour added.



"The industry's first 'ideal' high voltage switching device is no longer a future technology", commented Cree's CTO John Palmour the SiC MOSFET announcement

The SiC MOSFET can be used today for solar inverters, high-voltage power supplies and power conditioning in many industrial power applications. Over the next several years, SiC power switches and diodes could also expand into motor drive control, electric vehicles and wind energy applications. The market for power semiconductors in these applications is estimated at approximately $4 billion today, reaching nearly $6 billion by 2015. In contrast the market for SiC power semiconductors will grow significantly from today's $100 million to $400 million by the year 2013.

Cree's CMF20120D is suited for high voltage applications where energy efficiency is critical. Solar inverters are an example where SiC MOSFETs can be used in both the boost and inverter sections of the DC/AC converters. Switching losses are decreased by more than 30% using SiC MOSFETs; and when combined with SiC Junction Barrier Schottky diodes, overall system efficiency has been demonstrated at >99%. "Silicon Carbide technology is critical to developing the next generation of advanced, energy-efficient power electronic system designs", added Cengiz Balkas, Cree vice-president and general manager, Power and RF.

Samples of CMF20120D are available now from Digi-Key (www.digi-key.com).

Details of new SiC MOSFETs and Cree's strategy

PEE took the chance at the launch to interview Cree representatives on the product details and Cree's SiC power strategy, the answers came from John Palmour, Paul Kirestead and Michael O'Neil from Cree's Power Division.

PEE: 1200V all-SiC 1200V/100A modules have been introduced already 2 years ago (for military applications). What results in terms of reliability have been gained from this project and have they influenced the design of the SiC power MOSFETs?

The new SiC MOSFET, designated CMF20120D , provides blocking voltages up to 1200V

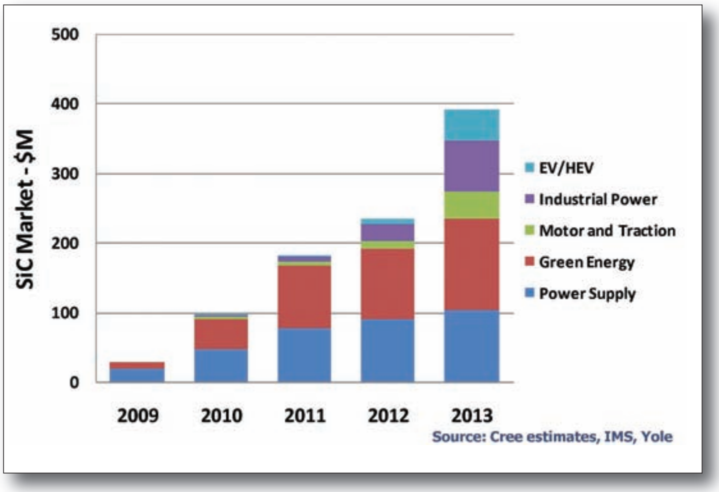
Cree has not ever offered a qualified MOSFET product. There have been modules that have been advertised by some customers of our's who were buying evaluation samples, but they were never advertised as a qualified product, and always had "Preliminary" stamped on the spec sheets. Our understanding was that these were being purchased by companies doing preliminary system design work. Cree has sampled a number of customers under non-disclosure agreements over the last couple of years, but has not offered them for general sale because it was not a released product.

The release we have announced means that parts are now widely available to everyone, and we now consider it a qualified and released part.

PEE: The mentioned module contains two switches rated each 50A. What is the reason for introducing commercially graded MOSFETs rated 20A, currently too high defect density on the wafer for achieving higher current ratings or simply the high price for the starting material compared to Silicon - or both?

While we have shown some modules using two 50A die as an R&D result, the modules you mention that were for sale by a customer on a sample basis have always been based on using five of these 20A die. We have demonstrated single die up to about 100A in R&D, but these have not been qualified or released yet. We do plan on expanding the family of products for 1200 V MOSFETs, going both up, and down, in current. The 80mΩ part is just the first of many offerings to be announced. We also plan to go up in voltage.

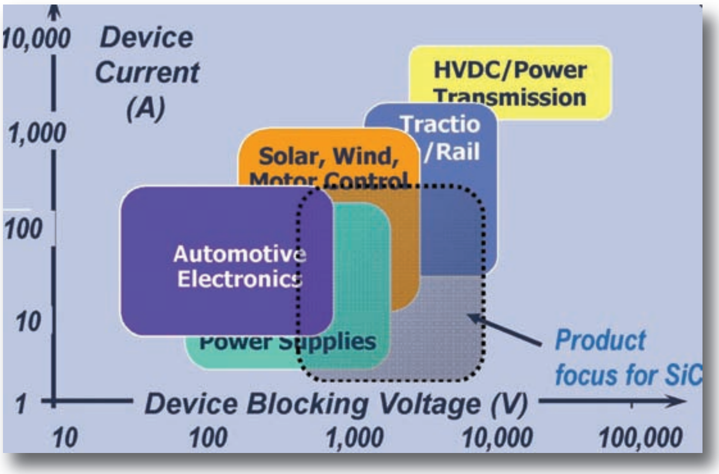
PEE: Can SiC FETs directly replace 1200V IGBTs in existing designs? What kind of drivers are required or



Market and applications for SiC power semiconductors

recommended by Cree? What rules has a designer to follow to implement a driver sufficiently?

Yes, this is one of the big advantages of the SiC MOSFET over any of the other SiC switches available on the market (JFETs).



Target markets for SiC power devices

Unlike the JFETs, SiC MOSFETs are normally-Off devices, which means you can use the existing gate drivers and circuits for IGBTs with some minor modifications. Gate resistance changes and tweaks for recommended gate-source voltage are the only changes required.

PEE: Is the body diode of the SiC FET suitable to serve as freewheeling diode? What is their reverse recovery charge and forward voltage drop? What are the respective specs of the discrete SiC diode?

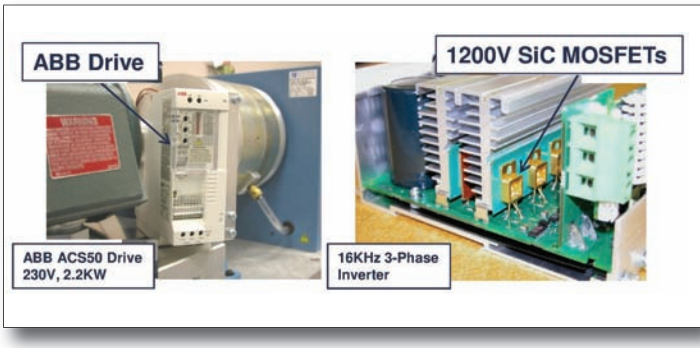
We are recommending using a 10A/1200V SiC schottky (C2D10120A) in anti-parallel to defeat the internal body diode. Although the body diode recovery characteristics are far superior to those in Silicon MOSFETs, the forward drop is significantly higher (over 3.1V). For optimal performance the SiC schottky is recommended, which has a voltage drop that is about 50% of that voltage. The body diode's forward and recovery characteristics are available on the datasheet. We do plan on bringing to market a co-pack TO-247 in the future to provide a single package solution.

PEE: Is the enhanced temperature capability of SiC devices a marketing factor in industrial and possibly automotive applications?

For industrial applications the main benefit will initially be the drive to higher efficiency and/or higher switching frequency. For automotive systems, temperature capability would be an advantage, but that is not currently our target market.

PEE: What switching frequency levels do you envision in industrial applications such as solar and drive inverters and how do these influence the properties of such inverters (no lab prototypes)?

For these systems we envision switching frequency increases to the 32kHz to 48kHz range. Although this SiC MOSFET gives the capability to move higher in frequency with comparable or higher efficiency, the majority of these systems will be designed below 50kHz to keep the fundamental frequency below the 50kHz lower limit of the conducted EMI testing range.



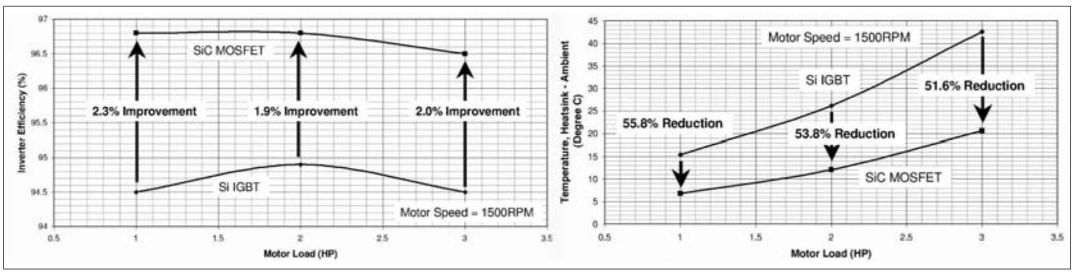
SiC MOSFETs enable high switching frequencies here in the example of an ABB drive

PEE: But pricing and availability for components is still important for some purchasers. What is pricing for end-users in usual quantities and availability. What are the trends by moving to 150mm SiC substrates with micropipe densities of less than 10/cm_? What price gains can be expected at system (inverter) level?

The initial pricing of the SiC MOSFETs will certainly be higher, with 1000 pieces quantities being quoted in the range of $75 or so, not unlike the pricing seen on the first HEXFETs or IGBTs that were introduced in the 1980's. There are many opportunities for further price reduction that will be attained through volume loading, further process refinement and simplification, yield improvement, etc. Additionally moving from 100mm to 150mm wafers would allow a significant reduction in price as well. However, the micropipe density must improve, and the volumes must increase before switching to 150mm makes economic sense. We expect to make this switch in 2-3 years.

Additionally, we want to point out that these MOSFETs should not be looked at in a direct component cost to component cost comparison. The advantage of SiC is overall system efficiency and cost, and is the reason our Schottky diode volume has been increasing rapidly despite its higher cost than Silicon rectifiers. The lack of switching losses means that snubber circuits can be discarded, heat sinks can be shrunk, and frequencies can be increased, which saves a lot of magnetics, size, weight, etc. Overall it is a win at the system level. These same advantages will be seen for the SiC MOSFETs.

AS



A 2% efficiency improvement (left) in the ABB drive reduce losses by more than 40% and could enable 3X in switching frequency while 50% operating temperature reduction (right) could increase output power


EXPERTISE • INNOVATION • RELIABILITY
POWEREX
Power Semiconductor Solutions
Impeccable Service
lenced Powerex applications
erve as an extension of your
equirements
optimal device or devices
mance
Supporting rapid
yping
Quality Products
Discrete Thyristo
Discrete Rectifier
Thyristor and Dic
dules
Fast Recovery Di
dules
Custom Modules
POWEREX, INC. ISO 9001 AS9100 REGISTERED FIRM
www.pwrx.com
001-724-925-7272


To receive your own copy of
POWER ELECTRONICS
EUROPE
subscribe today at:
www.power-mag.com


Looking for
High Performance MOSFETs?
PMPak®5x6, 3x3
More MOSFETs Now Available
RoHS compliant, halogen-free package,
with industry-standard 5x6 or 3x3 footprint
Rds(on) as low as 1.9mohms with
fast switching performance
AP1R803GMT-HF-3 30V/1.9mohms/PMPak5x6
AP3R604GMT-HF-3 40V/3.6mohms/PMPak5x6
AP94T07GMT-HF-3 75V/7.5mohms/PMPak5x6
AP9430GYT-HF-3 30V/4.5mohms/PMPak3x3
AP4435GYT-HF-3 -30V/21mohms/PMPak3x3
More parts at www.a-powerusa.com/pmp1
Advanced Power Electronics Corp. USA
3150 Almaden Expressway • San Jose CA 95118
+1(408) 717-4231 • Sales@a-powerusa.com
PMPAK® is a registered trademark of Advanced Power Electronics Corporation

Solutions for Buck Converters

Texas Instruments recently introduced two power management ICs and an extension of the NexFET offering for point-of-load applications raising the bar for size and power density.

