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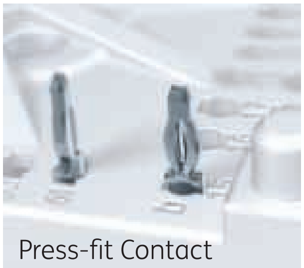

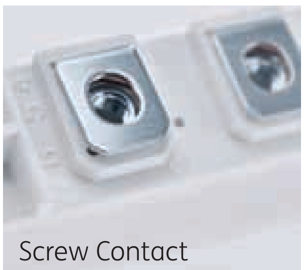

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WBGs Still Moving Forward

In 2013, SiC chip business has almost reached $100 million due to already well-established power factor corrector (PFC) applications, which still drives large volumes of diodes. In the second place, photovoltaic systems, despite a depressed market, are the beachhead for newly SiC-powered inverter or micro-inverter line-ups. Surprisingly, train traction has adopted SiC solution, sooner than expected. This strategic choice has been done by industrials, because of the availability of 1.7 kV full and hybrid modules that have been demonstrated and installed by Mitsubishi Electric in Japan. SiC in inverters is projected to grow at an annual rate of almost 12 percent. So far, main suppliers of SiC components are Infineon (diodes, JFETs) as well as US-based Cree (wafers, diodes, MOSFETs, modules) and Japan-based Rohm with a similar offering.

But also in Europe SiC wafer processing activities are in progress. AIXTRON i. e. , a leading German provider of deposition equipment to the semiconductor industry, has teamed up with research institution Fraunhofer IISB (Institute for Integrated Systems and Device Technology) in Erlangen/Germany, to develop 150 mm SiC epitaxy process. Fraunhofer IISB has developed fundamental understanding in low-defect-density SiC epitaxial processes which are elementary for the manufacturing of high-voltage SiC devices. Special characterization techniques like room temperature photoluminescence imaging and selective defect etching have been developed and adapted to the SiC material properties at IISB. In its laboratories complete SiC prototype devices can be processed and characterized. In order to facilitate a widespread adoption of SiC in power electronics cost reductions in SiC semiconductor material manufacturing and device processing are targeted by the implementation of the 150 mm SiC technology. And UK-based Anvil Semiconductors has secured a production source for its proprietary 3C-SiC on Silicon epiwafers with commercial SiC wafer and epitaxy supplier Norstel AB located in Norrkoping, Sweden. Anvil's technology enables the growth of device quality 3C-SiC epitaxy on 100 mm diameter Silicon wafers to thicknesses that permit the fabrication of vertical power devices. The use of Silicon substrates and epitaxial growth of cubic SiC enables fabrication of devices with the performance and efficiency benefits of SiC but at significantly lower material and manufacturing costs.

GaN, now able to answer 600 V segment needs, becomes a serious competitor for SiC technology. The power supply/PFC segment will dominate the GaN business from 2015-2018, ultimately representing 50 percent of device sales. At that point, automotive will then catch-up. In UPS applications, the medium-power segment is likely to be very much in line with the GaN value proposition, and savings at system level will be demonstrated. GaN technology could grab up to 15 percent of market share in this field by 2020.

2020 could see an estimated device market size of almost $600 million, ramp-up will be quite impressive starting in 2016, at an estimated 80 percent CAGR through 2020, based upon a scenario where EV/HEV begins adopting GaN in 2018-2019. Room for extra cost in motor drive applications is unlikely. Therefore, the incentives to implement new technologies such as GaN have to be serious and strong. Considering the possible improvement of conversion efficiency, and augmented by a predictable price parity with Silicon solutions by 2018, market researcher Yole expect GaN to start being implemented at a slow rate in motor control by 2015-2016, and reach around $45 million in revenue by 2020.

Meanwhile Transphorm announced that it has secured fundamental patents in the area of GaN power conversion, which are directed towards the operation and use of GaN transistors in a multitude of applications including half bridges, the basic building blocks of a variety of power conversion circuits. Bridge circuits are used in virtually all power converters/inverters including PV inverters, motor drives, DC/DC blocks of power supplies, and many power factor correction (PFC) circuits such as ultra-high efficiency Totem-Pole PFCs. These bridge circuits cover more than 60 percent of the total market. And On Semiconductor and Transphorm have announced a partnership to co-develop and co-market GaN based products and power system solutions for high-voltage applications in the industrial, computing, telecom and networking sectors. The first co-developed solutions based on 600 V GaN transistors will be sampled before the end of 2014. These will address applications in the 200 W to 1000 W power range for compact power supplies and adapters addressing the telecom and server markets. Under the terms of the partnership, the co-developed packaged transistor products will include low voltage MOSFET Silicon from ON Semiconductor for the cascoded switch, and GaN transistors from Transphorm. Co-packaging, assembly and test of the devices will be done at ON Semiconductor production facilities. This relationship is not only significant for faster penetration of GaN in the marketplace but also meaningful for the entire power conversion industry, both companies pointed out.

This and more will be covered in this issue – enjoy reading!

Achim Scharf
PEE Editor

Solar Power Market to Break $1 Billion Barrier in 2018

The global market for photovoltaic (PV) solar microinverters and power optimizers is forecast by market researcher IHS/IMS to more than triple in the coming years, rising to more than $1 billion in 2018, as both established and new regions increase their adoption of the emerging technology.

Worldwide market revenue for PV solar microinverters and power optimizers, collectively called module-level power electronics (MLPE), will rise at a compound annual growth rate of 27 % to total $1.1 billion in 2018, up from $329 million in 2013. Microinverters convert DC from a single solar module into AC. Although they are more costly, microinverters can in some cases harvest up to 25 % more electricity than conventional string or central inverter devices, which convert power from multiple solar panels. Power optimizers take a similar approach by performing the maximum power point tracking (MPPT) at a module level. However, a centralized inverter is still used for the DC/AC stage. "Demand for MLPE has been driven by key markets such as the United States, the United Kingdom and Australia," said Cormac Gilligan, senior analyst for solar inverters at IHS. "The market has grown to more than $300 million in size, despite continued price pressure due to new entrants into the business and decreasing PV system prices. Future demand for microinverters and power optimizers is expected to be spurred by continued acceptance in mature European PV markets, such as Germany and France. However, some of the major Asian markets, like Japan and China, will generate huge opportunity in the next few years as MLPE technology begins to penetrate these markets in larger volumes."

Although Enphase and SolarEdge continue to be the leaders in the microinverter and power optimizer market, this has not stopped new suppliers from entering the space. For example, leading inverter suppliers, such as Kaco and Delta, have released new microinverter models recently as they continue to expand and diversify their inverter portfolio. "Traditional inverter suppliers have been cautious to date in entering the microinverter market. But as the market has matured, an increasing number have moved in by acquiring a pure-play microinverter supplier or by designing in-house," Gilligan said.

In the power optimizer market, new suppliers like Maxim Integrated have recently developed partnerships with module suppliers, adding to the number of active suppliers in the trade. This will intensify the competition and may lead to lower power optimizer prices in the future. The entry of new suppliers will put further pressure on the existing players to innovate by developing next-generation models and new sales channels. While some prominent suppliers, such as SolarBridge and Tigo, have decided that integrating their products directly onto the module to create an "AC module" or "Smart module" is the way forward, other suppliers, including Enphase and SolarEdge, have had success with solar lease companies such as Sunrun and SolarCity in the United States as an alternative sales channel.

As a result of new microinverter and power optimizer suppliers entering the market and existing suppliers entering new markets, revenues of MLPE are forecast to increase 28 % per year to reach more than $1.1 billion in 2018. This represents a huge opportunity for new and existing suppliers alike to grow their business, with the market likely to attract new players in the next few years.

www.ihs.com

Transphorm Holds Fundamental GaN Patents

Transphorm Inc. announced that it has secured fundamental patents in the area of GaN power conversion. The United States Patent and Trademark Office (USPTO) patent number 8,816,751 titled "Inductive Load Power Switching Circuits" was granted August 26, 2014 and the patent application number 13/887,204 titled "Bridge Circuits and Their Components" was allowed by the USPTO on August 27, 2014. Both are directed towards the operation and use of GaN transistors in a multitude of applications including half bridges, the basic building blocks of a variety of power conversion circuits. Counterparts of these patents have also issued in China, Taiwan and are pending in several other countries.

These patents belong to a bridge circuit patent family based on the DIODE-FREE™ GaN solution, wherein a GaN transistor also serves the function of the conventional anti-parallel or fly-back diode required in traditional approaches. This not only helps eliminate diode components, but also eliminates the cost, space and energy loss associated with them. Bridge circuits are used in virtually all power converters/inverters including PV inverters, motor drives, DC/DC blocks of power supplies, and many power factor correction (PFC) circuits such as ultra-high efficiency Totem-Pole PFCs. These bridge circuits cover more than 60 % of the total market.

Over the last several years, GaN semiconductors have emerged as a leading technology enabler for the next wave of compact, energy-efficient power conversion systems – ranging from ultra-small adapters, high power density PCs, server and telecom power supplies, to highly efficient PV inverters and motion control systems. A strong IP position is essential to ramping any commercial GaN business. "Transphorm's patent portfolio comprises fundamental IP in all key areas, ranging from material growth of GaN-on-Silicon, device structures and fabrication, and packaging and circuits, with a particularly far reaching impact on the use of GaN in applications," said Primit Parikh, co-founder and President of Transphorm. "No matter how other GaN providers manufacture their products, they will have to consider Transphorm's GaN bridge circuit patent family for bridge applications, by far the largest market segment for high voltage GaN."

www.transphormusa.com

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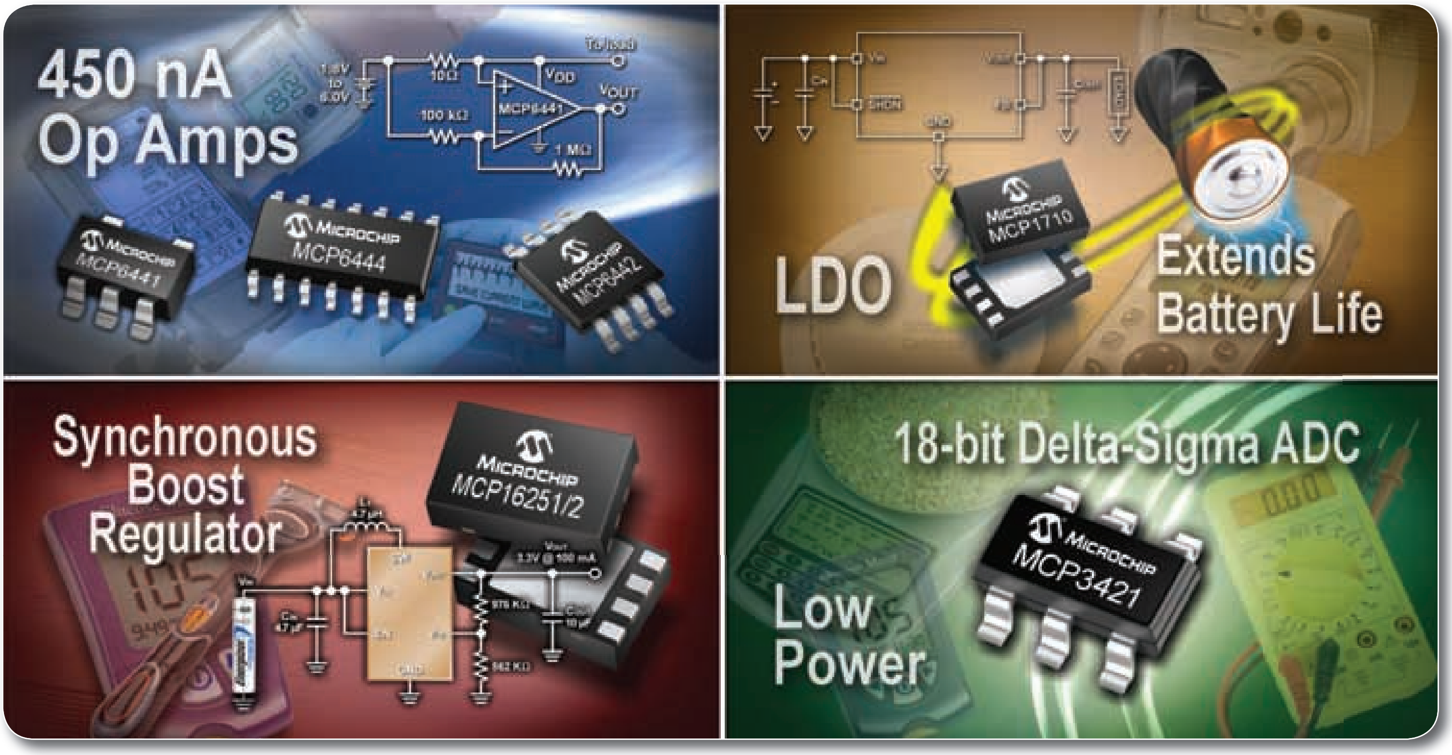

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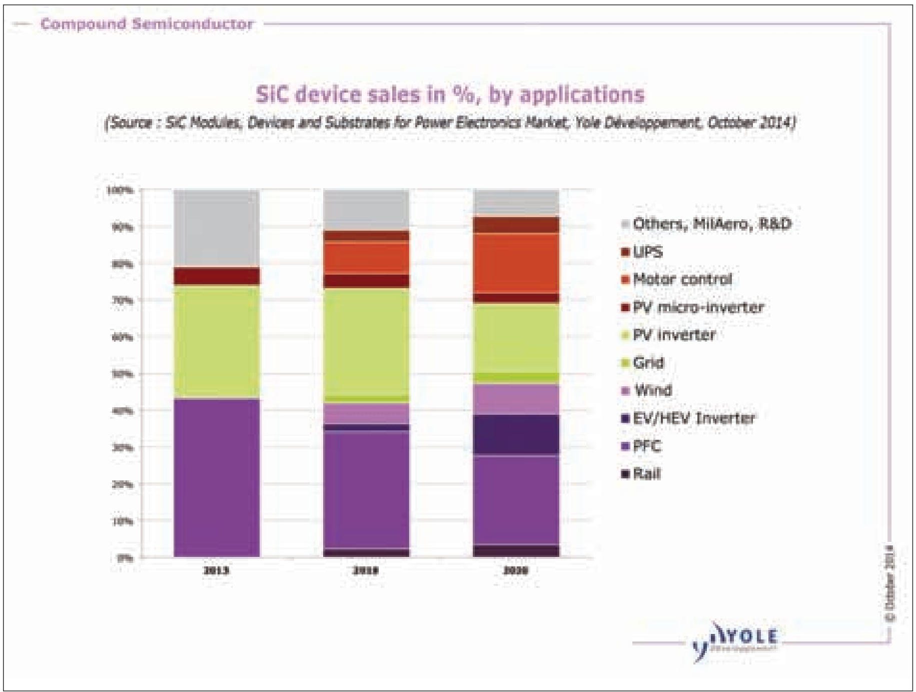
SiC Gains Acceptance

According to market researcher Yole Développement Silicon Carbide (SiC) propagates over all industrial segments. Power factor corrector (PFC), photovoltaic inverter, motor control and more represented a $100 million business in 2013.



