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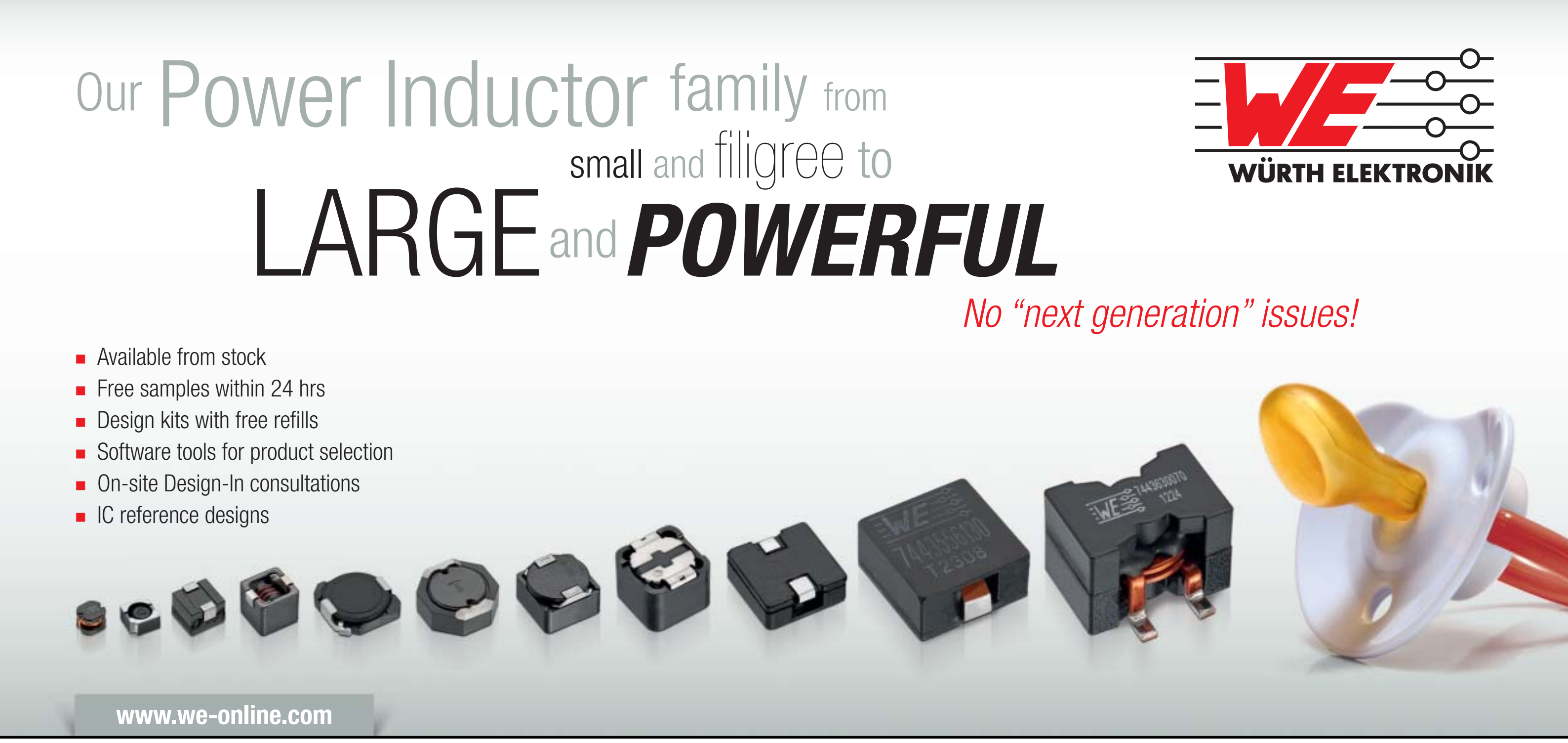
Bodo´s Power Systems®

Electronics in Motion and Conversion

December 2013

Optimising Water, Oil and Fuel Pumps with ANL2 Power MOSFET Technology


o-f.de
Medium voltage
A HIGH-WIRE ACT?



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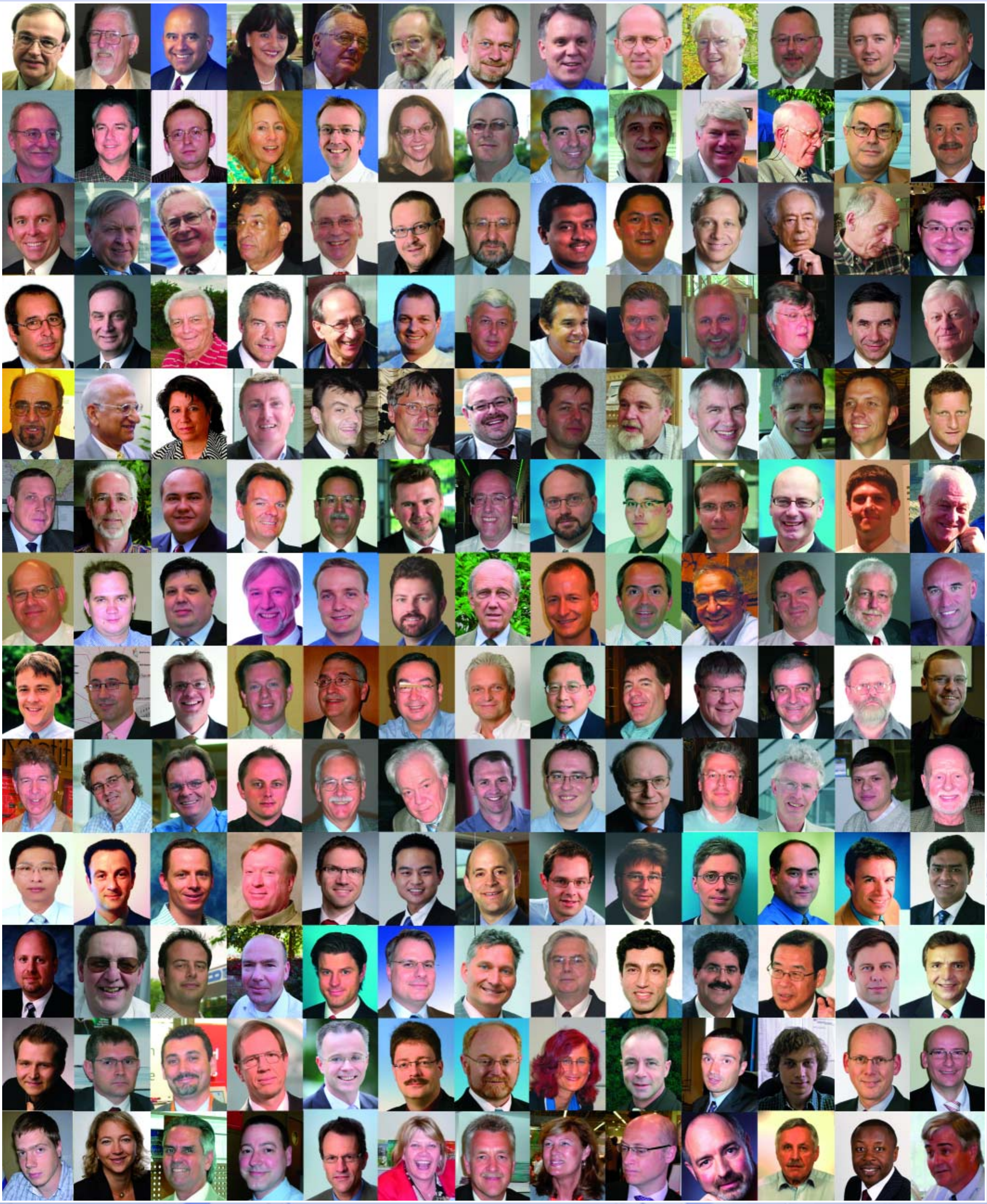
The Gallery



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Events

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Nuremberg, Germany, February 25-27
www.cips-conference.de

Embedded World 2014,
Nuremberg, Germany, February 25-27
www.embedded-world.de

EMC 2014,
Duesseldorf, Germany, March 11-13
www.mesago.de/en/EMV/home.htm

APEC 2014,
Fort Worth, Texas, March 16-20
www.apec-conf.org/

APEX 2014,
Las Vegas, Nevada, March 25-27
www.ipcapexexpo.org/html/main/default.htm

AMPER 2014,
Brno Czeck, March 18-21
www.ampr.cz

New Energy Husum 1014,
Husum, Germany, March 20-23
www.new-energy.de/

The IGBT in its Best Age

On March 25th 1980, a United States Patent application was filed for Hans W. Becke and C. Frank Wheatley, Jr., both working for RCA Corporation of New York. The patent, Nr. 4,364,073, for what would become the IGBT was issued on December 14th 1982. At the time RCA called the device "COMFET," but then adopted the JEDEC designation of "IGBT." So on December 14th we'll honor Becke and Wheatley, along with the 31st birthday of a device that has significantly influenced power switch designs for reduced conduction losses at higher voltages - an invention which has made a major contribution to the field of power electronics.

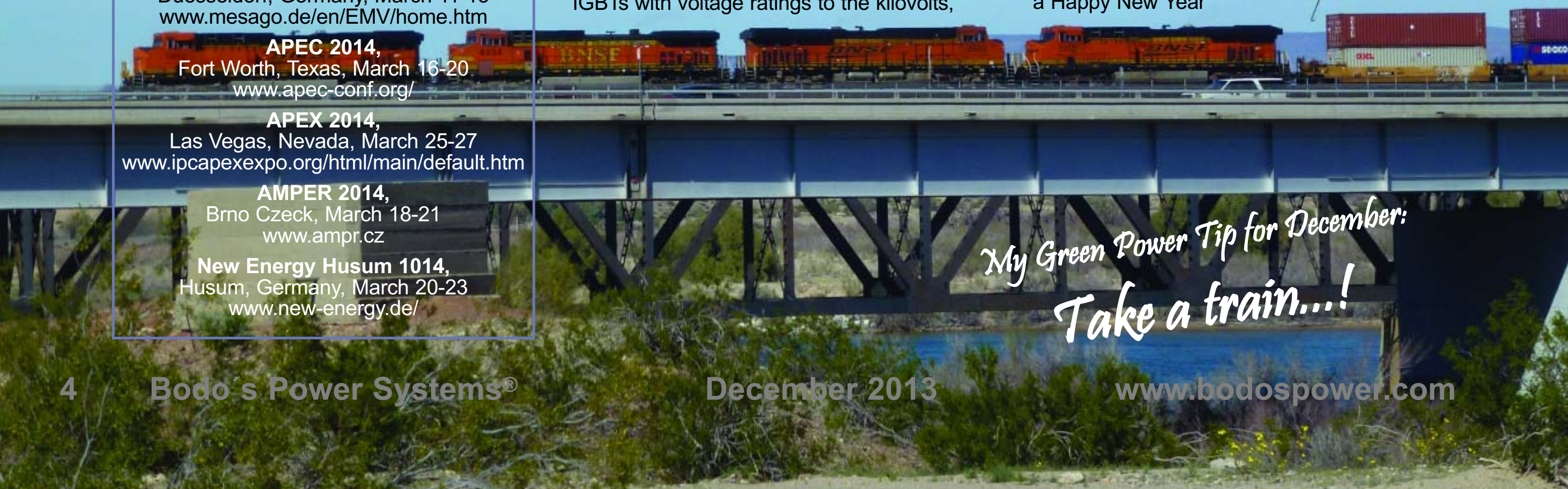
Patent 4,364,073 stated the summary of invention to be as follows:
A vertical MOSFET includes a semiconductor substrate which includes, in series, adjacent source, body, drain and anode regions of alternate conductivity type. The body region is adjacent to a substrate surface and the source and drain regions are spaced so as to define a channel portion in the body region at that surface. The conductivities and configurations of the body and drain regions are adjusted so that the device functions substantially as a non-regenerative transistor. During device operation the anode region provides minority carrier injection into the drain region, thereby reducing device threshold voltage and on resistance while enhancing forward conductance.