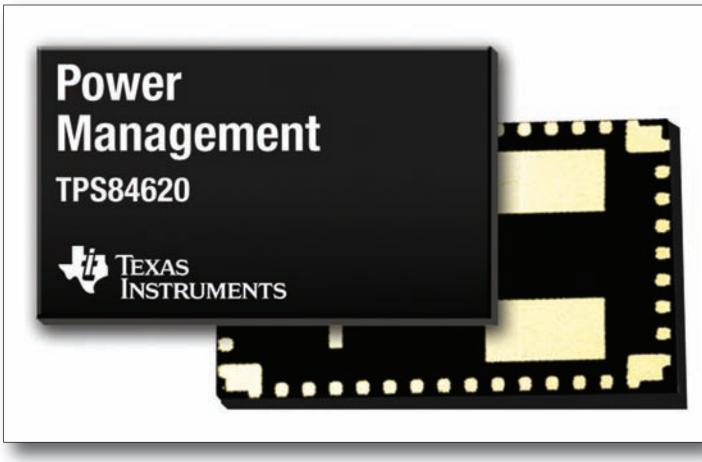
40A NexFET power block
The CSD86350Q5D NexFET™ power block is an optimized design for synchronous buck applications offering high current, high efficiency, and high frequency (up to 1.5MHz) capability in a small 5mm × 6mm outline. Optimized for 5V gate drive applications, this power package offers a solution capable of offering a high density power supply when paired with any 5V gate drive from an external controller/driver. "The Control FET and Sync FET are parametrically tuned to yield the lowest power loss and highest system efficiency. As a result, a new rating method is needed which is tailored towards a more systems centric environment", commented TI's Business Development Manager Miro Adzan. The Power Block has the ability to switch voltages at rates greater than 10kV/_s. Special care must be then taken with the PCB layout design and placement of the input capacitors, driver IC, and output inductor (see **www.ti.com/powerblock**).

"Within the NexFET power block the control and sync FET are parametrically tuned to yield the lowest power loss and highest system efficiency", commented TI's Miro Adzan

Integrated 6A buck converter
The TPS84620RUQ is an easy-to-use integrated power solution (efficiencies up to 96%) that combines a 6A DC/DC converter at output voltages 1.2V to 5.5V with power MOSFETs, an inductor, and passives into a low profile, BQFN package. Input voltage can range from 4.5V to 14.5V. Switching frequency is adjustable via resistors between 480kHz and 780kHz. The 9×15×2.8 mm BQFN package is easy to solder onto a PCB and allows a compact POL design with greater than 90% efficiency and power dissipation with a thermal impedance of 13°C/W junction to ambient. The device delivers the full 6A rated output current at 85°C ambient temperature without airflow. This total power solution allows as few as 3 external components (including input/output capacitors) and eliminates the loop compensation and magnetics part selection process.

Required output capacitance ranges between 200µF and 47µF. When using electrolytic capacitors in the output, high-quality, computer-grade electrolytic capacitors are recommended. Polymer-electrolytic type capacitors are recommended for applications where the ambient operating temperature is less than 0°C. Aluminum electrolytic capacitors provide adequate decoupling over the frequency range of 2 kHz to 150 kHz, and are suitable when ambient temperatures are above 0°C. The performance of aluminum electrolytic capacitors is less effective than ceramic capacitors above 150 kHz.

Multilayer ceramic capacitors have a low ESR and a resonant frequency higher than the bandwidth of the regulator. They can be used to reduce the reflected ripple current at the input as well as improve the transient response of the output. A minimum input capacitance of 100µF of ceramic and/or polymer-tantalum capacitors is also required (see **www.ti.com/tps84620-preu**).



6A DC/DC converter requiring three external components

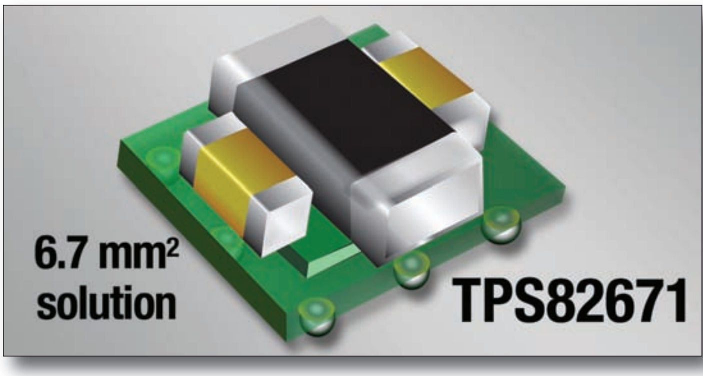
MicroSIP step-down converter for low-power applications
The TPS8267x is a stand-alone, synchronous, step-down converter operating at a regulated 5.5-MHz frequency PWM with 90% efficiency at moderate to heavy load currents (up to 600mA output current). At light load currents, the converter operates in power-save mode with pulse frequency modulation (PFM). The converter uses a unique frequency-locked ring-oscillating modulator to achieve best-in-class load and line response. One key advantage of the non-linear architecture is that there is no traditional feedback loop. The loop response to change in V_O is essentially instantaneous, which explains the transient response. Although this type of operation normally results in a switching frequency that varies with input voltage and load current, an internal frequency lock loop (FLL) holds the switching frequency constant over a large range of operating conditions. The low quiescent current of the device (approximately 17µA) helps to maintain high efficiency at light

load while that current preserves a fast transient response for applications that require tight output regulation.

The TPS8267x integrates an input current limit to protect the device against heavy load or short circuits and features an under-voltage lockout circuit to prevent the device from mis-operation at low input voltages. Fully functional operation is permitted down to 2.1V input voltage (4.8V maximum).

If the load current decreases, the converter enters power-save mode automatically. In this mode, the converter operates in discontinuous current, (DCM) single-pulse PFM mode, which produces a low output ripple compared with other PFM architectures. When in power-save mode, the converter resumes its operation when the output voltage falls below the nominal voltage. The converter ramps up the output voltage with a minimum of one pulse and goes into power-save mode when the output voltage is within its regulation limits. The IC exits PFM mode and enters PWM mode when the output current can no longer be supported in PFM mode. As a consequence, the DC output voltage is typically positioned (fundamental) and multiples of the operating frequency (harmonics). The internal spread spectrum architecture varies the switching frequency by approximately ±10% of the nominal switching frequency, thereby reducing the peak radiated and conducting noise on both the input and output supplies. The frequency dithering scheme is modulated with a triangle profile and a modulation frequency.

Because of the pulsating input current nature of the buck converter, a low ESR input capacitor is required to prevent large voltage transients that can cause mis-behavior of the device or interferences with other circuits in the system. For most applications, the input capacitor that is integrated into the TPS8267x should be sufficient. If the application exhibits a noisy or erratic switching frequency, experiment with additional input ceramic capacitance to find a remedy. Also the advanced, fast-response, voltage mode, control scheme of the TPS8267x allows the use of a tiny ceramic output capacitor. For most applications, the integrated output capacitor is sufficient. At nominal load current, the device operates in PWM mode; the overall output voltage ripple is



The TPS82671 allows a 6.7mm² solution for a 600mA buck converter

approximately 0.5% above the nominal output voltage. The transition between PFM and PWM is seamless.

Switching regulators can be particularly troublesome in applications where electromagnetic interference (EMI) is a concern. Switching regulators operate on a cycle-by-cycle basis to transfer power to an output. In most cases, the frequency of operation is either fixed or regulated, based on the output load. This method of conversion creates large components of noise at the frequency of operation the sum of the voltage step that is caused by the output capacitor ESL and the ripple current that flows through the output capacitor impedance. At light loads, the output capacitor limits the output ripple voltage and provides holdup during large load transitions. As the TPS8267x is designed as a POL regulator, adding a 2.2µF ceramic output capacitor (X7R or X5R dielectric) generally works from a converter stability point of view, but does not necessarily help to minimize the output ripple voltage (see **www.ti.com/tps82671-preu**).

Applied Power Electronics in Good Shape

The Applied Power Electronics Conference and Exposition (APEC) will celebrate its 26th anniversary from March 6 - 10 in Fort Worth, Texas. About 1200 attendants registered for the 2010 event, along with some 150 exhibitors, making it one of the most important power electronic conventions. With an expected growth of 15% for power management semiconductors in 2011 an adequate upturn is expected for this event.

As the 17th largest city in the United States and part of the no. 1 tourist destination in Texas, Fort Worth welcomes nearly 5.5 million visitors each year. The city boasts a mix of preserved Western heritage and artistic offerings such as rodeos. As such it is worth to visit along with the latest news in power electronics shown in the city's convention center. According to the organizer APEC focuses on the practical and applied aspects of the power electronics business. This is not just a designer's conference, APEC has something of interest for anyone involved in power electronics, from OEMs over designers and manufacturing to marketing.

Comprehensive seminar and conference program

APEC starts with Education Seminars on March 6. The session on Sunday morning will include topics such as "Soft Switching Circuits and Techniques (S.1) and Ground Rules for Designing Power Electronics into Evolving MicroGrid Applications (S.3). The afternoon seminars start with "Practical Data- and Telecommunction Power System Solutions to Meet Latest Efficiency and Power Saving Regulations (S.7), Using Digital Signal Controllers to Implement Switch Mode Power Supplies (S.8), LED Lighting Trends, Standards, Optics and Power Electronic Drivers (S.9), and Technology Trends in Automotive Power (S.10)". Seminars are continued on Monday morning, to mention are "Advanced Design for Fast Switching Power MOSFETs (S.16) or Power Electronics System Thermal Design (S.18)".

S.1: Transistor switching losses create an effective upper limit to both conversion efficiency and power density, particularly for off line power supplies. Soft switching offers a solution, but the practical reality is that these circuits are more complex and come with a whole new set of design issues specific to soft switching circuits. Achievement of the full benefits of soft switching circuits requires an understanding of the critical timing issues of these circuits and practical methods for

BELOW: Fort Worth's convention center will be the place for APEC 2011

designing auxiliary circuits that are necessary to accomplish soft switching. This seminar concentrates on circuits that have primarily square wave voltages and currents, rather than circuits with sinusoidal wave forms. Mostly these circuits are similar to well known hard switching circuits, but with circuit mechanisms in place to accomplish lossless switching over a broad range of line and load. A variety of practical soft switching circuits and the problems and practical solutions associated with these circuits and the differences in the design optimization processes for hard switching and soft switching converters are described. Well known and proven soft switching topologies are described by Ernest Wittenbreder from Technical Witts, Inc. as well as some new topologies which offer significant improvements over more commonly known topologies.

S.3: Power Electronics is integral to the future Smart-Grid Distribution System, particularly with growing emphasis on Microgrids, and DC generation and distribution. Such systems can occur in ships, vehicles and the utility grid. However, the fundamentals of power flow and system dynamics are the same from transmission through distribution to end-use. This seminar given by David Torrey from Advanced Energy Conversion, LLC, focuses on the requirements for designing power electronics into grid distribution and distributed energy systems, and requirements power controllers should meet for compatibility and interoperability. A microgrid case study with distributed generation and smart-grid interconnection of, e.g. batteries, fuel cells, PV, and wind turbines, is used to describe how power electronic networks affect the basics of power flow, transient system stability and protection. The study is also used to introduce design requirements covering the latest in power and communication standards and approaches to scalability.

