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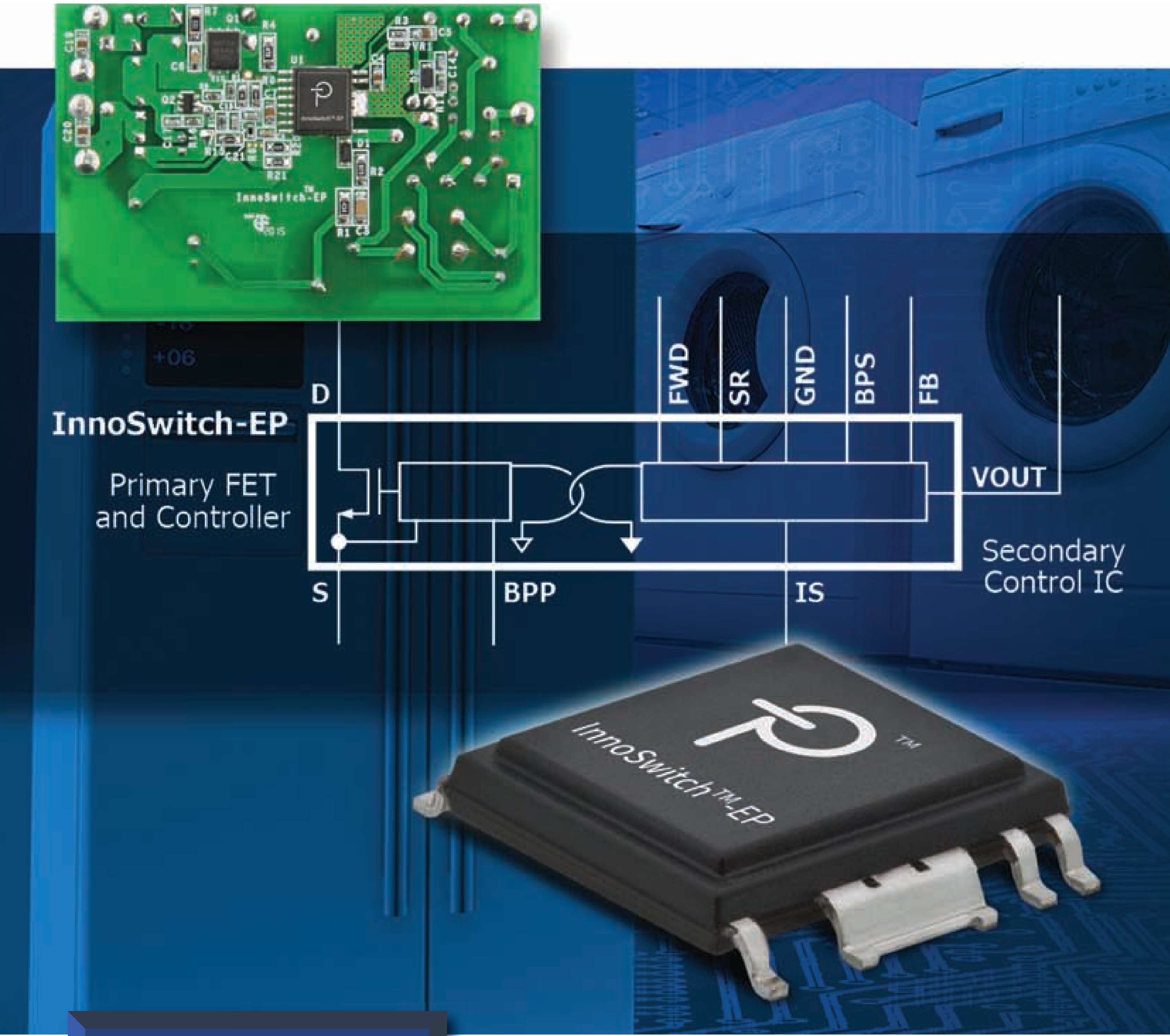
POWER ICs

Efficiency Revolution in Auxiliary and Standby Power Supplies



THE EUROPEAN JOURNAL FOR POWER ELECTRONICS AND TECHNOLOGY

Also inside this issue

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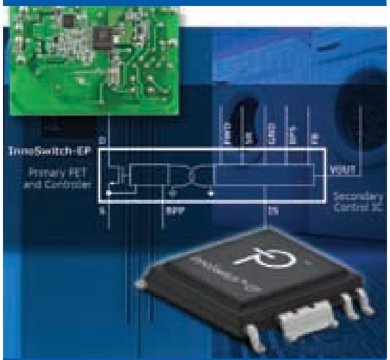
COVER STORY



Efficiency Revolution in Auxiliary and Standby Power Supplies

The new InnoSwitch TM-EP family of ICs simplify the development and manufacturing of low-voltage, high-current power supplies, particularly those in compact enclosures or with high efficiency requirements. Its architecture is revolutionary in that the devices incorporate both primary and secondary controllers, with sense elements and a safety-rated feedback mechanism into a single IC. It combines a high-voltage power MOSFET along with both primary-side and secondary-side controllers in one device. A novel inductive coupling feedback scheme using the package leadframe and bond wires o provide accurate direct sensing of the output voltage and output current on the secondary to communicate information to the primary IC. The first application for InnoSwitch ICs was increasingly power-hungry smart mobile devices, but auxiliary and standby power in appliances, HVAC, consumer electronics, computing, telecom and data communication applications would also gain substantial benefits from increased efficiency across the load range. InnoSwitch-EP ICs are an answer to engineers looking to address increasingly demanding Total Energy Consumption (TEC) regulations from bodies such as ENERGY STAR® and ErP with an easy-to-implement solution that improves power supply efficiency from standby to full load. For example, InnoSwitch-EP ICs enable a 20 W power supply to achieve 90 % efficiency in a multi-output design, while reducing no load consumption to less than 30 mW.

Full story on page 22.

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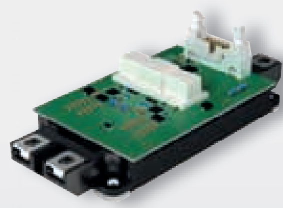

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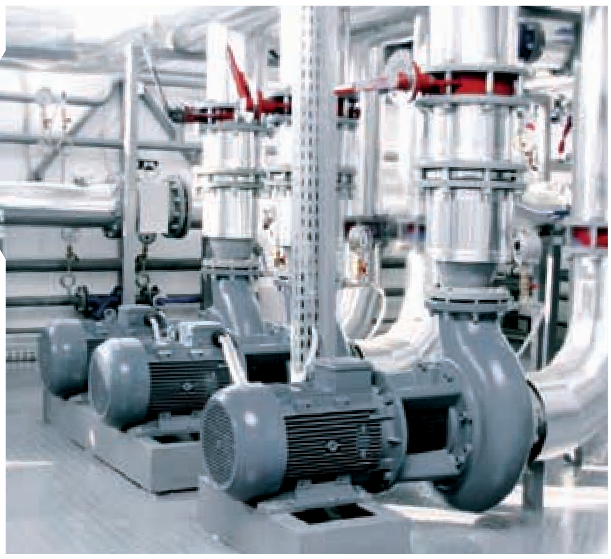


Power Electronics in Contest

Around two years ago Google and the IEEE initiated the “Little Box Challenge”, a contest addressing power electronic developers to design the smallest and most efficient inverter. The grand prize ($1 million) winner will be announced sometime in January, 2016. Inverters will become increasingly important to our economy and environment as solar PV, batteries, and similar power sources continue their rapid growth. More broadly, similar forms of power electronics are everywhere: in laptops, phones, motors drives, electric vehicles, wind turbines, to give just a few examples. The innovations inspired by this prize will have wide applicability across these areas, increasing efficiency, driving down costs, and opening up new uses cases that we can’t imagine today. It also doesn’t hurt that many of these improvements could make data centers run more safely and efficiently. By July, over 100 teams submitted Technical Approach and Testing Applications to have their inverters tested at the National Renewable Energy Laboratory’s Energy Systems Integration Facility in Golden, Colorado this fall. Out of this number 18 finalists have been selected – with impressing European contribution.

One promising set of new technologies which may allow for the achievement of higher power densities are wide bandgap (WBG) semiconductors, such as Gallium Nitride (GaN) and Silicon Carbide (SiC). The list of WBG device manufacturers who have made pages describing their technology, how it might enable contestants to win the competition and opportunities for obtaining some of their devices contains EPC, GaN Systems, GeneSiC, Infineon, Monolith Semiconductors, NXP, ROHM, ST, Transphorm, USCi, and Wolfspeed (formerly Cree). The GaN devices market is expected to explode, announced Yole in its technology and market analysis entitled “GaN & SiC for power electronics applications”. Under this report Yole proposes two scenarios, from 2014 to 2020, based on the penetration rate of GaN: The differentiating factor, compared with the Silicon Carbide solutions’ adoption, is mainly focused on below 200 V and 600 V applications, but after the adoption phase of the Wide Band Gap technologies, how will GaN and SiC technologies cohabite? Will they enter in direct competition or become complementary technologies? In the nominal scenario, Yole estimates the GaN device market size will be around $300 million in 2020, but in the accelerated scenario, where low voltage GaN and 600 V GaN are rapidly adopted, market figure for 2020 reaches $560 million.

The overall power semiconductor market, including both power discretes and power modules, is predicted by IHS to grow 5 % in 2015 to reach $17 billion. In 2014, year-over-year power discrete revenue grew 5 % and power module revenue grew 12 %. The global power module market is projected to comprise nearly one third (30 %) of the power semiconductor market by 2019, growing at twice the rate of power discretes from 2014 to 2019. Infineon continued to be the largest supplier for the global power semiconductor market in 2014, with an estimated market share of 13 %. With the acquisition of International Rectifier by Infineon last year, the market landscape for power semiconductors is changing. The merged companies held almost 27 % of the power transistor market in 2014. The transistor product category includes bipolar transistors, MOSFETs, and IGBTs, accounting for about two thirds of the total discrete power semiconductor market.

From the technology side first, the power module is becoming a key part in the power electronics value chain. And this evolution is directly impacting the supply chain with many new entrants willing to capture the power module added-value. At the geographic level then, Chinese companies are entering the IGBT devices market with their own disruptive technologies or with the acquisition of die manufacturers. With this strategy, Chinese players compete established companies mostly based in Europe and Japan. Under this context, the Japanese companies are expected by Yole to still dominate the market. But this industry will be progressively reshaping with the entrance of new players at the power module level. Most IGBT manufacturers have been involved in the field for decades. Relationships are deep-rooted between tiers and users, and business models are already drawn. However, evolutions are occurring: with the electrified vehicle market’s growth, the power module is becoming a key piece of the value chain and an important step to master. Modules integrating embedded dies are beginning to enter the market via areas like photovoltaics and automotive. Big players are also pursuing mergers and acquisitions in order to quickly acquire this know-how. In parallel, Chinese companies are entering the market to compete with European and Japanese leaders. In 2014, as in 2013, Chinese market represented around 1/3 of the global IGBT devices market. According to Yole’s IGBT analysis, many Chinese companies are involved in module manufacturing and buy the dies from foreign companies for integration. However, an increasing number of Chinese companies try to enter the die manufacturing market. To answer Chinese competition, Japanese and European players rely not only on their experience and product quality, but also on a strong in-house market. With an overall market fueled by electrified vehicles, these established players can benefit from a strong local supply chain in automotive, and look forward to attractive future growth.

With that outlook we wish all our readers a successful remaining year 2015 and a good jump into 2016!

Achim Scharf
PEE Editor

Chinese Challange in IGBTs

"The IGBT devices industry is about to change" announces Yole Développement (Yole) in its latest power electronics report, entitled "IGBT Market and Technology Trends".

From the technology side first, the power module is becoming a key part in the power electronics value chain. And this evolution is directly impacting the supply chain with many new entrants willing to capture the power module added-value. At the geographic level then, Chinese companies are entering the IGBT devices market with their own disruptive technologies or with the acquisition of die manufacturers. With this strategy, Chinese players compete established companies mostly based in Europe and Japan. Under this context, the Japanese companies are still dominating the market, even with International Rectifier's acquisition by Infineon Technologies beginning of 2015.

"The IGBT supply-chain is well-established", confirms Coralie Le Bret, analyst at Yole. "But we stay convinced this industry will be progressively reshaping with the entrance of new players at the power module level", she adds. Indeed most IGBT manufacturers have been involved in the field for decades. Relationships are deep-rooted between tiers and users, and business models are already drawn. However, evolutions are occurring: with the electrified vehicle market's growth, the power module is becoming a key piece of the value chain and an important step to master.

More and more companies are choosing to enter the power module market in order to capture this added value. Under its report, Yole identified lot of companies such as Nissan, Toyota and International Rectifier, still in the power module area even after its acquisition by Infineon Technologies.

However, many challenges must be faced by companies at the packaging level, such as yield increase, failure issue reduction, manufacturing ease, and cost competitiveness. To achieve these targets, new designs and new materials can be used, either to eliminate connection levels or improve interfaces. New solutions inspired by big-volume markets like smartphones are being adapted to higher power needs: for example, modules integrating embedded dies are beginning to enter the market via areas like photovoltaics and automotive. Big players are also pursuing mergers and acquisitions in order to quickly acquire this know-how.

In parallel, Chinese companies are entering the market to compete with European and Japanese leaders. In 2014, as in 2013, Chinese market represented around 1/3 of the global IGBT devices market. According to Yole's IGBT analysis, many Chinese companies are involved in module manufacturing and buy the dies from foreign companies for integration. However, Yole's analysts see an increasing number of Chinese companies trying to enter the die manufacturing market. Some are developing their own technology. Yole identified for example, MacMic, BYD. Other companies are choosing to acquire die manufacturers. Regardless of their preferred tactic, every company understands that developing a reputation for good quality is key in order to first enter their local market, and then compete with established IGBT manufacturers.

Yole's analysis highlight the role of the Chinese companies in the IGBT devices market and propose a comprehensive presentation of Chinese players split between power module makers and IGBT die makers, along with an associated power range. n terms of market share, Japanese companies still lead, even in light of the recent merger between International Rectifier and Infineon. To answer Chinese competition, Japanese and European players rely not only on their experience and product quality, but also on a strong in-house market. With an overall market fueled by electrified vehicles, these established players can benefit from a strong local supply chain in automotive, and look forward to attractive future growth.

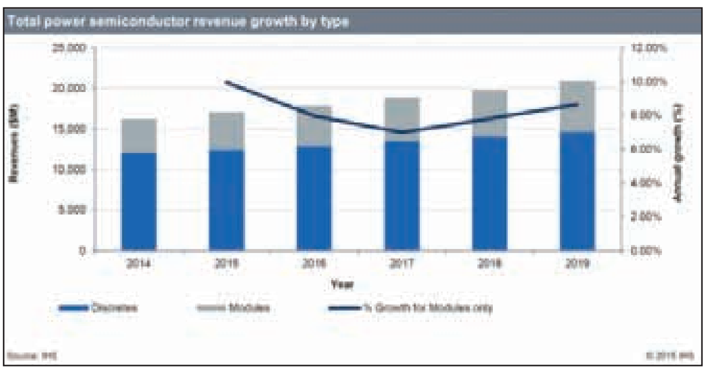
Additionally Gallium Nitride (GaN) devices market is expected to explode, announced Yole in its technology and market analysis entitled "GaN & SiC for power electronics applications". Under this report Yole proposes two scenarios, from 2014 to 2020, based on the penetration rate of GaN: The differentiating factor, compared with the Silicon Carbide (SiC) solutions' adoption, is mainly focused on below 200V and 600V applications, but after the adoption phase of the Wide Band Gap (WBG) technologies, how will GaN and SiC technologies cohabite? Will they enter in direct competition or become complementary technologies? "In the nominal scenario, we estimate the GaN device market size will be around $300 million in 2020," expects Hong Lin, Technology & Market Analyst at Yole. "In the accelerated scenario, where low voltage GaN and 600 V GaN are rapidly adopted, market figure for 2020 reaches $560 million".

www.yole.fr

Power Modules Outperform Discretes

According to market researcher IHS the global power module market is projected to comprise nearly one third (30 %) of the power semiconductor market by 2019, growing at twice the rate of power discretes from 2014 to 2019. The overall power semiconductor market, including both power discretes and power modules, is predicted to grow 5 % in 2015 to reach $17 billion. In 2014, year-over-year power discrete revenue grew 5 % and power module revenue grew 12 %.