In 2013, SiC chip business has almost reached $100 million due to already well-established power factor corrector (PFC) applications, which still drives large volumes of diodes. In the second place, photovoltaic systems, despite a depressed market, are the beachhead for newly SiC-powered inverter or micro-inverter line-ups. Surprisingly, train traction has adopted Silicon Carbide solution, sooner than expected. This strategic choice has been done by industrials, because of the availability of 1.7 kV full and hybrid modules that have been demonstrated and installed by Mitsubishi Electric in Japan. Train applications could dynamically expand, exhibiting a >80 % CAGR over 2015-2020. "Indeed, we expect other rolling-stock manufacturers will quickly adopt SiC, firstly in metro and then in the high-speed trains", explains analyst Philippe Roussel. "Here savings are made at the system level, where passives and other cooling can be dramatically reduced when moving to SiC. We also forecast PV inverters to keep on implementing SiC at an annual growth rate of almost 12 percent". But SiC in Electric Vehicle/Hybrid Electric Vehicle (EV/HEV) is delayed beyond 2018, and 6" SiC wafers for power electronic applications are expected to take place in 2016-2017.

Yole also takes into account, in its 2014 analysis, the competition with Gallium Nitride (GaN) devices in the PFC area. GaN, now able to answer 600 V segment needs, becomes a serious competitor for SiC technology. However Yole's analysts remain conservative regarding this market evolution and expect that PFC should switch to GaN in the coming years. The power supply/PFC segment will dominate the business from 2015-2018, ultimately representing 50 % of device sales. At that point, automotive will then catch-up. In UPS applications, the medium-power segment is likely to be very much in line with the GaN value proposition, and savings at system level will be demonstrated. GaN technology could grab up to 15 % of market share in this field by 2020.

2020 could see an estimated device market size of almost $600 million, leading to approximately 580,000 x 6" wafers to be processed. Ramp-up will be quite impressive starting in 2016, at an estimated 80 % CAGR through 2020, based upon a scenario where EV/HEV begins adopting GaN in 2018-2019. Room for extra cost in motor drive applications is unlikely. Therefore, the incentives to implement new technologies such as GaN have to be serious and strong. "Considering the possible improvement of conversion efficiency, and augmented by a predictable price parity with Si solutions by 2018, we expect GaN to start being implemented at a slow rate in motor control by 2015-2016, and reach around $45 million in revenue by 2020", Roussel pointed out. "The PV inverters segment has already adopted SiC technology, and products are now commercially available. It is possible that GaN could partially displace SiC thanks to better price positioning. However, now that SiC is in place, qualifying GaN may be more challenging".

www.yole.fr

On Semi Partners with Transphorm

On Semiconductor and Transphorm have announced a partnership to co-develop and co-market GaN based products and power system solutions for high-voltage applications in the industrial, computing, telecom and networking sectors.

"ON Semiconductor recognizes the inherent benefits that GaN technology can bring to the power electronics market and we are partnering with a recognized leader in this area in addition to pursuing our own GaN development work," said Bill Hall, General Manager of On Semiconductor's Standard Products Group. "This important collaboration combines our power system solution capabilities with Transphorm's GaN expertise. Together we can bolster customer confidence in this new technology and accelerate broad market adoption." The first co-developed solutions based on 600 V GaN transistors will be sampled before the end of 2014. These will address applications in the 200 W to 1000 W power range for compact power supplies and adapters addressing the telecom and server markets. Under the terms of the partnership, the co-developed packaged transistor products will include low voltage MOSFET Silicon from ON Semiconductor for the cascoded switch, and GaN transistors from Transphorm. Co-packaging, assembly and test of the devices will be done at ON Semiconductor production facilities.

www.onsemi.com

GaN Systems with Mouser

Canadian GaN Systems Inc has signed an exclusive worldwide distribution agreement with Mouser Electronics.

GaN Systems' Island Technology IP incorporates the wide-bandgap and superior switching speed, temperature, voltage and current performance of GaN into a unique structure that maximizes wafer yields and produces highly efficient transistors up to four times smaller than tradition design approaches. The company has also designed GaNPX packaging, which has no wire bonds, minimizing inductance and thermal resistance and increasing reliability. With current ratings from 8 A to 200 A, GaN Systems offers a comprehensive product range of GaN devices. Initial products distributed by Mouser Electronics will include the GS61008P, a 80 A/5 mΩ normally-off 100 V GaN transistor, and a low inductance, thermally-efficient 650 V transistor, the GS66508P, with reverse current capability, zero reverse recovery charge and source-sense for optimal high speed design.

www.mouser.com/gan-systems/

Infineon Ranks First in Power Semiconductors

Infineon Technologies AG consolidated its position as global market leader in power semiconductors in 2013. With a market share of 12.3 %, the company came in first for the eleventh time in a row, according to a study carried out by IHS. Infineon also took the lead for the first time in the market for MOSFET power transistors.

The global market for power semiconductors dropped by 0.3 % to around $15.4 billion in 2013. Despite this weaker environment, Infineon increased its turnover, thereby boosting its market share by 0.9 percentage points compared to the previous year to 12.3 %. In the MOSFET power transistor segment, the company enlarged its market share by 1.6 percentage points to 13.6 %, thereby becoming the largest provider in this segment for the first time. Infineon also gained market shares in the submarkets for discrete IGBT power transistors (first place with 24.7 %) and IGBT modules (second place with 20.5 %). As reported in our September issue, the company announced in August 2014 that they have signed a definitive agreement to acquire International Rectifier for $40 per share in an all-cash transaction valued at approximately $3 billion. This transaction will certainly lead to a more strong position including GaN devices in the year 2015.

www.infineon.com

AIXTRON partners with FHG IISB to enhance SiC Production Technology

AIXTRON, a leading German provider of deposition equipment to the semiconductor industry, has teamed up with research institution Fraunhofer IISB (Institute for Integrated Systems and Device Technology) in Erlangen/Germany, to develop 150 mm Silicon Carbide (SiC) epitaxy processes using the new G5WW Vapor Phase Epitaxy (VPE) system.

Fraunhofer IISB has developed fundamental understanding in low-defect-density SiC epitaxial processes which are elementary for the manufacturing of high-voltage SiC devices. Special characterization techniques like room temperature photoluminescence imaging and selective defect etching have been developed and adapted to the SiC material properties at IISB. In its laboratories complete SiC prototype devices can be processed and characterized. Today, a variety of SiC devices like Schottky Diodes and MOSFETs are commercially available. In order to facilitate a widespread adoption of SiC in power electronics cost reductions in SiC semiconductor material manufacturing and device processing are targeted by the implementation of the 150 mm SiC technology. "Based on the worldwide recognized experience of Fraunhofer IISB in SiC epitaxy technology and characterization, we will jointly enable the optimization of epitaxial production processes for 150 mm SiC wafers. The goal of the collaboration is the demonstration of high-volume manufacturing processes addressing the SiC material requirements of SiC power devices. With this joined effort we do support our customers moving from 100 mm to 150 mm SiC processing technology from the year 2015 to achieve efficient and economic manufacturing processes for future SiC power devices", commented Dr. Frank Wischmeyer, Vice President Power Electronics at AIXTRON. "Through this partnership we expect to further accelerate the implementation of 150 mm SiC technology in the industry by pairing our process know-how in manufacturing SiC epitaxial layers with AIXTRON's SiC equipment expertise", added Dr. Jochen Friedrich, Head of Department Materials at Fraunhofer IISB.

www.aixtron.com, www.iisb.fraunhofer.de

Fraunhofer IISB and AIXTRON start research program on Silicon Carbide Production Technology based on Planetary Reactor AIX G5WW

150 Millimeter SiC Wafers from Dow Corning

Dow Corning announced that it now offers 150 mm diameter SiC wafers under its Prime Grade portfolio. Recently launched to set new standards for 100 mm SiC wafer quality, the portfolio now also offers three tiers of manufacturing quality 150 mm SiC substrates – labeled Prime Standard, Prime Select and Prime Ultra. Each tier offers increasingly stringent tolerances on critical defect types that adversely impact device performance, such as micropipe density (MPD), threading screw dislocations (TSD) and basal plane dislocations (BPD).

Dow Corning is among the first to specify low tolerances of other defect types, such as TSD and BPD. Such defects reduce device yields, and inhibit the cost efficient manufacture of large-area, next-generation power electronic devices with higher current ratings. All Prime Grade SiC wafers offer consistent mechanical characteristics to ensure compatibility with existing and developing device fabrication processes. The newly expanded Prime Grade portfolio of 150 mm SiC substrates includes:

- **Prime Standard SiC wafers that guarantee MPD of < 1 cm-2, offering an attractive option for balancing performance and cost when designing simpler SiC power electronic components, such as Schottky or Junction Barrier Schottky diodes, with low to medium current ratings.**
- **Prime Select SiC wafers that deliver more stringent tolerances for MPD (< 1 cm-2) and TSD (< 300 cm-2), making them suitable for more demanding SiC devices like pin diodes or switches.**
- **Prime Ultra SiC wafers enable design of high-power devices that require the highest crystal quality. SiC substrates in this tier deliver extremely low MPD (< 1 cm-2), TSD (< 200 cm-2), BPD (< 3,000 cm-2) and a tightened wafer resistivity distribution for the design of today's most advanced SiC power electronic switches. In addition, the superior substrate quality in this tier can benefit high-voltage (3.3 kV and higher) and high-current device designs.**

"SiC wide-bandgap power semiconductors have rapidly evolved from a cutting-edge niche into an established technology sector that is increasingly focused on the manufacturing economies afforded by SiC crystal quality, wafer size and other critical factors," said Tang Yong Ang, Vice President, Compound Semiconductor Solutions at Dow Corning. "Our decision to expand the Prime Grade portfolio to include 150 mm diameter SiC wafers aims to meet this very competitive demand. As we rapidly scale production of these high-quality wafers, our customers will be able to more confidently pinpoint the SiC substrate that optimizes the performance and cost of their next-generation device design while leveraging the improved economies of scale offered by larger wafer diameters."

www.dowcorning.com

SiC on Silicon Wafers

UK-based Anvil Semiconductors has secured a production source for its proprietary 3C-SiC on Silicon epiwafers with commercial SiC wafer and epitaxy supplier Norstel AB.

Anvil's novel process for the growth of device quality 3C-SiC epilayers on Silicon wafers has been successfully transferred onto production reactors at Norstel's state-of-the-art facilities in Norrkoping, Sweden. Layers grown using Anvil's patented stress control techniques permit both 650 V and 1200 V devices to be realized. Its unique technology enables the growth of device quality 3C-SiC epitaxy on 100 mm diameter Silicon wafers to thicknesses that permit the fabrication of vertical power devices. The proprietary process overcomes mismatches in lattice parameter and thermal coefficient of expansion (TCE) and can be readily migrated onto 150 mm wafers and potentially beyond. The Anvil material has applications ranging from power devices and LEDs to medical devices and MEMS. It can be used to fabricate high performance SiC devices with significant reductions in manufacturing costs, or as a means to enable the growth of other compound semiconductor structures onto Silicon. Anvil is currently developing vertical SBDs and MOSFETs on its 3C-SiC on Silicon wafers for supply and license. The use of Silicon substrates and epitaxial growth of cubic SiC enables fabrication of devices with the performance and efficiency benefits of SiC but at significantly lower material and manufacturing costs. "Getting the process onto production equipment at Norstel underlines the capabilities of our technology. It opens the way for the use of multi-wafer reactors for our future production needs and a move to 150 mm diameter wafers", said Anvil's CEO Jill Shaw. "Our proven production expertise and capabilities in SiC epitaxy have helped Anvil to demonstrate the viability of their 3C-SiC solution and our manufacturing capacity will pave the way for Anvil's volume production", added Ronald Vogel, CCO of Norstel AB.

www.anvil-semi.co.uk, www.norstel.com

LEDs Dominate Future General Lighting

The 4th LED Professional Symposium from September 30 to October 2 in Bregenz/Austria attracted 100 exhibitors (+ 20 %) and 1.100 visitors. LED lighting is one of the major market drivers for power electronics, accounting for around $15 billion worldwide in 2014. According to market researcher Yole the market could grow up to $18 billion in 2020 with a strong growth path for general lighting, due to strong reduction in LED pricing.

Lighting consumes around 20 percent of the total energy supply in the developed countries, more efficient luminaires such as energy-saving fluorescent lamps or now LEDs can reduce this amount significantly while providing extra functionality, i. e. data transmission via LiFi. "The introduction of warm-white high-brightness LEDs opened the market for general illumination. Such a typical 1 mm? LED now exceeds 150 lumens at nominal drive levels. Although LEDs are much more efficient than incandescent and comparably better than fluorescent lamps, they only convert 18 to 35 percent of electrical energy into photons, so more research on even better efficiency and also thermal management is necessary", explained Dr. Mehmet Arik from Ozyegin University **(www.ozyegin.edu.tr)** in his keynote. "And this applies not only for the LEDs, but also for the driver power electronics. But for more efficient and thus less heat producing power semiconductors such as SiC and GaN the time for LED driver applications has not come yet".