S.7 given by Rais Miftakhutdinov from Texas Instruments addresses improved efficiency and power saving solutions for data- and telecommunications power systems to meet market demands and latest industry regulations. To reduce overall power consumption of telecommunication system per ever growing complexity and functionality, all design levels from the top system level down to each specific function and component have to be optimized. This seminar covers efficiency and power saving considerations of power system at facility level, then down to power distribution in a cabinet, power supply solutions inside the shelf line card, and finally focuses on power conversion topologies and control algorithms implemented in power conversion stages of the system. Special attention is provided to practical design aspects of front-end AC/DC telecom rectifier/charger, AC/DC server power supply and Intermediate Bus Converter that are critical enabling blocks of data- and telecommunications power system. Their requirements, parameters, popular topologies and design challengers are discussed in details with the design procedure implemented using MathCAD and SIMPLIS simulations.

Fort Worth boasts a mix of preserved Western heritage and artistic offerings such as rodeos (Source: Fort Worth Convention & Visitors Bureau)

S.8 given by Bryan Kris and Alex Dumais from Microchip Technology describes the forces, challenges, and benefits of designing switch mode power supplies using full digital control loops using Digital Signal Controllers. The presentation highlights three actual DSC based designs for LLC (resonant mode) DC/DC, Micro Solar Inverter, and HID Lighting. The focus of the presentation is on the control loop software, and the implementation details of successful designs.

S.9: This tutorial by Northeastern University and Exclara. Inc. is meant to introduce a power electronic engineer to the revolutionary advancements that have taken place over the past years in LED lighting and also introduce the engineer to the fundamental aspects to designing an LED lighting system. At first the tutorial will present various LED applications and markets, including streetlighting, backlighting, and general indoor illumination. Next, standards will be extensively (NEMA/ANSI, Energy Star, IEEE, etc.), focusing on topics such as testing procedures (CALiPER), power factor, and flicker. The tutorial will next present an introduction to color mixing (for a non-expert) and simple optical performance characteristics necessary to designing an LED lamp. Next, details on how to design an LED driver will be presented and topics will include: proper modeling of LEDs and their binning uncertainties, different power electronic topologies used to drive LEDs for various applications, and benefits and drawbacks of various LED driving strategies. A major emphasis will be placed on dimming of LEDs.

S.10 will present a comprehensive overview of the latest trends in power processing technology in automotive and is given by Ionel Dan Jitaru from Delta Energy Systems. The fast growing markets in hybrid and electric vehicles sets new demands for power conversion technology. There is a continue quest for higher power densities, higher efficiency, low weight, low cost while providing a reliable operation in harsh environmental conditions. These specific demands lead to significant innovation in automotive power technology in the recent years. The main goal of the seminar is to underline some progress made in these technologies and to place some light in potential trends in the future. The seminar will be focused on all the aspects of automotive power technology starting from topologies, magnetic, packaging and control New topologies developed for these specific application such as high voltage - high power battery chargers and auxiliary battery chargers will be presented. One focus will be on the magnetic technologies for automotive power, due to the specific cooling methodologies, form factor, weight and size requirements. The magnetic technology will be presented together with the most suitable topologies and integrated to the packaging technology. Magnetic, topology, packaging and control will be presented in unitary way as integrated in an optimized power-processing cell.

S.16 on the Monday morning given by Lutz Goergens, Johannes Schoiswohl, and Milko Paolucci from Infineon Technologies Austria covers the topic of how to get the most out of a fast switching power-MOSFET. The focus of the seminar is to identify the sources of power losses in converters and how to minimize these. Models based on the fundamental switching processes of MOSFETs - turn-on, turn-off and commutation, are derived relying strongly on data from the device datasheets. The seminar gives an in depth analysis on the causes for losses and how they can be

more sophisticated thermal analysis tools. The third section will be an in-depth presentation of specific and highly non-linear thermal failure mechanism, thermal runaway; whence it arises and how it may be analyzed. The focus will be within the particular context of power semiconductor devices, but it should also become evident how the concept may be applied more generally.

Focus on energy efficiency

The conference starts with the Opening Plenary on afternoon March 7. Smart grids, energy efficiency and electric mobility are some of the buzzwords covered within the seven presentations.

Intergrid: A Future Electronic Energy Network? This question will be raised by Dushan Boroyevich from Virginia Tech. Major energy savings and exciting improvements in quality of life will be enabled simultaneously by new electronic energy conversion systems in all energy consuming devices, from pacemakers and home appliances to electric vehicles and industrial waste processing plants. All alternative, sustainable, and distributed energy sources, as well as energy storage systems, will be connected to electric grid through agile and efficient power electronics converters. The current electric grid will be hugely expanded and made much "smarter" by equipping it with advanced information collecting infrastructure. This emerging electricity network, where practically all loads and sources are electronic energy converters, will require new concepts for electronic control of all power flows in order to assure system stability, improve energy availability, power density, and overall energy and power efficiency as is currently the case at low power levels from portable devices and datacom equipment to cars, airplanes, ships, and trains. Starting from the example of a computer power system, his presentation will contemplate possible future AC and DC electronic power distribution system architectures, especially in the presence of renewable energy sources. The proposed nanogrid/microgrid-...-grid structure achieves hierarchical dynamic decoupling of generation, distribution, and consumption by using bidirectional converters as energy control centers. This is illustrated by the description and simulation of static and dynamic operation of a DC nanogrid in a hypothetical future sustainable home. Several ideas for modeling, analysis, and system-level design of such systems, including power flow control, protection, stability, and subsystem interactions, will be presented.

The **PSMA Power Technology Roadmap 2011 Summary** will be presented by Fairchild's Aung Thet Tu. Every two years The Power Sources Manufacturers Association (PSMA) forms a team of industry experts to compile the latest trends shaping the power conversion technologies. From AC adapters to DC/DC converters, and from micro inverters to high-power embedded power supplies, the findings for key power conversion segments and the application ramifications are then compiled in the Power Technology Roadmap report which is published by the PSMA. This talk highlights some of the technology trends identified in the report that will shape power conversion products for the next two to five years.

Mobility in a Changing World will be emphasized by Burkhard Huhnke, Executive Director at Volkswagen Group of America, Inc.'s Electronics Research Laboratory. The complex management of engines - electrical or combustion, gearbox and driver assistance systems dependent on driving conditions, require intelligent modular system architecture to make driving not only safer and comfortable but also energy efficient. From advanced sensors and instrumentation, to intuitive user interfaces, artificial intelligence, energy efficient driving vehicles and even "social" vehicles, there are no limits to our innovations. Our cars are developing into our co_pilots because intelligent technologies make them safer and more comfortable. One noticeable change in cars will be the ability for vehicles to network with the infrastructure, other vehicles on the road, and the Internet. These developments will integrate the car into the seamless mobility system very efficiently. These innovations free up time for the driver, which is helpful, since we see the potential for vehicles to serve as your personal assistant. Imagine a future where your car can recognize you as soon as you approach it. Technology will enable the car to start itself, download your schedule, and provide you with the optimal route to arrive at your meetings on time. Cars that communicate with each other, infrastructure, emergency vehicles, and public transportation are the driving force behind a future free of traffic. The development of new and more powerful electrical drive trains with electrical energy storage systems and corresponding software is just as important for the electric vehicles of the future.

The **Application of GaN Based Power Devices to Power Electronics** will be presented by Tim McDonald, Vice President of IR's Emerging Technologies Group. A survey is presented of the current and future prospects for GaN-based power devices in power electronics application ranging from microprocessor power supplies, to AC:DC PFC, to motor drives and solar inverters. Advantages of this new technology include higher energy efficiency, lower noise generation, smaller sizes and reduced cooling requirements. The combination of superior technical performance and cost structures competitive to incumbent technologies provide a compelling value proposition which is expected to drive wide adoption of GaN-based power devices over the next 5-10 years. The status of International Rectifier's GaNpowIR(tm) technology platform and products will be discussed.

The numerous other Conference Sessions include within the Technical Sessions GaN Inverter, Si & Piezoelectric Devices; AC-DC Converters; Si and SiC Devices & Applications; Module Packaging. Within the Special Presentations Energy Harvesting & Power Electronics; Packaging Challenges with More Electric Vehicles; Lighting Technologies; Capacitors in Power Electronics; Component Applications; Nanotechnology: Enabling the Next Generation of Power Electronics; Powering Communications; Power Electronics and Alternative Energy; Computing. Rap Sessions will cover Green Technologies and Sustainability and AC vs. DC Distribution.

Also the exhibitors list with 172 companies looks like the who's who in power electronics.

AS

minimized. The trade-off between loss-generation and unintended oscillations in the system is analyzed and strategies for optimization are presented. The seminar provides basic information for entry level engineers and helps the experienced designer to further optimize their systems.

S.18 given by Roger Stout from ON Semiconductor is designed for entry- to mid-level electronics system engineers, who are reasonably comfortable with Excel. The first part will introduce the overall approach to semiconductor device thermal characterization. Pitfalls in the use and misuse of typically published semiconductor device thermal data will be discussed. The second part will focus on the principle of linear superposition as applied to thermal system design. The goal is to provide the attendee with sufficient understanding to construct and use relatively simple spreadsheet-based tools in real-life system thermal designs. In the process, the following points will be covered: how to correctly utilize published thermal data in a system level thermal model; how to predict actual operating temperatures of the significant power devices; how to predict the operating temperatures of low power but temperature sensitive devices; how this approach may be used in conjunction with

How to Handle Electricity from µW to MW in Windmill Applications

Within the complex entity known as "The Windmill", handling electricity in an extreme wide range of power levels is the omnipresent challenge. Data needs to be gathered, transferred and processed at the lowest power levels. Mechanics and hydraulics need to be controlled to operate the mill. The quality of fulfilment depends on several electric subsystems. These in turn need to be supplied with power magnitudes below the mills output. Channelling the harvested energy to the grid is the most obvious task focusing on megawatts and beyond. Infineon provides solutions within each of the 12 decades covering the power range from µW to MW. **Martin Schulz, Infineon Technologies, Warstein, Germany**

Looking at a windmill it is often only seen that it is a megawatt application but underestimated, that it can only operate because of the interaction of a multitude of electronic components as depicted in Figure 1.

The detailed observation of a startup procedure reveals that electronic of every power level is involved even before the rotor starts turning.

Microwatts to milliwatts

The regime from µW to mW relates to different types of sensors. Besides the electrical parameters to be measured, the data necessary to operate a windmill include angle measurement, temperature, moisture and pressure.

A basic parameter is the temperature inside the mill's nacelle that is measured and, depending on the installation site, regulated to the desired level. While in a windmill in colder regions the nacelle needs to be heated to operating temperature, other installation sites may require no thermal treatment, simple ventilation or even cooling utilizing air conditioning systems. Besides the nacelle's temperature, the thermal conditions of the generator, gearboxes, liquid cooling systems and power electronic subsystems need to be monitored. Wind speed and direction are detected using anemometer and vane①.