Power modules contain multiple discrete power semiconductor devices. Compared to discrete power semiconductors, power module packages provide higher power density and more reliability. "OEMs will continue to want



modular power solutions, which can be integrated easily into various subsystems and used in many different devices," said Richard Eden, semiconductor senior analyst IHS Technology. "Power modules are widely found in inverters for wind converters, photovoltaic solar energy systems and other renewable energy applications. They are also found in industrial motor drives and hybrid and electric vehicles. Standardized discrete power semiconductors have become commoditized with little differentiation. OEMs and ODMs typically multisource discrete products through distributors. Suppliers will continue to face challenges, when it comes to increasing profit in commodity segments of the power discrete market."

Infineon continued to be the largest supplier for the global power semiconductor market in 2014, with an estimated market share of 13 %. With the acquisition of International Rectifier (IR) by Infineon last year, the market landscape for power semiconductors is changing. The merged companies held almost 27 % of the power transistor market in 2014. The transistor product category includes bipolar transistors, MOSFETs, and IGBTs, accounting for about two thirds of the total discrete power semiconductor market. Mitsubishi ranked second, at 7 %. STMicrosystems moved up to the third market position, displacing Toshiba, with an estimated market share of 6 %.

Mitsubishi Electric was the largest supplier for power modules in 2014, although the company's estimated share of the market remained at 24 % for 2013 and 2014. Infineon maintained the second-ranked position at 20 %. The top four power module suppliers – Mitsubishi, Infineon, Semikron and Fuji Electric – accounted for 65 % of the global power module market in 2014.

www.ihs.com

Yokogawa Offer Accredited Power Calibration Up to 100 kHz

Yokogawa Europe has in October 2015 in Amersfoort/Netherlands introduced the world's first non-governmental ISO17025 accreditated lab for power measurements up to 100 kHz. Only four national institutes so far cover this frequency range. This is in addition to its established capability for providing high-accuracy calibration at 50 Hz, especially at very low power factors (down to 0.0001) and at high currents and its efforts starting in 1991 for internal ISO9001 accreditation.

"Due to more inverterized power systems such as drives or solar inverters, particularly with the growing focus on renewable energy markets and the need to optimize energy efficiency while complying with international standards on power quality, especially at low power factors, there is a growing demand for calibrated power mesurement and test system. In addition, the inverters used in renewable energy systems are switching at higher speeds: a scenario that introduces harmonics at higher frequencies", commented Erik Kroon, Yokogawa's Metrology Expert.

Thus power measurements have to be correct to meet the exacting requirements of modern design. Their power meters need to be calibrated at the frequencies present in their specific application and not just at 50 Hz. However good the calibration result at 50 Hz, it does not say anything about high-frequency performance. Frequency is just one factor being addressed in the calibration of power meters. Whereas in the past it was sufficient to list voltage and current measurements in a power meter's data sheet, today's power environment needs to address variables such as phase shift, power factor and the effects of distorted waveforms – which today are included in the instrument specifications.

Calibration of instruments delivered to customers is done mostly over night in an automated process. The calibration lab itself is located in a temperature/humidity stabilized room, where the master instruments run 24 h/7 d without switching off. Low-current measurements (up to 20 A) are provided via highly accurate (ppm tolerance rage) in-house made shunts, whereas higher currents are measured via in-house made current transducers (high-permeability cores, special winding).

Regarding instruments, in the efficiency validation stage of inverters for instance, the key factors that need to be tested are power analysis, conversion efficiency, harmonics, and in automotive applications perhaps the battery charge and discharge process. For tests of this type, the instrument of choice is the power analyser, offering high precision, high accuracy,

Yokogawa's Metrology Expert Erik Kroon showing high-accuracy shunt in front of master power calibration system

Photo: AS

high stability, and the ability to carry out calibrated measurements. Yokogawa's WT3000E Power Analyzer offers 0.01% of reading + 0.03% of range. It is the enhanced version of the industry standard WT3000. Along with high accuracy it provides a broad bandwidth of DC, and 0.1Hz to 1 MHz. The high measurement accuracy will provide engineers with the test data needed to evaluate power consumption and energy loss more precisely.

In addition to the dedicated instruments, engineers and R&D professionals are also looking for hybrid instruments that can be used at all stages of the development cycle. When the power consumed by the load varies at start-up of a motor, it may be necessary to measure power at much shorter intervals. A specific requirement is the time-based measurement functionality of an oscilloscope combined with the accuracy of a power analyzer. Such precision power scopes offer flexibility, accuracy and wide bandwidth, allowing for drawing the range of power readings needed to optimize the efficiency of boost-circuits and inverters. Yokogawa's PX8000 Power Scope brings transient analysis and high time-based accuracy to electrical power measurements. Its combination of accurate power measurements over precise time intervals is vital for analyzing energy loss and efficiency in high speed switching devices.

In addition to wide-band and high accurate power-meter calibration systems, the state-of-the-art calibration laboratory also includes systems for calibrating oscilloscopes, recorders and optical products, and is therefore capable of calibrating a wide range of instruments in the test & measurement industry. "Future requirements due to even higher switching frequencies of SiC and GaN power stages in solar inverters of power power supplies will be covered step-by-step", Kroon said. More technical details in our feature 'The Need for High-Frequency High-Accuracy Power Measurement'. **AS**

www.tmi.yokogawa.com/ea/

Moving Capacitor Production to China

Knowles announced that the new Capacitor facility in Suzhou, China is fully operational. This completes the relocation of Multilayer Ceramic Capacitor (MLCC) manufacturing from plants in the UK and Mexico.

Located in the Xiangcheng Economic Development Area in Suzhou, the factory has 10,000 m? of floor space. This reflects a significant investment in expanded capacity and provides space to grow the business. The facility makes a broad range of MLCC products including standard, high voltage, high Q and

application specific capacitors, as well as surface mount and feedthrough EMI filters. The Capacitor division of Knowles is the consolidation of Dielectric Laboratories (DLI), Novacap, Syfer Technology and Voltronics into a single organization with a combined history exceeding 175 years. Whilst the production facility is fully 'up and running' the original R & D operations in Norwich and North America continues to make strides in the development of single and multilayer capacitors. Notable achievements over the last decade being 'FlexiCap™', used in safety-critical environments, winning the UK Queens Award for Enterprise and more recently ProtectiCap™ and StackiCap™ product lines. "The completion of our new factory is a great achievement for the Knowles Capacitor business. It is the result of a lot of hard work, a big investment in time and money, and gives us a facility that we can use as a foundation to grow our business", remarked Dave Wightman, President of Knowles Capacitor Division.

www.knowlescapacitors.com

SEMIKRON Awards Power Electronics Engineers

The SEMIKRON Innovation Award and the Young Engineer Award which have been initiated and are donated by the SEMIKRON Foundation are given for outstanding innovations in projects, prototypes, services or novel concepts in the field of power electronics in Europe, combined with notable societal benefits in form of supporting environmental protection and sustainability by improving energy efficiency and conservation of resources. SEMIKRON Foundation is awarding the prizes in cooperation with the European ECPE Network.

With the awards the SEMIKRON Foundation wants to motivate people of all ages and organizations of any legal status to deal with innovations in power electronics, a key technology of the 21th century, in order to improve environmental protection and sustainability by energy efficiency and conservation of resources. The SEMIKRON Innovation (EUR 10.000,00) and Young Engineer Prizes (EUR 3.000,00) will be awarded in the frame of the ECPE Annual Event in March 2016 in Nuremberg. A single person or a team of researchers can be awarded.

The selection procedure for the prize winners is organized in cooperation with ECPE European Center for Power Electronics e.V.. The submitted proposals will be passed to an independent and neutral evaluation committee of experts for discussion and assessment. To apply for the SEMIKRON Awards own applications as well as proposals from third parties are welcomed.

Deadline for submission is 10.01.2016. The receipt of proposals will be confirmed by email.

Proposals resp. applications with the reference SEMIKRON Innovation Award should be sent by email to Thomas Harder, General Manager of ECPE e.V., thomas.harder@ecpe.org.

Field Lifetime Estimation of Power Modules using Active Power Cycling

The design of power electronics modules and power packages is heavily influenced by thermal concerns. New substrate materials, thinner and thermally more conductive attachment materials are used to decrease the thermal resistance of a given module. When a new material or technology is applied, its reliability has to be tested thoroughly before the module can be considered for production.

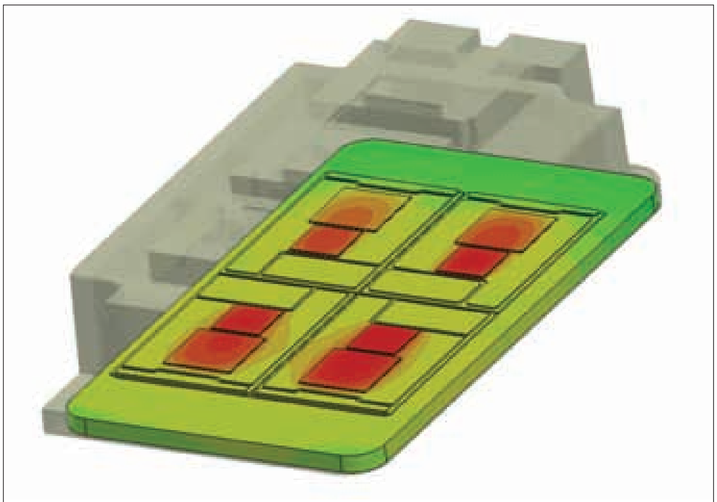
The two commonly used lifetime tests for power modules are Temperature Cycling and Active Power Cycling. Both test methods introduce a thermal load by periodically changing the device temperature, but are fundamentally different.

Accelerated testing strategies

In Temperature Cycling the device is unpowered. Temperature change is achieved by placing the part in a thermostatically-controlled environment such as an oven, which both heats and cools the part. Hence the heating is externally applied. The heating and cooling rates are relatively slow, of the order of several minutes, so the temperature within the part remains fairly uniform as it heats and cools. Temperature Cycling is mainly used to evaluate solder joints between the Direct Bonded Copper (DBC) substrate and the module's baseplate.

By contrast, in Active Power Cycling the part is heated internally, by passing current through the semiconductor device, thereby using it as a dissipating element. Heat is dissipated at the same location heat is dissipated during normal operation, resulting in a temperature distribution within the part that is similar to the application. As the heating is localized, significant temperature gradients result. These can be controlled by changing the rate of heating by changing the supplied current.

By using a low current and long heating and cooling times, Active Power Cycling can also be used to heat the solder joints between the DBC and module baseplate. Normally, Active Power Cycling uses shorter cycle times with heating times of just a few seconds. High currents are used to elevate the chip junction temperature in order to stress the bond wires and die attach solder joint. Hence the long term reliability of a package can be comprehensively investigated using Active Power Cycling. As temperature variations within the thermal structure trigger the various types of degradation, the effect on electrical parameters such as collector-emitter (drain-source) voltage drop or gate leakage current can be observed at each cycle. Degradation in the thermal stack can also be monitored by performing transient thermal testing periodically. The combination of the two allows to fully assess the evolution of the various interrelated damage mechanisms within a module.

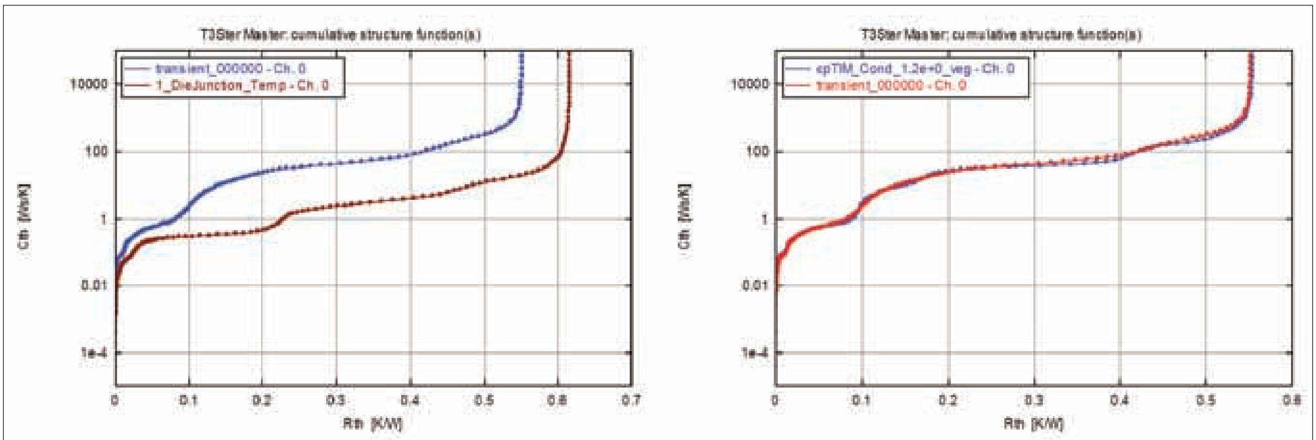


Detailed Thermal Model of IGBT in Mentor's FloTHERM XT

Determining the thermal load

The most frequent cause of failure of a power module is the cracking or delamination of different layers due to the thermally-induced stresses that arise from periodic cycling. The magnitude of the thermal stress is proportional to the temperature change induced by the power dissipated by the semiconductor devices. Consequently the next step is to turn the P(t) mission profile into a temperature vs. time function. As the dissipation is not constant, but rather a complex time function, the temperature function cannot be analytically calculated either. Most modern 3D thermal simulators can do transient simulations, and there are some that can handle arbitrary dissipation profiles as well. Even in case of quite complex package structures a detailed 3D model can be built.

Before the simulation model can be used to support reliability studies it needs to be calibrated so the transient behavior exactly matches with experimental results. The importance of accurate



Structure Functions for IGBT before and after model calibration

control of parameters affecting the lifetime during the experiment should not be underestimated. In tests on identical IGBT samples the junction temperature change was increased from 110°C to 120°C (a 9 % increase), the lifetime was shortened from ~57500 cycles to ~39000 cycles (a ~37% decrease).

As the lifetime is highly dependent on the junction temperature swing, it follows that the simulation model must be able to predict the junction temperature swing resulting from the load profile P(t) with high accuracy if it is to be used for lifetime prediction. A significant challenge when building high-fidelity thermal models of chip packages is ensuring that the models incorporate the correct thermal properties for the materials of construction and thicknesses of bond lines and soldered interfaces, such as the die attach layer. As a result, the simulated thermal response to a power step will be different to that observed in practice.

Precise calibration of the model requires highly accurate test data, having a high resolution in both temperature and time, makes it possible to convert the temperature time response into a Structure Function, showing the cumulative thermal capacitance vs resistance along the heat flow path.

A comparison shows the thermal response of an IGBT modeled in FloTHERM with the physical part measured with Mentor Graphics' T3Ster thermal characterization hardware (see also "1500 A Power Tester", PEE 4/2014, pages 22 – 24), T3Ster, as the model is initially set up (left) and after calibration (right). It is important that all parts of the curves match with high accuracy to ensure that all time constants along the heat flow path within the package are correct, ensuring the correct temperature rise is predicted irrespective of the length of the applied heat pulse.