At thirty-one years of age, we have a lot ahead of us. Having reached the sixties myself, I can attest to that. At that age, I worked for RCA, then GE Solid State and Harris to help bring COMFETs into volume use. In 1987 one of our customers was a well-known company that used it in a kitchen appliance for variable motor speed. The IGBT has come a long way since then.
In its 31 years, the IGBT has benefitted from continual improvements from many sources: IGBTs with voltage ratings to the kilovolts,

optimized conduction losses, improved switching behavior, and short circuit withstand capability. Used commonly in high-power equipment for variable speed drives, inverters, and wind turbines, IGBTs have also become standard in automobiles, saving gas through precise ignition timing and providing for the dissipation of unwanted high energy pulses through monolithic Zener diodes.
Gavin, from Bodo's Power China, has drawn a great picture of IGBT applications in China in his Guest Editorial. The market for IGBTs is growing continually, and research continues. Reports exist of IGBTs being built into wide band-gap semiconductor materials, like SiC. The Sonoscan article in this issue describes an IGBT module being inspected for perfect die attach to insure long lifetime. Long reliable operation is critical for offshore wind parks as well as in high-speed trains.
Communication is the only way to progress. We have delivered twelve issues this year, each month, on time, every time. With this December issue, we've now published 136 technical articles amongst 808 pages total. As a media partner, Bodo's Power Systems serves readers across the globe. If you speak the language, or just want to have a look, don't miss our Chinese version: www.bodospowerchina.com.

See you next year, again at APEC in Texas, and around the world.

Merry Christmas and
a Happy New Year



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- Full galvanic isolation
- 8 mm clearance/creepage + CTI 600
- Low offset and gain drifts
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- Through-hole and SMT packages

www.lem.com

At the heart of power electronics.

LEM®

PCB Service Portfolio and Assembly Service in Germany

Conrad has improved its Component and PCB Service and has launched an assembly service in Germany. The integrated online service allows engineers to design, layout and order fabricated, populated, printed circuit boards (PCBs). The service also supports the design, manufacture and supply of laser cut stencils for surface mount boards.
Conrad's Component and PCB Service meets industrial standards and is compatible with most popular layout programs including EAGLE, Altium, OrCad and TARGET 3001! Customers can order small quantities without extra charges and there are no film costs or limitations on the number drilled holes in a design.
As well as being able to access The Component and PCB Service directly via the company's website, Conrad customers can also download the full version of the popular TARGET 3001! PCB software free-of-charge to complete their design and layout. They can then link to the Conrad Component and PCB Service to order boards and components.
TARGET 3001! is configured such that all information and data for a project is contained within a single file. This simplifies the design process and means there are no inconsistencies between the schematic and the layout. Components can be amended in the schematic or layout individually; independent of the database. 3D visualization of the assembled PCB including the capability to export the board to mechanical CAD systems is a further advantage.

www.conrad.biz

Powerful Distribution Network Partners to Accelerate Growth in China

Amantys has followed the June opening of its Shanghai sales office with the announcement of three major distribution and representation partners, to promote and sell its IGBT Gate Driver family of products.
Westpac, Beijing Scilicontron Electrical Technology and Texin have this month signed agreements to promote the sale of the Amantys Power DriveTM family of IGBT Drivers in China; with each distributor offering the full range of gate drives in multiple package types and at operating voltages ranging from 1200V to 4500V.
The distributors will offer full commercial and technical support for the gate drives, and will promote the product range into applications as diverse as wind and solar energy generation, locomotive traction and medium voltage industrial motor inverters. They also expect to be successful in selling the products into the emerging opportunities of smart grid and HVDC transmission.
All distribution partners have completed a fully certified Amantys IGBT Driver Technical Training Programme, including the innovative monitoring and data logging capability of Amantys Power InsightTM.

www.amantys.com

Canadian Company Expanding into the United States

Not very often in the industrial power industry realm do you hear of a Canadian company expanding into the United States, let alone two companies. I.C.T. POWER Company Inc. and Innovation Plus Power Systems of Burlington Ontario Canada have done just that. The year 2013 is now referred to as "The Growth Year" by the companies' founder and President Afshin Montazeri.
"We have expanded and opened I.C.T. POWER USA and Innovation Plus Power Systems USA that share a facility in Saint Charles Illinois USA to better serve our USA, Mexico, Central and South American customers" Afshin explains.
I.C.T. POWER's sister company ICONOPOWER in Ottawa Ontario have just moved in to their new 17,000 sq. ft. custom facility at 1051 Ages Drive, about a 20 minute drive from Ottawa International Airport. This is a state of the art facility for ICONOPOWER's distribution and ISO 9001 based manufacturing.
I.C.T. POWER Company Inc. HQ in Burlington has added another 30,000 sq. ft. to the existing building and have bolstered their product offering by adding seven new lines including WIMA capacitors, Ohmite resistors, Wakefield-Vette thermal solutions, Hind Rectifier products, Motortronics softstarts - AC/DC drives - motor brakes, Kendeil capacitors, and full Genteq capacitor line, strengthening their product offering.
The Parent Company for the above mentioned Canadian and US companies is P.E.C.A.S. Group (Power Electronic Components and Systems Group).

www.ICTPower.com


HIGH VOLTAGE
All the power you need...
...for a reliable and safe future
Specification for low operation and storage temperature Tj = -50°C Available on request!

Worldwide Wind Capacity Close to 300 Gigawatt

The worldwide wind capacity reached 296'255 MW by the end of June 2013, out of which 13'980 MW were added in the first six months of 2013. This increase is significantly less than in the first half of 2012 and 2011, when 16,5 GW respectively 18,4 GW were added. All wind turbines installed worldwide by mid-2013 can generate around 3,5 % of the world's electricity demand.
The global wind capacity grew by 5% within six months (after 7 % in the same period in 2012 and 9 % in 2011) and by 16,6 % on an annual basis (mid-2013 compared with mid-2012). In comparison, the annual growth rate in 2012 was significantly higher (19 %).
Prof. He Dexin, WWEA President:
"The year 2013 is a difficult year for the wind industry worldwide, as the companies have to struggle with a decreasing market size. This situation has already led to decrease in wind turbine prices which will make wind power even more cost competitive. Though we face some challenges currently, we are still confident to the wind power development in the future. As a result, we see bright prospects for this technology which will become even more cost-competitive."
Stefan Gsänger, WWEA Secretary General:
"Wind power has already taken substantial market shares from the fossil and nuclear energy sector in several countries around the world. What we can observe now is an increasing resistance from the fossil and nuclear power sector who are more and more afraid of loosing market shares. However, we are very confident that the benefits of wind power - practically zero emissions, de-centralised economic and social benefits, security of supply and more - will make it very difficult to beat this technology."

The full version of the WWEA Half-year Report is attached and can also be downloaded from the WWEA homepage:
http://wwindea.org/home/index.php?option=com_content&task=view&id=402&Itemid=43

www.WWindEA.org

Appointment of Tsuneo Takahashi as Chief Sales Marketing Officer of Sales and Marketing Division

Renesas Electronics Corporation announced that it has appointed Tsuneo Takahashi as Executive Vice President and Chief Sales Marketing Officer (CSMO) as well as Chief of the Global Sales and Marketing Division. Takahashi will assume his new roles on November 1, 2013.
To make the responsibility for sales and marketing strategies on a global basis explicit, Renesas will rename the Sales and Marketing Division to the Global Sales and Marketing Division as of November 1. In his new role, Takahashi will take the leadership in coordinating the global sales divisions and, at the same time as grasping the needs of the customers worldwide, will aim at improving the value Renesas provides and work towards maximizing sales, profits, and joint development projects with customers.
Takahashi has extensive experience spanning over 30 years in business and management in the electronics industry. After working as a research and development engineer at Daini Seikosha Co., Ltd. (currently Seiko Instruments, Inc.) and at Fuji Xerox Co., Ltd. for computer graphics and workstation, he joined Intel K.K. (Japan) of Intel Corp. in 1989 and was appointed Director and General Manager of the Communications and Embedded Department in 2002. In 2004 when Motorola's semiconductor sector was spun off as Freescale Semiconductor, he was appointed both Vice President of Freescale Semiconductor, Inc. and President at Freescale Semiconductor Japan Ltd. In 2006, he was promoted to Senior Vice President at Freescale Semiconductor Inc. in recognition of significant contribution to the company. Since January 2010, Takahashi served for more than seven companies including TPG Capital as Senior Advisor and Audyssey Laboratories, Inc. as Advisor.

As of October 1, 2013, Takahashi serves as Vice President of Renesas Electronics Corporation

www.renesas.com

Best Prognosis for PCIM Europe 2014

The number of exhibitors and the booked floor space for PCIM Europe 2014 are already 16% up on the same time last year. The proportion of foreign exhibitors is 50%. With the strong growth in renewable energy, e-mobility and energy efficiency continuing, the visitor numbers are expected to increase further over the coming year. For power electronics is becoming increasingly important in these industries.
The rise in exhibitor and anticipated visitor numbers has led to an expansion of the show. So in 2014, PCIM Europe will be held in three halls. Due to the addition of Hall 6, the two entrances in "Mitte" and "Ost" now provide a better connection to the exhibition than last year.
The planning of the floor space is in full swing. The majority of exhibitors from 2013 have registered again for next year's event. Despite this, an attractive selection of booths will still be available to new exhibitors.

www.pcim-europe.com

Silicon Power Corporation Awarded $4,750,000

Silicon Power Corporation awarded $4,750,000 via funding thru ARPA-E's second open call for projects aimed at advancing high-potential research.
Silicon Power Corporation will develop a semiconducting device that switches high power and high voltage electricity using optical signals. This device will use light to trigger control circuits or mechanisms more rapidly, greatly simplifying the control of high-voltage equipment.
Unlike current switching technologies using silicon, this device shall employ silicon carbide to improve high-power motors and renewable energy technologies including wind and solar.
Silicon Power Corporation, selected from a field of 66 new projects derived from 11 different technology areas, including advanced fuels, advanced vehicle design, building efficiency, carbon capture, energy storage, grid modernization and renewable power.

www.siliconpower.com

http://arpa-e.energy.gov/

7th European Congress on ‚embedded systems' in Toulouse

The ERTS2 Congress is a unique European cross sector event on Embedded Software and Systems, a platform for top-level scientific with representatives from universities, research centers and industries. The previous editions gathered more than 100 talks, 500 participants and 60 exhibitors. The seventh edition of this event jointly organized by the French Society of Aeronautic and Aerospace (3AF), the French Society for Electricity, Electronics, and Information & Communication Technologies (SSE) and the French Society of Automotive Engineers (SIA) will be held from 5th -7th February 2014 in the Congress Center Pierre Baudis in Touluse.

www.erts2014.org

Hybrid Electric and Electric Vehicle Power Converters, Achieving Industry-Leading 96 Percent Efficiency

Cree, Inc. announces that Shinry Technologies, a premier high-tech enterprise focused on energy efficient applications in transportation and lighting, employed Cree's 1200V C2M family of SiC MOSFETs in its new, high-efficiency, hybrid electric and electric vehicle (HEV/EV) power converters to achieve industry-leading 96 percent efficiency. According to Shinry Technologies, Cree's C2M SiC MOSFETS also enabled a 25 percent reduction in product size and reduced peak power losses by over 60 percent compared to the traditional silicon versions.