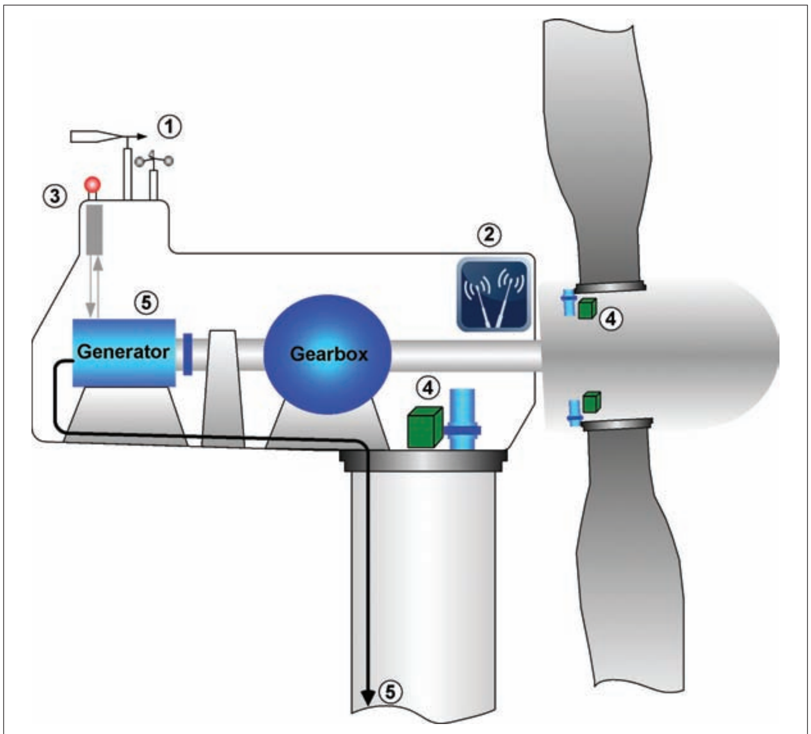


Figure 1: Schematic view of a windmill's components

Milliwatts to watts

The scale from mW to a few Watt is related to data transmission②. Most windmills are connected to networks that allow remote access to capture and monitor data on the operating conditions. Communication via D-Net, GSM or UMTS typically needs less than 10W to operate properly.

Watts to several hundred watts

Power systems from a few watts to several hundred watts include the air beacon, pumps for hydraulics and the liquid cooling systems, air condition compressors and some smaller ventilation assemblies③. Auxiliary drives need to be supplied to cover their own consumption, usually with switch-mode power supplies in a range below 100W. This power range is served using ASICS, moulded power components or discrete power electronic devices.

Kilowatt range

These decades are about controlling the mechanics of the windmill④. Two parameters dominate the tasks to be fulfilled before the mill's generator starts turning - wind speed and wind direction. First the nacelle has to be aligned with the wind's direction and additionally the blades orientation has to be fitted properly to create the starting torque. As blade control contributes to the safety of the mill and even enables emergency stop functionality,

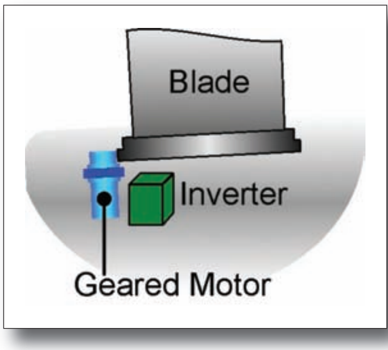


Figure 2: **Pitch-Control system for a single blade**

pitch-control drives feature an independent power supply so they can safely operate in case of grid failure or disconnection. During operation of the mill, ventilation will be needed to dissipate the generator's losses to the ambient using fans in the range of several kilowatts as well.

Up to megawatts

Depending on the windmill or wind park arrangement, energy generation and transmission starts at several hundred kilowatts while the largest windmill today has a maximum output of 6MW. In case of wind farms or arrays of a multitude of mills, 10^6 watts can easily grow to exceed 10^8 watts with the largest farm in Europe today delivering 500MW.

With a focus on power electronics, the most interesting sections refer to Pitch Control, Yaw Control and Energy Generation.

Pitch control

A drive train for a single blade is shown in Figure 2. It consists of a geared motor driving a toothed wheel to rotate the blade along its longitudinal axes. Electrically the system is connected to the grid and consists of a setup similar to UPS systems as shown in Figure 3.

In comparison to an industrial UPS, pitch-control is a far more demanding application in mechanical, electrical and thermal aspects. Additional mechanical stress comes as a consequence of the mounting location. Rotating with the mill's hub, the drive experiences centrifugal forces and a higher amount of vibrations compared to stationary designs.

To rotate the blade, the drive has to provide the initial breakaway torque. In a standstill condition this is not a critical task. If however the pitch-control has to realign the blade during operation, the forces that the wind applies to the blade have to be added. Keeping in mind that a single blade in a multi-megawatt mill has a weight of several tons, the inertia that has to be overcome is immense. Thus, electrically, the mode of operation is characterized by short bursts of maximum power leading to high demands in power cycling capability.

In normal operation the rotating speed of a blade reaches 3°/s while in case of an emergency stop up to 12°/s are demanded defining the accounting overload condition. Dimensioning of a proper drive additionally has to take into account, that the battery voltage usually is below the DC-link voltage driven by the grid. To achieve the same output power as in grid connected conditions even higher currents have to be considered in case the grid becomes disconnected. Thermally, the drive suffers from ambient temperatures in a range from -30°C to +70°C.

To serve all these needs, Infineon has cooperated with leading drive manufacturers and done extensive research especially regarding vibrations. Tests included multi-axis vibration of entire inverter designs to help developers identify weak spots in the inverter's construction and improve the design's overall stamina regarding mechanical stress. Amplitude, frequency spectrum and acceleration levels in the tests by far exceeded the values demanded by industrial standards. New

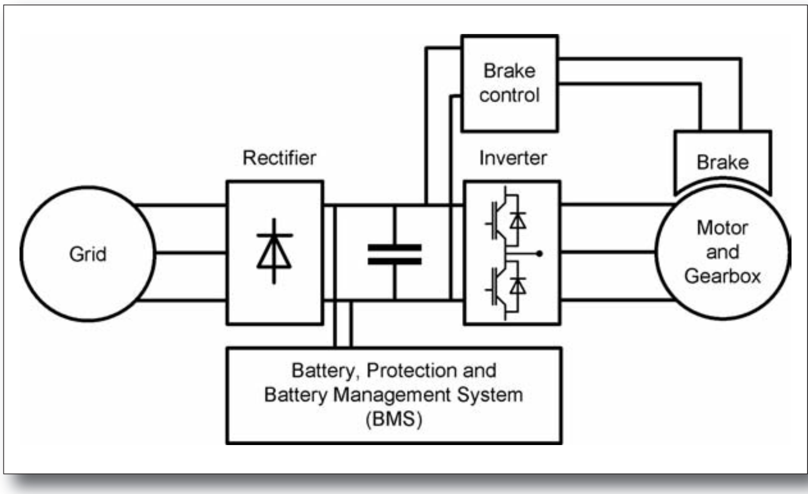


Figure 3: **Electric setup of the pitch-control drive**

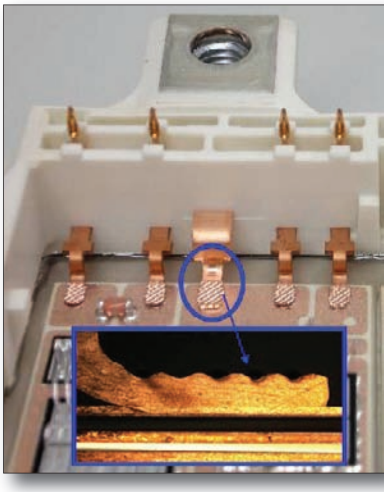


Figure 4: **EconoPACK™4 with highly reliable ultrasonic welding for the terminals**

power modules like the SmartPACK or the EconoPACK™4 were developed in accordance with the knowledge gained from such tests. One prominent result is the implementation of new interconnection technologies. Ultrasonic welding techniques to connect the electric terminals as shown in Figure 4 lead to increased capabilities in handling mechanical and thermo-mechanical stress [1]. Further improvement regarding interconnection is achieved by using PressFIT-connections. Infineon has first introduced this highly reliable and solder free connectors in low-power modules like the Easy- and Smart series [2] and migrated the approach to EconoPACK™3 as well as medium power devices like the EconoPACK™4 as depicted in Figure 5.

Yaw control

Rotating the nacelle, or Yaw-Control, is very similar to pitch control. However, the power levels are shifted by one decade. Adding up the weight from hub, blades, generator and housing, nacelles in the actual largest windmills exceed a mass of 600 metric tons. Usually hundreds of kilowatts are used to turn the nacelle, necessary simply to overcome the nacelles enormous inertia and the rotor's angular

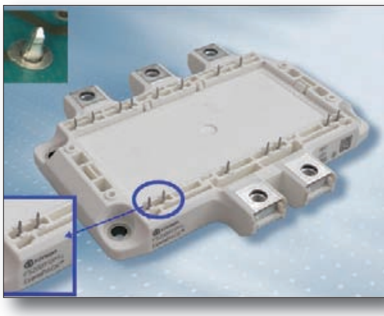


Figure 5: **EconoPACK4, detailed view to PressFIT control terminals**

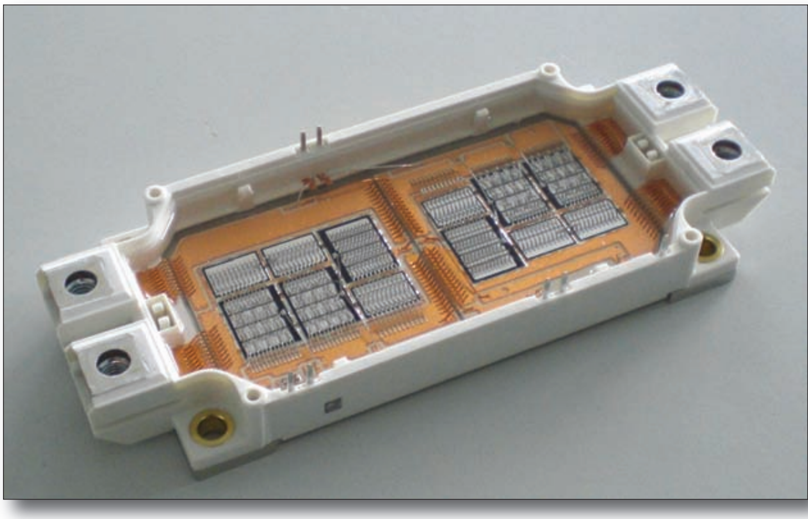


Figure 6: The new 600A/1200V EconoDUAL™3 featuring thermally optimized ceramic substrates and copper-wire bonding for high power density designs

momentum. As space in the nacelle is highly limited, inverter sizes are supposed to be as small as possible for this application too. The ongoing trend of reducing inverter sizes leads to increased power density demands towards power electronic devices. To serve this trend, Infineon has recently introduced the FF600R12ME4, a 600A/1200V half-bridge module in the well established EconoDUAL™3 package. Designed for high power densities, the package features thermally optimized ceramic substrates and achieves higher current carrying capabilities by implementing copper-wire bonding. Both these features can be seen in Figure 6.

If several drives are implemented, they can be used to reduce the backlash of the mechanical components by applying torque in opposite directions, usually this functionality is supported by mechanical brakes so continuous operation at a rotational speed of zero does not occur. Aligning the nacelle to the wind direction happens less often than acting the pitch control. Additionally, moving the nacelle does not need to be a high speed procedure. All these facts make the azimuth control a less critical application regarding power and thermal cycling.

Energy generation

The task of harvesting energy has, over the recent years, evolved in several topologies for power electronics to transfer energy from the generator to the mains. Full inverters on synchronous generators coexist with double fed induction machines. While in full inverters usually high-power modules like the PrimePACK are used, inverters powering the rotor of a double fed induction generator often feature medium power devices.