Developing failure models

There are number of models that take into account many more parameters, but the base of all these models is the well-known Arrhenius model that was primarily elaborated to describe chemical reaction rates:

$$N_f = e^{\left(\frac{E_a}{k_b \cdot T}\right)} \quad (1)$$

where Ea is the activation energy, kb is the Boltzmann constant, and T is the absolute temperature. This equation only takes into account the mean temperature. In order to take into account the empirical fact that the larger the temperature swing is, the shorter the lifetime will be, a ΔT_j term can be added yielding the thermo-mechanical stress model:

$$N_f(\Delta T) = A \cdot (\Delta T_j)^{\alpha} \cdot e^{\left(\frac{E_a}{k_b \cdot T}\right)} \quad (2)$$

where ΔT_j is the junction temperature change, and A and α are coefficients that are calculated using curve fitting.

Despite the fact that this model can give a fair approximation to the failure rate, it is also known that the cycle time also affects the lifetime. The same junction temperature change can be achieved either with a short high-power heating pulse, or a longer lower power heating pulse, but the choice influences the lifetime. If the heating power is high, some features in the package do not have enough time to heat up during this short time. Shorter heating pulses primarily stress the chip itself, the die-attach and the wire bonds. If the heating power is lower, requiring a longer heating time to achieve the same temperature change, the heat can spread further down into the DBC substrate and base plate, so the change in the temperature distribution within the package is quite different, despite both producing the same junction temperature swing. Longer pulses therefore stress solder

layers further way from the junction. To account for this, a further term, f_β is added to the above formula resulting in the Norris-Landzberg model

$$N_f(\Delta T) = A \cdot f^{\beta} \cdot (\Delta T_j)^{\alpha} \cdot e^{\left(\frac{E_a}{k_b \cdot T}\right)} \quad (3)$$

where f is the cycle time and β is another coefficient calculated using curve fitting. A similar model is reported to be used by some companies manufacturing power modules, e.g. in one of their application notes, Infineon (Application Note AN 2010-02, 2010) published a calculation in which they are using a similar expression for lifetime modeling, with the slight difference being that they take into account only the heating time rather than the whole cycle period. There are also more complex models available in the literature, that take into account even more parameters (e.g. electrical load conditions: current and voltage), however those cannot increase the accuracy of the prediction, because these parameters are not regulated in the same way during operation as they can be during reliability testing.

In the previous section it was shown how the lifetime of a device can be modeled based on the experimental power cycling results, but the resulting Nf lifetime only predicts the device lifetime at a certain constant load (at which it was calculated).

To calculate the expected total lifetime of the device, taking account of the variable load caused by the selected mission profile, the overall effect of the different load conditions has to be estimated. A commonly-used equation to sum the aging effects from different loads that arise in parallel is the following

$$N_{f\_sum} = \frac{1}{\sum_{k=1}^{n} w_i \frac{1}{N_{f\_i}}} \quad (4)$$

where N_{f_sum} is the number of times the load corresponding to the mission profile can be applied to the device until it is expected to fail, and the wi are the weight factors calculated from the histogram.

Finally, if this aggregated cycle number N_{f_sum} by the duration of the mission profile is multiplied, the operation lifetime can be calculated

$$t_{operation} = N_{f\_sum} \times t_{cycle} \quad (5)$$

Conclusion

Mission profile based power module design is becoming the state-of-the-art design method in the power electronics industry. To get an accurate prediction of the lifetime of a thermal system, a number of parameters have to be known, such as the mission profile, the mechanical properties of the system and the reliability characteristics of the power modules used. The accurate definition of these parameters, combined with calibration of the thermal model, allows the proper calculation of the temperature changes in the power device's junction using numerical methods. This information can then be combined with the data in the lifetime curves to give a fair lifetime prediction. Predicting the lifetime of a system based on a given mission profile may give power module designers greater confidence in their time-to-failure estimates, supporting new product introductions, and cost reduction efforts efforts, and opening up new applications and cooling solutions (see also 'Reliability of IGBT Modules Tested' in PEE 2/2015).

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Contest for Highest Power Density and Efficiency

The Little Box Challenge is a design contest presented by Google and the IEEE Power Electronics Society to spur innovation in power inverter design with the highest power density (at least 50 Watts per cubic inch) with a $1,000,000 prize. The inverter must demonstrate an efficiency of >95 percent.

In parallel with the Little Box Challenge, Google Research is soliciting proposals for groundbreaking research in the area of increasing the power density for DC/AC power conversion. This funding opportunity is available only to academics who are full time faculty at degree granting Universities. It is envisioned that award recipients could use their grant funding to assist in building a device that could win the competition. Applying for or receiving an award will not affect an entrant's chances of winning the grand prize.

Why little box?

Google believes that inverters will become increasingly important to economy and environment as solar PV, batteries, and similar power sources continue their rapid growth. More broadly, similar forms of power electronics are everywhere: in laptops, phones, motors drives, electric vehicles, wind turbines, to give just a few examples. The innovations inspired by this prize will have wide applicability across these areas, increasing efficiency, driving down costs, and opening up new uses cases that we can't imagine today. It also doesn't hurt that many of these improvements could make data centers run more safely and efficiently.

Up to 18 finalists will be notified of their selection for final testing at the testing facility. They are required to bring their inverters in person to a testing facility in United States by October 21, 2015. The grand prize winner will be announced sometime in January, 2016.

Google and the IEEE Power Electronics Society have announced that the National Renewable Energy Laboratory (NREL) in Golden, Colorado, USA will be the testing facility for the competition. Up to 18 finalist teams will be invited to bring their inverters for extended testing (up to approximately 100 hours) at NREL's Energy Systems Integration Facility (ESIF) using state of the art equipment and supervised by world-class technical staff. The results will help ensure that the best entry wins. Over 100 teams submitted a Technical Approach and Testing Applications to have their inverters tested. The 18 finalists are !verter (Germany/Switzerland), Adiabatic Logic (UK), AHED (Germany), AMR (Argentina), Cambridge Active Magnetics (UK), Energylayer (Ukraine), Fraunhofer IISB (Germany), Future Energy Electronics Center (USA), Helios (USA), LBC1 (Slovakia), OKE-Services (Netherlands), Red Electrical Devils (Belgium), Rompower (USA/Romania), Schneider Electric Team (France), The University of Tennessee (USA), Tommasi – Bailly (France), UIUC Pilawa Group (USA), and Venderbosch (Netherlands). Thus European teams are very well represented.

One promising set of new technologies which may allow for the achievement of higher power densities are wide bandgap (WBG) semiconductors, such as Gallium Nitride (GaN) and Silicon Carbide (SiC). The list of WBG device manufacturers who have made pages describing their technology, how it might enable contestants to win the competition and opportunities for obtaining some of their devices contains EPC, GaN Systems, GeneSiC, Infineon, Monolith Semiconductors, NXP, ROHM, ST, Transphorm, USCi, and Wolfspeed (formerly Cree).

Inverter specifications

The inverter must be contained within a rectangular metal enclosure with a volume of less than 40 in^3. Each face of the enclosure should be flat, since any bulging on a face will result in an increased assessment of the relevant dimension of height width or depth. The maximum dimension may not exceed 20 inches and the minimum dimension may not be less than 0.5 inches.

The inverter will be tested using a near ideal voltage supply set at 450 V. This power supply will be floating. Its positive terminal will be connected to a 10 Ω wire wound resistor which in turn will be connected to the positive DC input terminal of the inverter. The voltage source will be very close to ripple free. The voltage output must be 240 V RMS single phase AC, within a +/ 12 V band. After a transient change in the load the voltage should return to within acceptable bands in 1 second or less and not leave the band again until the next load change. The voltage will be measured at the output of the inverter to ensure it remains within acceptable bands. Unintentional DC voltage must not be more than 1.2 V present between the 2 AC terminals. The frequency output must be 60 Hz single phase AC, within a band between 59.7 to 60.3 Hz.

The amount of heat generated by the system will decrease as the efficiency of the system increases, but even at the required efficiency of >95 % at full load a 2 kVA inverter can generate up to 100 W of heat which must be dissipated in order to prevent an unacceptable temperature rise. The higher the power density of the inverter, the less surface area is available for this heat to be dissipated across. The local thermal management requirements in the system may be relaxed by using devices (e.g. wide bandgap semiconductors) that can operate reliably at elevated temperatures. New passive or active thermal management approaches may be used to manage the heat that does get generated and distribute it evenly across the surface area of the enclosure to avoid the presence of hot spots above 60°C. The technical approach document must describe what innovations in thermal management are being used to achieve the required specifications at these high power densities.

The inverter will be tested under dynamic load conditions. The load will be provided by an electronic load bank which can switch in and out a series of linear, resistive, inductive and capacitive loads in parallel in small (< 50 VA) increments. The maximum load will be 2 kVA. The power factors will vary between 0.7 and 1, leading and lagging. The load change profile will be similar to that seen in a residential setting, although only using linear loads.

The load can vary between 0 and 2 kVA with individual load jumps as high as 500 VA. AS

www.littleboxchallenge.com

Parameter	Value *(Template Example Only!)*
Grounding Configuration	240 V to ground
Maximum load tested	2.06 kVA / 28 Ω
Volume of the rectangular enclosure	35 in³
Dimensions of rectangular enclosure	7 inch x 5 inch x 1 inch
Resulting power density at 2 kW load	57.1 W/in³
DC voltage (RMS) input	395.8 V
DC current (RMS) input	5.4 A
AC voltage (RMS) output	240.2 V
AC current (RMS) output	8.6 A
DC to AC efficiency (CEC Method)	95.5%
Voltage total harmonic distortion + noise	4.4 %
Current total harmonic distortion + noise	4.4 %
Input ripple current	16.1%
Input ripple voltage	2.2%
Max Temperature of Enclosure	56°C
Ambient Temperature of Test	28°C

Testing application - LBS technical specification sheet

Silicon Carbide Components Enable Efficiency of 98.7 Percent

Researchers at the Fraunhofer Institute for Solar Energy Systems ISE have developed a highly compact and efficient inverter for use in uninterruptible power supplies (UPS) for electrical devices. The demonstrator, which contains innovative silicon carbide components, was developed in cooperation with an industry partner and achieved an efficiency of 98.7 %. The research and development findings can be applied to other areas of electronic power conversion in which weight and efficiency play a key role, e. g. electric mobility or portable power supply.

UPS inverters ensure that electrical devices continue to be supplied with power during disruptions to the power grid. In combination with a battery, they allow electrical power outages of varying lengths to be bypassed. For particularly critical loads, such as computer centers, online UPSs offer the highest protection as they are connected between the grid and the load and are thus able to compensate for any disruptions stemming from the grid. This does mean, however, that all energy is transferred via the UPS inverter even during periods of disruption-free operation. Efficiency therefore plays a very important role for this application, as it is closely connected with the costs required to operate the UPS. This context provided the starting point for the Fraunhofer ISE project, which has now been successfully completed.

Compact and highly efficient

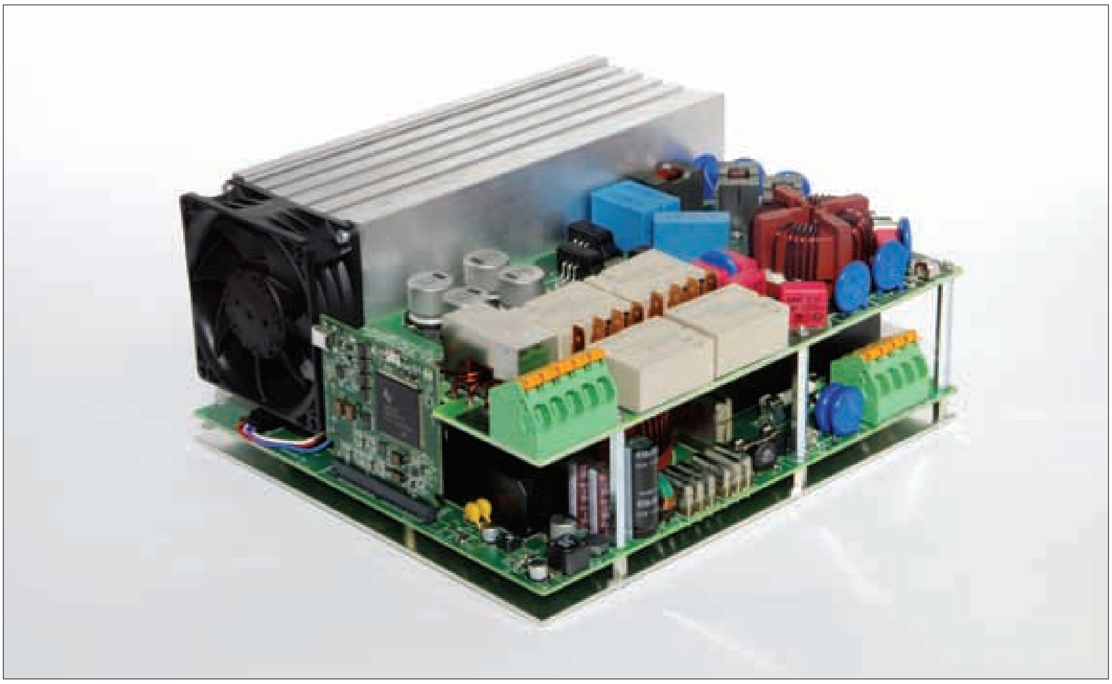
Using silicon carbide (SiC) transistors, scientists were able to showcase a UPS inverter with an output of 10 kW and a volume of just five liters. Despite its highly compact design, the inverter still achieved a very high efficiency. The good dynamic and static properties of the SiC transistors, such as on-state resistance and switching loss, permit a switching frequency of 100 kHz. This is around five times higher than that of conventional power electronic Silicon components, yet does not significantly increase losses in the semiconductors. Thanks to the high switching frequency, the passive elements in the system, such as inductors and capacitors, could also be reduced in size, while the low losses in the semiconductors permitted the implementation of a compact cooling system for the transistors. "On the whole, this design saves system-related costs and materials. In comparison to using a conventional switching rate of 16 kHz, we were able to reduce the size and price of the main inductance in our UPS inverter by around two thirds," says Cornelius Armbruster, development engineer at ISE.

For applications in online UPS systems, efficiency is even more important than reducing materials, as it not only compensates short-term voltage dips in the grid, but also ensures that electrical devices are continuously supplied with power via the UPS. The annual energy demand of a small server room with a typical capacity utilization amounting to half of the rated power of the UPS system is around 44,000 kWh. Depending on the efficiency of the UPS inverter, the energy demand increases to cover the losses that occur in the inverter, thus explaining the considerable impact that UPS inverter efficiency has on operating costs in the form of electricity costs. In comparison to a conventional system with an efficiency of around 97.4 %, the newly developed demonstrator (98.7 %) can reduce annual costs by around 40 %.