"Our customers care a great deal about efficiency, compact size and system weight and cost," said Dr. Wu Ren Hua, CEO of Shinry Technologies. "The new C2M family of SiC MOSFETs from Cree allows our new HEV/EV power converters for passenger cars and busses to deliver industry-leading efficiency of 96 percent in a compact size that is 25 percent smaller than current platforms not using Cree C2M SiC MOSFETs."

Based in Shenzhen, China, Shinry Technologies Co., Ltd. specializes in creating HEV/EV DC-DC converter, on-board charger and rapid charger solutions for a market that demands high reliability, efficiency and compact size. By implementing Cree's advanced second-generation SiC MOSFETs in its latest 3-10 kW DC-DC converters designed for use in electric busses, Shinry achieved considerable efficiency improvement and significant size and weight reduction.

"Cree is focused on delivering best-in-class energy efficiency through SiC innovation, so it's very exciting to see our new C2M SiC MOSFET family being used to break barriers in HEV/EV power conversion," said Cengiz Balkas, vice president and general manager, Cree Power and RF. "Shinry's rapid adoption of Cree's C2M MOSFETs provides state-of-the-art efficiency, power density and cost to their customers. We are very pleased to have Shinry using our products."

www.cree.com/power

Enhanced Measurement Accuracy Helps Minimise Losses in Transformer Industry

Work carried out by Yokogawa's in-house Calibration Laboratory at the company's European Headquarters in Amersfoort, the Netherlands, has led to a the development of a new version of the top-end WT3000 precision power analyser with a tenfold increase in accuracy. The new instrument, the WT3000T (transformer version), is specifically targeted at the manufacturers of the large transformers used in transmission and distribution by power utilities.

In today's modern society, transformers have made it possible to transmit large amounts of electrical energy over long distances. They have become an integral part of the value chain and play a key role in building an energy-efficient system. For many years the basic principle has remained the same, but today's transformers are now smaller and more efficient. There is a continuous demand for increase in the efficiency of these transformers in order to achieve cost savings. In the transformer world, these two aims go hand in hand.

A further consideration is that the global trend towards urbanisation has resulted in increased energy demand, and this increase will, in turn, create a higher CO_2 footprint. In order to meet the future demands and minimise the environmental impact, it is important that transformers have high efficiency throughout the life cycle. This not only reduces the energy losses but also lowers the total cost of ownership.

Cost savings

Transmission and distribution transformers can exhibit power losses even under no-load condition. If the transformer has losses which exceeds the specified limits under no-load condition, penalties imposed by the power utility can cost the transformer manufacturer as much as €11,000 per kilowatt lost. As a result, the manufacturer has to be able to measure the losses very accurately: the more precise the measurement accuracy, the less likelihood there will be penalty charges. The power measurement system must not only be precise and stable but also highly accurate.

In order to achieve this enhanced accuracy, Yokogawa's Calibration Laboratory has played a key part in achieving a tenfold improvement in the accuracy of the WT3000 power analyser, resulting in the new WT3000T (transformer version).

These units are typically designed for 3-phase operation and operate with voltages of hundreds of kilovolts and power ratings of thousands of megavolt-amperes. At these power levels, the power losses which are inherent in every transformer design can have a significant effect. It is therefore important for the transformer manufacturer to know the exact value of the power loss before the unit is shipped to the customer. The need for accuracy in these loss measurements is further emphasised by the fact that even an error of as little as 1% in the measured value could still represent an error of 100 kW: again, a significant amount in financial terms. The situation is further complicated by the fact that measurements need to be made at very low power factors - as low as 0.001 - where accuracy becomes an even more sensitive issue.

Modification and calibration

To achieve the higher levels of accuracy in the WT3000T, engineers at the Calibration Laboratory modify the standard WT3000 and carry out their own preliminary calibration before submitting the product to VSL, the National Metrology Institute of the Netherlands, which calibrates the instrument according to the ISO/IEC 17025 standard and issues the final calibration certificate.

Calibration is performed at a frequency of 53 Hz and at power factors of 1, 0.5, 0.05, 0.01 and 0.001. This enables the accuracy of the integrated transformer measurement system to be maintained within the limits described in the IEC60076-8 standard.

For commercial frequencies from 45 to 66 Hz, the WT3000T offers exceptional accuracy at low power factors, which normally have a dramatic effect on accuracy. However, even at a power factor as low as 0.01 the WT3000T offers an accuracy of better than 0.6% of reading at 100V and 1A.

User benefits

The WT3000T offers a number of benefits in both ease of use and performance enhancements. Clear overload/safety indicators alert the operator when the voltage and/or current

inputs of the power meter are overloaded. This prompts the operator to disconnect the power to the transformer under test in order to prevent damage and avoid substantial costs.

The 32-bit RISC processors and specially selected 16-bit A/D converters used in the WT3000T allow power readings to be displayed with a resolution as high as six digits. When this setting is used during calibration, it minimises uncertainties.

Because of its high stability and precision, the WT3000T can itself be used as a calibration standard. The long-term stability of the WT3000T means that its recommended calibration interval is two years, offering additional benefits in terms of minimising downtime and saving money.

The WT3000T provides direct readout of corrected power under small load conditions according to the formulas in the IEC and ANSI/IEEE standards. The large (8.4-inch) colour LCD screen makes measurements easy to read.

Other benefits include multiple inputs which enable the WT3000T to carry out simultaneous measurements on all three phases, plus a built-in oscilloscope-type display which allows engineers to view the current and voltage waveforms and see in real time the effects of those harmonics that can affect measurement results at low power factors.

Last but not least, with the high accuracy at low power factors customers can avoid penalties, thus saving money. This provides the customers a very high return on investment (ROI).

www.tmi.yokogawa.com


TI power design tools

China – New Growth for Power Electronics

By Gavin Hsu, i2i Group China

Most people are aware of the continuing robust growth of the Chinese power electronics market. As the market grows and becomes more important on a global scale, so does the need for greater information, education, training and networking through which businesses can grow together.

China power electronics growth is spurred through energy conversion, wind power, solar power, smart energy, high-speed transportation systems; all of which are critical to continued low carbon technology development. Power electronics technology is the cutting-edge application that makes these Chinese industries successful today and will certainly into the future. Four of the seven designated emerging industries sanctioned by the China State Council, the nation's governing political and economic body, for enhanced investment and growth, include new energy, energy conservation, environmental protection, electro-mobility and new materials development; all of which require enhanced and super-efficient power electronics systems and technologies.

These national Chinese policies will strongly affect renewable energy source development, smart power grids, rail transportation and new energy automobiles. The success of these initiatives and investment will be largely achievable through enhanced power electronics technology usability and functionality.

This growth and demand is propelling a need for better industry information and exchange. The recent PEC – Power Electronics China summit in Suzhou, just west of Shanghai, October 25-26, drew visitors from various regional industries and attracted over 250 high level delegates. General Secretary Xiao Xiangfeng, of the Power Electronics Society of China Electrical Equipment Industry Association, keynoted about the current status and future trends of the China power electronics industry. Additional China industry leaders join the event, including delegates from Shanghai Jiaotong University, Zhejiang University, The Chinese Academy of Science, as well as Infineon, Mitsubishi, Fairchild, Fuji, Vincotech, CREE, Transphorm, TDK, Amantys and others. The success of the event highlights the expanding need by industry for a China focused professional platform that includes information, education, exchange and networking opportunities.

Currently and in the foreseeable future, China's power electronics industry will continue to grow rapidly. China is becoming the world's largest power semiconductor marketplace. Between 2005 and 2008, China's power semiconductor market annual growth averaged 23%. In 2008, total sales exceeded 82 billion RMB (9.9 Billion Euros). By 2012, market size reached over 116 billion RMB (14 Billion Euros), nearly 50% of global sales.

China High Power Semiconductor Devices' Major Application Market and Scale (Unit: million RMB)

Application Market	2005	2006	2007	2008	2009	2010
Electric Power transmission	179	205	238	273	312	370
Metal -Refractory	833	958	1095	1289	1486	1691
Motor	387	477	579	710	876	1093
Rail Transit	655	792	973	1180	1454	1835
High Power Supply	357	430	525	645	807	1000
Welding	387	454	534	627	745	897
Others	179	234	312	411	528	681
Total	2977	3550	4256	5135	6208	7567

IGBT's are a vital component of power electronic devices, and sales continue to grow equally fast. In 2009, IGBT sales reached 4.5 billion RMB (540 Million Euros) and by 2012 achieving 8 billion RMB (966 million Euros) Today, IGBT market share in China is less than 10% of total power devices.

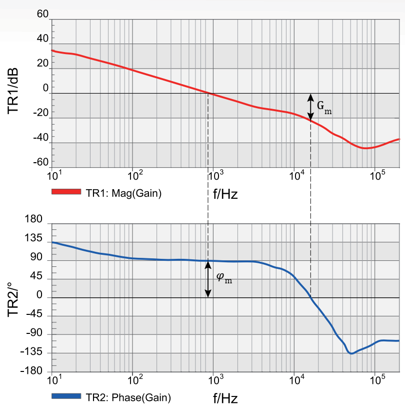
IGBT Market in China (Unit million RMB)

Year	2009	2010	2011	2012	2013	2014	2015
Sales	0.45	0.53	0.63	0.76	0.91	1.09	1.31
Growth	18.00%	18.05%	18.00%	20.00%	20.00%	20.00%	20.00%

China now manufactures a wide array of IGBT chips. 1200V/100A IGBT chips are now produced in mass, while 1700V/100A chips are produced in small quantity. 3300V chips have been produced and with CSR's acquisition of DYNEX, their 3300V-IGBT chips are in mass production. Starpower's IGBT chips for 1200V-1700V is also in mass production. CNR is now producing 3300V-IGBT's. MacMic Science & Technology has built mass production for 1200V-1700V chips and BYD is producing IGBT chip and packaging technology for EV. Other companies leading the China future are Phoenix Semiconductors, Nanjing MicroSilver, as well as Weihai Singa, all investing heavily in production capabilities on a similar scale and quality.

Most China watchers will agree that the market has matured from a follower to an up and coming leader. Companies that invest early and establish their foot hold will benefit from these early steps, while the ongoing demand for product spurs greater need for exchange and information throughout the country. Traditional ways of doing business are disappearing to the new ways and Bodo China as well as PEC are the best indicators of this new China. Welcome to the new China!

www.pe-china.asia



IGBTs are without Doubt the Most Commonly Used Power Devices

By Michele Rossitto, Senior Engineer for Power & Analog Marketing in the Industrial & Communications Business Group at Renesas

The world around us is changing fast driven by so called "mega-trends" such as demographic change, urbanisation, climate change and globalisation. Demand for electronics are consequently growing in specific areas such as healthcare, renewables, industrial and consumer applications.

Renesas is placing itself at the heart of these megatrends, ready to help customers address the inevitable challenges that arise. Some talk about the Smart Grid as if it's the answer to the world's energy needs but we recognise that managing energy demand goes much deeper than that. It starts of course with the need for more renewable energy generation, then involves the distribution of power (through the smart grid - it plays its part) and finishes in (for example) the home or in buildings where energy is consumed creating the need for energy efficient equipment. Recognising that motors consume more than 60% of generated electrical energy, Renesas focuses not only on the application, but on software and device solutions that enable increased energy saving in customers products themselves.

Although the increasing energy demand cannot be stopped, it is commonly recognized that we should pay more attention to the use of such resources. New energy efficient compliant regulations are continuously enacted on a global basis to force manufacturers to increase the system's efficiency. In parallel high energy costs are stressing consumers to use the energy with carefulness. Electrical equipment manufacturers are challenged with such new prospective of smart and efficient requirements.

As a commitment to contribute into such an energy saving mission, Renesas has invested in new leading edge technologies enabling high efficiency solutions.