LEFT: "With more than thousand visitors and hundred exhibitors the 4th LED Professional Symposium + Expo was a great success", organizer Siegfried Luger stated

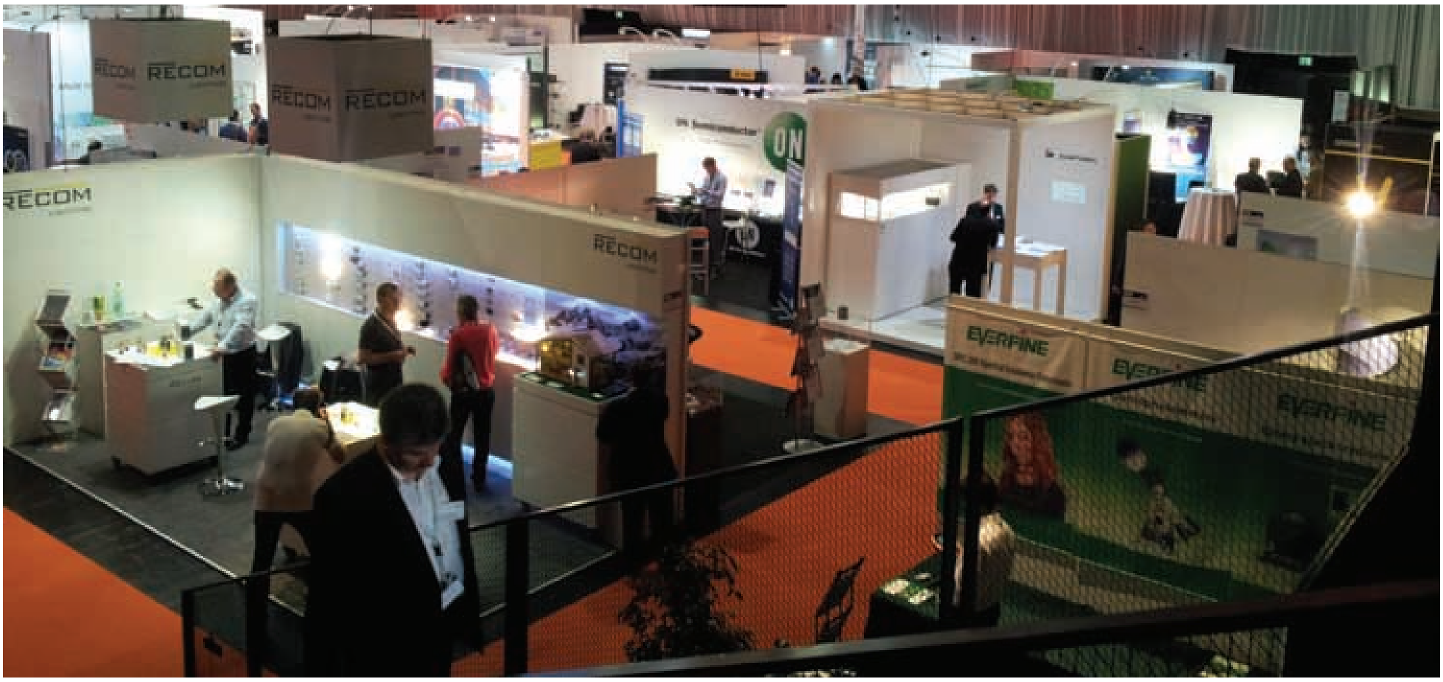
BELOW: View at the exhibition site of the LED Symposium covering around hundred companies

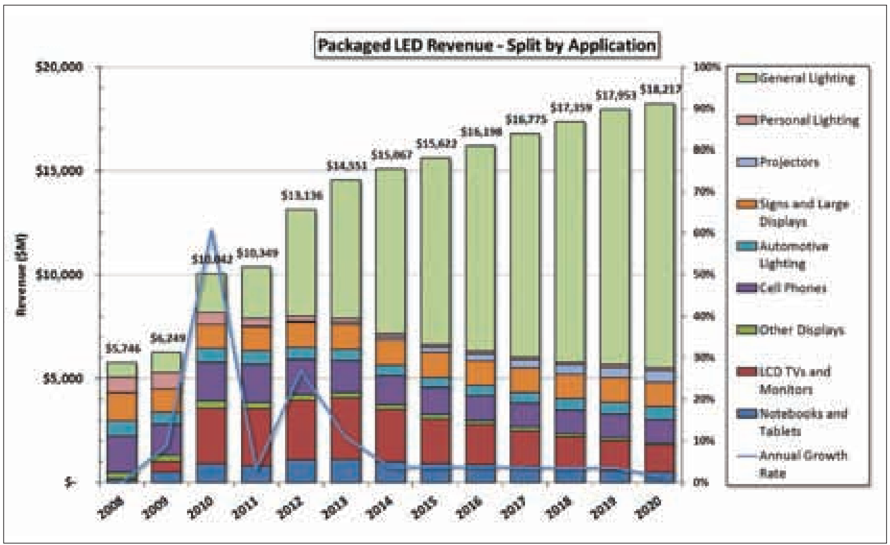
The pace of development in LEDs will bring them over the next years to be the most commonly used light source due to their long life time (50,000 hours) and still increasing efficiency of 200 lumen/watt along with high color rendering. "LEDs will penetrate the lighting market and remain in a leading position for a long time. Newer technologies such as OLEDs will struggle to get off the ground commercially and will succeed in market niches", underlined Dr. Paul Hartmann from Joanneum Research **(www.joanneum.at)** in Austria. The laser could make a major breakthrough in automotive headlighting, i. e. BMW's new i8 is equipped with Osram's laser diodes increasing the visible range substantially. "But laser diodes today have low efficiency around 30 percent and feature thermal runaway".

Transformation of the lighting market

"The transformation of the lighting market in Europe is in full swing, growing at an even faster rate envisioned some years ago. All the signs of a mass LED market adoption are now there, such a superior performance to fluorescent lamps, fast rising volumes, aggressive price erosion and the emergence of standardization", commented Annetta Kelso, Senior Marketing at Philips LED Systems in Eindhoven **(www.ecat.lighting.philips.com)**. "Most estimates of the rate of adoption come from the comparing revenues from LED products with the total lighting. Several of the largest lighting companies such as Acuity, Osram, Philips and Zumtobel report that around 30 percent of their 2013 revenues came from LEDs. In Japan the fraction is larger, but in other countries much lower. We suggest that the global global total LED-based lighting market in 2013 was $20 billion", added Consultant J. Norman Bardsley.

In the race of new light sources LED will be the dominant technology by offering good performance at affordable cost. "However, to be able to replace





LEFT: Market by application for packaged LEDs
Source: Yole Développement Oct. 2014

incumbent technologies, developments towards technical innovations and manufacturing excellence still appear as mandatory conditions to decrease the $/lumen. Recent trends have highlighted chip-on-board modules, flip-chip structure and chip-scale packaging. In the future, however, manufacturers should not focus only on reducing LED chip and packaging cost, but also decrease other component costs such as drivers, power supplies and optics – as light source cost reduction will reach its limits", said Pars Mukish from market researcher Yole Développement **(www.yole.fr)**. According to the latest report, the LED packaging materials market, including packaging substrates, phosphors, encapsulation and primary optic materials, ESD (Electrostatic Discharge) protection diodes, will grow by a factor x1.5 (from $2 billion to $3 billion) during the period 2014-2019. Encapsulant and optic materials will follow the same trend. According to Yole's analysis, this market is about $300 million in 2013 and should reach to $700 million in 2019, driven mostly by the increased use of silicone material. Silicone offers better reliability and lifetime than traditional epoxy material.

Driving LEDS efficiently

Regarding power electronics, LED drivers have to be adopted to the market needs in terms of performance and cost.

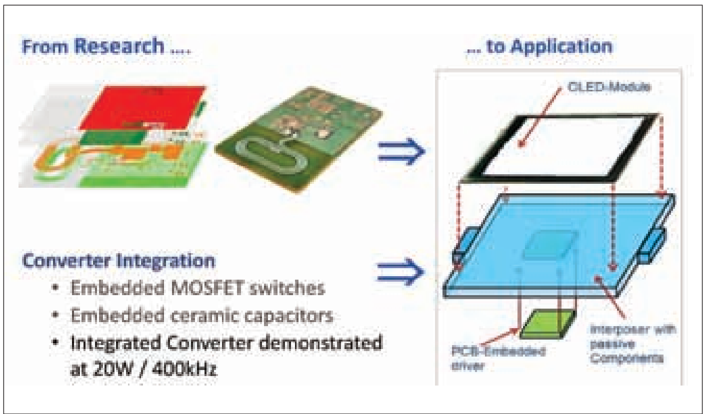
In LED light bulbs the driver is located inside the socket, for high-power lamps the driver is mounted in the lamp housing. Integrated drivers with embedded electronics can provide a planar outline, intended for a flat luminaire shape. In this case the heat can be dissipated vertically perhaps from both sides. Embedding electronics is one solution to reduce tolerances and to provide a compact and inherently safe design. A 20 W OLED/LED demonstrator featuring two 100 V/100 A MOSFETs at 400 kHz switching frequency has been designed at RWTH Aachen **(www.isea.rwth-aachen.de)**. The backside of the dies (drain) are mounted by silver-filled epoxy adhesive. The top contact (gate and source) are coated with a copper layer. Laser drilling of holes and copper galvanic plating ensure electrical connections.

"The embedding of active and passive components into PCBs allows for new degrees of freedom in the layout phase. By integrating the components in-between two wiring layers a complete planar package can be achieved. This allows placement of driver ICs or capacitors on top while the backside can be used for cooling. And the direct connection to the MOSFET die without bonding reduces inductance and thus enables faster switching", explained Christoph Loef, Senior Scientist Power Electronics. "Integrated magnetics are suitable for switching frequencies between 1 and 10 MHz, inductance can reach up to 10 µH. And integrated drivers allow for incorporation of Silicon Carbide and Gallium Nitride power semiconductors for even higher switching frequencies".

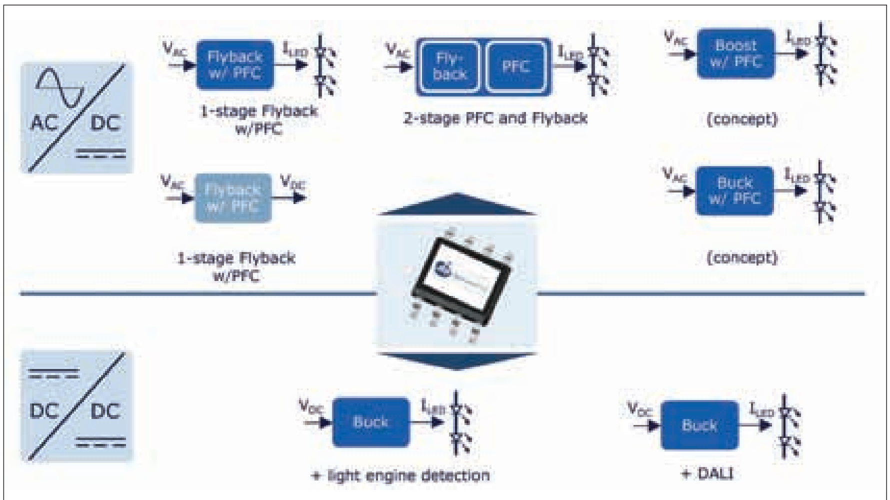
Towards digitally controlled LED drivers

Infineon Technologies **(www.infineon.com)** introduced an approach for LED drivers derived from so-called digital power. "The world is becoming digital and with upcoming software-controlled digital LED driver technology, digital designs will now find inroads into mainstream applications such as LED drives. This topic is heavily impacting any R&D head as well as design engineers", stated Infineon's Marketing Director Digital Power Ulrich vom Bauer.

Next generation integrated software-controlled digital power conversion IC or Digital Power 2.0, can be an interesting alternative to simplify LED driver designs. Based on self-adapting digital control loops, the driver can automatically feed different loads such as power down in idle mode or at full load highest efficiency at outstanding PFC. One more degree of optimization is parameter setting via software allowing compensation of the remaining external components. Some fine-tunig of a parameter set can be done during the production process. This feature can be used to accommodate for components with higher tolerances – and lower cost – to further enhance the efficiency of the design. "Thus we expect a rapid migration towards software-controlled LED drivers, especially in the mid- and low-power class driver segment. The typical mass market applications such as downlights, troffer, tracks and spotlight for offices and shops which will demand it in line with the already existing high designs", vom Bauer expects. **AS**



ABOVE: Embedding power electronics into the OLED/LED can lead to compact and reliable designs



LEFT: Software can control various LED driver topologies

The Whole World of Electronics

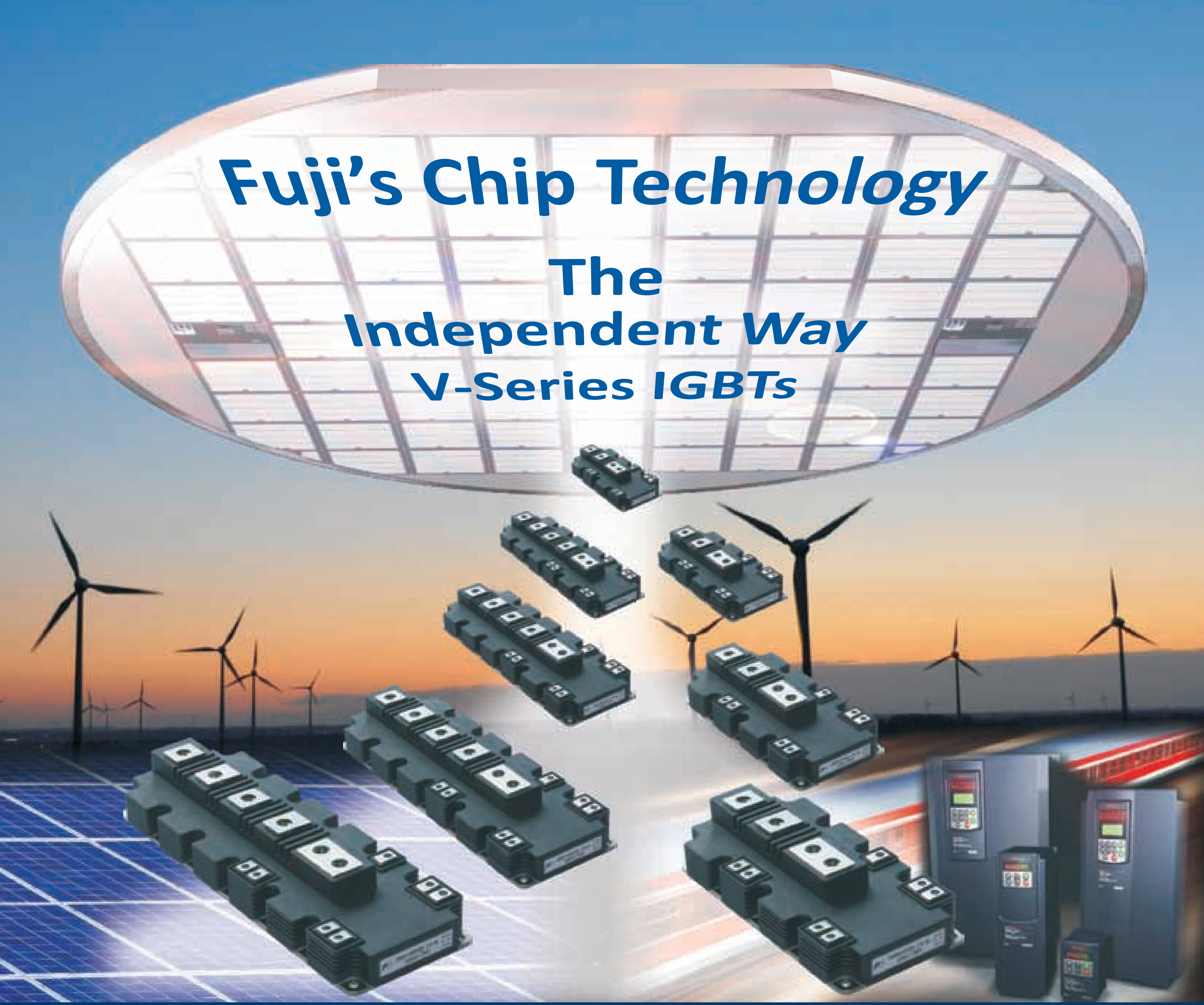
From November 11 to 14, 2014, visitors to Electronica 2014 in Munich can expect to see the whole portfolio of electronics - from components and systems to applications and services. This year's international trade fair revolves around automotive, embedded systems, medical electronics and lighting, as well as the overarching themes of security and energy efficiency. The program of conferences and forums will explore these exhibition topics in greater depth. And, by the way, the history of this fair stems 50 years ago – the first Electronica was held in 1964 featuring 13,000 visitors. In 2012, almost half of the 73,000 visitors and 63 percent of the 2,670 exhibitors were from abroad.