Material with prospects

The Fraunhofer Institute for Solar Energy Systems ISE has been researching and developing highly efficient power electronics for renewable energy systems and the application of the latest components made from Gallium Nitride and Silicon Carbide. The technology demonstrator showcased, which was commissioned by ROHM Semiconductor, once again highlights the potential of these semiconductor materials. The SiC transistors used in the demonstrator were provided by ROHM Semiconductor. "Thanks to this semiconductor material, transistors will be available for even higher currents in the future, allowing systems to achieve considerably higher output powers", Armbruster stated.

www.ise.fraunhofer.de/en



Fraunhofer ISE developed a three-phase 10 kW UPS inverter with a volume of just five liters and an efficiency of 98.7 percent

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- Top-view camera
- Infotainment head unit
- Smart sensors

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Cross Switch XS - Silicon and Silicon Carbide Hybrid

Due to the inherent advantages of wide bandgap (WBG) semiconductor materials such as Silicon Carbide (SiC) and Gallium Nitride (GaN), WBG based power devices are fabricated on much thinner and higher doped n-base regions when compared to silicon. Therefore, in principle they can provide a wide range of voltage ratings with improved electrical performance in terms of low conduction losses, very low switching losses and low leakage currents making them suitable for applications targeting lower losses and higher operational frequencies and temperatures. **Munaf Rahimo, Charalampos Papadopoulos, Francisco Canales, Renato Amaral Minamisawa, Umamaheswara Vemulapati, ABB Semiconductors Lenzburg, Switzerland**

For high power applications in particular, SiC based power devices are the preferred choice today for exhibiting relatively high current ratings due to the vertical structure such devices are based on. Whereas Silicon based unipolar power devices such as MOSFETs and Schottky Barrier Diodes (SBD) do not exceed 1200 V with respect to the voltage blocking capability, unipolar SiC devices on the other hand can extend this range to well beyond 6.5 kV.

In this particular voltage range, the SiC MOSFET and SBD are destined to compete with today`s popular Si IGBT and diode solutions for a wide range of power electronics circuits. In addition to the above-mentioned advantages, SiC MOSFET also provides very low losses at low currents compared to the Silicon IGBT having an inherent pn-junction barrier potential of around 0.7 V. Therefore, for many applications where losses are taken into account for the full current range (i. e. sub-load conditions), the SiC MOSFET becomes an attractive prospect. Nevertheless, many challenges need to be overcome for permitting the widespread employment of SiC based devices in mainstream power electronics systems. One major obstacle is the significantly higher cost associated with SiC devices, in particular due to starting substrate material manufacturing cost and expensive epitaxial growth processing especially for higher voltage devices with thick n-base regions.

High performance at lower cost

To reduce cost, the utilization of less SiC device area is one approach but at the expense of higher thermal resistances and higher conduction losses. In relation, high voltage SiC unipolar devices display a strong positive temperature coefficient of the $R_{ds(on)}$ during current conduction which results in higher losses at higher temperatures. Furthermore, on the device performance front, unipolar SiC devices suffer from oscillatory behavior during switching transients due to the absence of excess carriers which normally provide bipolar devices with a slow declining current tail during turn-off for achieving softer characteristics. Finally, unipolar SiC devices provide less fault current handling capability such as short circuit withstand capability for MOSFETs and surge current handling capability for SBDs compared to bipolar devices. To resolve some of the above hindering issues for SiC technologies, while at the same time benefiting from the advantages of the well proven Silicon based devices, we demonstrate here a Cross Switch "XS" hybrid solution consisting of a parallel combination of a Si IGBT and SiC MOSFET. The cross sections of the two structures are shown in Figure 1 along with the described parallel combination.

In practice, hybrid arrangements of different power semiconductor device structures target optimized performance by providing the combined advantages of the diverse device properties for a given application. With reference to Si and SiC devices, a popular hybrid combination utilizing a SiC SBD as the anti-parallel diode for a Si IGBT has been widely investigated and is currently employed in some applications for achieving lower reverse recovery and turn-on losses when compared to employing the standard Silicon bipolar fast recovery diode. Hybrid concept combining a Si IGBT and a Si MOSFET have also been investigated in the lower voltage range <600 V in line with Si MOSFET performance capabilities. This approach combines the advantages of both devices

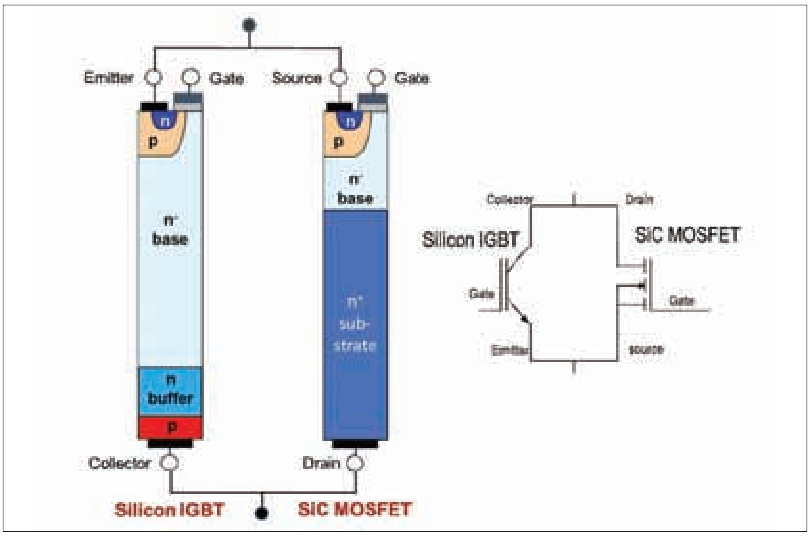


Figure 1: Si IGBT and SiC MOSFET structures for the hybrid Cross Switch

with low conduction losses for the IGBT and low switching losses for the MOSFET. Building on this trend and for a wider voltage and current range by employing SiC MOSFETs, the basic hybrid combination of an IGBT and MOSFET provides a potential solution to obtain overall improvements at lower cost for a given application requirement.

Hybrid 1200 V demonstration

The Cross Switch "XS" combines a Si IGBT and a SiC MOSFET in parallel. The main targets of such a combination are to provide low static and dynamic losses while improving the overall electrical and thermal properties due to the advantageous features both devices can offer in many power electronics applications. To investigate and validate the above concept, XS hybrid test samples were manufactured consisting of a single 1200 V/25 A Si Soft Punch Through (SPT) IGBT (6.5 mm x 6.5 mm) in parallel to a 1200 V/30 A SiC MOSFET (4.1 mm x 4.1 mm) with an $R_{ds(on)}$ of 80 mΩ on a single test substrate. The active area ratio of the IGBT to the MOSFET was close to 3:1. The assumed nominal current rating of the combined XS hybrid was set at 50A.

Both gates are connected and controlled by the same single gate unit. For comparison, reference samples were also made with one consisting of two paralleled Si SPT IGBTs and the other having two paralleled SiC MOSFETs to provide the same 50A rating per test sample. The same gate voltage signal was also applied for all chips in parallel. Furthermore, to analyze the behavior of the XS hybrid, test samples containing a single Si SPT IGBT and others containing a single SiC MOSFET were also fabricated. For the static parameters, Figure 2 shows the IV transfer curves at 25°C and output characteristics at 150°C for the XS hybrid. Curves for the single Si IGBT and SiC MOSFET are also depicted to show that the XS hybrid is a combination of both device characteristics.

For the same 50A current rating, the IV output characteristics at 150°C comparing XS hybrid to the 2 x Si SPT IGBT and 2 x SiC MOSFET samples are provided in Figure 3 which also shows the same IV output characteristics but only up to 10 % of the nominal current. It is shown that the parallel combination offers the possibility to provide IGBT characteristics at high currents while still maintaining low losses at very low currents as for a MOSFET. This particular feature has always been a major hurdle for bipolar devices and thus such a combination offers an important advantage in power device performance. In addition, the XS hybrid offers improved thermal resistance due to the large Si IGBT area. More reductions in MOSFET Rds(on) values will further lower the XS hybrid conduction losses when compared to the full Si IGBT. The switching characteristics were measured using a double pulse clamped inductive test circuit having a stray inductance value of 60 nH. A SiC SBD diode rated at 1200 V and 50 A was employed as the freewheeling diode. Figure 4 shows the turn-off performance of the XS hybrid compared to the 2 x Si SPT IGBT and 2 x SiC MOSFET samples under

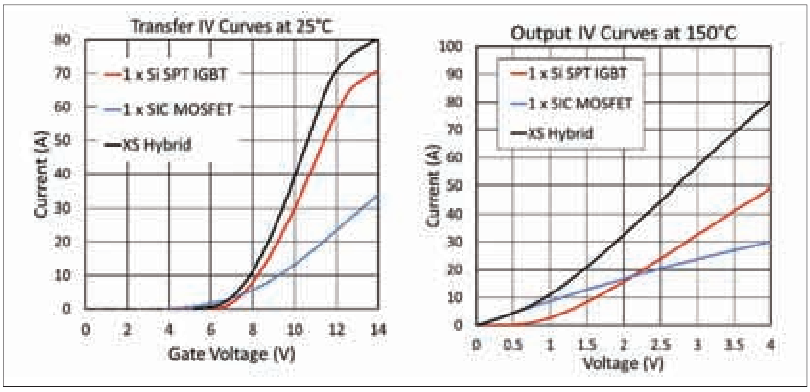


Figure 2: IV transfer characteristics at 25°C (left) and IV output characteristics at 150°C comparing the XS hybrid to a single Si SPT IGBT and a single SiC MOSFETs

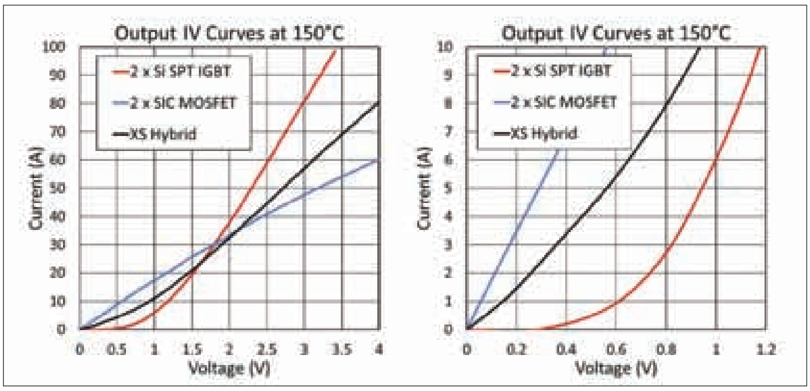


Figure 3: IV output characteristics at 150°C (left) comparing the XS hybrid to 2 x Si SPT IGBTs and 2 x SiC MOSFETs up to twice and 10% of nominal current

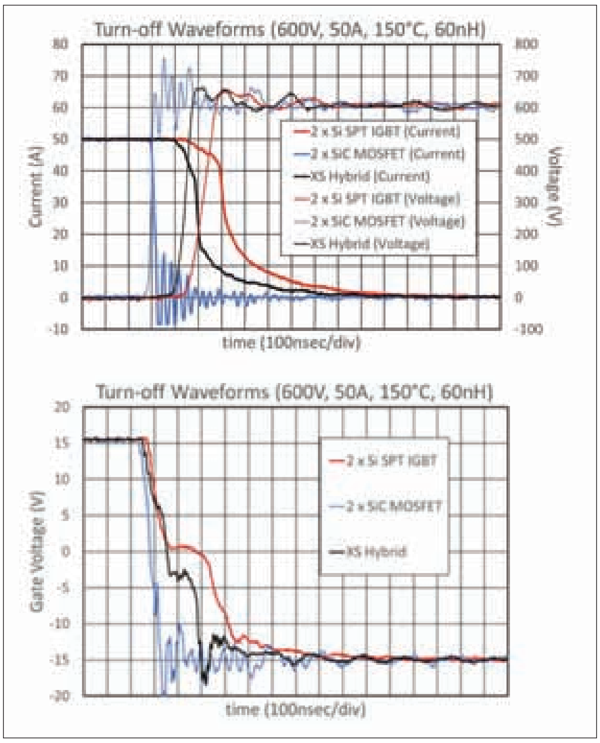


Figure 4: Turn-off switching waveforms comparing the XS hybrid to 2 x Si SPT IGBTs and 2 x SiC MOSFETs at 50 A, 600 V, 150°C

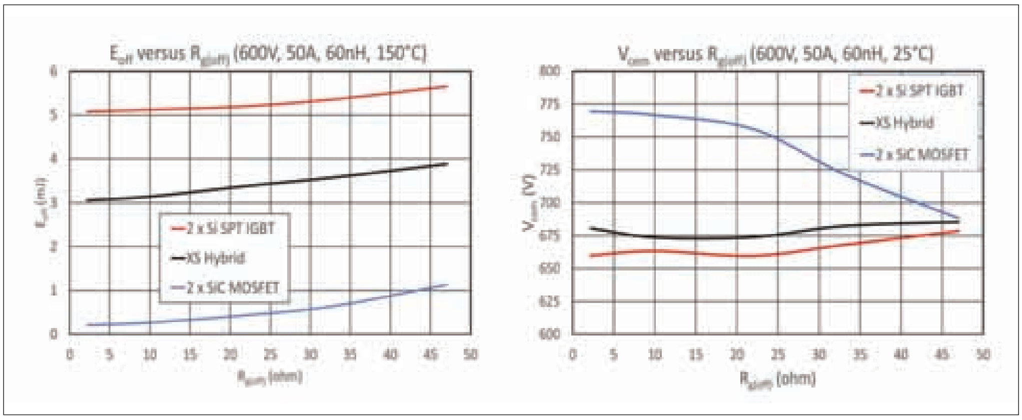


Figure 5: E_{off} at 150°C (left) and V_{cem} at 25°C as a function of R_{goff} comparing the XS hybrid to 2 x Si SPT IGBTs and 2 x SiC MOSFETs at 50 A/600 V

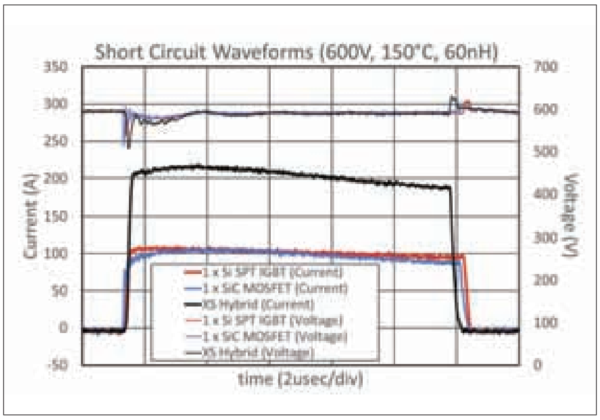


Figure 6: Short Circuit switching waveforms for the XS hybrid, a single Si SPT IGBT and a single SiC MOSFETs at 600 V and 150°C

nominal conditions and with an $R_{g(off)}$ of 10 Ω at 150°C.

Under such switching conditions, the XS hybrid provides again a combination of the two device distinctive turn-off characteristics. The switching event is initiated with the SiC MOSFET turning off at an earlier time compared to the Si IGBT. The XS hybrid is therefore displaying a switching behavior corresponding to both device behavior patterns while clearly exhibiting a soft current tail due to the remaining excess charge in the IGBT. The softness of the XS hybrid is also confirmed with a low overshoot voltage when compared to the SiC MOSFET. In general, SiC MOSFETs are normally slowed down by increasing the gate resistor $R_{g(off)}$ to reduce the EMI and overshoot voltages especially at high currents. Therefore, the turn-off softness will improve in the XS hybrid by providing a current tail during turn-off and the possibility to employ the concept in high voltage and high current modules with a moderate stray inductance. To gain further understanding, the turn-off switching losses and softness dependence on the turn-off gate resistor $R_{g(off)}$ was further investigated.

Figure 5 shows such dependency for the turn-off losses Eoff at 150°C and maximum overshoot voltage V_{cem} at 25°C. Over the full $R_{g(off)}$ range, the XS hybrid offers 40 % lower Eoff compared to the Si IGBT reference sample and softer performance than the SiC MOSFET. By comparing the Eoff when achieving similar overshoot voltages, the XS hybrid shows approximately 3 mJ compared to 5 mJ for the full Si IGBT at an $R_{g(off)}$ of 2.2 Ω, and 1 mJ for the full SiC MOSFET at an $R_{g(off)}$ of 47 Ω.