The power IGBT product family exploits new and advanced technology processes, to maximize efficiency, to address several attractive applications segments such as Home Appliances, Industrial Inverters for Welding, Solar, UPS, Pumps, Industrial Drives and Automation.

The so called thin wafer trench process technology dramatically reduces conduction and switching power losses.

Technically it is made possible by using sophisticated equipment to process mechanically critical wafers (thin). Compared to a standard IGBT, i.e. same chip area, the thin structure of the bulk of the (thin)-wafers features a lower resistivity therefore lower conduction losses. Moreover lower switching losses can be reached by reducing the gate oxide area of the driving MOSFET making the overall system operation more efficient. The positive coefficient temperature (increase of bulk resistivity with temperature increase), generally due to the light punch-through behaviour of Collector Base junction of the Bipolar Transistor, allows also the parallelization of more devices, an easy way to design topologies with multiple parallel switches

Classes of products, trade-off between conduction losses, switching losses and short circuit withstanding capability, with different voltage and current ratings are developed with reference to the applications operation (frequency, duty cycle, short circuit capability, peak currents, packages), for cost effective market requirements.

IGBTs are without doubt the most commonly used power devices, offering a cost effective solution for switching applications leading to a total demand in Europe in the region of €110M. We invite you to discover the merits of the Renesas IGBT line up (http://www.renesas.eu/products/discrete/igbt/index.jsp) to see how they can contribute to more energy efficient application design in your own end equipment.

www.renesas.eu

Electronics Industry Digest

By Aubrey Dunford, Europartners

SEMICONDUCTORS

Worldwide sales of semiconductors reached $ 25.87 billion in August 2013; an increase of 6.4 percent compared to August 2012, marking the industry's largest year-over-year growth since March 2011, so the WSTS. Sales in August were 1.3 percent higher than the previous month. Global semiconductor sales have now increased for six consecutive months, and the industry is well ahead of last year's pace. Regionally, August sales topped sales from the same month last year in the Americas (23.3 percent), Asia Pacific (7.6 percent), and Europe (5 percent), but decreased in Japan (-16.4 percent), in large part because of the devaluation of the Japanese yen.

Renesas Electronics Europe has promoted Günther Elsner to the position of general manager of Renesas' automotive business group. Previously head of European sales for the automotive business group, Elsner replaces Gerd Look, who has been appointed president of Renesas' European operations.

The Graphene Flagship – one of Europe's first ten-year, € 1 billion flagships in future and emerging technologies – was officially launched during a ceremony in Gothenburg, Sweden. Graphene Flagship was selected as one of Europe's first technology flagships by the European Commission in January 2013. The mission is to take graphene and related layered materials from academic laboratories to society, revolutionise multiple industries and create economic growth and new jobs in Europe. The voyage of Graphene Flagship is divided into two separate phases: a 30-month ramp-up phase under the 7th Framework Programme (1 October 2013 – 31 March 2016) with a total European Commission funding of € 54 M, and a steady-state phase under the Horizon 2020 programme, starting 1 April 2016, with expected European Commission funding of € 50 M per year. The consortium of Graphene Flagship initially includes 75 academic and industrial partners in 17 European countries.

SEMI silicon wafer shipment forecast shows polished and epitaxial silicon shipments totalling 8,876 million square inches in 2013; 9,230 million square inches in 2014; and 9,684 million square inches in 2015. Total wafer shipments are expected to remain below the all-time high set in 2010 this year but reach record levels in 2014 and 2015. SEMI expects 2013 silicon shipment volumes to remain essentially flat (+1 percent) when compared to 2012 and increase in 2014 (+4 percent) and 2015 (+5 percent).

OPTOELECTRONICS

Global revenue for packaged LEDs used in lighting applications is set to soar to $ 7.1 billion in 2016, up from $ 3.6 billion in 2013, so IHS. As retail prices for LED lamps have fallen, shipments of LED lamps for lighting are set to increase dramatically in the coming years, rising to 2.4 billion units in 2016, up from 520 million in 2013. IHS forecasts average selling prices for packaged LEDs in lighting to fall to $ 0.19 in 2018, down from $ 0.25 in 2016 and $ 0.41 in 2013.

PASSIVE COMPONENTS

Germany's PCB sales in August dropped by 1.5 percent year-on-year, so the ZVEI. The figure also was also nearly 4 percent below the average of the last 10 years. Likewise, incoming orders were slow; compared to August of last year, incoming order was 12.4 percent lower. However, total incoming orders for the first eight months of 2013 reached the same level as that of last year. The book-to-bill ratio in August, meanwhile, was 0.89. In terms of workforce, the number of employees in the PCB industry in August was 4.5 percent lower compared to last year, driven mainly by the closure of a multinational company.

OTHER COMPONENTS

The Electronic Design Automation industry revenue increased 3.8 percent for Q2 2013 to $ 1653.4 M, compared to Q2 2012, so the EDA Consortium. Sequential EDA revenue for Q2 2013 decreased 0.9 percent compared to Q1 2013. The total revenue for the most recent 4 quarters (Q3 2012 through Q2 2013) was $ 6720.9 Million. Revenue in Europe, the Middle East, and Africa (EMEA) was up 7.4 percent in Q2 2013 compared to Q2 2012 on revenues of $ 280.5 M.

EMS PROVIDERS

Cemtrex, a supplier of advanced instruments for emissions monitoring, process analysis, instrumentation and controls for industrial applications, has entered into an agreement to acquire the ROB Group, a German electronics manufacturing company placed in administration in August. The ROB Group, consisting of 4 distinct operating companies, serves the electronics and cabling needs in the medical, automation, industrial, and renewable energy industries. The Rob Group had annual turnover of € 42.1 M in 2011 and also has a production facility in Romania.

CTS, a manufacturer of electronic components and sensors and a provider of services to OEMs, has entered into a definitive agreement with Benchmark Electronics under which Benchmark has acquired CTS' EMS business for $ 75 M in cash. The business acquired has five locations (4 in North America and 1 in Asia) and approximately 1,000 employees. The transaction is expected to generate annual revenues in excess of $ 200 M. The acquired business is strategically focused on complex, high-mix and lowvolume manufacturing in the industrial, aerospace, defense, medical, and communications markets. Benchmark's global operations include 21 facilities in seven countries.

This is the comprehensive power related extract from the " Electronics Industry Digest ", the successor of The Lennox Report. For a full subscription of the report contact:

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Strong Competence in Materials Enables more Efficiency

Small, smaller, smallest - that's the main message TDK Technologies has. The company is convinced that it has achieved another milestone regarding the on-going miniaturisation. In addition to the ultra-flattest multilayer varistors for ESD protection, TDK claims to have the world's smallest common-mode choke for automotive Ethernet and the smallest automotive-grade MLCCs in the mega cap class. Addionally, there are more NTC sensor solutions available.

By Marisa Robles Consée, Corresponding Editor; Bodo's Power Systems

ESD protection devices are needed wherever there is electronics. The demand on high safety and reliability is not only a topic of telecommunication and industrial electronics. More and more smartphones and tablets require ESD/EMI protection in order to achieve high data rates. Automotive ECUs are demanding high system integration in applications sensitive to ESD. "Miniaturized ESD guards at interfaces and connectors offer greater safety for more complex designs", Dr. Oliver Dernovsek, Director Multilayer Product Development of the Piezo and Protection Devices Business Group of TDK Technologies, is convinced. That's the reason why the company has started a R&D project with the Austrian printed circuit board manufacturer AT&S in order to develop technologies for embedding active and passive electronic components. The aims of the partnership include driving forward standardisation of these technologies, which play a decisive role in the fabrication of extremely miniaturised modules.

Figure 1: The new CeraDiodes are about 80 percent smaller than their predecessors and simultaneously offer reliable ESD protection.

Ultra-flat multilayer varistors for ESD protection

Facing the technical challenge of higher functional density together with higher data rates in mobile communications, the company has developed a series of ultra-flat and compact multilayer varistors for ESD protection. The smallest CeraDiode device has a footprint of 0.47 mm x 0.47 mm at a height of 0.1 mm in LGA packaging. These new SMD protection components are available in EIA case sizes of 0402, 0201 and even smaller. This enables the production of varistors about 80 percent smaller than their predecessors for reliable ESD protection. The CeraDiodes have an ESD immunity of 15 kV or 25 kV which more than satisfies the higher requirements on the ESD protection of sensitive ICs. Their clamping voltage is 70 V or 90 V at a pulse voltage of 8 kV (IEC-61000-4-2). Thanks to their low capacitance, the signal integrity of high-speed interfaces such as HDMI is not impaired.

TDK has achieved this breakthrough in the miniaturization of its protection components by combining an efficient semiconductor material with its micro core technology. The new ZnO material also possesses significantly more grain boundaries per volume which increases the ability of the components to absorb ESD pulses by a factor of 50. These micro core components can also be incorporated directly into 3D circuits and modules. Size, performance and cost can make the CeraDiodes an attractive alternative to TVS diodes.

Common-mode choke for automotive Ethernet

The new series of common-mode chokes for automotive Ethernet ACT45L features fairly high common-mode noise suppression.

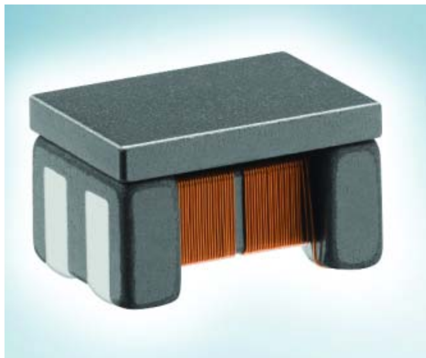

Figure 2: With the ACT45L series, TDK presents a common-mode choke that features satisfactory common-mode noise suppression.

Measuring in with a footprint of 4.5 mm x 3.2 mm and an insertion height of just 2.8 mm, the "miniaturized series is the world's smallest common-mode choke for automotive Ethernet and fulfils the standard´s stiffest requirements", states Norbert Peters, Director Product Marketing Europe of the Magnetics Business Group of TDK. Mass production has started in November 2013. "Ethernet, which supports data rates of up to 100 Mbit/s, is quickly becoming the networking protocol of choice for high-speed multimedia infotainment applications in cars", he adds. Because it employs lightweight unshielded twisted-pair (UTP) wires, automotive Ethernet can save space and weight. The specifications of the new automotive Ethernet standard with regard to common-mode noise suppression are significantly more demanding than the requirements of CAN and FlexRay. "The higher the noise attenuation, the better the performance of the common-mode choke." According to TDK, the ACT45L's noise suppression of the is 15 dB to 25 dB better than that of existing products over a frequency range of up to 100 MHz.

The ACT45L series is designed to be manufactured using fully-automated processes that include a high-precision autowinding process and the bonding of ferrite cores with a highly temperature- and moisture-resistant adhesive. The result is a series of automotive components qualified to AEC-Q200 with suitable reliability and consistent quality.

Automotive-grade MLCCs

"As more and more electronic control units are deployed in and near the engine compartment, the capacitors used in such harsh environments must be extremely heat-resistant, reliable and compact", says Marc Frankenberg, Manager Product Marketing Europe of the Ceramic Capacitors Business Group of TDK. Therefore, TDK has expanded its CKG series of Megacap-type MLCCs to include miniature 1608 to 3216 packages (EIA 0603 to 1206). Until now these MLCCs were available only in 3225 to 5750 packages (EIA 1210 to 2220). With dimensions of 1.9 mm x 1.3 mm x 1.5 mm, Mr. Frankenberg claims the new 1608 components to be "the world's smallest automotive-grade MLCCs in the mega cap class". The expanded series offers even higher reliability thanks to their high-precision metal cap fitting structure that enables mounting without adhesives or solder. The novel lead frame design is supposed to offer resistance to thermal and mechanical stress. Moreover, the new MLCC series has a wider and higher capacitance range from 0.1 µF to 22 µF and rated voltages from 16 V to 630 V. The structural design of the CKG series of Megacap-type MLCCs allows for an operating temperature range of -55 °C to +150 °C and high reliability for use in ECUs.