The EconoPACK+ was introduced in 2000 in conjunction with IGBT3. The 1700V derivate became a de-facto standard for this application very soon. Here too, effort is done to toughen up the existing design. The redesigned EconoPACK+ now also features PressFIT-Control-Terminals along with ultrasonic welding for the power terminals. Additionally the new power terminals now are injection moulded to increase their mechanical robustness. Figure 7 shows the actual D-Series type. Despite the changes in detail, the connections of the module remain compatible to its progenitors in mechanical and electrical aspects.

To cope with the needs of grid connected inverters in the range of several megawatts, the PrimePACK was developed especially for applications with increased lifetime demands. The PrimePACK was the first high-power module making use of ultrasonic welding for power terminals. It also offered the modularity to mount modules in half-bridge topology from 600A to 1400A in a common footprint. The modules as seen on the photograph in Figure 8 are designed with prolonged creepage distances mandatory for 3.3kV-designs. The modules equipped with 1700V IGBT are therefore predestined to operate in harsh environments.

Especially in offshore wind parks the combination of atmospheric conditions, temperature, humidity and load profile forms a challenging environment for power electronic designers.

Being aware of these challenges,

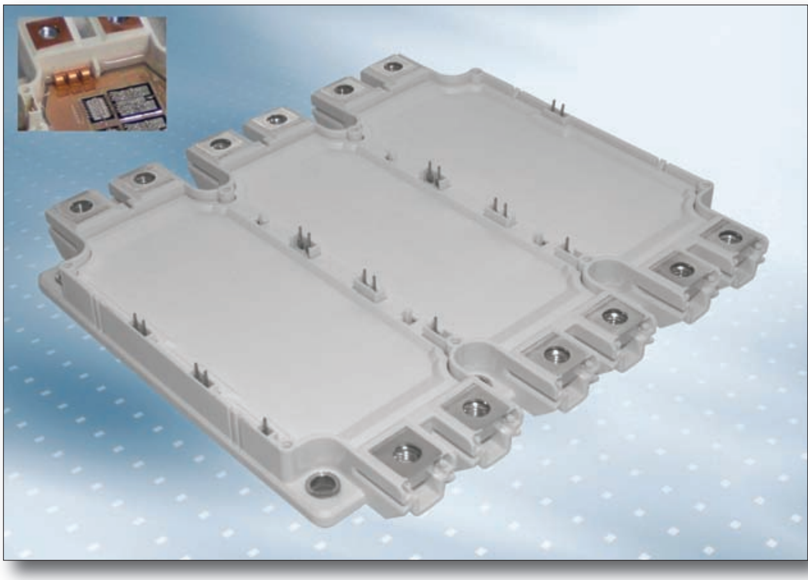


Figure 7: The new EconoPACK™+ D-Series, featuring PressFIT and ultrasonic welding for the injection moulded power terminals

Figure 8: PrimePACK2 and 3, offering enlarged creepage and clearance distances to operate in harsh environment and demanding applications

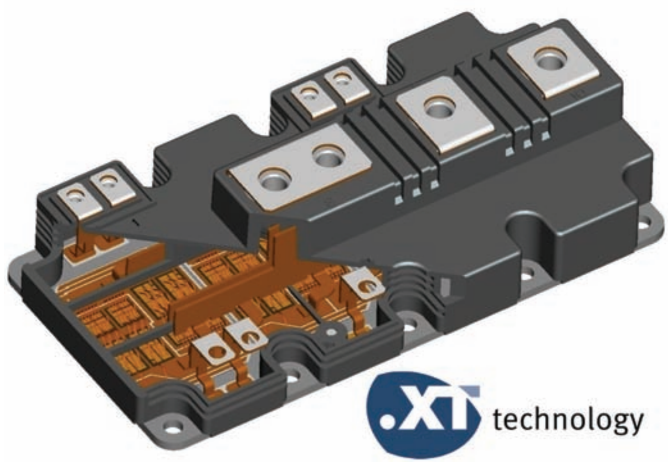


Figure 9: PrimePACK2 with .XT-Technology featuring copper wire bonding, diffusion soldering of the Silicon dies and the high reliability soldering joint for DCB-substrates

Infineon has developed a new set of interconnection technologies called .XT, concentrating on the improvement of every interconnection included in a power electronic module [4].

Next generation of power modules

Three major failure mechanisms toady limit the lifetime of power electronic devices depending on the load profile:

- Power Cycling leads to bond-wire failure,
- at long cycles the solder joint between silicon chips and DCB-substrate becomes the limiting factor,
- Thermal Cycling today leads to delaminating of the solder joint between ceramics and base plates.

Furthermore, the ongoing trend of increasing power densities, accompanied by increased junction temperatures, will be enforced by the implementation of wide band gap materials like Silicon Carbide (SiC) in the future. This in turn makes the development of new interconnection technologies an inevitable necessity as today's soldering processes cannot cope with the temperature levels to be expected.

The .XT-Technology therefore includes three essential changes to be used in the next generations of power modules. First the soldering of ceramics is migrated to the so called high reliability solder connection to achieve higher thermal cycling capabilities. The second step targets the chip soldering joint substituting soft soldering by diffusion soldering. Finally, the chip's surface changes to allow copper wire bonding. The combination of these changes leads to lifetime improvement of a factor 10 compared to today's designs. Parts of the .XT technologies were already implemented in further module families. The copper wire bonding used in the FF600R12ME4 shown in Figure 6 is a spin-off of the .XT-development. The first module to be fully equipped with all details of the .XT-Technology will be the 900A/1200V PrimePACK FF900R12IP4LD as it is sketched in Figure 9.

Though the lead type today is a 1200V module, the technology is expected to be exported to 1700V modules later as well. It is also targeted to use .XT for a variety of different module types in the future.

The reoccurring request of having a pre-constructed high-power subsystem has lead to Stack-Assemblies. Consisting of the power semiconductor itself, heat transfer management and driver

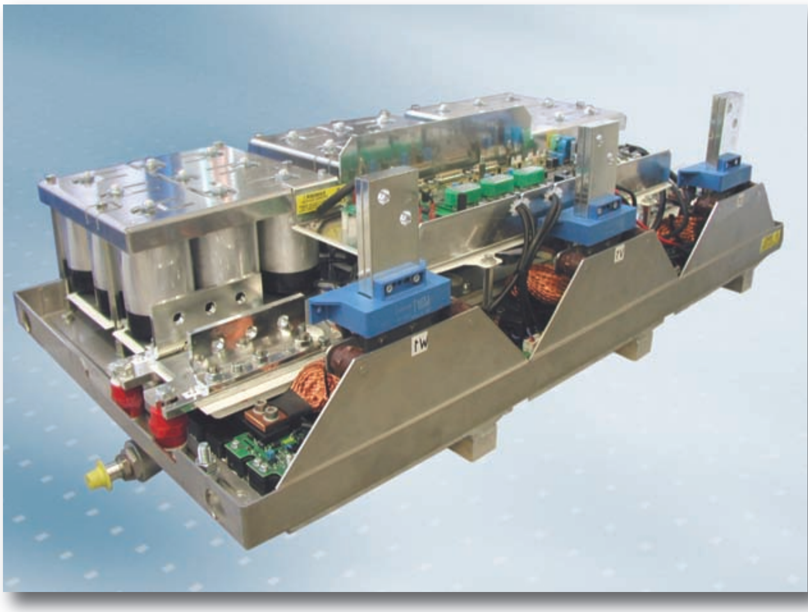


Figure 10: **Pre-assembled ModSTACK HD**

electronic, building blocks like the ModSTACK HD were designed to assist the customer in solving individual problems. Due to not having a control electronic or processor attached, these are not complete inverters. Stacks are thorough designed subsystems allowing the customer to attach the desired control unit. As driver electronic, protection mechanisms, thermal management and DC-Bus construction are complete, using Stacks as a power section speeds up development and reduces time-to-market. Figure 10 shows a ready to use ModSTACK HD capable to operate up to a DC-link voltage of 1100V and providing 2MW of output power.

Due to the modular design, these Stacks can easily be combined to form the topology needed for the particular windmill design. Furthermore paralleling is possible in case the 2MW are not enough. Customizing is an option, depending on customer's demand.

Conclusions

Having an in depth knowledge and detailed understanding on the application "Windmill" is a key factor to develop electronic components that fulfil the high expectations in lifetime, reliability and efficiency. Starting from sensors in a μW range and offering solutions and support to develop power electronics within 12 decades of power, Infineon is a competent partner to serve the demanding market of renewable energies.

Literature

[1] R. Tschirbs, G. Borghoff, T. Nübel, W. Rusche and G. Strotmann: Ultrasonic metal welding as contact technology for state-of-the-art power modules, PCIM 2010

[2] M. Schulz, R. Dillig and U. Hetzler: Innovative Module Features for Advanced Inverter Designs, Bodo's Power, September 2009

[3] R. Ott, M. Bäßler, R. Tschirbs, D. Siepe: New superior assembly technologies for modules with highest power densities, PCIM 2010

[4] K. Guth et. al.: New assembly and interconnects beyond sintering methods, PCIM 2010

More Wind Power for China

Infineon Technologies and Xinjiang Chinese Goldwind Science and Technology recently signed a license agreement for core components needed in manufacturing of wind turbines.

According to the agreement, Goldwind gains the license to produce Infineon IGBT stacks used in converters of megawatt-grade wind turbines. Furthermore, Infineon will supply IGBT stacks to Goldwind. "Introduction of the technology and the subsequent in-house production will effectively secure supply of the core converter component, deliver larger cost effectiveness and strengthen the in-house converter development. This will enhance competitiveness of our products," commented Wu Gang, board chairman of Goldwind. "From this partnership, we can learn from sophisticated process technologies and quality control experience from Infineon, which is expected to contribute to improvement of our production management and control."

Infineon plans to set up an application engineering centre in Beijing. As wind turbines evolve toward higher capacity and grid friendliness, the full-power converter has become one of the most critical elements of PMDD (Permanent Magnet Direct Drive) wind turbines, for example those manufactured by Goldwind.

Infineon has been supplying IGBT stacks as a subsystem to build and develop converters to be manufactured by Goldwind since 2007. From their first installed base at Beijing Guanting Reservoir in July 2009, Goldwind converters featuring Infineon IGBT stacks have achieved an availability of over 99% and survived several tests under extreme conditions. Having applied the IGBT stacks in its 1.5MW wind turbines, Goldwind plans to utilize it in its 2.5MW and further to 3.0MW units now under volume production after the local ramp-up.

Goldwind is China's premier wind turbine manufacturer, with strong independent R&D capabilities and the longest operating history in the domestic wind energy sector. Goldwind turbines are in operation throughout China and are also sold in major international markets including Europe and the Americas. As of June 30, 2010, the company's cumulative sales amounted to more than 8,000 turbines, potentially replacing 7 million tons of standard coal and reducing carbon dioxide emissions by 17 million tons per year.

www.goldwind.cn, www.infineon.com/power

Fast Switching IGBTs Create New Challenges

Fast switching power semiconductors are needed to reduce dynamic power losses. A typical system consists of dozens of power semiconductors connected in parallel that switch several thousands of Amperes at DC link voltages in the Kilovolt range. The resultant power losses are particularly challenging for application engineers, who strive to keep switching times as short as possible. But this is easier said than done. **Stefan Schuler, Development Engineer, Semikron, Nuremberg, Germany**

Application engineers call for higher switching speeds and lower dynamic losses at the same time. This is owing to the fact that for good enough approximation, a minimum PWM frequency is needed to obtain a sinusoidal output signal. Higher clock speeds reduce the harmonics which cause losses and mechanical stress in drive systems. The latest generation of fast switching IGBTs opens up all sorts of possibilities. The downside, however, is that they also bring about problems that have a particularly strong impact on the height of turn-off voltage peaks.