The turn-on losses E_{on} of the XS hybrid under nominal conditions and $R_{g(on)}$ of 22 Ω at 150°C was measured at 2.8 mJ. The turn-on measurements for the different samples including the full Si IGBT and full SiC MOSFET show that the losses are not influenced by the switch type but mainly dependent on the SiC SBD characteristic and switching conditions. Finally, the short circuit performance of the XS hybrid was verified at a DC voltage of 600 V and a gate voltage of 15 V at 150°C. Figure 6 shows the short circuit waveforms of the XS hybrid while also providing the short circuit waveforms of the single Si SPT IGBT and single SiC MOSFET. As expected, the total short circuit current of the XS hybrid is the sum of the short circuit current of both paralleled device. The test was repeated successfully with increased gate voltages up to 19 V.

Compared to previous work on Silicon based IGBT/MOSFET hybrids, the XS Hybrid concept enables a very high voltage rating up to 6.5 kV and potentially beyond. Future work will focus on a more advanced high voltage XS Hybrid combining in parallel a Silicon Reverse Conducting RC-IGBT or BIGT and a SiC MOSFET to provide the XS Hybrid with Bimode operation with integrated diode functionalities while eliminating the need for an external freewheeling diode.

Conclusion

The above demonstrations provide an initial insight into the XS hybrid concept and validate the potential of such a combination for future power electronics applications. Results confirm that in addition to the potential lower cost, the main expected advantages of the XS hybrid combinations are (a) low conduction losses over the full current range, (b) low switching losses, (c) low thermal resistance, (d) soft turn-off performance, (e) high switching robustness and (f) improved fault current protection in short circuit and surge current capability. The XS hybrid also provides a conceivable path for further optimization for a given targeted power electronics application at the required operational frequency.

Efficiency Revolution in Auxiliary and Standby Power Supplies

The new InnoSwitch TM-EP family of ICs simplify the development and manufacturing of low-voltage, high-current power supplies, particularly those in compact enclosures or with high efficiency requirements. Its architecture is revolutionary in that the devices incorporate both primary and secondary controllers, with sense elements and a safety-rated feedback mechanism into a single IC. It combines a high-voltage power MOSFET along with both primary-side and secondary-side controllers in one device. A novel inductive coupling feedback scheme using the package leadframe and bond wires o provide accurate direct sensing of the output voltage and output current on the secondary to communicate information to the primary IC.

Silvestro Fimiani, Senior Product Marketing Manager, Power Integrations, San Jose, USA

Usually, different methods for solving similar problems arise because a designer is trying to optimize one particular characteristic – size, efficiency, cost etc. However, an optimized performance in one aspect of a specification often leads to a compromise somewhere else. This is especially true in power supply design. When we look at the available switching power topologies there are many types that have evolved to suit specific requirements Nonetheless, true break-through developments occur from time-to-time when designers develop a new idea that radically changes the traditional balance of engineering trade-offs.

This is perhaps why the word 'revolutionary' has been used to describe a new series of switcher ICs launched last year. The new devices combine primary and secondary switcher circuitry, reducing component count and eliminating optocouplers. In addition to benefits over traditional opto-based topologies, the new ICs outperform primary-side controllers in efficiency at full-load and standby power and in transient load response. The first devices – named InnoSwitch-CH™ - targeted smart mobile devices; now the company has introduced InnoSwitch-EP™ ICs (Figure 1) designed to bring the same benefits to higher power applications.

Figure 1: InnoSwitch-EP™ CV/CC flyback switching ICs

New power IC topology

These new CV/CC flyback switching ICs feature an integrated 725 V MOSFET, synchronous rectification and precise secondary-side feedback sensing controller. InnoSwitch parts employ a proprietary high speed magneto-inductive communication – termed FluxLink™ – incorporated in the device package which creates a magnetic coupling between the primary and secondary side. No integrated magnetic core is required and the bill-of-materials for the manufacture of the IC package remains the same. FluxLink technology provides very accurate control of the switching function, enabling synchronous rectification techniques to be employed, delivering high efficiency without complex control circuitry (Figure 2).

Replacing the traditional Schottky diode with a MOSFET is the basis of synchronous rectification. MOSFETs have a very low on-resistance ($R_{DS(ON)}$), so the voltage drop across the transistor is much lower than for diodes, resulting in a significant increase in efficiency. However, moving to synchronous rectification is not straightforward. Control circuitry is required to correctly phase the drive for the transistor on the primary side with that of the transistor on the secondary side. This control circuit must ensure that current only flows through one of the transistors at any given time.

To prevent overlap in the switching of the primary (flyback) and synchronous rectification MOSFETs which would result in highly destructive cross conduction, controllers typically introduce a delay between the turn off of one transistor and the turn on of the other. This 'dead-time' must be sufficient to account for the variable propagation delays associated with

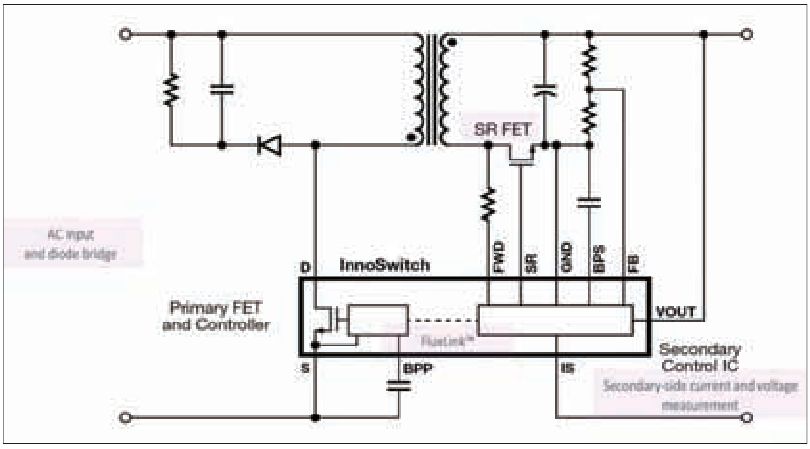


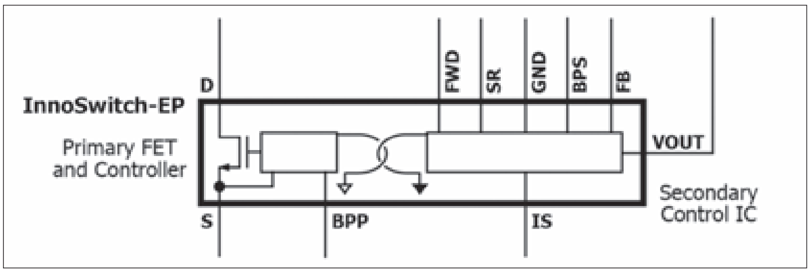
Figure 2: **High-speed magneto-inductive communication FluxLink**

the circuitry necessary to drive transistors on opposite sides of an isolation barrier. Integration of key switching elements (controller, MOSFETs and drivers) reduces this uncertainty and allows the dead-time to be reduced with a corresponding increase in efficiency.

MOSFETS contain an integral body diode and in the synchronous rectification MOSFET will conduct during the dead-time. The body diode has a slow turn-off characteristic and significant forward voltage-drop leading to a 1 to 2 % drop in efficiency. A Schottky diode placed in parallel with the body diode of the synchronous rectification MOSFET prevents the body diode from conducting and reduces the loss in efficiency.

So although synchronous rectification has advantages, it can be difficult to implement because the timing of the MOSFET's switching is challenging. The ideal approach is to control the primary-side switch from the secondary-side of the power supply. This avoids the need to predict of the state of either MOSFET allowing greatly reduced dead-time whilst ensuring that the two MOSFETs are never simultaneously in the on-state.

However, until recently, synchronous rectification required a complex and expensive circuit often involving multiple pulse transformers, limiting the utility of synchronous rectification in compact and/or high-reliability applications. FluxLink technology (Figure 3) within InnoSwitch ICs eliminates the need for this extra circuitry. Accurate feedback is provided and precise control made possible, so that circuits are neither too conservative - which would adversely affect efficiency - nor too aggressive which would risk the damaging effects of shoot-through. InnoSwitch ICs sit across the isolation barrier utilizing what would otherwise be dead-space on the PCB.

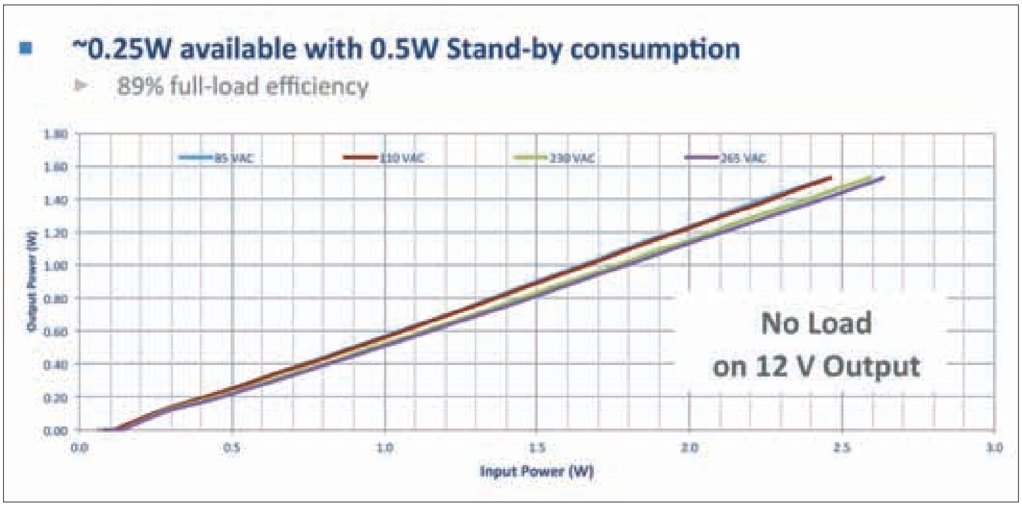


ABOVE Figure 3: **FluxLink technology provides accurate feedback enabling precise control**

Typical applications

The first application for InnoSwitch ICs was increasingly power-hungry smart mobile devices, but auxiliary and standby power in appliances, HVAC, consumer electronics, computing, telecom and data communication applications would also gain substantial benefits from increased efficiency across the load range. InnoSwitch-EP ICs are an answer to engineers looking to address increasingly demanding Total Energy Consumption (TEC) regulations from bodies such as ENERGY STAR® and ErP with an easy-to-implement solution that improves power supply efficiency from standby to full load. For example, InnoSwitch-EP ICs enable a 20 W power supply to achieve 90 % efficiency in a multi-output design, while reducing no load consumption to less than 30 mW. Voltage regulation across line is highly accurate at +/-5 % with tightly controlled over-current protection also provided (Figure 4).

As well as efficiency, InnoSwitch-EP CV/CC flyback switching ICs also deliver excellent multi-output cross-regulation without requiring linear regulators, and provide full line protection and instantaneous transient response. With appliances becoming increasingly sophisticated and correspondingly high cost items, reliability is crucial, especially for brands that promise long life and uninterrupted service by offering lifetime guarantees. Multi-output regulation is also an important consideration for appliance designers who deal with multiple functions that need power – clocks, motors, displays, microprocessors etc. Some functions require very tight voltage tolerances and to meet this engineers have previously used



RIGHT Figure 4: **High efficiency at light loads**

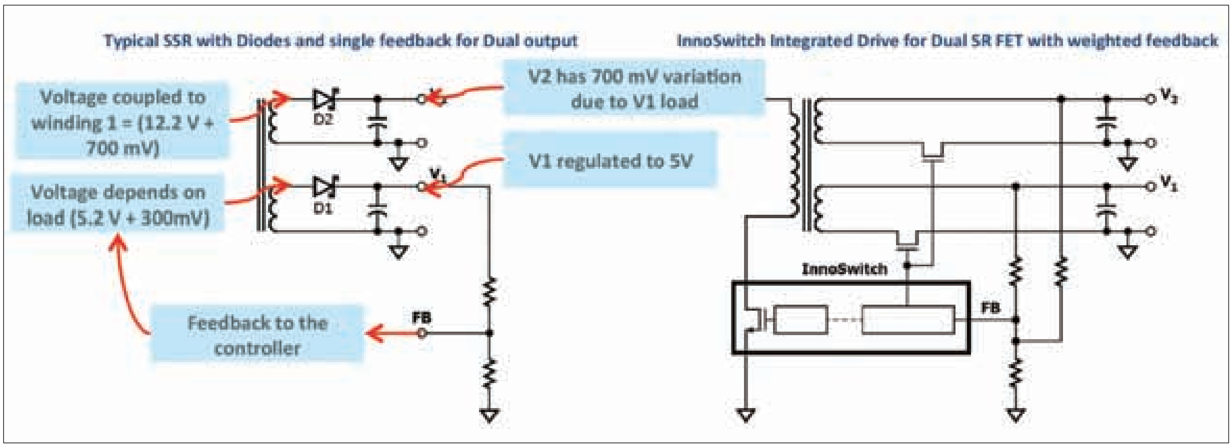


Figure 5: InnoSwitch-EP uses a synchronous rectification MOSFET which is relatively insensitive to changes in load current, reducing cross regulation effects on the other outputs

complex multi-stage architectures.

Figure 5 compares a design using a Schottky diode rectifier with an InnoSwitch-based circuit using synchronous rectification. In the circuit on the left, a Schottky diode is used for output rectification. The forward voltage drop of a Schottky diode is current sensitive (and can be modeled as a diode plus a series resistor) causing forward voltage drop to increase with rising load current. Primary side regulation cannot control multiple outputs, so the other outputs increase when the controller acts to regulate the primary output to compensate for this increase in voltage drop.

The circuit shown in the right had side of the diagram – based on InnoSwitch-EP - uses a synchronous rectification MOSFET which is relatively insensitive to changes in load current. This reduces cross regulation effects on the other outputs.

InnoSwitch-EP ICs feature advanced protection and safety features including: primary sensed output OVP; secondary sensed output overshoot clamping; secondary sensed output over-current protection down to zero output voltage; hysteretic thermal shutdown; and an input voltage monitor with accurate brown-in/brown-out plus line over-voltage protection.

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InnoSwitch-EP switcher ICs can safely be connected across the isolation barrier. All parts undergo HIPOT compliance test during production equivalent to 6 kV DC/1-sec and have reinforced insulation with an isolation voltage of greater than 3500 V AC. They are UL1577 and TUV (EN60950) safety approved and EN61000-4-8 (100 A/m) and EN61000-4-9 (1000 A/m) compliant.

A reference design (RDR 469) is freely downloadable at: https://ac-dc.power.com/design-support/reference-designs/design-examples/rdr-469-dual-output-20-w-embedded-power/ (Figure 6). It describes a dual output 20 W embedded power supply based on the InnoSwitch-EP INN2605K which has universal 85 – 264 V AC input and 12 V, 1.5 A and 5 V, 0.5 A outputs. A reference design kit is also available for purchase.