According to calculations by the German Electrical and Electronics Manufacturers' Industry Association (www.zvei.org), the global market for electrical and electronic products grew by 3 % last year to approximately €3.7 trillion. The Asian and American markets have been mainly driving this growth. The corresponding market for electronic components is $500 billion and for semiconductors around $320 billion.

Energy efficiency paving the way for new developments

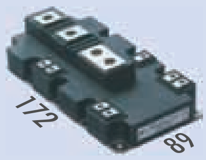
Machines account for two-thirds of all electricity consumed by the industrial sector. According to the German Electrical and Electronic Manufacturers' Association (ZVEI), 10–15 percent of all energy used in Germany's industrial sector could be saved through the use of intelligent automation systems alone. That corresponds to a potential savings of at least €4 billion. Improving the network infrastructure could increase efficiency even further. Expanding renewable energies as part of the energy transition is presenting networks with major challenges due to fluctuating power flows. Intelligent networks, or so-called smart grids, can measure these fluctuations and respond accordingly.

Energy efficiency is increasingly becoming a key criterion for several industrial sectors. That is why this topic plays an important role in all exhibition sectors at electronica. That also applies to Infineon Technologies (www.infineon.com), who is presenting its entire range of power semiconductors, microcontrollers and sensors. "As part of our focus topic, we have identified various markets and regions where energy efficiency continues to increase in importance, for environmental as well as cost-related reasons. In China, entire fleets of busses for inner-city transport are switching to electric drive systems. In the United

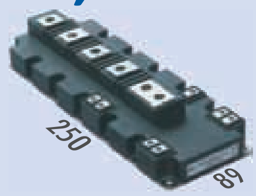


- Trench-FS IGBT
- High thermal cycling capability
- Low spike voltage & oscillation free
- Excellent turn-on $^{dIc}/_{dt}$ control by R_G

High Power IGBT-Modules, 2-Pack & Chopper



	I_C	1200 V E-Type	1200 V P-Type	1700 V E-Type	1700 V P-Type
2-Pack	600A	E			
	650A			E E+	
	900A	E	P		
Chopper	650A			E	
	900A		P		
Chopper	650A			E	
	900A		P		



	I_C	1200 V E-Type	1200 V P-Type	1700 V E-Type	1700 V P-Type
2-Pack	1000A			E E+	P
	1400A	E	P	E	P
Chopper	1000A			E	
	1400A		P	E	
Chopper	1000A			E	
	1400A		P	E	

E : E-type (low switching losses) E+ : E-type with large Free Wheeling Diode P : P-type (low $V_{CE,sat}$ & soft turn-off)

From November 11 to 14 it's again time for Electronica Fair in Munich

States, they are experimenting with electrified highways for trucks. And regulated drives for industrial facilities are catching on in Europe. Energy efficiency is also developing into an important sales argument for household appliances and intelligent building-control systems," explains Dr. Helmut Gassel, Head of the Business Unit for Industrial Power Control at Infineon.

Major part automotive electronics

Automotive electronics is one of the most important segments in the market for electronic components. Automobiles already have on-board computers as well as infotainment and assistance systems with a constantly growing range of functions. Electromobility, or the increased networking of automobiles and the development of autonomous driving, could mean additional potential for the industry. The economic development agency Germany Trade and Invest expects that global market volume for automotive electronics last year will be worth some $190 billion. According to a forecast by the German Electrical and Electronic Manufacturers' Association (ZVEI), market volume is expected to increase to more than €430 billion by the year 2025. with a strong focus on (H)EV's drive train.

"The future of driving is electrified, automated and networked," expects Klaus Meder, Chairman of the Automotive Electronics Division at Robert Bosch (www.bosch.de). Electronics plays a key role in that development. That is why the value of hardware and software in the automobile will continue to increase in the years to come. Expanded Euro NCAP guidelines, which are used to assess vehicle safety, are driving the spread of assistance systems such as advanced emergency braking systems. Customers and manufacturers alike are putting their money on more and more networked functions in the automobile. However, energy efficiency is also an important topic: "New drive solutions will make it possible to further reduce CO2 emissions and conserve resources," explains Meder. "Electromobility in particular calls for new products, particularly when it comes to power elements". To demonstrate how much progress developments in this area have already made, Robert Bosch is presenting its latest solutions in the semiconductor, sensor and power-module sectors.

The Automotive Forum and the lectures and panel discussions offer also the opportunity to gather information about the latest developments and trends. During the four days of the 2014 fair, the topics of power electronics and automotive software will be the focus of special attention. The Automotive Conference is held on November 10. Leading executives and researchers will meet to exchange ideas and information about topics that play a key role in the transition that is affecting the entire industry. The lectures at this year's conference are divided into three subject areas, i.e. Lighting, Sensor Fusion and Connectivity.

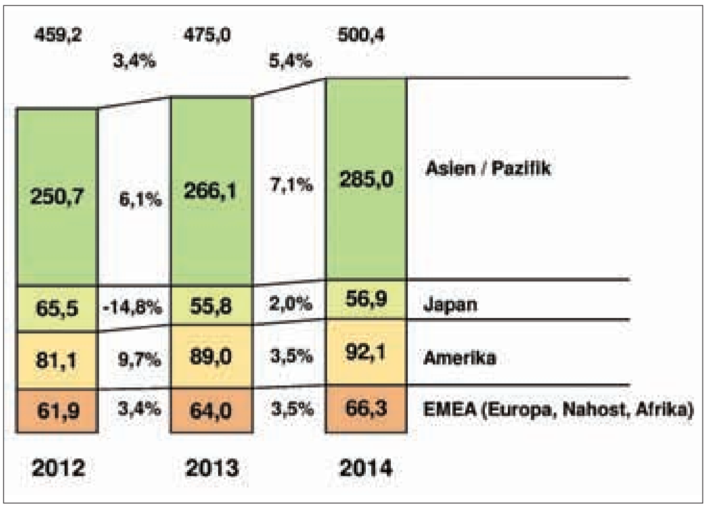
LEDs for modern lighting

Now that the second phase of EU Regulation 1194/2012 on stricter guidelines for light bulbs and high-voltage and low-voltage halogen lamps went into effect on September 1, 2014, there will also be new regulations on energy-efficient lighting technologies in 2015. These requirements are not just coming from the officials: In the automotive sector in particular, manufacturers are searching for more productive lighting alternatives. That is why modern LED technologies will be one of the most important topics. Lectures about trends in lighting technology will be held with Luger Research (www.lugerresearch.com) as part of the Electronica Forum. It all revolves around the International Year of Light.

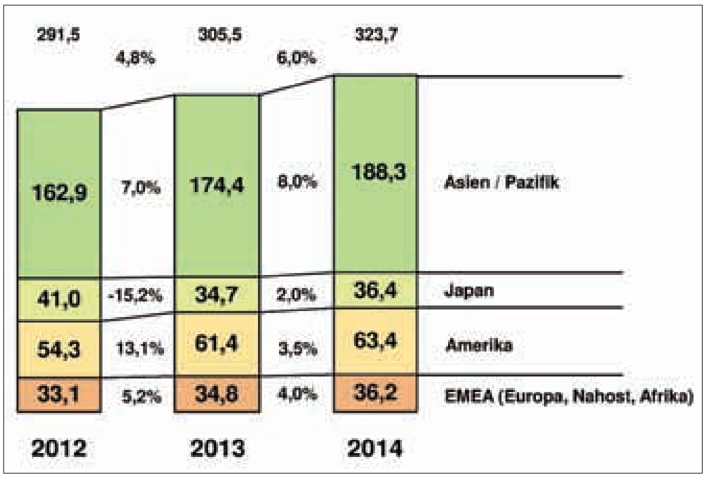
While the forum and the conference focus on theory, exhibitors' presentations are more application oriented. OSRAM Opto Semiconductors (www.osram.com) will present several new developments in the Automotive, Consumer, Industry and General Lighting segments. It is focusing on increasingly compact components that are no larger that the light-generating element itself. Another relevant area: Increasing light intensity and luminance more efficiently to improve light output and, in doing so, reduce costs at the same time. The Oslon Black SFH 4715A is an example. Thanks to a 30 % increase in efficiency, the new chip generation makes infrared illumination at more than 100 meters possible.

Power related exhibits

The formation of a new power industry consortium will debut at Electronica, the Architects of Modern Power (AMP, www.ampgroup.com). The founding members are CUI (www.cui.com), Ericsson Power Modules (www.ericsson.com/ourportfolio/products/power-modules, A4-260) and Murata (www.murata-ps.com, B5-107). The aim of the alliance is to create the most technically advanced, end-to-end distributed power solutions – a



World market electronic component 2012-2014 ($ billion) (Source: ZVEI)



World market semiconductors 2012-2014 ($ billion **(Source: ZVEI)**

complete ecosystem of hardware, software and support. A level of software compatibility will be required in order to achieve a true multi-source solution, including compatibility of PMBus commands, proprietary controller commands, and configuration files. The AMP Group was formed to address this challenge. The AMP Group's work will extend well beyond defining mechanical dimensions and product footprints for intelligent DC/DC power modules and AC/DC power supplies. The consortium's long-term strategic alliance will foster close collaboration between members to develop shared technology roadmaps. The AMP Group will announce its first set of standards, for digital Point-of-Load regulators and advanced bus DC/DC converters, at Electronica.

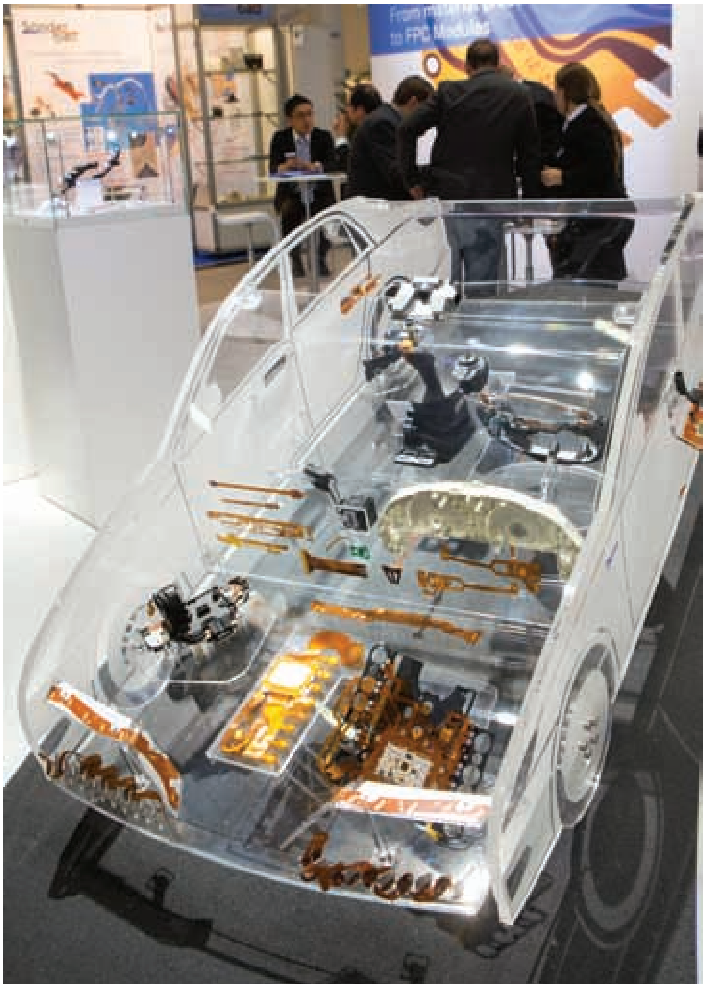
Murata will also display the addition of the OKD series of non-isolated POL DC/DC converters. Available in three different package formats, through-hole, single-in-line, and surface mount, the OKDx-T/40 is a 40 A, 132 W digital DC/DC converter. These highly efficient (typically 97.2 %), fully regulated converters offer a high power density and measure just 30.85 x 20.0 x 8.2 mm. The PMBus™ interface facilitates power management features not previously available in analog POL converters. By interfacing the OKD converter to the system's I?C bus, a systems engineer can monitor critical system-level performance parameters, set warning flags and customize parameters.

CREE (www.cree.com/power, hall A4-booth 260) has expanded the SiC 1.2 kV six-pack power module family with a 20A all-SiC module suited for 5-15 kW three-phase applications based on C2M SiC MOSFETs and Z-Rec® SiC Schottky diodes. The six-pack features lowest switching losses due to the zero turn-off tail current in the MOSFET and the zero reverse recovery current in the Schottky diode. When compared to similar Si IGBT modules, the new SiC module operates at a much lower junction temperature allowing designers to aggressively pursue new paradigms in high frequency and power density. The power module (part number CCS020M12CM2) and companion gate driver evaluation board (CGD15FB45P) are available at authorized distributors, including Mouser (www.mouser.com, A5-524)), Digi-Key (www.digikey.com, A5-565), and Richardson RFPD/Arrow RF & Power (www.richardsonrfpd.com, A4-225).

Richardson RFPD also announced the availability and full design support for three new 650 V non-punch-through (NPT) IGBTs from Microsemi Corporation (www.microsemi.com, A4-207).

These ultra-fast 650V NPT IGBTs feature near-zero reverse recovery, low leakage, anti-parallel SiC diodes, low saturation voltage, low tail current, short-circuit withstand ratings, and high-frequency switching capabilities. Available in 45 A and 70 A current ratings, these IGBTs allow developers to reduce total system cost by replacing more costly 600 V to 650 V MOSFETs in industrial applications up to 150 kHz such as induction heating (IH), motor control, general purpose inverters, and uninterruptible power supplies (UPS).

Exar (www.exar.com, A6-169) will



Automotive electronics is one of the most important segments in the market for electronic components as can be seen at Electronica

showcase its 10 A/15 A power DC/DC modules XR79110/115 and an improved AC step driver for LED lighting applications. The company recently has completed its merger with Integrated Memory Logic Limited (iML) a provider of power management and color calibration solutions for large and medium-sized flat panel displays used in televisions and tablets. The iML8684 stems from this merger and provides a complete solutions for LED light bulb and LED tube applications. Unlike conventional AC driver solutions which use a single large driver, iML has patented a unique distributed architecture of multiple small, low cost drivers. This solution provides increased flexibility and a lower overall BOM cost as it uses much lower voltage technologies. It also improves heat dissipation as multiple devices are used across the PCB, evenly distributing the thermal load. IML devices remove the need for electrolytic capacitors and inductors that are mandatory for AC/DC driver solutions. The new iML8684 offers improved circuit stability in sub 3 V AC situations created by TRIAC dimming, resulting in high light quality at low dimming. This improvement also increases the number of compatible dimmers in both 120 V AC and 230 V AC countries.

Within its Automotive portfolio Intersil (www.intersil.com, A5-167), representing 10 % of the company's business, the new ISL78692, a 4.1V single-cell battery charger designed to extend the life of lithium-ion (Li-ion) batteries in automotive emergency call (eCall) systems. The ISL78692 battery charger dissipates low leakage current (3 µA), allowing the backup battery to remain charged for a longer period of time. The ISL78692 charger's ability to monitor the battery's temperature and its low, 4.1 V output voltage both help to extend the life of popular LiFeP04 batteries. Highly integrated, the ISL78692 requires five external components to program the charging current. When combined with the charger's compact 3 mm x 3 mm DFN package, the complete solution easily fits on space-constrained PCBs. The ISL78692 also offers a unique charge current thermal foldback feature that prevents overheating by automatically reducing the battery charging current.