Efficient turn-off control

The requirement is clear: fast turn-off of power semiconductors. This, however, is not without its problems: beside greater EMC interference, dangerous voltage peaks are produced at the power semiconductor that is being turned off. If the maximum permissible blocking voltage is exceeded, the power semiconductor may be destroyed, usually resulting in a short circuit.

Figure 1 shows a half-bridge with a short circuit inductance L_B between the DC link voltage and the center AC tap. In this example, turning on transistor T_2 will cause the current i_{ZK} (u_{CE} is negligible) to rise continuously (equation 1):

$$i_{ZK} = \frac{U_{ZK}}{R_{ZK}} * \left(1 - e^{-t/\tau}\right) \quad (1)$$

with $$\tau = \frac{L_{ZK} + L_B + L_{Module}}{R_{ZK}}$$

During turn-off (equation 2), i_{ZK} must drop to zero within the IGBTs turn-off time. The magnetic field stored in L_{ZK} tries to maintain the current i_{ZK} , but this is only possible if this current is taken up by the snubber capacitor C_{ZK}. As this combination is a resonant circuit type [3], a decaying sine wave superimposition, corresponding to the resonance frequency of L_{ZK}, C_{ZK} and R_{ZK} is generated:

$$f_{Res,ZK} = \frac{1}{2\pi} * \frac{1}{\sqrt{L_{ZK} C_{ZK}}} * \sqrt{1 - \frac{C_{ZK} R_{ZK}^2}{4 L_{ZK}}} \quad (2)$$

The magnetic energy stored in the inductor L_{ZK} charges the snubber to the voltage U_{ZK}+Â by t=π/2. At the same time, the former current through the short-circuit inductor L_B is commutated to diode D1. In addition, due to this current impression and the diode forward recovery (Figure 3), an additive voltage component is generated. What must also be observed are the parts of the current branch that represent an open mesh after the switching operation. Owing to the di/dt, the parasitic inductances, aggregated in L_{Module}, ensure that the voltage peak is high and also superimposed.

The voltage curve u_{CE} at transistor T_2 during turn-off (Figure 2) comprises three parts:

$$u_{CE} = U_{ZK} + u_{Module} + u_{ZK} \quad (3)$$

1) The constant DC link voltage U_{ZK}.

2) Voltage curve u_{Module} during turn-off owing to the high di/dt at L_{Module}, and a high di/dt at the freewheeling diode D_1.

3) Oscillation between the snubber and the DC link inductor, caused by their resonance and the energy stored in L_{ZK} (the parasitic inductance of the snubber and its leads L_{Sn} causes a slightly higher sine wave amplitude by t=π/2, since this is still uncharged at the time of turn-off).

The different shares should be defined on the basis of a real u_{CE} curve. Here, at the moment the turn-off process begins the u_{ZK} share is zero to begin with, since the snubber is still charged to the DC link voltage level and energy transfer of the parasitic L_{ZK} is just beginning at this moment.

The voltage caused by the parasitic module inductance, as well as the diode forward recovery time is a function of di/dt and coupled to the turn-off behavior of T_2. The only di/dt parameter that can be influenced is the switching time, since the

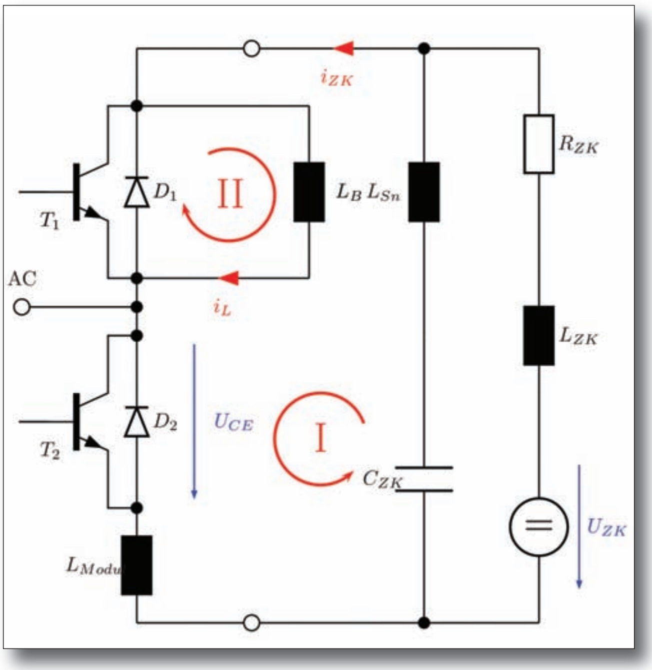


Figure 1: DC link circuit and half-bridge with short-circuit inductance L_B (simplified)

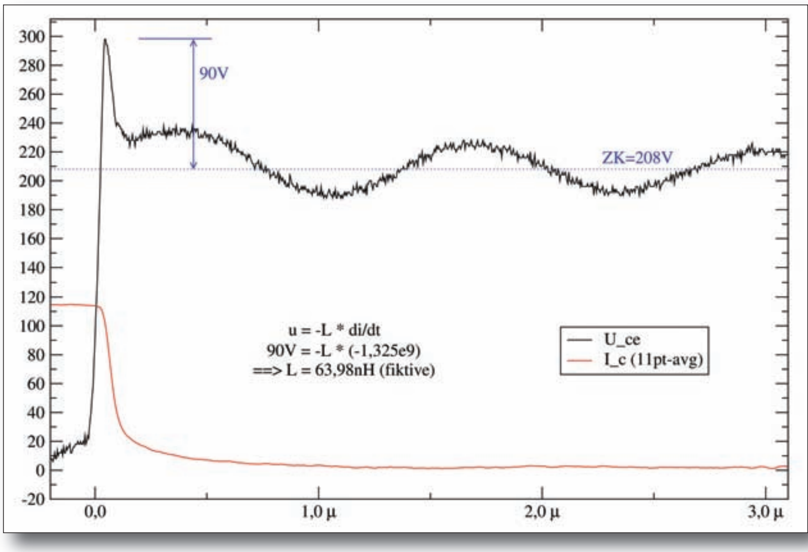


Figure 2 : Voltage u_{CE} and current iC at T_2

amount of current is defined as a load-dependent value. As soon as the turn-off process is complete, this voltage share will disappear again. Only the swing-out transient of the DC link circuit can still be seen.

Influence of the DC link circuit

In order to try to minimize the voltage peak caused by the parasitic DC link inductance, a snubber capacitor is a mounted directly at the module [4]. The voltage curve u_{ZK} during turn-off can be modeled using a sine wave with exponential decay:

$$u_{ZK} = U_{ZK} + \hat{A} * \sin(\omega_{Res} t + \varphi) * e^{-t/\tau_X} \quad (4)$$

The amplitude of the envelope Â is a function of the current provided by the DC link circuit shortly before turn-off of T_2, as well as the constant share of the DC link voltage. The magnetic energy that is stored in the parasitic DC link inductor L_{ZK} at the beginning swings periodically to the snubber C_{ZK} and back (the effective capacitance of the DC link capacitors is large enough in comparison to C_{ZK} and is therefore negligible) with decaying intensity (due to losses in R_{ZK}). At t=π/2, when the entire energy W_L is present in C_{ZK}, the amplitude of Â can be determined as follows:

$$W_C = \frac{1}{2} C * (U_{max}^2 - U_{ZK}^2)$$

$$\rightarrow U_{max} = \sqrt{\frac{2 * W_C}{C_{ZK}} + U_{ZK}^2}$$

$$\text{where} \quad W_C = W_L = \frac{1}{2} L_{ZK} * I_{ZK}^2 \quad (5)$$

$$\rightarrow U_{max} = \sqrt{\frac{L_{ZK} * I_{max}^2}{C_{ZK}} + U_{ZK}^2}$$

$$\text{where} \quad \hat{A} = U_{max} - U_{ZK}$$

Figure 4 shows a slightly higher amplitude of the sinus wave at t=π/2. This is owing to the (in this case neglected) influence of L_{Sn}.

Influence of the module

In the power module itself the conditions are different. Here, for reasons of space and operational safety (high temperatures) no snubber can be mounted. The parasitic inductances inherent in the module, e.g. busbars, DBC layout and bond wires, therefore have to be minimized by way of suitable design measure. In addition, the turn-off voltage peak can only be influenced by way of suitable switching time modulation, since this value depends on the di/dt:

$$u_{Module} = -L_{Module} * \frac{\partial i}{\partial t} + u_{D1}$$

$$\text{with} \quad u_{D1} = f(t, i_{D1}) \quad (6)$$

The formula above contains the diode voltage uD1 as an additional component. This voltage, which is also denoted the forward recovery time voltage [1], occurs if a high current with a high di/dt is injected into the diode operating in forward direction, as is the case with freewheeling current of an inductive load. Figure 3 shows the voltage curve of a power diode (for different injected current values) which reaches its maximum after around 10..20ns and then drops to the normal forward voltage. The maximum voltage can reach as much as several hundred volts.

The curve in Figure 2 is intended to show how to define the key characteristic values. The sample curve refers to a small experimental set-up with a 200V DC link circuit, a 0.68µF snubber and a short-circuit inductance of 350µH.

DC link share analysis

To define the time constants _ for the selected DC link voltage, two meaningful measuring points are taken from the curve:

$$\tau = \frac{t_2 - t_1}{\ln(U_1 - U_{ZK}) - \ln(U_2 - U_{ZK})} \quad (7)$$

$$\tau = 3{,}872\ \mu s$$

The parasitic DC link inductance can be calculated from the defined frequency (f_R=763.5kHz) using resonance condition for a series resonant circuit (R_{ZK}, L_{ZK} and snubber C_{ZK} are in equation 8):

$$L_{ZK} = \frac{1}{\omega_{Res}^2 C_{ZK} + \frac{1}{4 R_{ZK}^2 C_{ZK}}} = 62{,}3nH \quad (8)$$