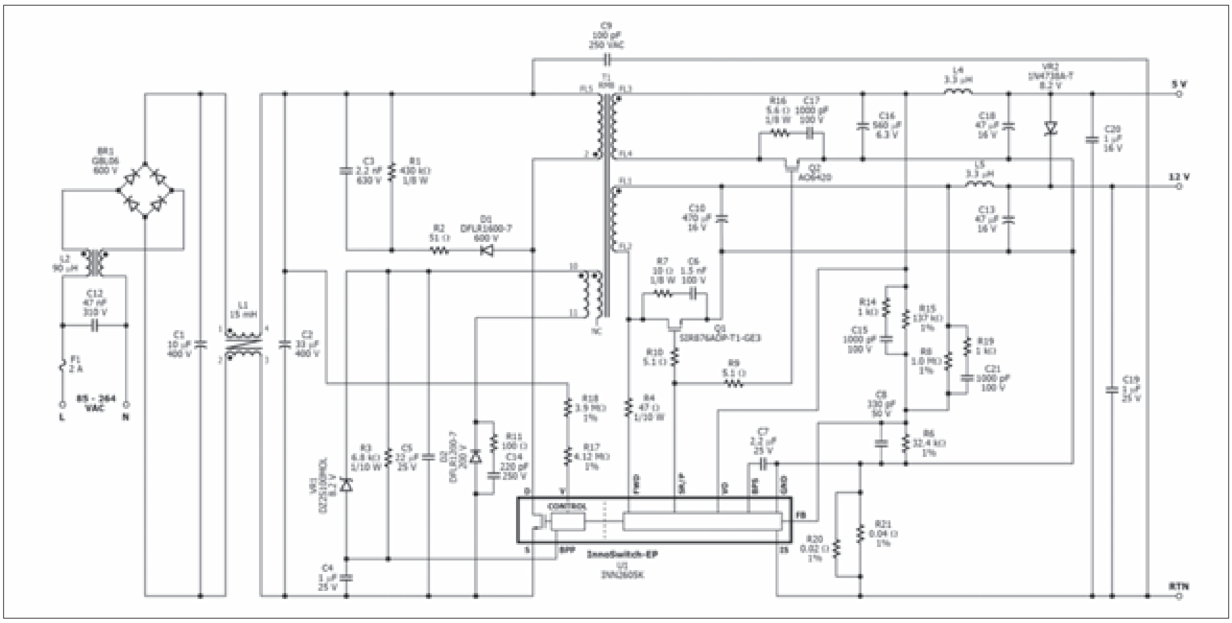

Figure 6: A dual output 20 W embedded power supply based on the InnoSwitch-EP INN2605K

New Energy Harvesting ICs Power Sensors

So far various types of sensors were routinely connected by wires to their power sources. Today it is possible to install reliable, industrial-strength wireless sensors that can operate for years on a small battery, or even harvest energy from sources such as light, vibration or temperature gradients. Furthermore, it is also possible to use a combination of a rechargeable battery and multiple ambient energy sources too. Moreover, due to intrinsic safety concerns, some rechargeable batteries cannot be charged by wires but require being charged via wireless power transfer techniques. Linear Technology has introduced energy harvesting ICs designed to work with different battery voltages. **Tony Armstrong, Director Product Marketing Power Products, Linear Technology Corp., Milpitas, USA**

State-of-the-art and off-the-shelf energy harvesting technologies, for example in vibration energy harvesting from piezo transducers and indoor photovoltaic cells, can yield power levels in the order of milliwatts under typical operating conditions. While such power levels might initially appear restrictive, the operation of harvesting elements over a number of years can mean that the technologies are broadly comparable to long-life primary batteries, both in terms of energy provision and the cost per energy unit provided. Furthermore, systems incorporating energy harvesting will typically be capable of recharging after depletion, something that systems powered by primary batteries cannot do. Thus, the additional cost of adding energy harvesting to power a sensor can be offset by the maintenance cost of having to change primary batteries every 7 to 10 years, or so.

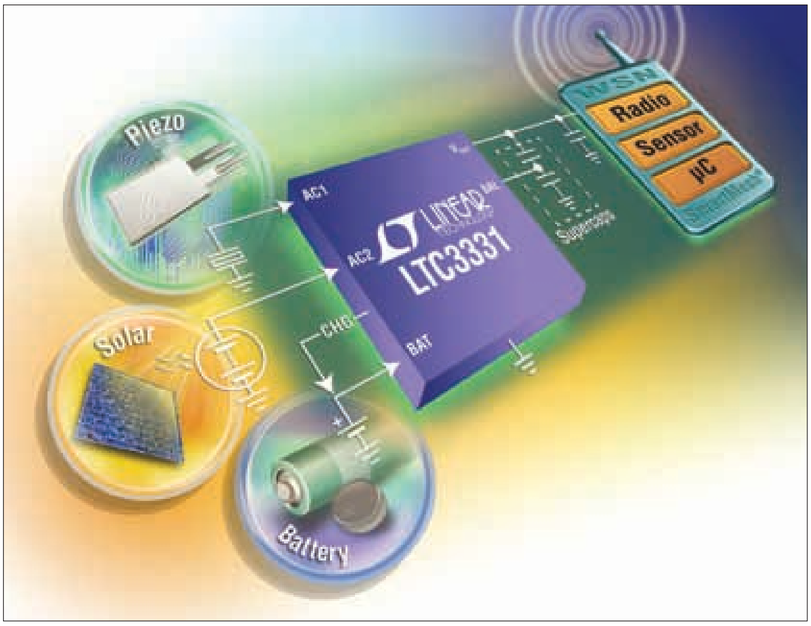

Figure 1: **The LTC3331 converts multiple energy sources and can use a primary rechargeable battery**

Overcoming barriers

Wireless and wired sensor systems are often found in environments rife with ambient energy, ideal for powering the sensors themselves. Today it is generally accepted that energy harvesting can significantly extend the lifetime of installed batteries, especially when power requirements are low, reducing down time in addition to long-term maintenance costs. In spite of these benefits, a number of adoption roadblocks still persist. The most significant is that ambient energy sources are often intermittent, or insufficient to power the sensor system continuously, where primary battery power sources are extremely reliable over the course of their rated life. As a consequence, some system designers may be reluctant to upgrade their systems to harvest ambient energy, especially when seamless integration is paramount.

Nevertheless, most implementations will use an ambient energy source as the primary power source, but will supplement it with a battery that can be switched in if the ambient energy source goes away or is disrupted. This battery can be either be rechargeable or not and this choice is usually driven by the end application itself. So it follows that if the end deployment allows for easy access to change a non-rechargeable battery, where maintenance personnel can readily swap it out in a cost effective manner, then this makes economic sense. However, if changing the battery is cumbersome and expensive, then the utilization of a rechargeable battery makes more economic sense.

Even if a rechargeable battery is selected, the question of the optimum method to charge it remains open. Some of the factors that will affect this decision are:

- Is there a wired power source to charge the battery
- Is there sufficient power available from the ambient energy sources to have sufficient power available to power the wireless sensor network (WSN), and also charge the battery
- Is wireless power transfer required to charge the battery due to intrinsic safety requirements due to the hazardous nature of its deployment

Simple IC solutions

The LTC3107 is a highly integrated DC/DC converter designed to extend the life of a primary battery in low power wireless systems by harvesting and managing surplus energy from extremely low input voltage sources such as TEGs (Thermoelectric Generators) and thermopiles.

With the LTC3107, a point-of-load energy

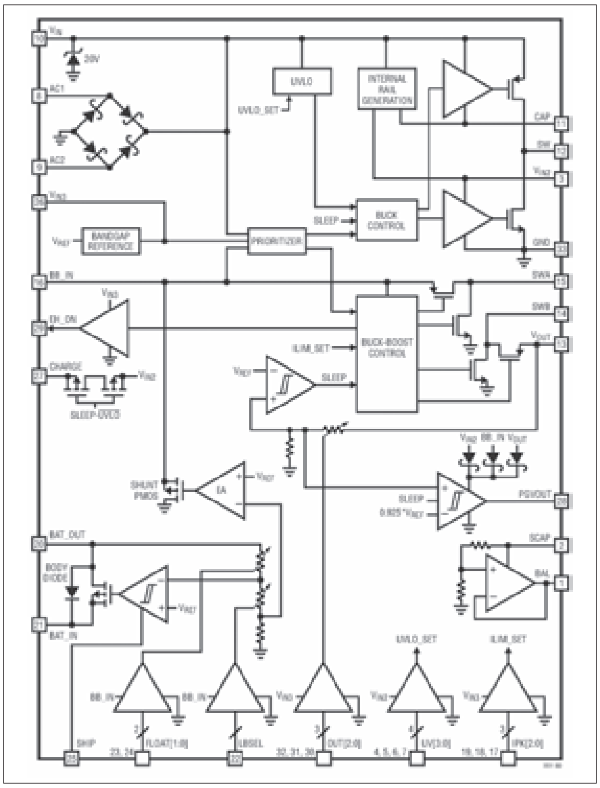

Figure 2: LTC3331 block diagram

harvester requires little space, just enough room for the IC's 3 mm × 3 mm DFN package and a few external components. By generating an output voltage that tracks that of the existing primary battery, the device can be seamlessly adopted to bring the cost-savings of free thermal energy harvesting to new and existing battery-powered designs. Along with a small source of thermal energy, the device can extend battery life, in some cases up to the shelf life of the battery, thereby reducing the recurring maintenance costs associated with battery replacement. The LTC3107 was designed to augment the battery or even supply the load entirely, depending on the load conditions and harvested energy available.

Another example is the LTC3331 (see Figure 1, 2), a complete regulating energy harvesting solution that delivers up to 50 mA of continuous output current to extend battery life when harvestable energy is available. It requires no supply current from the battery when providing regulated power to the load from harvested energy and only 950 nA operating when powered from the battery under no-load conditions. This device integrates a high-voltage energy harvesting power supply, plus a synchronous buck-boost DC/DC converter powered from a rechargeable primary cell battery to create a single non-interruptible output for energy harvesting applications such as wireless sensor nodes (WSNs) and Internet of things (IoT) devices.

The LTC3331's energy harvesting power supply, consisting of a full-wave bridge rectifier accommodating AC or DC inputs and a high efficiency synchronous buck converter, harvests energy from piezoelectric (AC), solar (DC) (see Figure 3) or magnetic (AC) sources. A 10 mA shunt enables simple charging of the battery with harvested energy while a low battery disconnect function protects the battery from deep discharge.

The rechargeable battery powers a synchronous buck-boost converter that operates from 1.8 V to 5.5 V at its input and is used when harvested energy is not available to regulate the output whether the input is above, below or equal to the output. The battery charger has a very important power management feature that cannot be overlooked when dealing with micropower sources. The IC incorporates logical control of the battery charger such that it will only charge the battery when the energy harvested supply has excess energy. Without this logical function the energy harvested source would get stuck at startup at some non-optimal operating point and not be able to power the intended application through its startup. Automatically transitions to the battery are performed when the harvesting source is no longer available. This has the added benefit of allowing the battery operated WSN to extend its operating life from 10 years to over 20 years if a suitable EH power source is available at least half of the time, and even longer if the EH source is more prevalent. A supercapacitor balancer is also integrated allowing for increased output storage. Figure 4 shows the battery charging process.

Conclusion

To facilitate the adoption of ambient energy harvesting into a wide range of new and existing primary battery-powered applications, Linear Technology has introduced energy harvesting ICs designed to work with different battery voltages. This includes most of the popular long-life primary batteries used in lower power applications, such as 3 V lithium coin cell batteries and 3.6 V lithium-thionyl chloride batteries. These products easily offer the best of both worlds – the reliability of battery power and the maintenance cost savings of energy harvesting with minimal design effort.

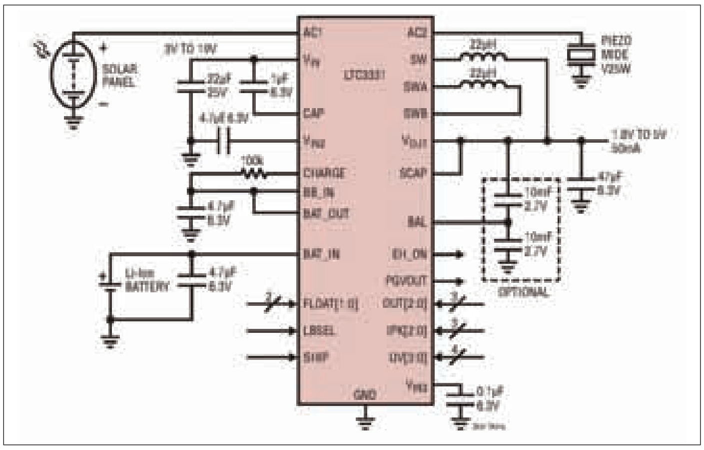

Figure 3: LTC3331 solar energy harvesting application

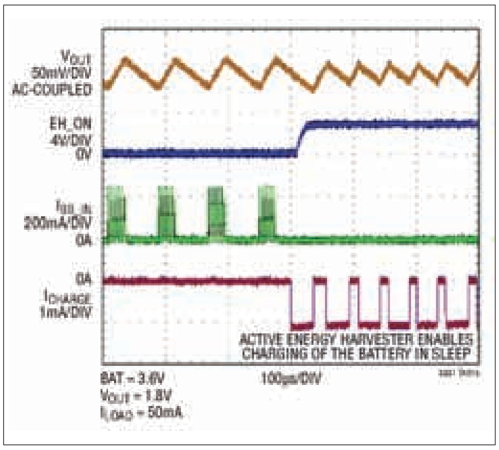

Figure 4: Battery charging process

Asymmetrical Inductance to Support Long Cables in Low-Power Motor Drives

High capacitive turn-on current often overload IGBTs in low-power inverter applications that use long shielded cables. A simple workaround can reduce losses and electromagnetic interference and ensure more reliable performance. **Michael Frisch, Head of Product Marketing, Vincotech, Unterhaching/Munich, Germany**

Capacity and current for charging are independent of the output current. In low-power inverter applications, the additional losses for this capacitive load account for a significant share of overall power dissipation.

The additional dissipated energy is thus calculated according to equation 1:

$$E = \tfrac{1}{2} C{*}U^2 \qquad (1)$$

The IGBT has to charge the capacity before it is able to turn on completely. The voltage drop between the DC voltage and capacitor voltage is dissipated in the switch. The losses are also proportional to the switching frequency and DC voltage. The problem with a long cable is perhaps most pronounced in low-power applications with 700 V DC and a PWM frequency of 16 kHz.

Countermeasure 1 - increase active current rating

A simple countermeasure is to increase the inverter IGBTs' current rating. A better cooling system would be necessary because of the increased losses, so selecting an inverter with a higher rating for applications with long cables is a simple solution, but certainly not the best economically speaking. The higher dissipation is a disadvantage and EMI increases with the high turn-on current, which compounds the EMI filter circuit's complexity.

Countermeasure 2 - add an output filter

A sine wave output filter is one way of reducing turn-on losses in the inverter. This kind of filter would rule out any increase in turn-on current, which in turn would reduce losses and EMI in the inverter. However, placing sine wave filters in the output would easily double the cost, so this is too expensive for most low-power applications.

Countermeasure 3 - add a small output inductor

Another approach would be to use low inductance in the output to achieve the required voltage drop with reactive power, the idea being to smooth out the slope of the output turn-on voltage and thus the cable capacitor's charging current. An inductor with just 2 µH would not add much to the inverter's cost. Unfortunately, this won't work. Once the inductor has charged the parasitic capacity of the cable, it will continue driving the current $I = I_{(motor)} + I_{(charge)}$. This would increase voltage at the output, alternating with increased current, which would culminate in heavy undamped oscillation.

Countermeasure 4 - use asymmetrical input inductance

Adding inductance to the DC input would work. A small snubber capacitor with a diode would have to be connected to prevent resonance with the output capacitance and voltage overshooting at turn-off (see Figure 2).

Although the IGBT turns on, the current is limited by the inductor. The inductor current includes the cable capacitance charging current. The current decreases once the output capacitance is charged. The stored energy in the inductor flows through the diode into the transient capacitor and is dissipated by a resistor.

Inverter with asymmetrical input inductance

Let's see what such an inverter could look like. The dimensions of the additional components would depend on cable capacitance.