The MAX17503 synchronously-rectified DC/DC step-down converter from Maxim Integrated Products (www.maximintegrated.com, A4-266) integrates two MOSFET switches and eliminiates an external Schottky diode. It operates from 4.5 V to 60 V at 200 kHz – 2.2 MHz switching frequency and delivers up to 2.5 A output current. According to the company the MAX17503 saves up to 50 % space and reduces component count by 75 %. reduces heat dissipation, and improves reliability. Designers with widely varying loads can use pulse-frequency modulation (PFM) for enhanced efficiency at light load currents. Specifically designed for industrial control and automation applications, the device is suited for programmable logic controllers (PLCs), process variable transmitters (PVTs), computerized numerical control (CNC), and distributed I/O modules in industrial process control, motor control, power grid, and building automation applications.

ROHM Semiconductor (www.rohm.com/eu) will present in hall A5-booth 562 its most recent developments from the company's R&D centers as well as co-developments with partners which have been manufactured in its fully integrated production sites. ROHM currently offers 1200V/120A and 1200V/180A full SiC power modules. New SiC half-bridge modules and a new 1200V/300A type expand this portfolio. Next-generation SiC MOSFETs featuring low on-resistance and high speed switching add to this as well. Also new Schottky barrier diodes utilize a special metal optimized for high temperature operation, resulting in lowest reverse recovery. In addition, thermal runaway is prevented. The company also welcomes visitors to join its expertise in LED driver technology at the Automotive Forum (November 11th, 16.00/hall A6-booth 330).

Texas Instruments (www.ti.com, A4-420) will showcase seven SIMPLE SWITCHER regulators that simplify wide input synchronous power supply design and help engineers to create energy-efficient, electromagnetic interference (EMI) compliant products. The LM43600/1/2/3 and LM46000/1/2 DC/DC converters feature an input voltage range of up to 60 V and 27 µA of standby current. The synchronous regulators support an input voltage range from

The Automotive Forum, lectures and panel discussions offer the opportunity to gather information about the latest developments and trends

DC/DC converters and a broad line of passive components are on display at Murata

3.5 V to 36 V and generate output currents of up to 0.5 A, 1 A, 2 A and 3 A, respectively. The LM46000, LM46001 and LM46002 support an input of 3.5 V to 60 V and output currents of up to 0.5 A, 1 A and 2 A. The converters integrate compensation, control features and MOSFETs. TI's new TPS82740A and TPS82740B micro step-down converter modules support 200 mA output current with 95 % efficiency and consume only 360 nA of quiescent current during active operation and 70 nA during standby. The tiny modules rely on a fully integrated, 9-bump MicroSiP package, which incorporates a switching regulator, inductor and input/output capacitors to achieve a solution size of 6.7 mm?.

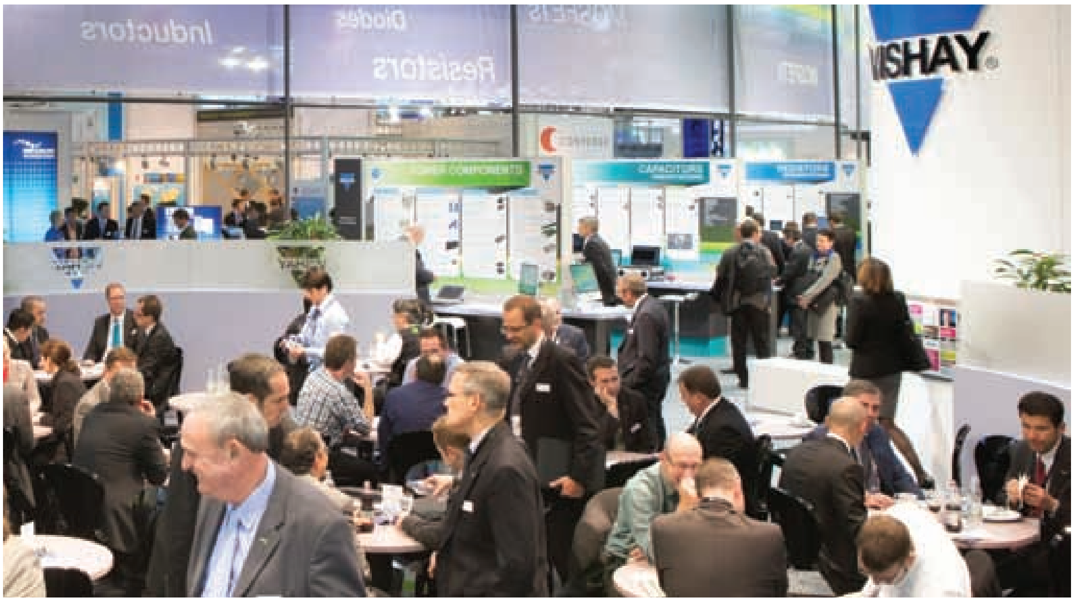
Finally, the UCC28910 is the first TI high-voltage switcher that incorporates a controller. This 700-V Power FET has a 700 V current source for start-up and is dedicated to off-line isolated flyback power converters. It uses primary-side regulation and senses all the needed quantities to perform output voltage and current regulation, from auxiliary winding, without the need for an optical coupler (see PEE 5-14, pages 30-31).

The regulators are fully supported in TI's WEBENCH® online design tool containing libraries of more than 24,000 components from 120 manufacturers. "We are working also on HV-MOSFETs, IGBTs, SiC and GaN", underlined Steve Anderson, TI's General Manager Analog.

At Vicor (www.vicorpower.com, A5-237), attendees can meet with experts to learn more about the company's solutions for a wide range of applications requiring high power density, high efficiency, and improved design flexibility. New products exhibited will include front-end power conversion components and point-of-load power conversion products in the Converter housed in Package (ChiP) and System in Package (SiP) form factors. Attendees can also learn more about Vicor's online PowerBench™ design tool suite. Additionally, Vicor will be presenting a range of topics including HVDC Distribution & Conversion in Datacenters, Aerospace, Microgrids & Transportation on Wednesday, Nov 12, 12:00 – 12:30 at Hall B5-151. Interest in 400V DC remains high because, in the right applications, it presents several potential advantages over traditional AC and 48 V DC architectures. For example, 400 V DC power significantly reduces the cost of copper cabling and installation in traditional 48 V telecom applications. In data centers, it simplifies the power chain, which improves availability and potentially efficiency compared to AC power.

Vishay Intertechnology (www.vishay.com, A5-143) exhibits among others 27 new 4 A to 10 A FREDHyperfast and Ultrafast recovery rectifiers in the compact, low-profile SMPC (TO-277A) eSMP® series package. Combining extremely fast and soft recovery characteristics with low leakage current and low forward voltage drop, the AEC-Q101-qualified rectifiers reduce switching losses and over-dissipation in automotive and telecom applications. They ffer reverse voltages of 100 V, 200 V, and 600 V; reverse recovery time down to 24 ns; and typical forward voltage drop down to 0.72 V in single- and dual-die configurations. Specified for output and snubber operation, the FRED Pt rectifiers are optimized for DC/DC converters and power factor correction (PFC) in automotive engine control units (ECUs), antilock braking systems (ABS), and LED lighting, in addition to telecom DC/DC bricks.

A new powdered-iron-based, WPC-compliant (Wireless Power Consortium) wireless charging transmitter coil for Qi wireless charging pads. Offering a durable construction and high permeability shielding, the new Vishay Dale IWTX-4646BE-50 provides high efficiency greater than 70 % at a 19 V input voltage when tested using WPC-compliant transmitter and receiver chipsets and a Vishay Dale IWAS-4832FF-50 receiver coil with 2.7 mm spacing. Designed for use in conjunction with Vishay's WPC-compliant wireless receiver coils, the IWTX-4646BE-50's high-saturation powdered iron is not affected by permanent locating magnets. As an alternative to larger ferrite-based solutions ? which can saturate in the presence of a strong magnetic field ? the new coil offers a magnetic saturation of 50 % at 4000 gauss. AEC-Q200 certification for use in automotive applications is pending, and expected to be complete in Q1 2015. **AS**



Passive and power components are of great interest at Electronica as exhibited by Vishay

A Two-Phase Interleaved One Cycle Control PFC for Charger Applications

The electrification of cars is bringing new challenges to the power electronics designers, AC/DC and DC/DC converters are now also needed in the automotive world and car manufacturers and OEMs are striving to address this need in an economical and efficient way. **Davide Giacomini, Product Management Director, Automotive Division, International Rectifier, Italy**

This article discusses the implementation of a two-phase interleaved OCC PFC, used in an AC/DC charger for automotive applications, delivering up to 3 kW output power. Shown are the several steps of the OCC-PFC implementation, from the current sensing to the synchronization and interleaving of the two or more phases of the converter. Results of the real hardware implementation are presented and discussed using waveforms and performances measured in the demo-board.

Hardware implementation

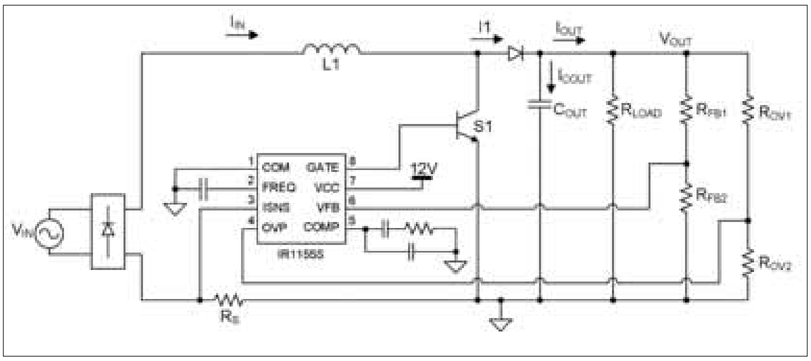
Figure 1 shows the basic application circuit of the IR1155S, the only real OCC IC controller available in the market. In this topology the input voltage sensing is missing and the current sensing is done by reading the negative voltage across the Rs resistor, since the IR1155S ground pin sits on the power ground of the converter for proper IGBT gate driving.

Current sensing stage

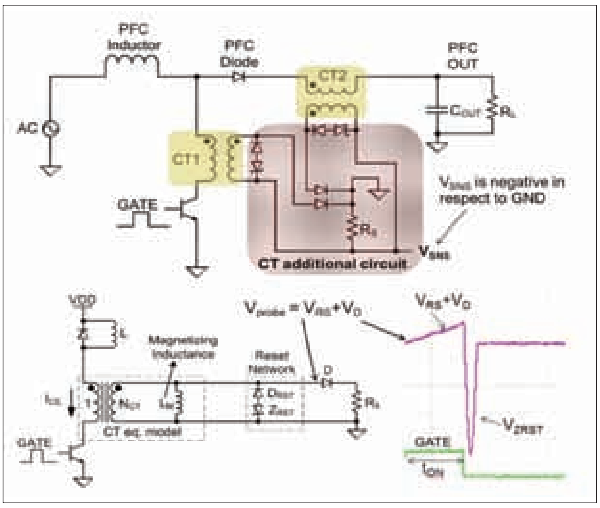
For proper operation of the interleaved system each phase current information is needed, as for what it is observed in Figure 1 this is not immediately feasible by duplicating the same schematic since the two channels information will not be independent.

Figure 2 shows the simple circuit used to perform the current measurements, by inserting to small high frequency CT in series to the switch and to the rectifying diode the complete current waveform can be reconstructed and the information correctly fed back into the V_{sns} pin of the IR1155S controller.

The solution, despite apparently complicated, allows an excellent reconstruction of the full current waveform in each phase of the PFC and the correct OCC algorithm implementation on each stage.



ABOVE **Figure 1: OCC PFC implementation using IR1155S control IC**



LEFT **Figure 2: OCC-PFC current sensing using current transformers and current transformer reset network**

Clock synchronization and interleaving

The IR1155S uses an internal oscillator that is also internally mirrored to obtain the information for the integration slope of the OCC controller. For this reason we cannot simply use an external clock signal but we need to synchronize each controller clock to an external signal and let it generate its internal ramp.

By observing the oscillator block schematic of the controller, we noticed that the oscillator does not accept a simple external turn-off signal to earlier terminate it, instead we need to tweak it to do it by itself and to maintain a minimum dead time as well. Figure 3 shows the hardware solution used and the related waveforms. The comparators are open-collector output type pulled-up to a voltage higher than 4 V, so to force the internal set of the IR1155S; after the input clock rising the dead time period also starts and will end when the comparator input has gone below the 2.5 V reference. The dead time is now defined by the external RC derivative network.

Current sharing between phases

The current sharing has been implemented in a novel and simple

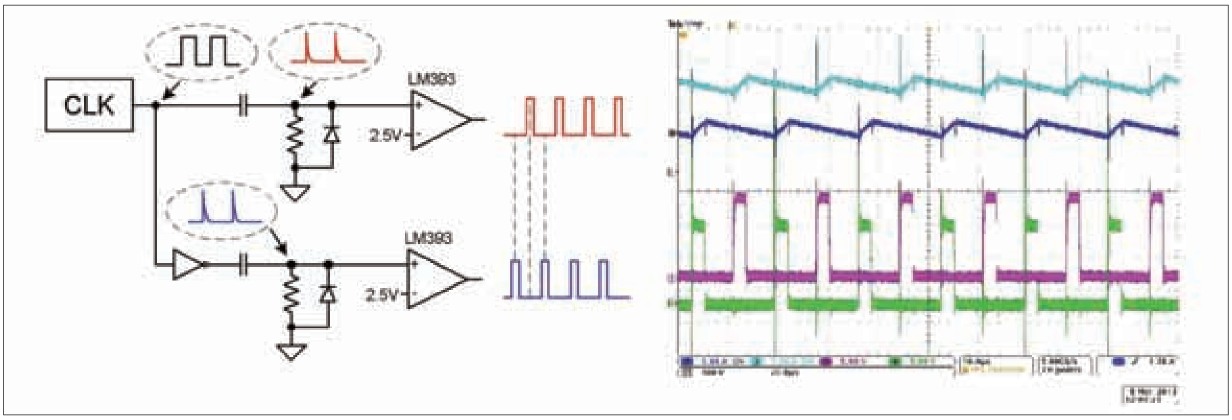


Figure 3: Synchronisation and interleaving circuit and waveforms (CH1: L1 current, CH2: L2 current, CH3: gate 1, CH4: gate 2)

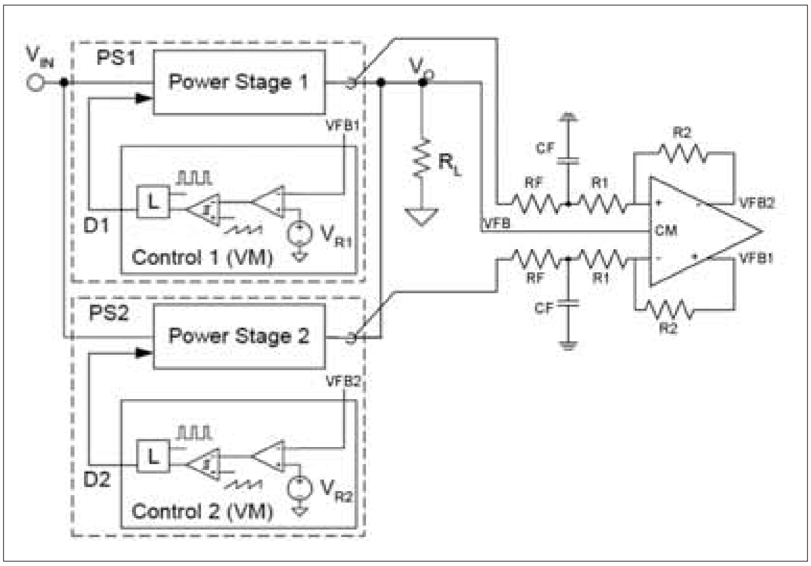


Figure 4: Novel current sharing technique

solution, here called *Current Dependent Voltage Feedback*, which allows using any pair of single phase PFC controllers though these have not been designed for current sharing. The idea is based on integrating the current feedback information on top of the voltage feedback on each controller loop, Figure 4 shows the implemented solution block schematic.