The magnetic loss resistance is calculated as follows:

$$R_{ZK} = \frac{2 L_{ZK}}{\tau} = 0{,}0326\ \Omega \quad (9)$$

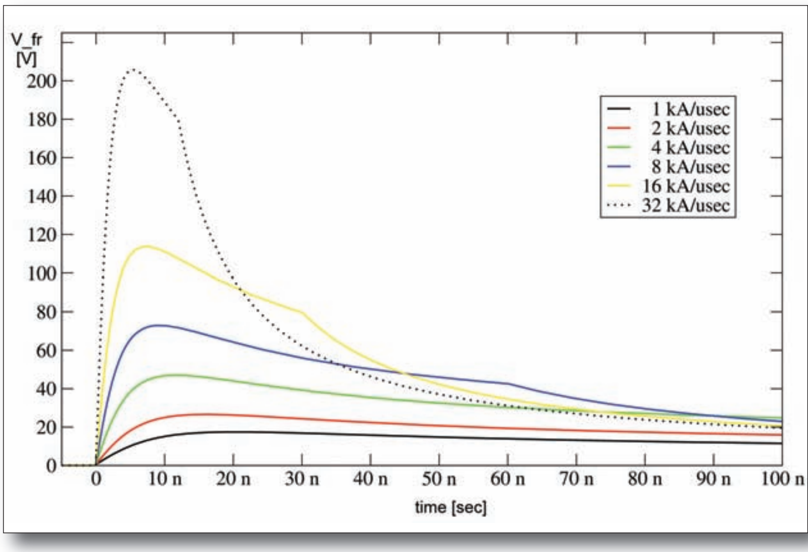


Figure 3: Forward recovery time of a power diode for various di/dt

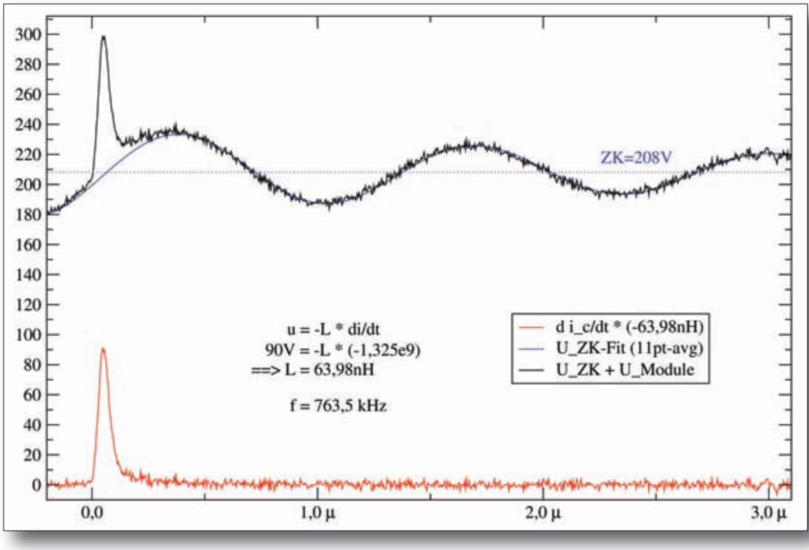


Figure 4: Calculated curves for uZK and uModul based on uCE und iC

The quality of the series resonant circuit is thus:

$$Q = \frac{\omega_0}{\Delta\omega} = \omega_0 * \frac{L_{ZK}}{R_{ZK}} = 9{,}29 \quad (10)$$

A more elegant and precise way of defining ω, τ, U_{ZK} and the amplitude Â is to use the numerical data processing and visualization tool xmgrace [2]. Here, the following formula is fit to an area between the voltage peak and after several oscillations:

y = a0 + a1 * sin(a2*g0.s1.x-a3) * exp(-(g0.s1.x-a3)/a4) (11)

The parameter results after 20 iterations for this non-linear fit are shown in Table 1. The resultant curve can be seen in Figure 4.

Analysing the module share

The module share of the over-voltage can be dealt with in two steps: first through a differentiation of the collector current curve i_c, (with e.g. xmgrace). Scaling is then performed to insert the new curve into the first u_{ce} voltage peak accordingly. Here, the (negative) scaling factor found does not correspond to the parasitic module inductance, since the influence of the diode still has to be taken into account. This is why the term fictitious module inductance $L_{Module,fict.}$ is introduced according to equation 12:

$$u_{Module} = -L_{Module} * \frac{\partial i}{\partial t} + u_D(i,t) \quad (12)$$

$$L_{Module,fikt.} = 64\,nH \text{ (fiktive value!)}$$

In actual fact, the voltage curve u_{Module} depends not only on the switching behaviour of the semiconductor and the parasitic module inductance, but also on the diode forward recovery time. For this reason, $L_{Module,fict}$ has to be corrected on the basis of the diode forward recovery time. The maximum share of the forward recovery time in the total voltage increase should be estimated using the maximum di/dt (Figure 3) as a basis: below 10kA/µs the forward recovery voltage $U_{fr,max}$ of a standard power diode can be approximated rather accurately using the following equation 13:

$$U_{fr,max} = 6{,}93^{-6} * \left(\frac{\partial i}{\partial t}\right)^{0,71}_{max} \quad (13)$$

For di/dt=1.3kA/µs in this example, this amounts to around 20.5V. Thus, the over-voltage drops to around 70V as a result of the inductive share, and the inductance of the test module itself drops to 49.8nH (computed value).

The superimposition of both curves (Figure 4) results in the curve calculated originally u_{ce}, which is applicable as of t=0. Now the characteristic for an alternative snubber, for example, can be easily determined.

Table 1: Fitting results

a0	voltage U_{ZK}	208,3 V
a1	amplitude Â	44,4 V
a2	resonance ω_R	4,797e6 Hz
a3	time offset	362,4e-6 s
a4	time constant τ	3,64e-6 s

Critical behavior

Together with the snubber, the DC link circuit behaves like a resonant circuit with resonance frequency $f_{Res,ZK}$. For this reason, critical states may occur. This would happen, for example, if the switching frequency were an even factor of f_0. In this case, if the quality of the resonance circuit is good enough, the energy injected into the snubber during the next switching operation is in phase. This can lead to a critical over-voltage after just a few clock pulses. Owing to the comparatively poor quality of the test module shown, this effect can be expected for switching frequencies of 30kHz and above.

Furthermore, poor interconnection of various DC link circuits and/or modules can also lead to undesired excitation, which should be checked in the individual cases.

Conclusions

The analysis of u_{ce} and i_c measurement during switch-off illustrates the interplay between parasitic DC link inductance and module inductance. This makes it easy to analyse the weak points of a given application and exploit optimization potential in simulations.

What can be seen is that pure modification of the turn-off speed merely reduces the over-voltage peaks generated by the module. The over-voltages in the DC link circuit are primarily a function of the current level and can only be reduced very slightly by decreasing the di/dt.

The formal description of the turn-off process reveals both possibilities and restrictions that apply when choosing the right switching speed, snubber and module design. A balanced combination of measures is a good way to optimize costs and improve reliability - directly on the PC, without the need for complex testing.

Literature

[1] Josef Lutz: Halbleiter-Leistungsbauelemente, Springer-Verlag 2006

[2] Weizmann Institute of Science: grace / xmgrace

[3] Steinbuch, Rupprecht: Nachrichtentechnik, Bd1: Schaltungstechnik, Springer-Verlag 1982

[4] Application Note AN7006: IGBT Peak Voltage Measurement and Snubber Capacitors Specification

Rugged Automotive Qualified Planar MOSFETs

TInternational Rectifier introduces a family of automotive qualified planar MOSFETs for a variety of applications used in Internal Combustion Engine (ICE), hybrid and full electric vehicle platforms. IR's planar technology includes 55V and 150V standard gate drive N-channel MOSFETs, and -55V and -100V standard gate drive P-channel MOSFETs suitable for high-side switch applications, requiring no additional charge pump for gate drive. The 30V, 55V and 100V logic level gate drive N-channel MOSFETs simplify gate drive requirements and help reduce board space and component count. All of the new devices are optimized for low on-state resistance. The new devices are qualified according to AEC-Q101 standards, feature an environmentally friendly, lead-free and RoHS compliant bill of materials, and are part of IR's Automotive focused Zero Defect Initiative. Spice models are available on request.

www.irf.com

Rectifier Module with Integrated MOSFET Chopper for PFC

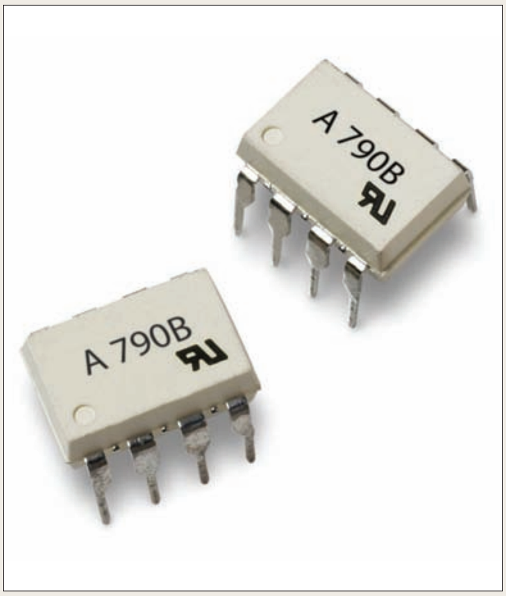
Infineon Technologies offers new Easy 1B single-phase rectifier modules with MOSFET chopper for Power Factor Correction. Applications for these new modules include drives, air conditioning, pumps, fans and welding. The new modules come with several advantages: CoolMOS™ Power Transistors plus ThinQ!™ Silicon Carbide Schottky diodes enable highest efficiency of the PFC stage. Infineon's 50A rectifier diodes provide very low conduction losses. Higher output currents can be achieved using the same line input. Up to 5.5 kW inverter rating are achievable from only 16A single phase input current. Highest reliability can be achieved due to PressFIT contacts.

www.infineon.com

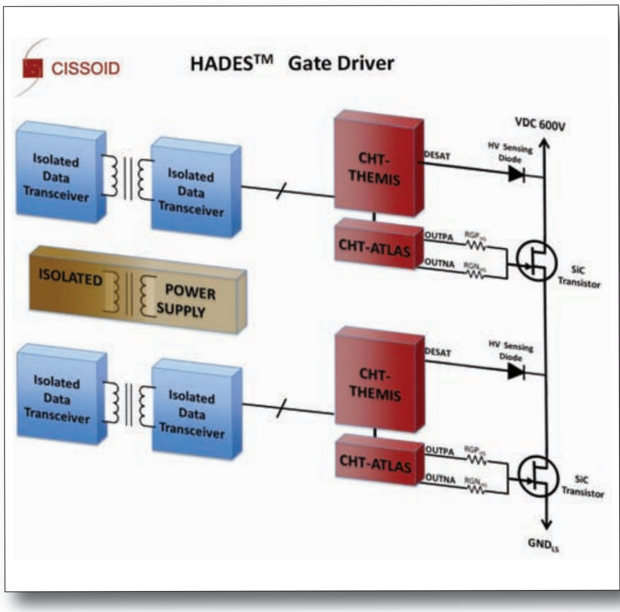
Isolation Amplifiers for Motor Drivers

Avago's new precision optical isolation amplifiers (ACPL-790B, ACPL-790A and ACPL-7900) are suited for current and voltage sensing in AC and brushless DC motor drives, industrial inverters, servo motor drives, wind power generation, solar panel power systems and general analog isolation. As current flows through the external resistor in a motor drive implementation, the resulting analog voltage drop is sensed by an ACPL-790B/790A/7900 isolation amplifier, and it allows a proportional output voltage to safely be created on the other side of the optical isolation barrier. The ACPL-790B precise isolation amplifier provides up to 0.5% high gain accuracy, and offer 200kHz bandwidth and 1.6µs response time to enable capture of transient signals in short circuit and overload conditions. The devices operate from a single 5V supply that is compatible with 3.3V outputs. This performance is delivered in a compact DIP-8 package that is suitable for automated assembly and meets worldwide regulatory safety standards.