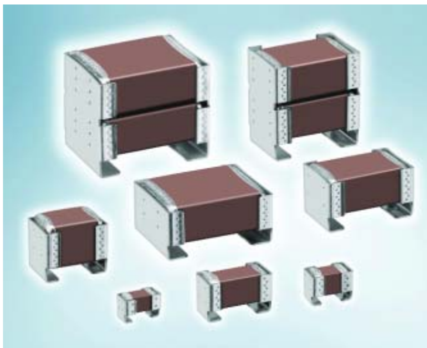

Figure 3: TDK has expanded its CKG series of Megacap-type MLCCs to encompass miniature 1608 to 3216 packages (EIA 0603 to 1206).

"Until now it was extremely difficult to create Megacaptype MLCCs with lead frames in such miniature case sizes", the expert says focussing on the fully-automated high-precision assembly process of TDK.

Figure 4: Material know-how enables new NTC temperature sensors.

The new manufacturing technologies can also be applied to larger sizes. The devices are available as single or stacked types. Customer-specific multiple stacked types are available on request. The mass production is scheduled to start in April 2014.

NTC sensor technology

Finally, the generation of NTC temperature sensors fulfils the requirements of the RoHS directive without exception and "are simultaneously characterized by their high precision and durability", claims Holger Hegner. The Executive Vice President NTC Sensors of the Sensors Business Group of TDK adds: "The development of ever more exact temperature sensors is driven especially by the increasing demands on temperature measurement in automotive and industrial electronics applications. The overriding goal is to further boost the energy efficiency of motor vehicles as well as equipment and installations." To ensure that temperature sensors continue to operate reliably even under harsh conditions, the requirements on their ruggedness and durability are continuously increasing.

The devices are halogen and lead-free, and their measurement accuracy has supposedly been increased by a factor of ten. The devices' high resistances are due to ion migration at the terminals.

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Trends in AC-DC, DC-DC, and More-than-Moore Power Markets

By Jeff Shepard, President, Darnell Group

Whether you are involved in the ac-dc power supply market or the market for dc-dc converters, you are in for challenging times. In both cases the drivers for growth have moved away from the traditional sources and into a variety of emerging markets. The result is not only the need to look in new places for growth, but the drivers for growth are also becoming diverse and diffused. Darnell has identified and quantified these mostly-hidden, but critical changes in two of our recent reports: the Eleventh Edition of **"AC-DC Power Supplies: Worldwide Forecasts"** and the Twelfth-Edition analysis of **"Worldwide DC-DC Portable Power Converter IC Forecasts Applications, Amperages, Products and Competitive Environment."**

And in the first-quarter of 2014, Darnell will release the industry's first analysis of **"More than Moore (MtM) and Granular Powering."** This ground-breaking analysis will: identify the technology challenges to these advanced powering solutions; identify and prioritize potential applications expected to adopt MtM and Granular Powering; review activities at major research organizations, consortia and universities; identify companies currently developing products for this emerging market area, and companies likely to enter this space in the future; determine and quantify the performance expectations of customers and identify pricing requirements for the successful entry into this emerging market; and quantify medium-term and long-term sales potential for MtM and Granular Powering.

In addition to the recently-released reports on ac-dc power supplies and dc-dc converters described below, Darnell has started an analysis into the emergence of **"More than Moore (MtM) and Granular Powering"** that will provide unique and invaluable insights into this disruptive development. Darnell has already identified over 100 companies and organizations actively involved in technologies related to MtM and Granular Powering. Moore's law is the observation from Intel founder Gordon Moore that computer processing power doubles about every 18 months.

But the power-consumption trend called Koomey's law is expected have even greater relevance than Moore's law as portable, battery-powered devices proliferate. Koomey's law describes a long-term trend in the history of computing hardware: The number of computations per joule of energy dissipated has been doubling approximately every 1.57 years. **Koomey's law is "more than Moore" and has growing relevance in the development of advanced power conversion technologies and architectures.**

This trend identified by Koomey's law has been stable since the 1950s (R2 of over 98%) and has actually been somewhat faster than Moore's law. Jonathan Koomey articulated the trend as follows: "at a fixed computing load, the amount of battery you need will fall by a factor of two every year and a half." The implications of Koomey's law are that the amount of battery needed for a fixed computing load will fall by a factor of 100 every decade. As computing devices become smaller and more mobile, this trend may be even more important than improvements in raw processing power for many applications. Furthermore, energy costs are becoming an increasing factor in the economics of data centers, further increasing the importance of Koomey's law.

Companies involved in this area range from potential customers, potential suppliers and a wide variety of research laboratories and universities. The list of potential customers is long and includes makers of microprocessors for servers such as Intel and IBM, major suppliers to the portable market such as Qualcomm and Samsung, suppliers to the automotive market such as Bosch and Fujitsu, and so on. Potential suppliers include an even broader range of companies from well-established firms to start-ups such as Efficient Power Conversion, Sarda Technologies, FinX, and others.

Research organizations involved in MtM and Granular Powering range from focused efforts such as Europe's PowerSwipe (Power Supply on Chip with Integrated Passives) consortium, to ITRI in Taiwan (and other national labs), to university-sponsored projects. The majority of companies and organizations in all categories will be interviewed as part of the process to develop the in-depth analysis needed to accurately project a complex emerging market such as MtM and Granular Powering.

The development of successful commercially-viable MtM and Granular powering technologies will have far-reaching impacts. Those impacts are likely to extend beyond even what can be anticipated today. At the minimum, these developments will result in: New internal powering architectures for digital ICs such as microprocessors, ASICs/FPGA, etc. It will drive the adoption of new materials such as GaAs and GaN for power switches. It will rely on the development of new converter control schemes such as dynamic voltage and frequency scaling, thread-motion fine-grained power management, predictive energy balancing, and more.

It will require a completely new approach to passive devices such as capacitors and inductors and will result in the replacement of conventional passives with a new class of embedded passives such as on-chip trench capacitors in place of discrete devices or the replacement of today's magnetic-core-based inductors with completely new structures and materials. In sort, it will result in a major disruption to the power conversion market and to the entire power conversion supply chain as it currently exists.

The overall **embedded ac-dc power supply** market is projected to see considerable growth over the next five years, with the dollar market increasing from $20.0 billion in 2013 to $26.8 billion in 2018, a compounded annual growth rate (CAGR) of 6.0%. Still dominated by a number of traditional (and very slow-growth or shrinking) applications including communications, computers and industrial growth will rest on a number of rapidly-growing emerging applications being driven by worldwide demand for energy efficiency. Over 80 tables, graphs and figures are presented in this report covering the embedded power supply market for 41 applications. The focus of this comprehensive analysis will provide you with a detailed and insightful look at the current and future opportunities available in the embedded power supply market.

Unlike the slower growth seen over the past several years, the projected 6.0% growth rate for this market is a result of a dynamic combination of trends including the early demise of the large and once dominant desktop power supply market and the rise of a large number of high-growth emerging applications. These trends should provide manufacturers with a host of opportunities over the next several years as the traditional desktop power supply market was made up of just a few standard form factors and wattage ranges, while the emerging applications are expected to be made up of a variety of power levels, form factors, design types and package styles.

The forecasts presented in this edition of **"AC-DC Power Supplies: Worldwide Forecasts"** are based on a detailed quantitative analysis of 41 applications divided among eight categories: Communications, Computers, Industrial, Solid State Lighting, Medical, Mil/Aero, Consumer and Smart Grid. Additional power supply forecasts are generated for merchant/captive production, wattage, package style, packaging by industry and design type. The forecasts and analysis presented in this report consider application drivers, technology trends, regulatory considerations, market sizes and other factors for each segment.

The dc-dc converter IC market is a large and important market for makers of power management ICs. Driven by traditional applications including the three C's - communications, computers and consumer, the total worldwide Portable Power dc-dc converter IC market is projected to grow from about 31 billion units in 2013 to over 50 billion units in 2018, a CAGR of 10.3%. The addition of new architectures, smaller form factors, more efficient designs and improved power management is expected to create new opportunities. Driven by the tablet computer market, the computer segment is projected to be the second largest and fastest growing market for converter ICs. It is expected to be driven by the large switching regulator and controller IC markets. This 83-page analysis includes over 30 tables and graphs covering the worldwide portable power converter IC market for 22 applications.

Communications applications such as mobile phone handsets that have been the primary growth engine for this market for nearly a decade are no longer the dominant source of growth. Emerging applications in the portable computing segment such as tablets and ultra books have become the new growth engine for this large and important market.
The emergence of portable computing as the dominant engine driving growth in this market is a very significant event. And it is only the first of several market and technology changes that will challenge power management IC makers in the next several years. External developments such as the emergence of GaN and GaAs power semiconductors and the development of commercially-viable power-system-in-package and power-system-on-chip technologies will also emerge as significant threats.

The Forecasts presented in this year's edition are based on a detailed analysis of 22 portable power applications divided among five categories: communications, computer, consumer, portable medical and portable military/aerospace segments. In past editions, forecasts included both portable and non-portable applications. This report will focus exclusively on the portable segment. Converter IC forecasts include converter/regulator ICs, charge pumps, low drop out regulators (LDOs), switching regulators, PMICs, and controller ICs.

Information on all three of these reports is available at:

www.Darnell.com

Optimising Water, Oil and Fuel Pumps with ANL2 Power MOSFET Technology

Electric motors are increasingly being used in today's cars to pump water, oil and fuel. The most efficient solution is brushless direct current (BLDC) motors combined with high-performance power MOSFETs.

By Abdullah Cam, Senior Engineer, Analog & Power Marketing, Automotive Business Group, Renesas Electronics Europe

The block diagram in Figure 1 shows a BLDC motor and its controllers. The electronic components of a water, oil and fuel pump can be divided into three types. First, the power electronics that directly supply the motor with electrical power. Second is the gate driver that controls the power MOSFETs. The third type is the microcontroller that takes care of control and regulation tasks. This article will demonstrate the various options available for increasing the efficiency of a BLDC motor application.

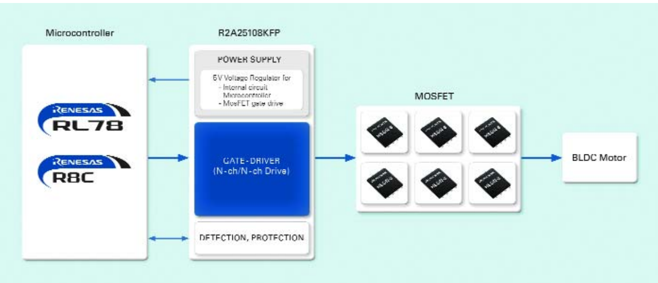

Figure 1: Block diagram of a BLDC motor with electronic components

Power electronics

The most important component in the power electronics is the actual power switch that supplies electricity to the motor coils. In automotive applications, BLDC motor control is provided by B6 power MOSFET bridge circuits. The power requirements of the motor and the surrounding conditions determine the electrical requirements of the power transistors. The design also includes the MOSFET used for the startup current, which can be up to three times higher than when the motor is running. It is important that these power MOSFETs have low channel resistance - 40V MOSFETs are usually used for this purpose.

In order to increase the system's efficiency, the power dissipation of the power MOSFETs must be minimised. The total power loss is made up of conduction losses when the MOSFET is on (static power dissipation), the losses from switching the power FETs on and off (dynamic switching losses), and gate losses. With today's trench MOSFETs, gate losses are such a small proportion of overall losses that they can be ignored.