The same current sense information used for the OCC algorithm implementation is here used for the current sharing: each current feedback is filtered to recover the average value information and then amplified by a pure differential amplifier whose common mode output is set by the resistor divider connected to the PFC output voltage and it will be equal to the reference voltage of the controller in static conditions.

To be noted is that the amplifier output relative to the input section 1 actually sets the voltage feedback of the controller of section 2, by doing this an increase in the current of section 1 results in a lower Vfb2 signal to the controller of section 1 that then increases its duty cycle and current to compensate the difference.

Figure 5 shows the circuit implementation and the resulting waveforms in steady state at 1.5 kW output of this novel current sharing technique.

Experimental results

A two-phase interleaved OCC PFC for automotive charger application has been

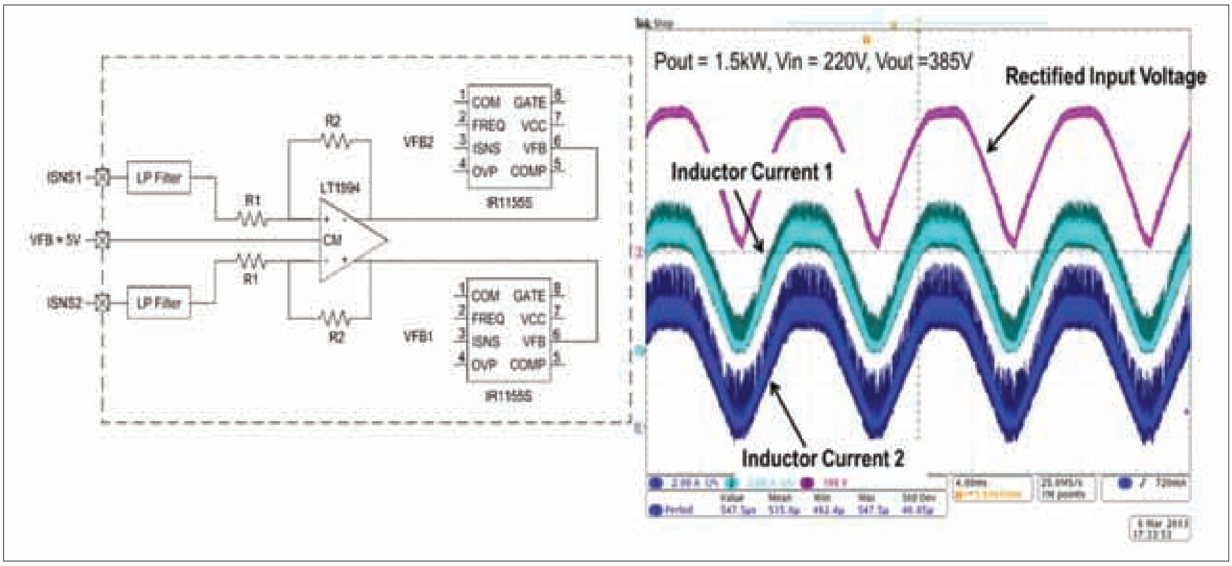
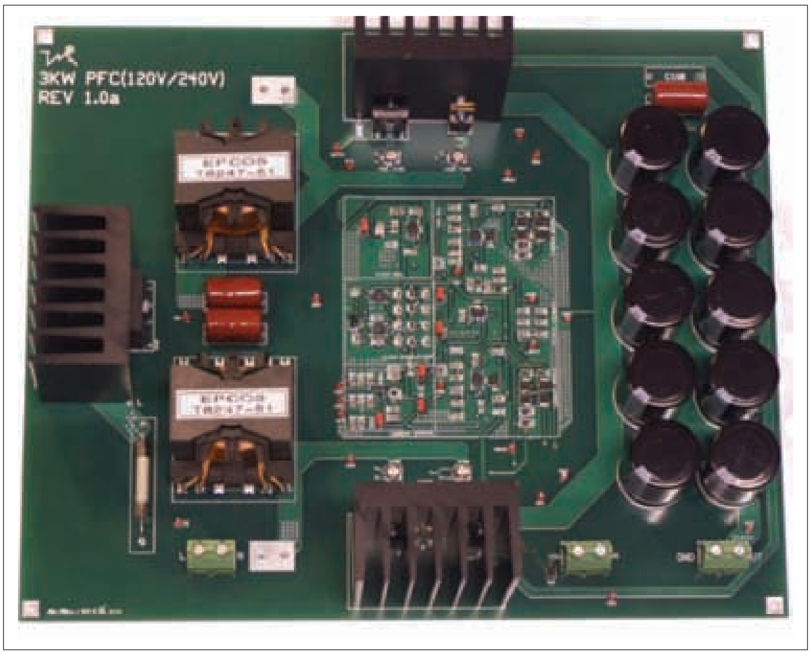


Figure 5: Current Dependent Voltage Feedback implementation (CH1: L2 current, CH2: L1 current, CH3: rectified input voltage)

RIGHT Figure 6: **Two phase interleaved OCC-PFC demo-board**



implemented with the following targets:

- V_{IN}: 100 V AC/240 V AC
- Max I_{IN}: 16 A
- V_{OUT}: 385 V
- L: 250 μH
- C_{OUT}: 3 mF
- Freq: 50 kHz – 100 kHz
- P_{OUT} : 3 kW

Since the high power output the switches of choice have been the IGBTs, considered more reliable and rugged than SuperJunction MOSFETs in this application, the rectifying diodes selected are of Ultrafast family, though also SiC diodes have been successfully tested in the same board.

Main power devices used in the solution are the following: AUIRGP65G40N (IGBTs, 2x), ETX1506 (diodes, 2x) and IR1155S (OCC controllers, 2x). The board has been tested at different input voltages and switching frequencies to verify the performances and efficiency of the solution.

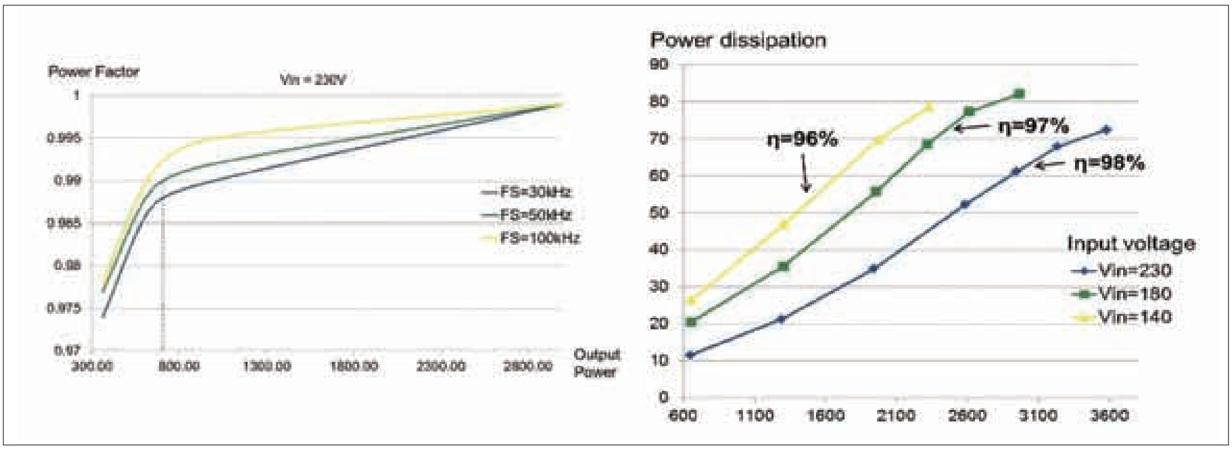
Figure 6 shows the demo-board, the large area in the center of the PCB is the control area with all external electronics needed to interleave the two IR1155S sections. Most of those components can be integrated in a single chip solution for future optimization of the circuit.

The board has been tested at different switching frequencies; Figure 7 shows the final PFC factor vs. output power and switching frequency (50 kHz) and the total power dissipation and efficiency vs. power output, of the two phases OCC-PFC converter. Maximum PFC factor is achieved at higher frequency, however a good balance between PFC and efficiency is reached at this power level for 50 kHz switching frequency. A maximum efficiency of 98 % is achieved at 230 V AC input.

Conclusion

A novel two-phases interleaved One Cycle Control PFC for Automotive Applications has been proposed and verified both in simulation and hardware, each phase uses a IR1155S OCC-PFC controller and some external electronics has been added to synchronize the two stages and equally share the current. The advantages of the chosen topology and control strategy are evident; no high voltage sense input, simple implementation with easy compensation, rugged IGBT switches and robust control system compared to standard CCM PFCs. Performances of the demo-board are confirming the expected results with an efficiency in excess of 98 % and a power factor coefficient above 99 % for > 700 W output. The proposed solution presents a viable alternative for a reliable realization of the PFC stage for level 1 and 2 Automotive AC/DC chargers and verifies the applicability of the dual phase OCC-PFC concept.

BELOW Figure 7: **PFC performances vs. output power, total power dissipation and efficiency**



Thyristors for >10 Gigawatt Power Transmission

A new thyristor platform with voltage ratings 6.7 kV, 7.2 kV and 8.5 kV was developed to enable an optimal design of converter valves with DC link voltages above 1 MV. Maximal area utilization of 150 mm silicon wafer and optimized cathode layout of the electrically triggered thyristor improved on-state current ratings by >20 % thanks to a reduced on-state voltage drop by 10 %. The new platform provides more efficient and powerful converter valves for the next generation UHVDC systems with rated power ranging from 8 to 13 GW. Prof. **Dr. Jan Vobecky, Dr. Chunlei Liu, ABB Switzerland Ltd., Semiconductors**

For long-distance and multi-gigawatt power transmission, Current Source Converters (CSC) with large-area Silicon phase-controlled thyristors (PCT) are used due to overall low system losses. As the length of these transmission lines can reach over 2,000 km, extreme demands are laid on energy efficiency. This dictates the usage of direct current (DC) transmission line cables operating at ultra-high voltages (UHV). These systems are therefore called UHVDC systems.

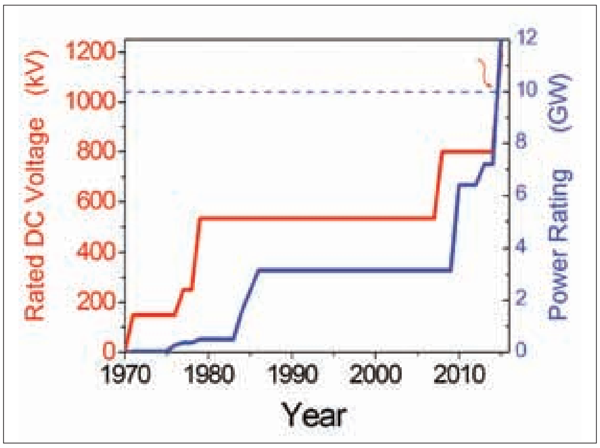


Figure 1: Evolution of maximal ratings in HVDC technology

Most of the UHVDC systems are nowadays installed and further planned in China, where bulk energy sources of hydroelectric power are available in the west, while the industrialized regions with high consumption of electrical energy are located in the east and south. Following the success of UHVDC lines operating with a rated DC voltage of ~800 kV and a rated power of 7 GW, China is investigating the possibility of increasing the voltage rating up to 1,100 kV for power transmission breaking the 10 GW limit [1]. This intention manifests itself in the steep rise of ratings in Figure 1, which shows the evolution of HVDC technology.

Demands on thyristors for future UHVDC systems

UHVDC systems for transmitted power over 10 GW lay new demands on converter valve, valve hall, transformer, transformer and wall bushing, by-pass switch, surge arrester and DC yard.

Regarding the converter valve, a new PCT platform with higher rated currents for the same blocking voltages had to be developed. To fulfill this demand, the PCTs with lower on-state voltages (V_T) for equivalent turn-off losses and recovery charge Q_{rr} were designed and qualified. Since the PCT is a non punch-through device, higher blocking voltages require thicker Silicon, which increases the V_T and reduces the rating current. Assuming the same thermal resistance of an available package, the maximal rated current then decreases with an increasing rated blocking voltage.

The optimal voltage class of the PCT for

Figure 2: New six inch PCT for UHVDC technology

given valve target parameters can be rigorously chosen only when the current rating of the HVDC system is known. In reality, the development of a new PCT generation starts before the maximal rating current of a given target application is confirmed. It is therefore advantageous to develop a new PCT platform, which comprises several voltage classes, because it provides flexibility in valve design. For this purpose, ABB has developed a new PCT platform with three voltage classes, namely 6.7 kV, 7.2 kV and 8.5 kV with improved ratings of the on-state current (see Figure 2).

The maximal rating current of the new PCT is over 6 kA for voltage ratings of 6.7 kV and 7.2 kV PCTs, and 5 kA for 8.5 kV. For an UHVDC system with the maximal rating current over 6 kA this means that valve designers can use PCTs with 6.7 kV or 7.2 kV voltage ratings. In case that minimal count of PCTs in series is favored, fewer serially connected 8.5 kV PCTs can be used provided that the maximal rating current is limited to 5 kA.

New thyristor platform characteristics

Processing of six inch PCTs with repetitive peak blocking voltages up to 8.5 kV is attributed by the use of

1. high purity float zone neutron transmutation doped (FZ NTD) silicon wafers with optimal resistivity and thickness,
2. advanced diffusion techniques, which provide the required purity after long-running diffusion,
3. a high quality junction termination including surface passivation for stable forward and reverse blocking,
4. an electrically-triggered thyristor design which provides maximal cathode area for conduction of the on-state current,
5. optimal lateral structuring of amplifying gate and cathode shorts for lower V_T, robust turn-on and turn-off capability,
6. maximal utilization of 6" wafer,
7. optimal parameters of lifetime control for the banding of reverse recovery charge Q_{rr},
8. a housing with low thermal resistance and high surge current capability.