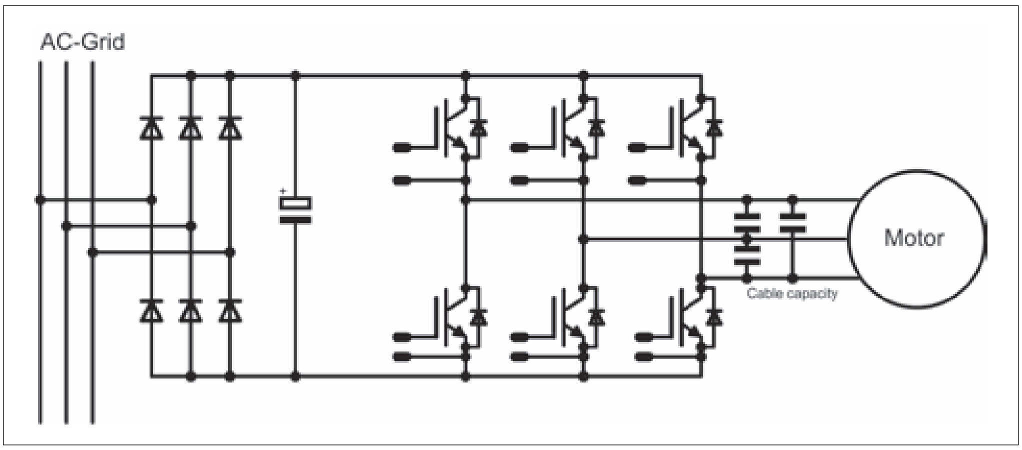

Figure 1: An inverter circuit with a capacitive load generated by a long motor cable

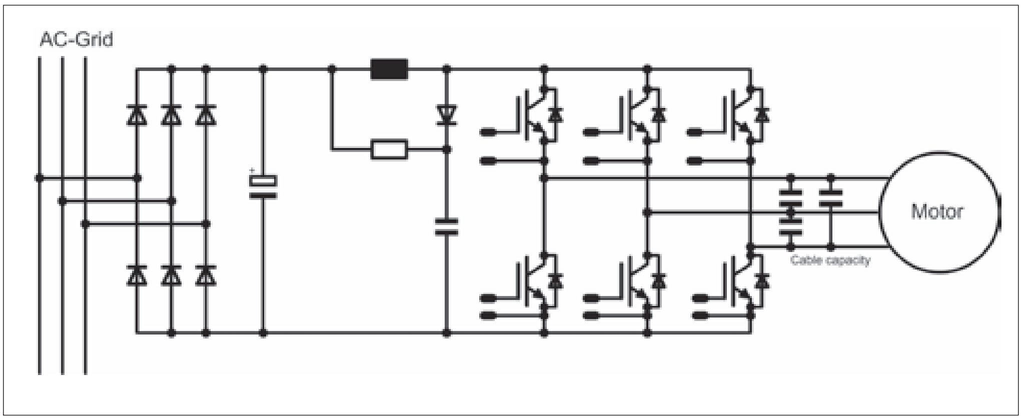

Figure 2: An inverter with a snubber circuit to reduce turn-on losses in the IGBT

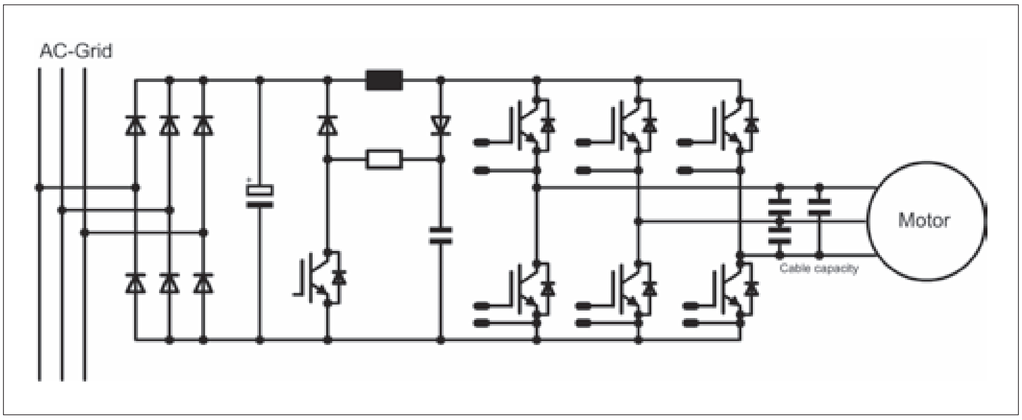

Figure 3: An inverter with snubber circuit where the brake resistor serves to dissipate parasitic energy

Energy according to equation 2

$$E = ½ C*\Delta U^2 = ½ L*\Delta I^2) \quad (2)$$

is transferred into the transient capacitor, and the majority of it is dissipated by a resistor according to the following example and equation 3:

- Long cable (100 m) with 5 nF output capacitance
- Transient capacitor: 2 µF
- DC inductance: 2 µH
- DC voltage VDC=600 V
- f_{PWM} = 16 kHz
- Output power: 2 kW to 4 kW
- I_{Out}(max) = 10 A

$$E = ½ C*U^2 = ½ * 5 \text{ nF} * (600 \text{ V})^2 = 0.9 \text{ mWs} \quad (3)$$

The voltage increase in the transient capacitor is less than 60V. The resistor then has to dissipate at turn-on

$$P_{ON} = 16 \text{ kHz} * 0.9 \text{ mWs} = 14 \text{ W} \quad (4)$$

and at turn-off

$$P_{OFF} = f_{PWM} * ½ I^2 * L, P_{OFF} = 16 \text{ kHz} * ½ * (10 \text{ A})^2 * 2 \text{ µH} = 1.6 \text{ W} \quad (5)$$

and in total

$$P = P_{ON} + P_{OFF} = 15.6 \text{ W} \quad (6)$$

The IGBT losses of 15.6W are transferred into the resistor. The inductor will also reduce the main DC capacitor's pulse load. And EMI is reduced because of the limited turn-on current.

Required components are 1 transient diode, 1 inductor (2 µH / 4 A), 1 DC capacitor (2 µF / 1000 V), and 1 resistor (100 Ω-200 Ω / 20 W).

Use of a brake resistor

In applications with a brake chopper, the brake resistor could be used to dissipate energy stored in the transient capacitor (see Figure 3). Required components are 1 transient diode, 1 inductor (2 µH / 4 A), and 1 DC capacitor (2 µF / 1000 V). The brake resistor serves to dissipate stored energy.

Benefits are reduced power dissipation in the IGBTs and in particular -15.6 W (reduced rating), reduced pulse load in the main DC capacitor resulting in a lower value, reduced peak current at turn-on resulting in a lighter workload for the EMI filter. The brake resistor also serves to dissipate transient energy at no extra cost.

Stored energy can be regenerated for applications demanding highest efficiency.

Conclusion

The combination of asymmetrical input inductance and a brake resistor that dissipates stored energy is the perfect solution to the problem with long cables in low-power inverter applications. The DC capacitor's reduced pulse load and the improved EMC more than compensates for the additional outlay. This new approach minimizes expenses, particularly for applications with a brake chopper where the brake resistor can be used to this end.

The Need for High-Frequency High-Accuracy Power Measurement

As more and more innovation focuses on energy efficiency and the use of renewable energy resources, engineers are increasingly demanding accuracy and precision from their power measurements. At the same time, new standards such as IEC62301 Ed2.0 and EN50564:2011, covering standby power consumption, and the SPEC guidelines, covering power consumption in data centres, demand more precise and accurate testing to ensure compliance. But these levels of precision can only be achieved if the measuring instruments are properly calibrated with reference to national and international standards. **Clive Davis, Marketing Manager T&M and Erik Kroon, Metrology Expert, Yokogawa T&M Center Europe, Amersfoort, Netherlands**

The need for new levels of higher precision in power measurement arises, but these levels of precision can only be achieved if the measuring instruments are properly calibrated with reference to national and international standards. Regular calibration by a laboratory, which can provide very low measurement uncertainties at the specific measurement points applicable to individual users, should enable instrument makers and their customers to have confidence in their test results.

High-frequency power measurement

One key area which is often neglected in traditional specifications is that of power measurements at high frequencies. Traditionally, AC power meters are calibrated at frequencies of 50-60 Hz. Nowadays, however, there is a demand for power measurement at high frequencies on devices such as switch-mode power supplies, electronic lighting ballasts, soft starters in motor controls and frequency inverters in traction applications.

Calibration of high-frequency power has lagged behind the development of power meters to address these applications, and few national laboratories can provide traceability up to 100 kHz: the frequency at which instruments have to be calibrated to provide accurate results in these application sectors.

There are a number of other parameters involved in power measurements that determine the performance of an instrument in a particular application. It is no longer sufficient merely to list voltage and current specifications: today's power environment needs to address variables such as phase shift, power factor and the effects of distorted waveforms.

It is also important to calibrate the instrument under the right conditions. Many test houses still use pure sine waves at only 50 Hz to calibrate power meters, which renders the results virtually useless for users carrying out tests under "real world" conditions. It is therefore important for users of power measuring instruments to look at the actual 'calibrated' performance of different manufacturers' products rather than just comparing specifications. This is the key behind Yokogawa's opening of its own European Standards Laboratory. It has become recently the first non-governmental facility to receive full ISO17025 accreditation for power measurements at up to 100 kHz.

Why calibration?

Calibration can be defined as the comparison of an instrument's performance with a standard of known accuracy because no measurement is ever correct. There is always an unknown, finite, non-zero difference between a measured value and the corresponding "true" value.

It is important to understand the difference between 'calibration' and 'adjustment'. Calibration is the comparison of a measuring instrument (an unknown) against an equal or better standard. A standard in a measurement is therefore the reference. Instruments are adjusted initially at the factory to indicate a value that is as close as possible to the reference value. The uncertainties of the reference standard used in the adjustment process will also dictate the confidence that the indicated value is 'correct'.

As the instrument ages, the indicated value may drift due to environmental factors (temperature, humidity, oxidation, loading etc.) which will also be dependent on the quality of its design and manufacture. To ensure that the instrument continues to operate within the manufacturer's tolerances, the instrument should be compared to the reference value on a regular basis (usually annually). If necessary, the instrument can then be re-adjusted. If there is no appreciable change in the calibrated results, this means that the instrument's design is inherently highly stable. In this case, there is no need to adjust it, and the user can also rely on the fact that the unit will exhibit the same stability on a day-by-day basis.

Yokogawa's calibration capabilities

At the heart of the laboratory is a special calibration system with the capability to calibrate power up to 100 kHz (see Figure 1). Housed in a climate-controlled environment (23.0 ± 1.0)°C, the system is able to calibrate voltage, current, DC power, AC power, frequency and motor functions, all under fully automatic control.

The system consists of two parts, a

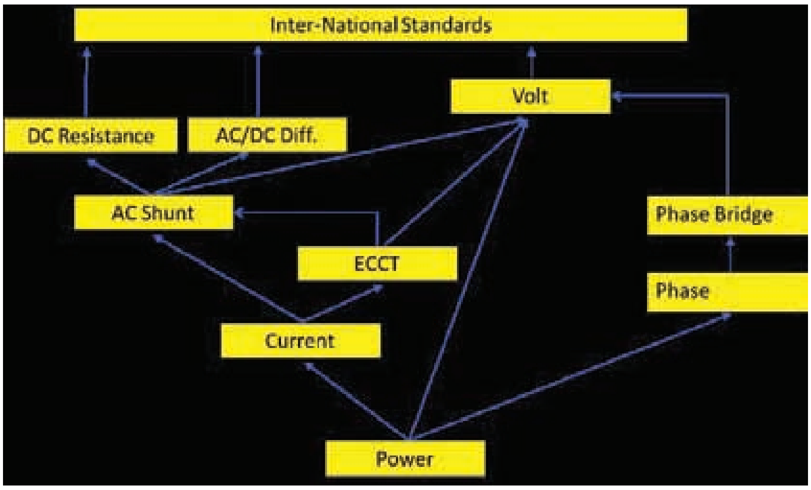

Figure 1: **Traceability overview**

signal generator section and a reference measuring unit. Those two parts are separated by a metal shield in order to prevent the heat generated by the signal sources from affecting the reference meters. Different sources are used to generate the calibration signal because a single source is not sufficient to generate all the signals required. Instead, multiplexers are used to select the sources needed for any particular measurement. Similarly, different reference power meters are selected via a multiplexer. This allows the selection of the best reference power meters for high-current, low-current or low-voltage calibrations. The reference power meters are from Yokogawa and are special models modified with aged components and firmware to enhance the resolution.

The power meter under calibration is connected via a multiplexer on the calibration system. Each element of the power meter under calibration is calibrated separately. A power meter with mixed inputs is easily calibrated. Extra instruments are added to the calibration system to calibrate any additional options of the power meter such as the motor function and analogue output.

The system is designed to minimize effects such as capacitive leakage and crosstalk, with special attention given to the wiring harness and multiplexers. For voltage, twisted and screened coaxial cables are used, while current uses coaxial cabling. The multiplexers use special relays to avoid leakage and crosstalk. The influence of the wiring harness is now kept to a minimum. With a worst-case measurements using 100 V at 100 kHz, the crosstalk suppression to the current channels is better than -93 dB. For mixed-input units, every element is calibrated separately to minimize the effects of loading.

A calibration is normally based on the internal Quality Inspection Standards (QIS). If the QIS is passed, it is demonstrated that the measured values are within specifications. However, on request it is possible to calibrate additional points. The system is able to communicate with the power meter under calibration by GPIB, RS232, USB or Ethernet.

A typical calibration of a power meter takes a few hours, depending on the number of elements. For each element, tests are made at about 45 voltage calibration points, 65 current calibration points and 78 power calibration points. Using all those points the voltage gain, voltage linearity, voltage flatness, current gain, current linearity, current flatness, power gain, power linearity, power flatness, power factor and frequency are calibrated at DC and from 10 Hz to 100 kHz. This includes also the external current sensor (shunt) if applicable. A total of about 180 calibrations are done for each element. The system is also able to calibrate the motor function by using analogue or pulse shape signals. A 30-channel multiplexer measurement system is installed to measure the analogue output of the power meter.

When the calibration is finished, the results are used to generate the calibration certificate.

Traceability

Traceability for power is based on values for voltage, current and phase. Using these units, it is possible to calculate power by the equation P = U x I x cos phi which is valid only for sine waves, so that special attention has to be taken into account for the harmonic distortions of the generated signals.

The measurement of voltage is straightforward using a digital multimeter. However, using a digital multimeter to measure the current is limited due to the frequency capability and uncertainty, and therefore two different options are used. If the current frequency is 50 to 60 Hz, an electronic compensated current transformer (ECCT) is used to measure the current, but if the frequency is higher current shunts have to be used for the other frequencies. Yokogawa has built its own current shunts to measure from 1 mA up to 10 A at up to 100 kHz with a maximum AC/DC difference of 3 parts in a million (ppm) at 100 kHz. Measuring the voltage over the shunt allows the current to be calculated.