Losses from switching the power FETs on and off are due to the switching times and the resulting overlap of current and voltage. Switching losses are heavily dependent on the switching frequency f_{sw} and the MOSFET type. The losses are very low at frequencies up to 5kHz. However, the switching losses of a "slow" MOSFET increase at higher frequencies and may be higher than its conduction losses.

Losses can be calculated using the MOSFET parameters $R_{DS(on)}$ (on-resistance), t_r and t_f (rise time and fall time, or on-off switching times), which are available in the product datasheet.

Calculating dissipation for a power MOSFET

Power dissipation is calculated from two values as shown in the equation 1.1 below. These comprise the static power loss Pon shown in equation 1.2 and the dynamic power loss Psw that arises from the switching process and is shown in equation 1.3.

Formula for total power dissipation:

$$P_{ges} = P_{on} + P_{SW} \qquad (1.1)$$

Formula for static power dissipation:

$$P_{on} = R_{DS(on)} \cdot I_D^2 \cdot \frac{t_{on}}{T} \qquad (1.2)$$

P_{on} … static power loss $[W]$

I_D … cutoff current from drain to source $[A]$

$\frac{t_{on}}{T}$ … PWM signal duty cycle

$R_{DS(on)}$ … On - resistance $[m\Omega]$

Formula for dynamic power loss:

$$P_{SW} = 0{,}5 \cdot V_{DS} \cdot I_D \cdot f_s \cdot (t_r + t_f) \qquad (1.3)$$

P_{SW} … dynamic power loss $[W]$

V_{DS} … voltage from drain to source $[V]$

f_s … switching frequency PWM – signal $[Hz]$

$t_r + t_f$ … on – off switching times $[s]$

It is clear from the above that the power MOSFETs must combine low on-resistance with the smallest gate charge possible if they are to increase the application's efficiency. To respond to this need, Renesas Electronics Europe now provides new ANL2 process technology that delivers low on-resistance as well as an improved figure-of-merit factor (FOM, corresponding to $R_{DS(on)} * Q_G$). FOM provides a way of measuring the efficiency of a technology in switching applications in which power dissipation is determined by losses while the power MOSFET is operating, and by losses from switching. The smaller the FOM, the better suited the technology is to switching applications like motor control.

Renesas' Automotive N-Channel Low-Voltage (ANL2) technology is an evolution of its ANL1 (Superjunction1), which uses the well-known super-junction principle of charge compensation for low-voltage power MOSFETs with breakdown voltage under 100 volts. Its objective is to reduce on-resistance while minimising the FOM factor and maintaining breakdown voltage. Figure 1.3 shows a cross-section of the ANL2 cell structure compared to conventional UMOS trench technology. The charge carrier concentration in the N- epi layer significantly influences the specific on-resistance. The more N- material in the epi layer, the lower the layer's - and the power MOSFET's - resistance when conductive. The amount of material also largely determines the component's breakdown voltage. The lower the N- in the epi layer, the higher the breakdown voltage when blocking (B_{VDSS}).

As shown in Figure 2, ANL2 technology integrates additional P areas into the N^- epi layer under the active P sink. They comprise individual P columns made in several high-energy steps and separated by thin N^- zones, ensuring a strict separation of the P and N channels. The integration of the P columns into the N^- epi layer can result in optimised charge compensation with the right combination of P column structure, amount of N^- material, and the thickness of the N- layer. This means that the N^- epi layer can be increased. When blocking, the charge carriers are compensated by the P areas, maintaining a high level of breakdown voltage. By contrast, more charge carriers are available when conducting, reducing the resistance of the N^- epi layer. In addition, the cell structure has been reduced from 1.92µm to 1.60µm, so that the $R_{DS(on)}$ is significantly lower than with UMOS4 technology.

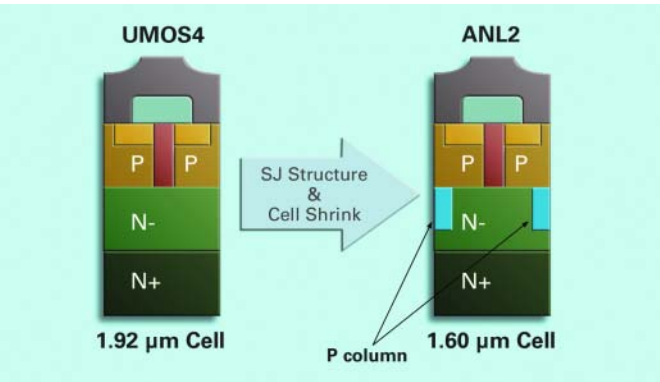

Figure 2: Improved cell structure in ANL2 compared to conventional UMOS-4 trench technology

With the introduction of each new technology, Renesas continually strives to improve power MOSFET parameters. For example, on-off switching times are faster and the $R_{DS(on)}$ is lower, producing regular reductions in power dissipation for switching transistors. This makes it possible to provide power transistors with maximum energy performance in smaller packages. With this in mind, Renesas launched the HSON-8 package that measures just 5.4mm x 6.0mm = $32.4mm_2$. This corresponds to half the mounting area of the TO-252 package (DPAK), which measures $64mm^2$, while still maintaining the DPAK's good thermal and electrical properties.

The components in DPAK packages have only been available with a maximum $RD_{S(on)}$ of 4.0 mΩ. By contrast, the new ANL2 technology achieves 2.8 mΩ. In terms of static power loss per power MOSFET, the lower on-resistance enables a reduction in power loss of up to 42 per cent.

For applications with space limitations, such as water, oil and fuel pumps, Renesas has developed dual channel MOSFETs in an HSON-8 package. As a result, the mounting surface can be reduced even further. The PCB surface required for the six power MOSFETs with dual HSON-8 has been reduced by almost 75 per cent compared to the standard TO-252 packages. Figure 1.5 lists the MOSFETs currently under development that will be available in the dual HSON-8 package.

Development partnumber	Polarity/ Process	V_{DSS}	P_T (T_c=25°C)	ID (DC)	Ron(max) @VGS=10V	Ron(max) @VGS=4.5V	Sample schedule	
							ES	CS
VA0266QU04	Nch/ ANL2	40V	73W	30A	8mΩ	-	OK	OK
VA0304QU04			55W	30A	10.1mΩ	-	Q1/'14	Q3/'14
VA0266QD06		60V	71W	30A	12.6mΩ	21mΩ	Q1/'14	Q3/'14
VA0304QD06			54W	30A	17mΩ	29mΩ	OK	OK
VA0304QU06			54W	30A	17mΩ	-	Q1/'14	Q3/'14
VA0316QL06			34W	16A	32mΩ	54mΩ	OK	Q3/'14

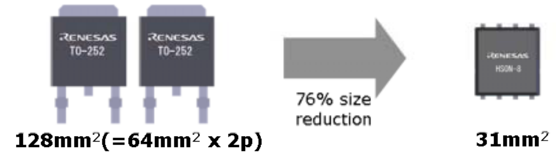

Figure 3: Overview of dual HSON-8 products

As these transistors have a high current carrying capacity of up to 30A, developers can add a compact B6 bridge without the need for complex cooling.

Renesas' new NP series of ANL2 MOSFETs is suitable for applications like water, oil and fuel pumps with voltages up to 60V.

Gate drivers

The microcontroller's voltage supply of 3.3V and maximum current of 15mA is not sufficient to operate MOSFETs. This is why Renesas provides gate drivers that form an interface between the control electronics and the power electronics.

The gate driver converts the uC signal into higher voltages and currents and uses them to control the MOSFET gate. The driver also checks that only one of the two half-bridge transistors is conductive at any one time - otherwise there is a risk of short circuit and thermal shutdown.

The following are important points to consider when selecting the driver with the right power levels:
1) The driver must be able to provide the required power level.
2) The driver's maximum output current must be equal to or greater than the maximum gate current.

Renesas provides the appropriate gate driver ICs for its MOSFETs, including the R2A25108KFP in a 9.0mm x 9.0mm P-LQFP48 package. This driver IC comprises a driver to control six N-channel power MOSFETs with PWM frequencies of up to 20kHz, as well as a wide range of protection and diagnostic functions. The comprehensive protection features of the R2A25108KFP include a protection circuit to guard against thermal overload, short-circuit protection (in relation to mass or battery), as well as over- and under-voltage protection. The dead time between the high-side and low-side FETs can be set with a very high level of precision in order to ensure optimal control. An additional feature of the R2A25108KFP is its low standby power consumption of 50uA. The gate driver IC has been designed specifically for vehicles with 12V voltage on board.

The following is a list of the component's key features:

- + Power supply: 5.0V to 40V at <500 ms
- + On-chip 3-phase pre-driver circuit
- + PWM up to 20 kHz
- + Dead time
- + On-chip charge pump circuit
- + On-chip safety functions, including:
- + Low voltage detection (LVD)
- + Over-voltage detection (OVD)
- + Short-circuit protection
- + Thermal shutdown protection
- + AEC-Q100 qualified

Microcontroller

The microcontroller is used to regulate rotation speed and for control tasks. Its role is to detect the position and continually adapt the rotation field to it via the power electronics. Two circuit breaker switches must always be turned off in order to ensure power is supplied to the motor windings. As a result, the power flows through two motor coils when the motor is configured with Wye windings. Renesas has a wide range of 16-bit and 32-bit microcontrollers suitable for use in water, oil and petrol pumps.

Conclusion

Renesas' power MOSFETs with ANL2 meet the requirements of today's water, oil and fuel pumps - from the point of view of performance as well as size. The new ANL2 fabrication process improves the FOM - the product of on-resistance multiplied by gate charge - by up to 40 per cent compared to conventional N-channel power MOSFETs based on the UMOS4 process.

62 products X.X: Under development (R_{DSon} max / mΩ)

VDSS	40V						55V/60V					
PKG	TO 263-7p	TO-263	TO-220 262	TO-252	HSON-B Single	HSON-B Dual	TO 263-7p	TO 263	TO-220 262	TO-252	HSON-B Single	HSON-B dual
180A	1.05 1.25						1.4 1.75					
160A	1.5						2.1					
120A			1.95 2.15									
110A		1.4 1.75						1.75 2.2				
100A		2.3						3.25				
90A		2.95	2.8 3.3	2.8				4.0 4.5	3.8 4.4	3.85 4.5		
75A				6	3.3						4.5	
60A		4.3	4.3	3.85				6.6	6.0 6.6	5.5 6.6		
50A					4.8							
45A								10		10		
35A											6.7	
30A						8 12					1.65	11 17
16A												32

Figure 4: Product portfolio using ANL2 technology

Renesas has already started releasing the first modules with breakdown voltage of 40 or 55/60 volts in various package types, including both SMD and THD. Figure 4 shows the product lineup. As these products are part of Renesas' well-known NP series, the components for automotive applications are fully AEC-Q101 qualified and compliant with RoHS and ELV regulations.

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Using Optical Isolation Amplifiers in Power Inverters for Voltage, Current and Temperature Sensing

Many industrial equipments and home appliances employ power inverters to perform their designed functions. In the inverter operating control loop, key feedback information on current, bus current and voltage are required to achieve smooth control. To protect the key devices in the inverter such as the IGBTs, temperature sensing is often required to protect the expensive IGBTs from being damaged due to fault conditions. As a result, miniature isolation amplifiers with built-in safety insulation have been designed to fulfill these application needs at a much better price/performance than traditional current/voltage transducers.

By Hong Lei Chen, Product Manager, Avago Technologies

A power inverter is an electrical power converter that changes DC power source to AC power source. The converted AC can be at any required voltage and frequency with the use of appropriate power switching devices, signal isolators, and control circuits. Power inverters are used in a wide range of applications, from industrial equipments such as variable-frequency motor drive, uninterruptible power supply (UPS), solar inverter, to home appliances such as induction heating, air conditioning.