www.avagotech.com



Driver for Silicon Carbide Switches

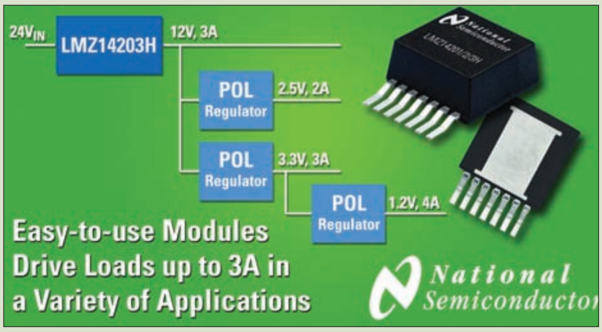


CISSOID's THEMIS and ATLAS are new power transistor drivers meant for high efficiency motor drives and power converters. The devices are especially designed to drive the most advanced power switches, including Silicon Carbide (SiC) MOSFETs and JFETs as well as Silicon IGBTs and MOSFETs. THEMIS and ATLAS are respectively the controller and the push pull driver stages of the power transistors. ATLAS features 2 distinct channels capable of sourcing (or sinking) 2A each to the gate of the power transistor, hence 4A total. For applications that require higher power, the solution is scalable and can control up to 5 ATLAS circuits per THEMIS, with a current of up to 20A to drive the gate of the power transistors, which can typically turn on/off SiC transistors in less than 50ns. A complete set of built-in protection features such as under-voltage lockout, de-saturation detection, soft-shutdown and active miller clamping are included. THEMIS and ATLAS are guaranteed for operation up to 225°C, thus designers can place the drivers next to the SiC die, reducing the parasitic inductance to a few nH and hence reducing switching losses because of faster transitions. Lower switching losses allow increased switching frequency of power converters, which in turn reduces the size of passive components. THEMIS and ATLAS ICs pave the way for a complete isolated gate driver technology called HADES™, which will be launched in the coming months.

www.cissoid.com

High Output Voltage Simple Switcher

National Semiconductor offers three new SIMPLE SWITCHER® power modules, the first to drive high output voltage applications in a variety of markets. The LMZ14201H, LMZ14202H and LMZ14203H power modules provide the efficiency of a synchronous switching regulator with the simplicity of a linear regulator, eliminating the external inductor and complex layout placement challenges typical of switching regulator designs. The devices accept an input voltage rail between 6V and 42V and deliver an adjustable and highly accurate output voltage up to 24V. A single resistor adjusts the switching frequency to enable greater flexibility of design. Pin-to-pin compatible with other family members, the modules integrate a shielded inductor and feature efficiency up to 97%. The integrated inductor alleviates EMI concerns as the modules comply with both CISPR 22 Class B radiated and conducted emissions standards. The LMZ14201H, LMZ14202H and LMZ14203H drive loads from 1A to 3A and are well-suited to generate intermediate bus voltages in systems using a distributed POL architecture without airflow.



www.national.com/pf/LM/LMZ14203H.html

AC/DC Connverters

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

Busbars

www.auxel.com
Auxel FTG
Tel: +44 (0)7714 699967

Capacitors

www.powersemiconductors.co.uk
Power Semiconductors Ltd
Tel: +44 (0)1727 811110

Certification

www.productapprovals.co.uk
Product Approvals Ltd
Tel: +44 (0)1588 620192

Connectors & Terminal Blocks

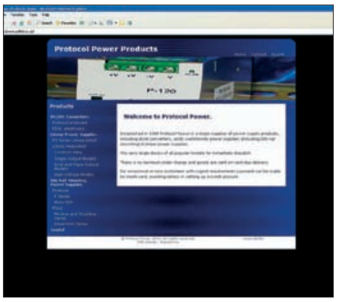
www.auxel.com
Auxel FTG
Tel: +44 (0)7714 699967

DC/DC Connverters

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

DC/DC Connverters

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399



www.protocol-power.com
Protocol Power Products
Tel: +44 (0)1582 477737

Diodes

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

www.mark5.com
Mark 5 Ltd
Tel: +44 (0)2392 618616

www.microsemi.com
Microsemi
Tel: 001 541 382 8028

www.neutronltd.co.uk
Neutron Ltd
Tel: +44 (0)1460 242200

Direct Bonded Copper (DPC Substrates)

www.curamik.co.uk
curamik® electronics GmbH
Tel: +49 9645 9222 0

Discrete Semiconductors

www.digikey.com/europe
Digi-Key
Tel: +31 (0)53 484 9584

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

www.mark5.com
Mark 5 Ltd
Tel: +44 (0)2392 618616

www.microsemi.com
Microsemi
Tel: 001 541 382 8028

Drivers ICS

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

Fuses

www.powersemiconductors.co.uk
Power Semiconductors Ltd
Tel: +44 (0)1727 811110

GTO/Triacs

www.mark5.com
Mark 5 Ltd
Tel: +44 (0)2392 618616

Hall Current Sensors

www.dgseals.com
dgseals.com
Tel: 001 972 931 8463

Harmonic Filters

www.murata-europe.com
Murata Electronics (UK) Ltd
Tel: +44 (0)1252 811666

IGBTs

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

www.mark5.com
Mark 5 Ltd
Tel: +44 (0)2392 618616

www.microsemi.com
Microsemi
Tel: 001 541 382 8028

www.neutronltd.co.uk
Neutron Ltd
Tel: +44 (0)1460 242200

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

Magnetic Materials/Products

www.rubadue.com
Rubadue Wire Co., Inc.
Tel. 001 970-351-6100

Mosfets

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

www.mark5.com
Mark 5 Ltd
Tel: +44 (0)2392 618616

www.microsemi.com
Microsemi
Tel: 001 541 382 8028

www.neutronltd.co.uk
Neutron Ltd
Tel: +44 (0)1460 242200

Optoelectronic Devices

www.digikey.com/europe
Digi-Key Tel: +31 (0)53 484 9584

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

Packaging & Packaging Materials

www.curamik.co.uk
curamik® electronics GmbH
Tel: +49 9645 9222 0

Power ICs

www.digikey.com/europe
Digi-Key Tel: +31 (0)53 484 9584

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

Power Modules

www.auxel.com
Auxel FTG
Tel: +44 (0)7714 699967

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

www.mark5.com
Mark 5 Ltd
Tel: +44 (0)2392 618616

www.microsemi.com
Microsemi
Tel: 001 541 382 8028

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

Power Protection Products

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

Power Substrates

www.universal-science.com
Universal Science Ltd
Tel: +44 (0)1908 222211

Resistors & Potentiometers

www.isabellenhuette.de
Isabellenhütte Heusler GmbH KG
Tel: +49/(27 71) 9 34 2 82

RF & Microwave Test Equipment.

www.ar-europe.ie
AR Europe
Tel: 353-61-504300

Simulation Software

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

www.universal-science.com
Universal Science Ltd
Tel: +44 (0)1908 222211

Smartpower Devices

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

Switches & Relays

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

Switched Mode Power Supplies

www.biaspower.com
Bias Power, LLC
Tel: 001 847 215 2427

Switched Mode Power Supplies

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

Thermal Management & Heatsinks

www.curamik.co.uk
curamik® electronics GmbH
Tel: +49 9645 9222 0

www.dau-at.com
Dau GmbH & Co KG
Tel: +43 3143 23510

www.denka.co.jp
Denka Chemicals GmbH
Tel: +49 (0)211 13099 50

www.lairdtech.com
Laird Technologies Ltd
Tel: 00 44 1342 315044

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

www.universal-science.com
Universal Science Ltd
Tel: +44 (0)1908 222211

Thyristors

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

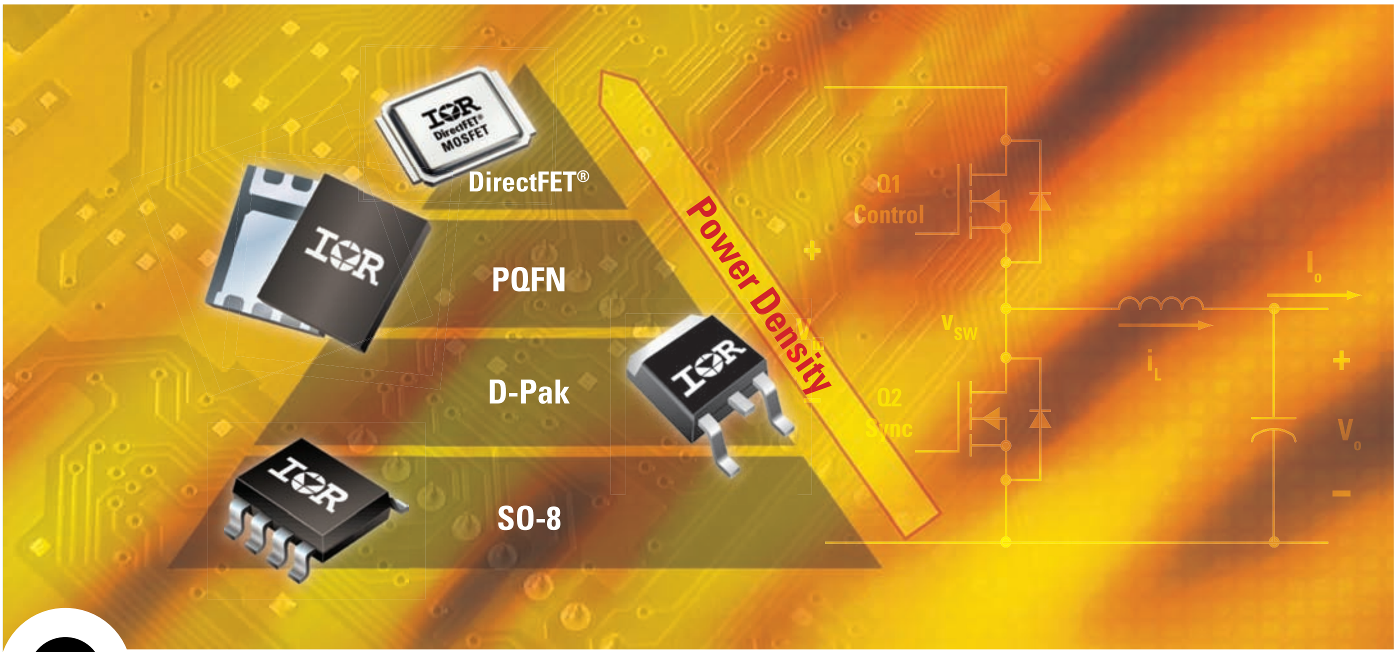
www.mark5.com
Mark 5 Ltd
Tel: +44 (0)2392 618616

Voltage References

www.irf.com
International Rectifier Co.
(GB) Ltd
Tel: +44 (0)1737 227200

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

ADVERTISERS INDEX



Select The Best MOSFET Pair to Meet Your Power Density Needs

Scalable Solutions for DC-DC Buck Converters

Part Number	BV_{DSS} (V)	Function	Package	$R_{DS(on)}$ Max. V_{GS}=10V (m)	Q_G V_{GS}=4.5V (nC)
IRFH5306	30	Control	High Current PQFN 5 x 6	8.1	7.8
IRFH5302	30	Sync	High Current PQFN 5 x 6	2.1	29
IRFHM831	30	Control	PQFN 3x3	7.8	7.3
IRFHM830	30	Sync	PQFN 3x3	3.8	15
IRFHM830D	30	Sync	PQFN 3x3	4.3	13
IRFH7911	30	Control	Half-Bridge Asymmetric PQFN 5x6	8.6	8.3
		Sync		3.0	34
IRLR8729	30	Control	D-Pak	8.9	10
IRLR8726	30	Sync	D-Pak	5.8	15
IRF8714	30	Control	SO-8	8.7	8.1
IRF8734	30	Sync	SO-8	3.5	20
IRF8513	30	Control	Half-Bridge Asymmetric SO-8	15.5	5.7
		Sync		12.7	7.6

The IR Advantage

- Optimized Sync and Control MOSFETs for high system efficiency
- High light-load efficiency
- Improved thermal performance with DirectFET® top-side cooling
- Scalable solutions for different power density requirements
- Benchmark performance
- Wide range of packages

Your FIRST CHOICE for Performance

For more information call +49 (0) 6102 884 311
or visit us at www.irf.com

International Rectifier
THE POWER MANAGEMENT LEADER