To obtain the phase, a phase measurement device based on a high-speed, high-resolution digitizer is used, equipped with differential inputs to avoid ground loops. The biggest uncertainty here is the phase angle deviation of the current shunts, which is corrected by calibrating the shunt at different frequencies. The phase measurements

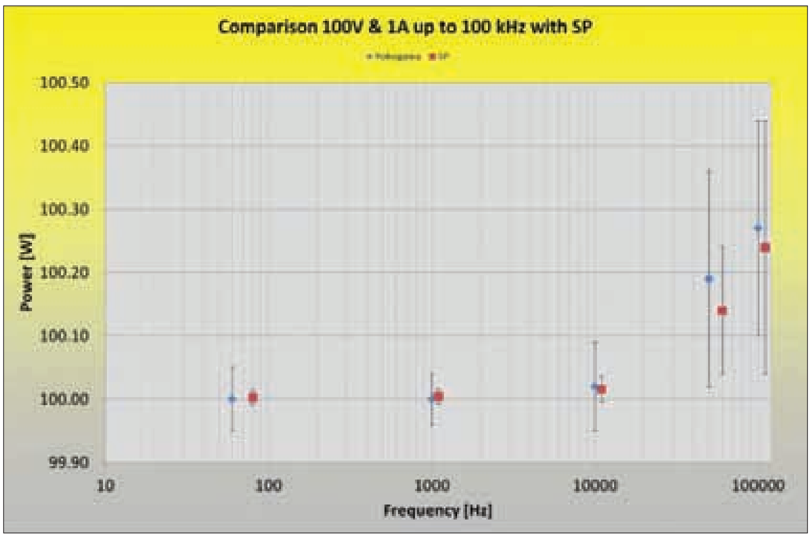

Figure 2: **Power comparison with national Standards Laboratory of Sweden (SP)**

Figure 3: **Differences between the ISO9001 and ISO17025 certificates**

ISO 9001 Calibration Certificate:

Power Calibration 60 Hz PF=1

Range	Applied	Lowlimit	Measured	Highlimit	Unit	Deviation %	Result
15V 1A	15.000	14.970	14.995	15.030	W	-0.036	Pass
30V 1A	30.000	29.940	29.989	30.060	W	-0.035	Pass
60V 1A	60.00	59.88	59.98	60.12	W	-0.036	Pass
150V 1A	150.00	149.70	149.95	150.30	W	-0.035	Pass
300V 1A	300.00	299.40	299.90	300.60	W	-0.035	Pass

ISO 17025 Calibration Certificate:

Power Calibration 60 Hz PF=1

Range	Applied	Measured	±Uncertainty	Unit	Deviation %
15V 1A	15.000	14.995	0.002	W	-0.036
30V 1A	30.000	29.989	0.003	W	-0.035
60V 1A	60.00	59.98	0.01	W	-0.036
150V 1A	150.00	149.95	0.02	W	-0.035
300V 1A	300.00	299.90	0.02	W	-0.035

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CALIBRATION RvA K 164

device is calibrated via a phase standard, which in turn is calibrated using self-calibrating phase bridges. This setup enables power to be made traceable at up to 100 kHz.

To confirm the calibration setup, a Yokogawa WT3000 power analyzer was calibrated by Yokogawa, and then sent to the national Standards Laboratory of Sweden (SP). At SP they also calibrated the Yokogawa WT3000 at the same points which verified the results (Figure 2).

The importance of accreditation

The familiar ISO 9001 standard aims at confirming the traceability of a measurement but does not define how the measurement is carried out. Laboratories that are accredited to ISO 17025 (General requirements for the competence of testing and calibration laboratories), however, have demonstrated that they are technically competent and able to produce precise and accurate calibration measurements. Figure 3 shows an ISO 17025 certificate complete with measurement uncertainties, which confirms that the power meter is truly much more accurate than its specification. There is no guarantee that the measurements on an ISO9001 certificate are correct.

ISO17025 accreditation also reflects the attention paid to the design of the input circuits of Yokogawa's precision power analyzers, with an emphasis on wideband, high-linearity characteristics that make them the most accurate instruments in their class (Figure 4).

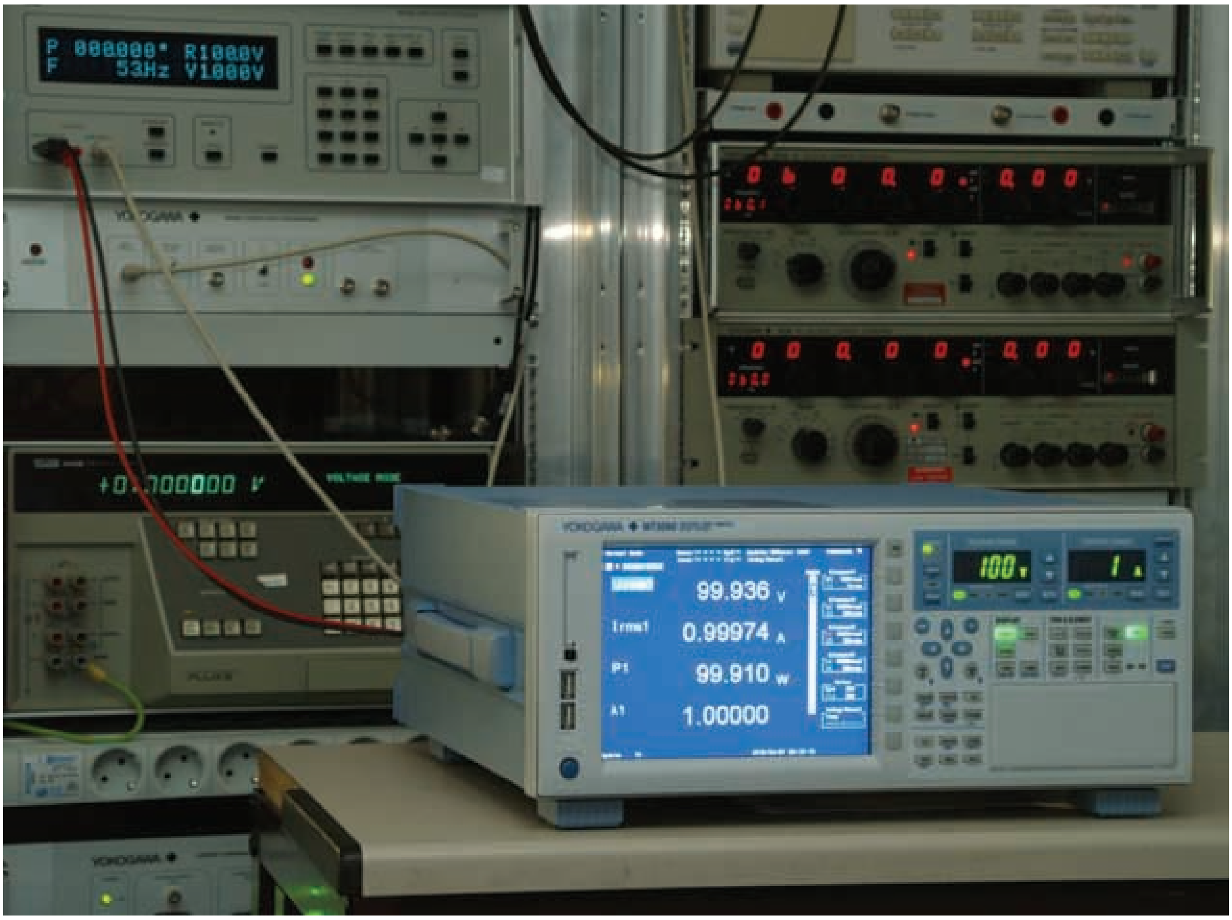


Figure 4: **Yokogawa WT3000 Power Analyser**

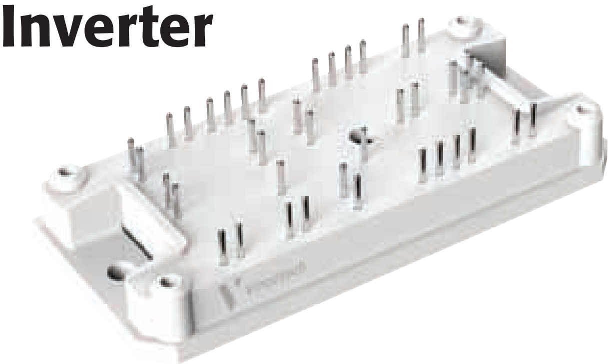
Two-Wire Hall-Effect Latch

The new A1245 from Allegro MicroSystems Europe is a two-wire Hall-effect latch with high magnetic sensitivity for automotive and industrial speed and position sensing applications.

The latch is produced using BiCMOS wafer fabrication process, and implements the company's patented high-frequency 4-phase chopper-stabilisation technique to achieve magnetic stability over its full operating temperature range from -40° to +150ºC. Two-wire latches of this type are particularly advantageous in cost-sensitive applications because they require one less wire for operation compared with the more traditional open-collector output switches. In addition, the system designer inherently gains diagnostic capabilities because there is always output current flowing, which should be in either of two narrow ranges. Any current level not within these ranges indicates a fault condition. The Hall-effect latch is in the high output current state in the presence of a magnetic south polarity field of sufficient magnitude, and remains in this state until a sufficient north polarity field is present. The A1245 is designed for speed and position sensing of ring magnets or other moving/rotating assemblies in applications that are safety-critical and/or have long wiring harnesses. Typical automotive applications include internal mode switch transmissions and transmission range switch/manual lever position sensor shift selectors; electronic parking brake motors; electronic power steering; and sunroof, tailgate and other motors. The device is also suited to industrial and consumer applications including white goods, industrial control and factory automation, and automatic doors.

www.allegromicro.com

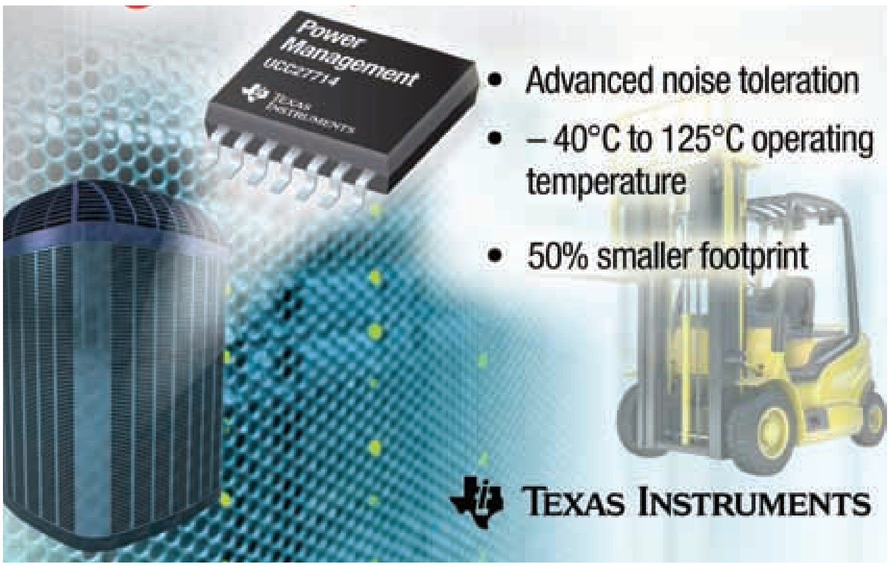
One Module Contains Rectifier and PFC and Inverter



Vincotech announced the flowRPI 1 family, a new 3-in-1 solution that integrates three topologies into one flow1 housing. This module is designed for welding, charger and SMPS applications rated from 1.5 to 7 kW. The new flowRPI 1 family combines a rectifier with highly efficient low-voltage drop diodes, a two legs PFC featuring ultrafast 650 V IGBTs and diodes, integrated filtering capacitors and diodes for current sensing via external transformer, and an inverter with H-bridge open emitter topology and optional capacitors into a single module. A special version comes with a PFC featuring IGBTs with higher current ratings for a wider input voltage range. It is rated for applications with 110 – 220 V AC input voltage. The enhanced layout of the flowRPI 1 is more EMC-friendly. With the latest IGBT H5 chip technologies on board, the module delivers ultra-fast switching at ultra-low conduction and switching losses. Given the option of three power stages in a single module, engineers will find it very easy to design highly compact PCBs. Various power ratings are available in the same flow1 housing with the same pinout, so applications may be scaled up with PCB design remaining intact. This latest generation module covers application power ranges from 1.5 up to 7 kW in various steps. The new flowRPI 1 family comes in flow1 12 mm and 17 mm housings. Press-fit pins and phase-change material are available on request. These modules will be manufactured in series in early 2016.

www.vincotech.com

600 V Gate Driver



Texas Instruments introduced a new half-bridge gate driver (UCC27714) for discrete power MOSFETs and IGBTs that operate up to 600 V. The high-side, low-side driver with 4-A source and 4-A sink current capability delivers 90 ns propagation delay, tight control of the propagation delay with a maximum of 125 ns across -40°C to 125°C and tight channel-to-channel delay matching of 20 ns across this temperature range. The device eliminates the need for bulky gate drive transformers, saving significant board space in high-frequency switch-mode power electronics. With the UCC27714 and TI's recently released UCC29950 combination PFC + LLC controller, designers can develop a complete, offline AC/DC power supply rated up to a few hundred watts. The fully internalized PFC compensation of UCC29950 reduces design steps enabling fast time-to-market while the three-level over current protection and hiccup mode operation ensures a robust operation under short circuits and overload conditions. The high-speed 600 V high-side low-side gate driver comes in a small outline integrated circuit (SOIC)-14 package and is priced at $1.75 in 1,000 unit-quantities.

www.ti.com/UCC27714-pr-eu

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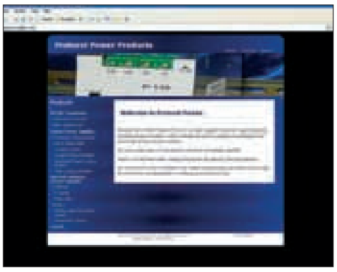

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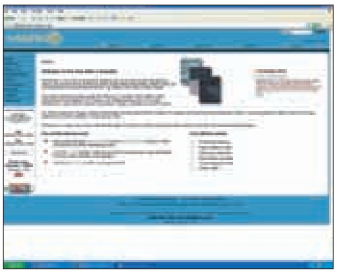

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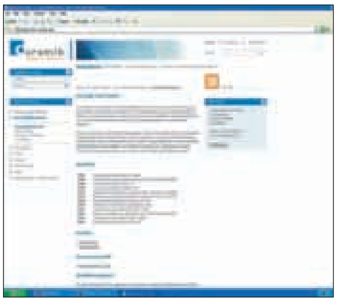

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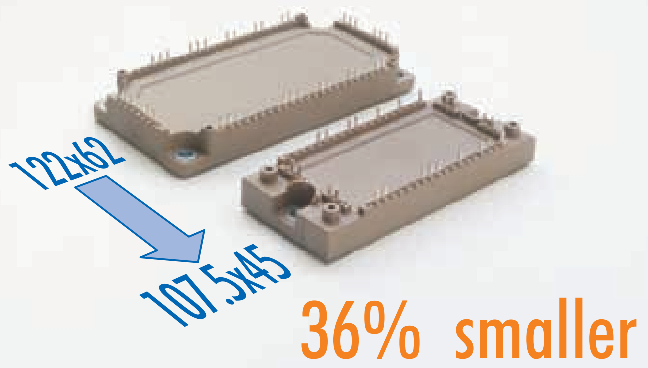
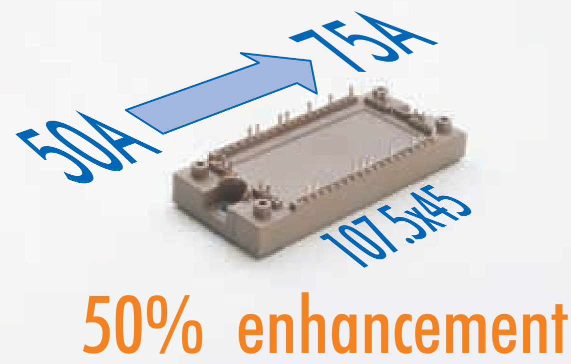
Downsizing package / Upgrading current rating

Downsizing package
Example 75A PIM-IGBT



Upgrading current rating
Example 50A PIM-IGBT



Main Features and Improvements

- Reduced power dissipation
- Reduced thermal impedance
- More output power
- 175°C operating temperature at high reliability level

Voltage and current range

650V	1 200V	1 700V
10A - 600A	10A - 1 800A	75A - 1 800A

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