Figure 1 shows a typical block diagram of a power inverter in an AC motor drive. It consists of an inverter that converts the DC bus voltage to AC power at a variable frequency to drive the motor. IGBTs are expensive power switches that form the heart of the inverter. These power devices must operate at a high frequency and must be able to withstand high voltages.

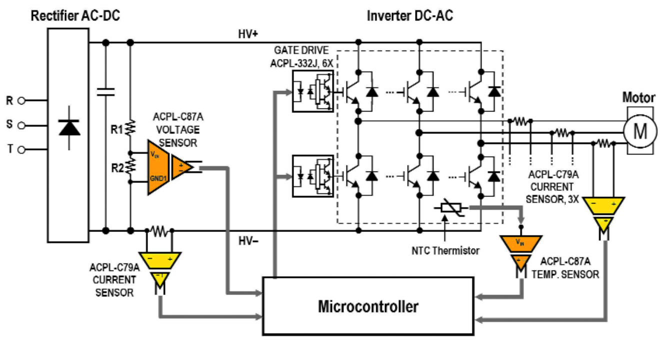


Figure 1: Block diagram of power converter in a motor drive

The isolation amplifier (iso-amp) ACPL-C87A [1] works as a precision voltage sensor together with a resistive divider consists of R1 and R2, monitoring the DC bus voltage. The ACPL-C79A[2] works in conjunction with a shunt resistor to provide accurate current measurement. These voltage and current sensing are performed even in the presence of high switching noise. The isolated voltage sensor ACPL-C87A can also be used in isolated temperature sensing designs. In this application, the voltage sensor must linearly and accurately measure temperature and send it across the isolation barrier thus providing safety insulation.

These voltage, current and temperature information from the iso-amps are collected by the microcontroller, which uses the data to calculate the feedback values and output signals needed to provide effective control and fault management in the power converters.

How the Optical Isolation Amplifiers Work

As an example, functional blocks of the ACPL-C87A are shown in Figure 2. First the isolation amplifier senses the input voltage (single-ended analog signal) and converts it to a digital bit stream. The bit stream is then transmitted across the optical coupling pair consisting of an LED and a photodetector. This optical signal path provides the electrical insulation barrier. Because the transmitted signal is optical rather than electrical, it is immune to magnetic fields and electrical noise. The photodetector recovers the optical signal and converts it back to an electrical signal, which is decoded and filtered to reproduce an analog output signal. The output voltage, provided in differential mode for better common mode noise rejection, is proportional to input voltage with unity gain.

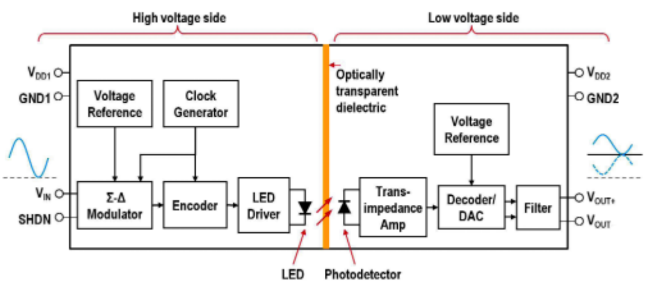


Figure 2: Internal block diagram of the ACPL-C87A

The voltage sensor ACPL-C87A provides ±1% measurement accuracy. Other options include ±0.5% (ACPL-C87B) and ±3% (ACPL-C870). The ACPL-C87X family features a stretched SO-8 package

EconoPACK™ 4

The world standard for 3-level applications

The EconoPACK™ 4 is an optimized module for 3-level applications like

- Uninterruptible Power Supply
- Solar Inverter
- High Speed Drives

where a robust design, high efficiency and less harmonics are needed.

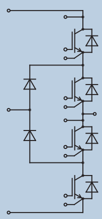
For these applications starting with 50 kW up to 125 kW, the EconoPACK™ 4 can be used to build up one phase. For higher power ratings modules can be switched in parallel. All modules are equipped with the state-of-the-art IGBT4. Further information are available on request.

The degree of efficiency for the two 3-level topologies, NPC1 and NPC2, has to be evaluated depending on the switching frequency.

- EconoPACK™ 4 NPC2 topology for low and medium switching frequencies (approx. $f_{sw} < 12$ kHz)
- EconoPACK™ 4 NPC1 topology for high switching frequencies (approx. $f_{sw} \geq 12$ kHz)

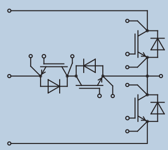
NPC1 topology

- 650V IGBT4
- Optimized for $f_{sw} \geq 12$ kHz
- Portfolio
  - F3L200R07PE4
  - F3L300R07PE4



NPC2 topology

- 650V/650V IGBT4
- 650V/1200V IGBT4
- Optimized for $f_{sw} < 12$ kHz
- Portfolio
  - F3L400R07PE4_B26
  - F3L300R12PT4_B26
  - F3L400R12PT4_B26



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that is 30% smaller than a DIP-8 package. These iso-amps have a double protection rating of 5000 V_{RMS}/1 min per the UL 1577 safety standard. The 1414 V_{PEAK} maximum working voltage specification per IEC/EN/DIN EN 60747-5-5 ensures circuits on the low voltage side are not damaged by hazardous high voltages.

The current sensor ACPL-C79A shares all the key functional blocks of the ACPL-C87A as shown in Figure 1, except that the former is configured as differential inputs (V_{IN+}, and V_{IN}) instead of a single-ended input (V_{IN}) and shutdown (SHDN). The other differences between the voltage sensor and current senor are input range and gain settings. The ACPL-C87A accurately measures 0-2 V input signal, while the ACPL-C79A measures ±200 mV linear input range. The different input ranges are optimized for voltage sensing and current sensing respectively. The ACPL-C87A has unity gain, while the ACPL-C79A is configured with 8.2 times gain. The ACPL-C79A family shares the same package and insulation capability as that of the ACPL-C87X family.

Voltage Sensing
Using the ACPL-C87X as an isolated voltage sensor is straightforward. Select resistors to form a voltage divider to scale down the voltage signal to be measured to a level within the sensor input range. With an integrated isolation and sensing circuit, the application circuit is significantly simplified compared to alternative solutions that employ separate devices to perform sensing and isolation functions.

A detailed voltage sensing circuit with the ACPL-C87X is shown in Figure 3. Given that the ACPL-C87X's nominal input voltage for V_{IN} is 2 V, a user needs to choose resistor R1 according to Equation 1:

$$\mathbf{R1} = \frac{\mathbf{V_{L1}} - \mathbf{V_{IN}}}{\mathbf{V_{IN}}} \times \mathbf{R2}.$$ Equation 1.

For example, if VL1 is 600 V and R2 is 10 kΩ, then the value of R1 is 2990kΩ.

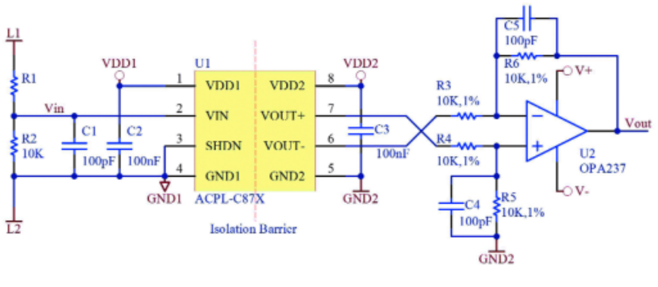

Figure 3: High voltage measurement with conversion to an isolated ground referenced output.

Choosing resistors is flexible. One method is to combine several resistors to match the target value; for example, 2 MΩ, 430 kΩ and 560 kΩ resistors in series make 2990 kΩ exactly. A V_{IN} of 2 V corresponds to a V_{L1} of 600 V. However, in the cases that V_{L1} is not 600 V, specific resistance values might be difficult to find. Another method is to round up the target value to a convenient value, for example 3 MΩ, to make resistor selection easier. In such cases, the scaling relationship may need fine tuning. In the same example with a V_{L1} of 600 V, R1 of 3 MΩ, and R2 of 10 kΩ, V_{IN} is solved to be 1.993 V.

The down-scaled input voltage is filtered by the anti-aliasing filter formed by R2 and C1, with corner frequency of 159 kHz (the value of R1 is usually much larger than R2, therefore neglected in calculation), and then sensed by the ACPL-C87X. The galvanically isolated differential output voltage (V_{OUT+} - V_{OUT-}) is proportional to the input voltage. The OPA237, configured as a difference amplifier, converts the differential signal to a single-ended output. This stage can also be made to amplify the signal, and, if required, low-pass filter the signal to limit bandwidth. In this circuit, the difference amplifier is designed for a gain of one with a low-pass filter corner frequency of 15.9 kHz. Resistors R5 and R6 can be changed for a different gain. The bandwidth can be reduced by increasing the capacitance of C4 and C5. The isolated output voltage VOUT, which is linearly proportional to the line voltage on the high voltage side, can be safely connected to the system microcontroller.

With the ACPL-C87X gain of 1, the overall transfer function is simply:

$$\mathbf{V_{OUT}} = \mathbf{V_{IN}}$$ Equation 2.

or

$$\mathbf{V_{OUT}} = \frac{\mathbf{V_{L1}}}{(\mathbf{R1/R2})+\mathbf{1}}$$ Equation 3.

The input stage of the application circuit in Figure 3 can be simplified as shown in Figure 4. R2 and R_{IN}, the input impedance of the ACPL-C87X, create a current divider that results in an additional measurement error component that will add on top of the amplifier gain error. With the assumption that R1 and R_{IN} have a much higher value than R2, the resulting loading error can be estimated to be R2/R_{IN}.

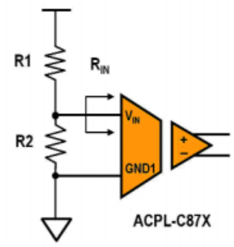

Figure 4: Simplified input stage of the ACPL-C87X circuit

With an R_{IN} of 1 G for the ACPL-C87X, the loading error is negligible for R2 values up to 1 MΩ, where the error is approximately 0.1%. Though this error is small, it can be reduced by lowering R2 to 100 kΩ (error of 0.01% approximately).

Current Sensing
As shown in Figure 1, using the isolation amplifier to sense current can be as simple as connecting a shunt resistor to the input and get-

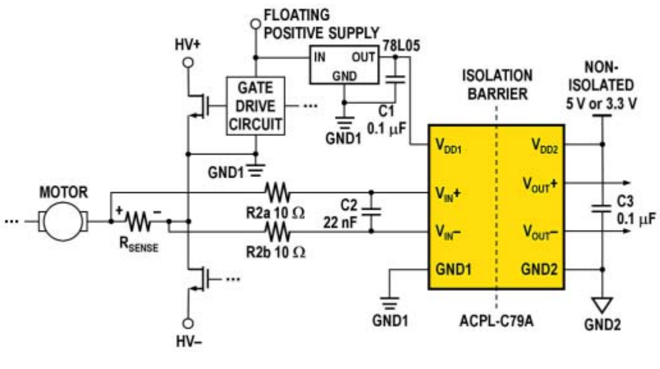

Figure 5: Typical application circuit for motor phase current sensing

ting the differential output. By choosing an appropriate shunt resistance, any range of current can be monitored, from less than 1 A to more than 100 A. In operation, currents flow through the shunt resistor and the resulting analog voltage drop is sensed by the ACPL-C79A. A differential output voltage is created on the other side of the optical isolation barrier. This differential output voltage is proportional to the current and can be converted to a single-ended signal by an op-amp or sent to the controller's ADC directly.