The items 1 - 3 above assure us the achievement of stable DC and AC blocking characteristics with low leakage currents and rugged dynamic blocking in case that the valve converter is subject to a lightning strike and the PCTs are driven to avalanche regime.

The Q_{rr} banding (item 7) is dictated by the fact that the PCTs are connected in series to support the rated valve voltage. If they have similar magnitudes of Q_{rr}, less additional PCTs must be added into the stack to compensate for non-uniform voltage sharing. Narrowing of the Qrr band is achieved using the classical electron irradiation technique with optimized energy and dose.

The items 4 – 6 are important for the achievement of smallest possible electrical valve losses caused by the PCTs. To judge these losses at thyristor level, the trade-off curves between V_T and Q_{rr} are usually used. For the new PCT platform, they are shown in Figure 3. These curves show that lower turn-off losses (characterized by Q_{rr}) provide higher on-state losses (characterized by V_T) and vice versa. It also implies that PCTs of a higher voltage class give higher overall losses, because the higher blocking voltage requires a thicker Silicon wafer which causes a higher V_T.

Using the improved press-pack housing with lower thermal resistance for the new PCT platform (item 8) together with lower VT (items 4 - 6), the maximal current rating of the PCT of the 8.5 kV class has increased from 4 kA to 5 kA. At the same time, that of the 6.7 kV or 7.2 kV PCTs could be specified at more than 6 kA. The

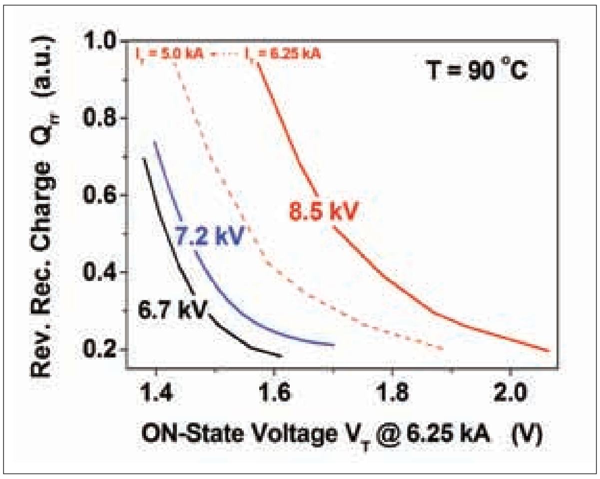


Figure 3: Trade-off curve between V_T and Q_{rr} for the new PCT platform

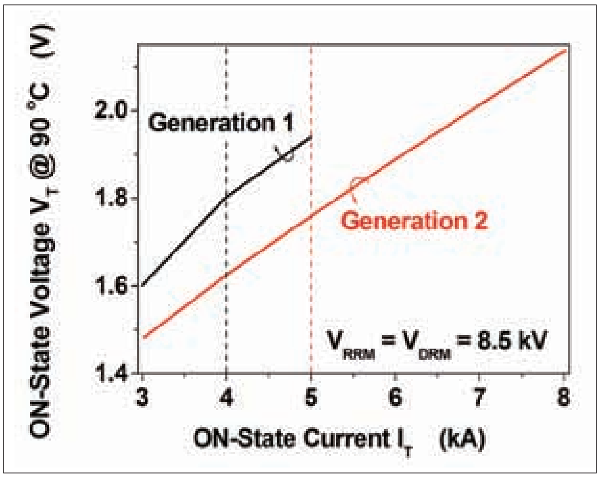


Figure 4: Improvement of on-state voltage drop (mean value) at the new 8.5 kV generation

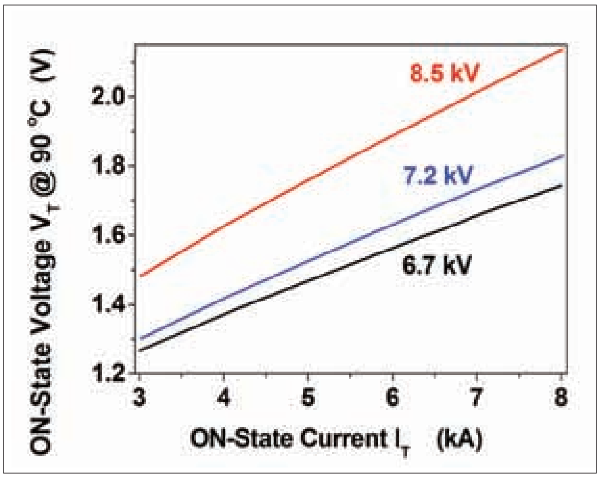


Figure 5: Mean value of on-state voltage drop vs. on-state current for the new PCT platform

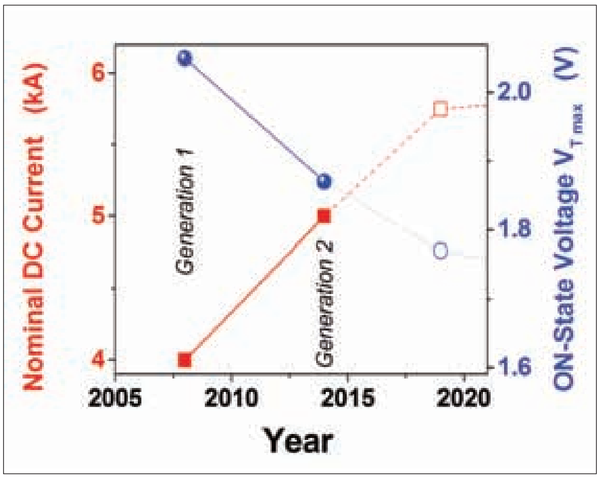


Figure 6: Evolution of 8.5 kV PCT capability with outlook to the future

surge current capability then increased around 10% compared to the first generation. The improvement between the first and second 6" PCT generations is illustrated in Figure 4 for the voltage class 8.5 kV with an equivalent Q_{rr} band. This figure shows that the reduction of V_T by 10 % allows us to increases the maximal current rating from 4 kA to 5 kA.

The dependence of V_T on on-state current is shown for the whole PCT platform in Figure 5. It is evident that the significantly lower V_T of 6.7 kV and 7.2 kV voltage classes predetermine these parts for the usage in the UHVDC systems with the highest current ratings (> 6 kA) and therefore with the highest power ratings (> 10 GW).

Outlook

The UHVDC systems, which require PCTs described in this paper, are installed mainly in China. Today´s installed capacity of 800 kV DC transmission systems is more than 20 GW. The total planned capacity up to 2020 is over 100 GW [2].

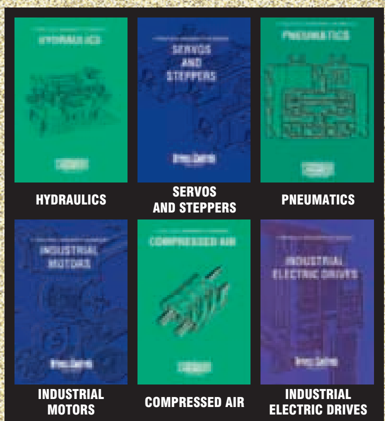
To satisfy these demands, the new PCT generation has been developed for UHVDC lines operating with a rated DC voltage of 1,100 kV with higher current-carrying capability as presented in this paper.

For the periods beyond 2020, further development of UHVDC systems is needed. From the perspective of PCTs there is still room for further improvement in on-state voltage drops and on-state current ratings to support further improvement in energy efficiency. This prediction is illustrated in Figure 6 for the 8.5 kV voltage class processed from six inch silicon wafers as presented above. The voltage classes 6.7 kV and 7.2 kV should behave accordingly with correspondingly lower on-state voltage drops and higher nominal rated currents.

Literature

[1] R. Montano, B. Jacobson, D. Wu, L. Arevalo, "Corridors of power", ABB Review, Special Report: 60 years of HVDC, 2014.

[2] J. Cao, J. Cai, "HVDC in China", 2013 HVDC and FACTS Conference, Palo Alto, CA, USA, August 28-29, 2013.



New 3-Level Topology for Efficient Solar Applications

Three-level topologies' most persuasive selling points are high efficiency and reduced filtering effort. Several three-level topologies feature prominently single-phase solar applications. This article presents a new alternative that also meets the requirements for reactive power and the need to drive down costs. Pro and cons are benchmarked against two established three-level solutions and the discussion concludes with a first look at power modules designed to support this new approach. **Michael Frisch and Temesi Ernö, Vincotech Germany and Hungary**

Solar inverters must generate sinusoidal output current to be fed into the public power grid. The simplest way of producing sinusoidal current is to use an H-bridge inverter with pulse width modulation (PWM) of DC voltage and an output filter. The three-level topology serves to reduce switching losses and the output filter's effort. With two-level modulation, the power semiconductor has to switch at higher voltages, e.g. 400 V. In a single-phase, three-level system the filter's primary output is shorted during freewheeling, this will reduce the switched voltage.

This reduces switching losses and the size of the output filter by half, albeit while still using the same PWM frequency. Excitation is the same as in the standard two-level H-bridge with bipolar switching, but the output of the H-bridge is shorted during freewheeling. In a single phase 3 level system is the output primary of the filter shorted (Figure 1 right), this will reduce the switched voltage.

Advantages of 3-level operation

In 2-level operation energy will be regenerated during freewheeling back to the DC-ling capacitor according to equation 1

$$E_{regeneration} = U_{DC} * I_{Output} * t_{(off)} \quad (1)$$

The energy injected into the grid results to:

$$E_{Out} = E_{Exication} - E_{regeneration} = U_{DC} * I_{Output} * t_{ON} - U_{DC} * I_{Output} * t_{off} \quad (2)$$

$$E_{Out} = U_{DC} * I_{Output} * (t_{on} - t_{off}) \quad (3)$$

The regenerated energy has to pass the inverter twice without value (excitation and regeneration) and it will each time cause additional power dissipation.

With 3-level operation the voltage at a symmetrical output filter is changing between VDC (e.g. +400 V) and half of the actual output voltage (e.g. 0..160 V at 230 V AC grid). The switching losses and the size of the output filter may be minimized using still the same PWM frequency. The excitation works like in standard 2-level H-bridge with bipolar switching, but during freewheeling the H-bridge is turned off and the output shorted.

HERIC-and H5-topology

The HERIC-based inverter circuit (Figure 1) implements a dynamic short connection at the output using two sets of IGBTs and diodes in serial array. The sets are connected in an anti-parallel circuit at the H-bridge's output. For every half-wave, two different IGBTs of the H-bridge are switched with PWM during real power (where the current and voltage have the same polarity). The IGBTs at the output are turned on and off during the corresponding half-wave.

Pros - low static losses in third-level mode:

- Voltage drop at real power during ON - 2 IGBTs
- Voltage drop at real power during OFF and freewheeling - 2 IGBTs + 2 diodes
- Voltage drop at reactive power during OFF and freewheeling - 2 diodes

Cons - complex structure:

- Requires 6 IGBTs (four of the ultrafast switching variety) and 6 fast diodes

The H5-topology (Figure 2) offers a different solution for the same approach. The additional IGBT is switched via PWM together with the low-side IGBTs, while the high-side IGBTs are turned on and off during the corresponding half-wave at real power.

Pros - fewer components:

- Requires 5 IGBTs and 5 fast diodes
- Just three of the five IGBTs have to be of the ultrafast switching variety (if the focus is on real power efficiency)

Cons - high static losses:

- Voltage drop at real power during ON - 3 IGBTs

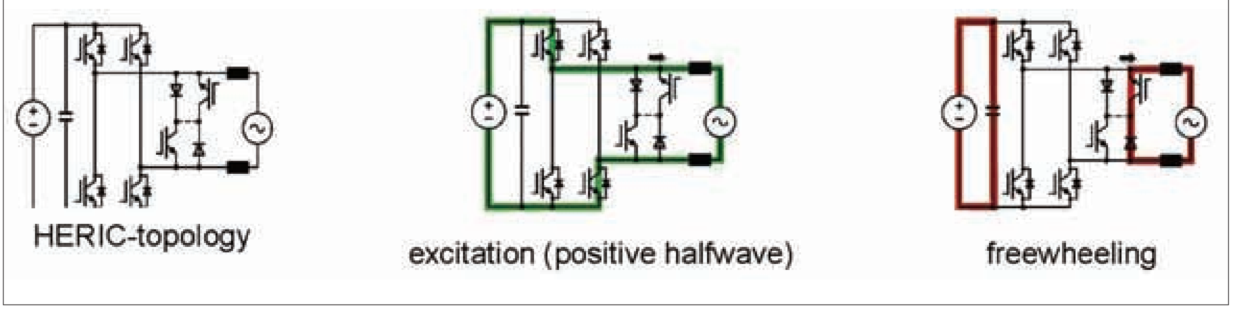


Figure 1: HERIC-topology in excitation and freewheeling mode

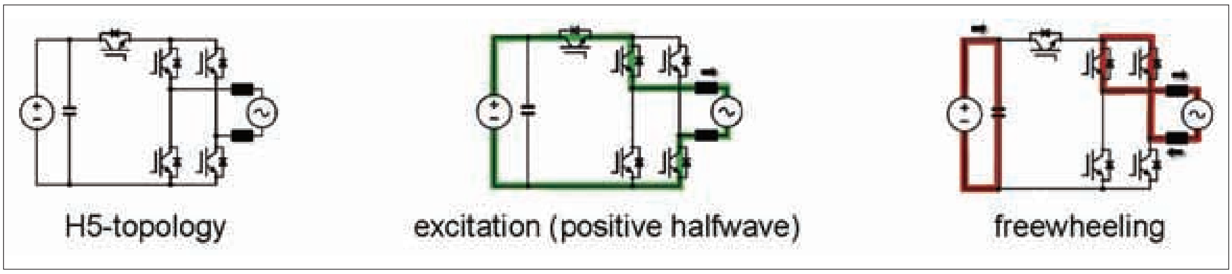


Figure 2: **H5-topology in excitation and freewheeling mode**

- Voltage drop at real power during OFF and freewheeling - 1 IGBT + 1 diode
- Voltage drop at reactive power during OFF and freewheeling - 3 diodes
- 5th switch requires an extra power supply for its gate drive

New H6.5-topology

The new topology also uses six IGBTs like the HERIC topology, but it requires just five diodes (Figure 3).

The new topology achieves the same real power performance as the HERIC topology. There is a price to pay for reducing the number of diodes from six to five, namely one additional junction at freewheeling during reactive power. However, this is of negligible importance in solar applications.

Pros - low static losses at real power operation:

- Voltage drop at real power during ON - 2 IGBTs
- Voltage drop at real power during OFF and freewheeling - 2 IGBTs + 2 diodes

Cons - complex structure:

- Requires 6 IGBTs (four of the ultrafast switching variety) and 5 fast diodes

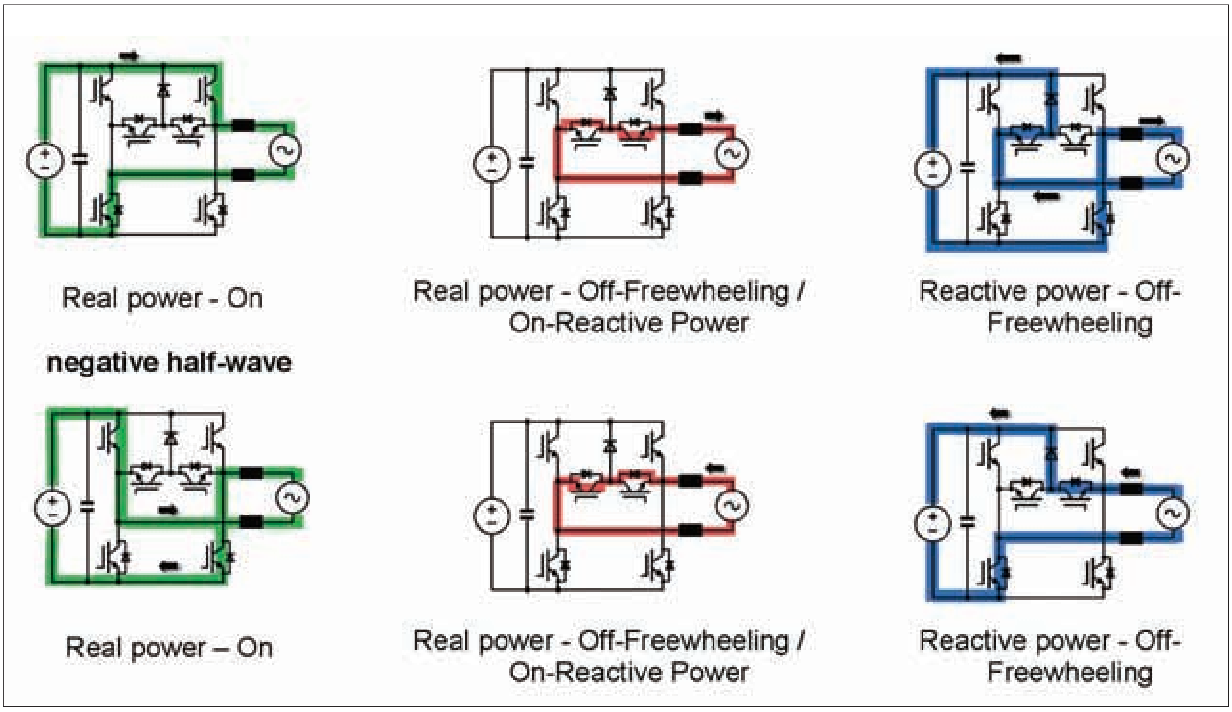


Figure 3: **H6.5-topology working in different modes**

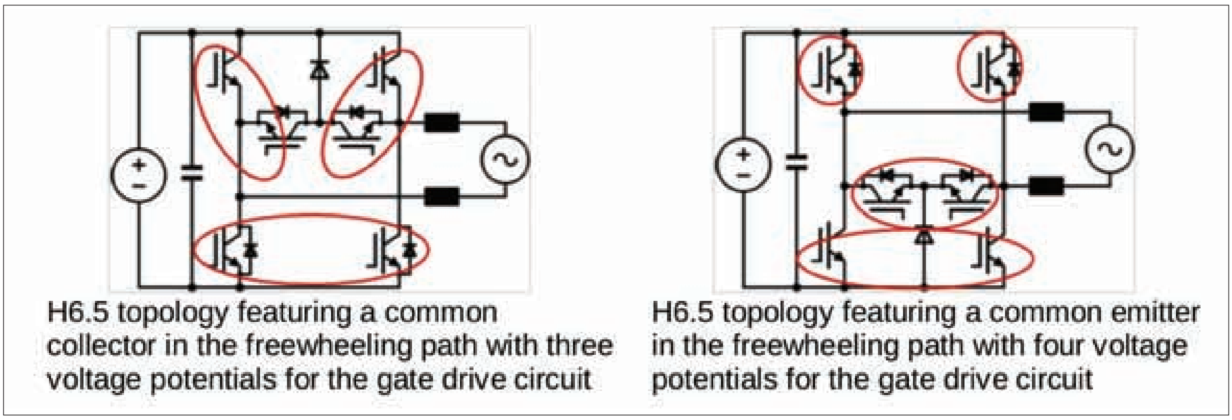


Figure 4: **H6.5-topology with common collector (left) and common emitter**

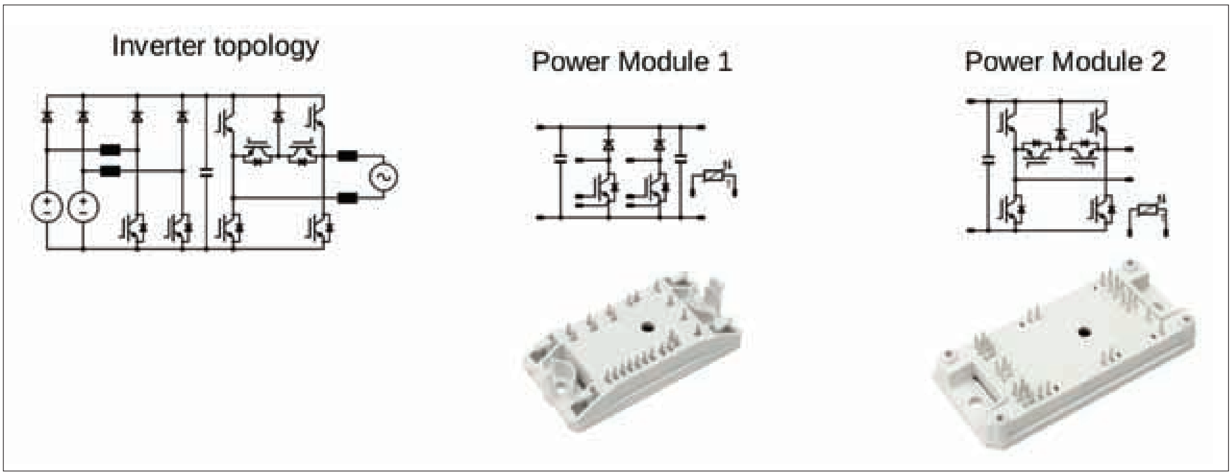


Figure 5: 2x Boost + H6.5 Inverter

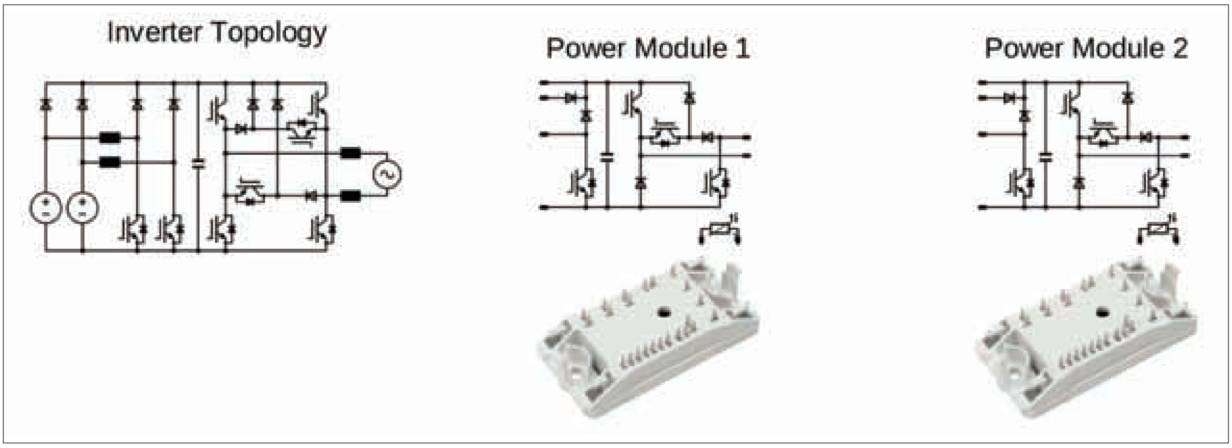


Figure 6: 2x Boost + Halfwave Inverter

- Voltage drop at reactive power during OFF and freewheeling - 3 diodes

Power modules designed to support the new topology

To integrate the semiconductors, the power module will have to

- provide two independent boost stages for MPP (maximum power point) tracking
- incorporate the new H6.5 topology
- handle a high switching frequency, e.g. 40 kHz
- enable low-inductance integration of DC capacitors
- integrate all components in the commutation circuit, even at reactive power
- feature a temperature sensor
- furnish a good thermal interface.

The new topology may be implemented with a common collector or common emitter (see Figure 4) for the freewheeling path. The advantage of using a common collector for the IGBTs in the freewheeling path is that no additional power supply will be required because the emitter is shared with the high-side IGBTs of the H-bridge.

This input provides the underpinning for two new modules.

The 2x Boost + H6.5 Inverter (Figure 5) uses a standard 2x booster module and implements the new topology in a second module based on the flow 1 housing. This structure also supports designs where the MPP tracker and inverter are sited at different locations on the PCB.

The 2x Boost + Halfwave Inverter (Figure 6) combines one boost stage and the inverter components for one half-wave in a single module. The advantage is that the two modules' power dissipation is identical, regardless of the input voltage. Two identical modules can make up the inverter's power electronics core. The corresponding IGBT of the switching device is located in the other module, which makes this solution extremely resilient to X-conduction at fast turn-on.

Both options incorporate all components of the commutation circuit inside one module. If they are distributed between two modules, the inductance of both modules' electrical interfaces causes over-voltage at turn-off, which limits options for using fast components.

Conclusion

An unprecedented three-level topology for single-phase solar inverters provides a new alternative to legacy solutions such as HERIC and H5 topologies. This new topology may be used in real power and reactive power modes. Two different power module designs are available with this new topology.

Primary-Side Controller Supplies More Power

Dialog Semiconductor plc released its new iW1770 PrimAccurate™ primary-side controller that offers a 60 W peak power mode from a 40 W supply, eliminating the need to oversize the power supply design and enabling compact, light-weight, high power density adapters. Conventional power supply designs must be sized to match the peak (maximum) power requirements of the system, which may be significantly higher than the normal system operating power. Dialog's peak power mode technology provides more than the maximum continuous output power for a pre-determined period of time, without the need to oversize the transformer and output capacitors. This enables designers to produce higher power adapters that are the same size and cost as power supplies with a nominal rating of 40 W. With an average output power range of 15 W to 40 W and the ability to handle peaks up to 60 W, the iW1770 also offers less than 50 mW no-load standby power consumption, fast dynamic load response and high efficiency. This allows power adapters to meet stringent global energy standards including the final 2014 U.S. DoE(1) and European CoC version 5, tier 2(2) regulations.

www.dialog-semiconductor.com

Integrated DC/DC Digital PWM Controller

Intersil's new ZL8801 dual-phase, DC/DC digital PWM controller, expands the company's fourth generation controller family by enabling a simple dual-phase solution for higher current applications ranging from 40 A to 100 A. With the ability to current share across multiple devices, its range can be extended up to 300 A for high-end FPGAs and ASICs employed in densely populated power supplies in servers, storage equipment and basestations. Used in conjunction with PowerNavigator™ GUI, the ZL8801 simplifies system power conversion and speeds the design process. The ZL8801's fully digital control loop corrects errors cycle-by-cycle, eliminating the need for compensation. The device can be paired with the ISL99140 40A DrMOS (Integrated Driver and MOSFET) output stage to create a complete voltage regulator solution. The ZL8801 supports Intersil's proprietary DDC (digital DC) bus for inter-controller communication allowing for system-based sequencing, fault management and current sharing in conjunction with other Intersil digital power ICs, all on a single wire. Configuration is easily managed with the GUI to provide drag and drop sequencing control, which is autonomously managed in system. Even current sharing is enabled by the DDC bus, allowing up to four ZL8801's to be paralleled providing for high current power system designs.

www.intersil.com/products/ZL8801

Snap-In Electrolytic Capacitors

DK Corporation presents a new series of EPCOS snap-in aluminum electrolytic capacitors. They are characterized by a ripple current capability that is up to 25 percent higher than for the types of the preceding EPCOS series. The capacitors of the new B43642 series are manufactured in compact sizes with diameters ranging from 22 mm to 35 mm and heights of 25 mm to 55 mm. These components are designed for rated voltages of 200 V DC to 450 V DC and cover a capacitance range from 82 µF to 3300 µF. Under continuous operation at 105 °C, the useful life of these capacitors is 3000 hours. Applications of these new snap-in aluminum electrolytic capacitors are converters and power supplies for use in industrial electronics.

www.epcos.com

Fast Switching 650 V IGBTs

Ranging from 15A to 90A, the new IRGP47xx family of IGBTs from International Rectifier utilizes trench thin-wafer technology to reduce conduction and switching losses to deliver increased system efficiency. Available as discrete devices or co-packaged with a soft recovery diode, the new IGBTs are optimized for ultra-fast switching (8 kHz-30 kHz), offering an increased short circuit rating of 6 µs, and positive temperature coefficient for easy paralleling. The higher breakdown voltage provides extra reliability during extreme weather variations and AC-line instability, and eliminates the requirement for voltage suppression devices. The IRGP47xx family features low forward-voltage drop of 1.7V (typical) at 100°C and low total switching energy (ETS) to reduce power dissipation. Offered as packaged devices, other key features include maximum junction temperature of 175°C and low EMI for improved reliability.

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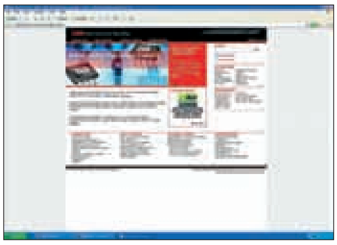

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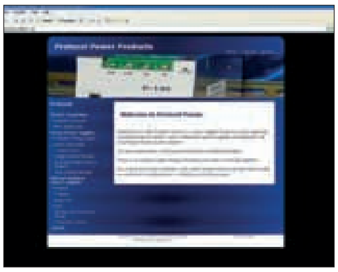

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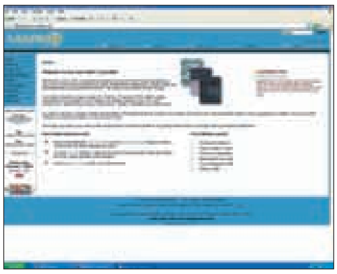

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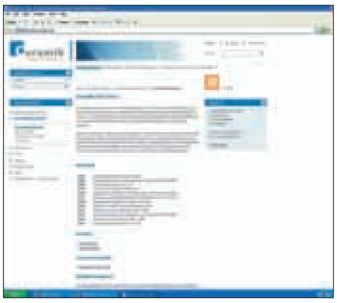

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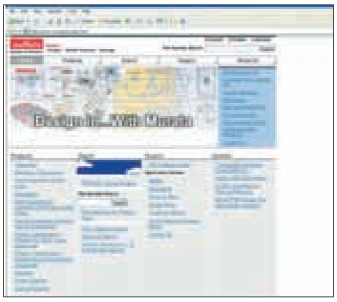

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Voltage References

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

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

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

The COOLiRFET™ Advantage:

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

Key Applications:

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- Pumps
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