One of the benefits of using an isolation amplifier is that one sensor can fit in all the models with the shunt changed accordingly. The designer can then focus on optimizing sensor performance and easily port over the design to other models.

Selecting a shunt is easy. For example, if a compact motor has a maximum current of 10 Arms and can experience up to 50 percent overload, then the peak current is 21.1 A (= 10 × 1.414 × 1.5). Assuming the sensor input voltage of 200 mV for optimal performance, the shunt resistance would be about 10 m . The maximum average power dissipation is about 1 W. Various shunt resistors are available to fulfill this type of application need. They are offered in a case size of 2512 or similar at an inexpensive price, featuring a 3W power rating, decent tolerance and temperature coefficient.

Over-current conditions in an IGBT can occur due to a phase-to-phase short, a ground short or a shoot through. The shunt + iso-amp current sensing devices on the output phases and DC bus provide fault detection in addition to current measurement (see Figure 1), and the requirement is fast response to current surges.

The ACPL-C79A has a fast 1.6 µs response time with a step input. This allows the iso-amp to capture transients during short circuit and overload conditions. The signal propagation delay from input to output at mid point is only 2 s, while it takes just 2.6 s for the output signal to catch up with input, reaching 90% of the final levels [2].

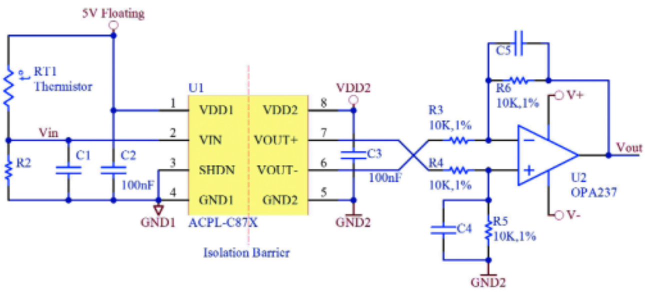

Figure 6: A simple isolated temperature sensing circuit

Besides fast response time, the ACPL-C79A provides ±1% gain accuracy, excellent nonlinearity of 0.05% and a signal-to-noise ratio (SNR) of 60 dB. Also available are the ACPL-C79B, which offers a higher-precision gain accuracy of ±0.5%, and the ACPL-C790, which has a ±3% gain tolerance.

Isolated Temperature Sensing using a Thermistor

Thermistors are widely used to measure temperature. Galvanic isolation between the potential of the thermistor and that of the system analog-to-digital converter is often required, especially when the thermistor is mounted near high voltages or in electrically noisy or poorly grounded environments. A lack of isolation can impair safety and induce electromagnetic interference (EMI).

A simple isolated temperature sensor circuit is shown in Figure 6. RT1 and R2 form a voltage divider from the floating, constant 5 V voltage source that also powers the voltage sensor. Choose RT1 and R2 so that the voltage fed into the ACPL-C87X isolation amplifier does not exceed the full-scale range of 2.46 V. The high impedance input terminal of the ACPL-C87X allows a relatively high resistance of R2 without causing a significant loading error. Select the resistor and capacitor values after reviewing the thermistor manufacturer data sheet.

Conclusion

Power inverter applications require isolated voltage sensing, current sensing for effective control, and temperature sensing for system protection against various conditions that cause overheat in the power switching devices. Designed specifically for high-voltage sensing, new generation optically isolated amplifiers, such as the ACPL-C87X, make monitoring and system protection circuits more accurate and easier to design. This iso-amp is also suitable for isolated temperature sensing. Sharing the same miniature package of the ACPL-C87X, the ACPL-C79A series are optimized for current sensing.

References

- ACPL-C87B/C87A/C870 Precision Optically Isolated Voltage Sensor Data Sheet. Avago Technologies, AV02-3563EN.
- ACPL-C79B/C79A/C790 Data Sheet, Avago Technologies, Publication No. AV02-2460EN.
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- HCPL-7800A/7800 Isolation Amplifier Data Sheet. Avago Technologies, AV02-0410EN.

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A Simple, Low-cost Technique for Compensating Isolated Converters

The majority of flyback regulators today are controlled by IC´s with ever increasing integration of functions. Where the classic UCC regulators from Unitrode/TI expected the user to decide on voltage mode or current mode control, generate their own PWM ramps, compensating ramps (where appropriate) and current limit circuitry, the modern controller or integrated-MOSFET regulator takes care of all of these functions internally. As always there is a trade-off for the increase in simplicity, and the price paid is in flexibility.

By Christopher Richardson, Power Induced Design

This article focuses on a control loop compensation technique for modern ICs that include a fixed bias voltage and fixed internal pullup resistor for the phototransistor side of the optocoupler. When the pullup voltage and resistance are both fixed a hard limit for phototransistor current is established, and when the photodiode side of the optocoupler is biased from the converter´s output voltage the minimum mid-band gain in the compensator´s transfer function is also fixed. Several authors have discussed this limitation at length, in particular Christophe Basso in [1]. The most common solution is to power the photodiode side of the optocoupler with a separate, independently-regulated voltage. Creating this independent source requires more parts, using more PCB area and increasing cost. A simple alternative is shown in Figure 1, whereby a resistor is placed in series with an MLC capacitor of fairly high value - 1 µF or more - and this chain is connected from the phototransistor´s collector to ground. From a large signal perspective the R1-C2 branch is an open circuit, but in the small signal domain the capacitor is a short circuit, and the resistor can be selected as needed to reduce the compensator´s mid-band gain.

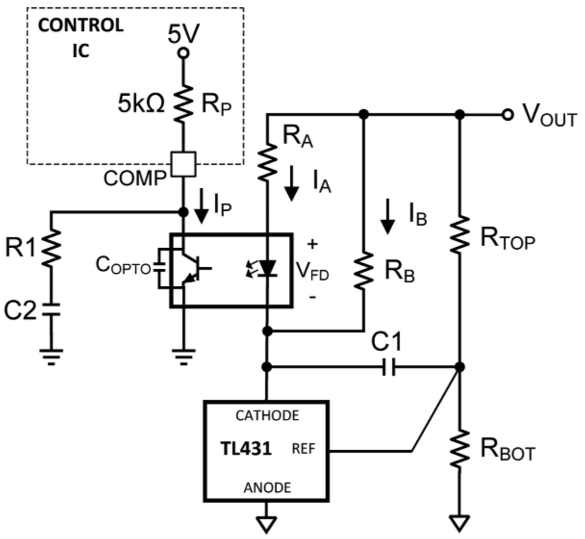

Figure 1: Simple Isolated Feedback and Control Compensation

If C2 were eliminated R1 and R_P would form a pure resistor divider, and while this works quite well in simulation, in practice fixing the maximum voltage at the COMP pin of the control IC fixes the maximum duty cycle and in turn limits the maximum output power.

Limitations of Basic Type II Compensation

If R1 and C2 are removed from the circuit of Figure 1 then the small signal transfer function can be written in an intuitive, factored form as shown in [1]:

$$G_{COMP}(s) = \frac{R_P}{R_A}\frac{CTR}{C1\times R_{TOP}}\frac{(1+s\times C1\times R_{TOP})}{s\times(1+s\times C_{OPTO}\times R_P)} \quad \text{EQ.1}$$

$$f_{ZERO} = \frac{1}{2\pi\times C1\times R_{TOP}} \quad \text{EQ.2} \qquad f_{POLE2} = \frac{1}{2\pi\times C_{OPTO}\times R_P} \quad \text{EQ.3}$$

This is a simple Type II compensation with a pole at the origin and a zero whose frequency can be set as desired. Pole 2 allows very limited control over frequency, especially when using control ICs such as the LM5001 from Texas Instruments, the ICE3AR series from Infineon or others where R_P is the fixed internal pullup resistor. To make matters worse, the optocoupler´s parasitic output capacitance, C_{OPTO} is not adjustable and it changes with operating conditions. A network analyzer is the best tool to test this value. Pole 2 is generally used to cancel the ESR zero of the power stage, and/or to roll off the overall loop gain to ensure a wide gain margin. Adding resistance in series to R_P or adding capacitance in parallel to C_{OPTO} can lower f_{P2}, but there is no way to increase the frequency. In many cases the control loop design must accept this limitation and work around it.

Improving the Basic Type II Compensation

Returning to the circuit of Figure 1, if C2 is assumed to be sufficiently large so that it becomes a short circuit in the small signal domain then R1 and R_P are in parallel. The simplified, factored transfer function and new Pole 2 then become:

$$G_{COMP}(s) = \frac{\frac{R_P\times R1}{R_P+R1}}{R_A}\frac{CTR}{C1\times R_{TOP}}\frac{(1+s\times C1\times R_{TOP})}{s\times\left(1+s\times C_{OPTO}\times\frac{R_P\times R1}{R_P+R1}\right)} \quad \text{EQ.4}$$

$$f_{POLE2} = \frac{1}{2\pi \times C_{OPTO} \times \frac{R_P \times R1}{R_P + R1}} \quad \text{EQ.5}$$

This provides the dual benefits of making mid-band gain adjustable to almost any value needed and also increases the frequency of Pole 2. Since lowering fP2 is relatively easy, the result is a "win-win" situation.

Example with CCM Flyback Converter

Continuous Conduction Mode regulators are most likely to benefit from this technique due to their power stage gain, which is higher than a DCM converter´s gain at the same operating point. The

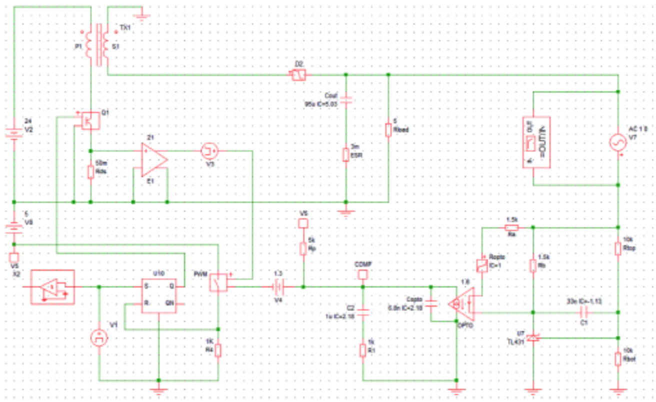

Figure 2: Circuit Schematic for an Isolated, CCM Flyback Converter

LM5001 Isolated Flyback Evaluation Board [2] is a good example of a CCM flyback when operated in the following conditions:

V_{IN} = 24V, V_O = 5V, I_O = 1A, f_{SW} = 250 kHz
PS2811-1M optocoupler: CTR = 150%, C_{OPTO} = 6,8 nF (tested using network analyzer)

Figure 2 shows a simplified circuit diagram of the LM5001 running as a flyback and Figure 3 shows a Bode plot of the power stage (duty cycle modulator plus output filter). SIMPLIS and other simulation tools or linear models (also available in reference [1]) can be used to predict the power stage response when a network analyzer is not available.

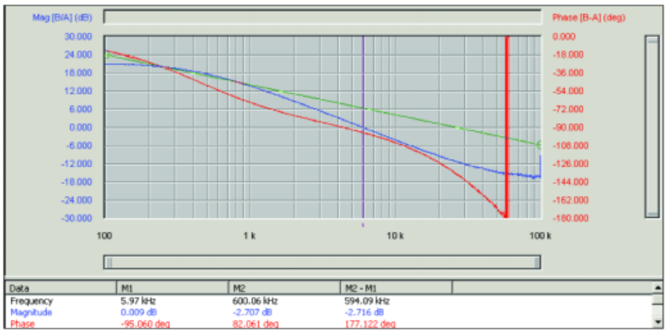

Figure 3: Gain (Blue) and Phase (Red) of the Power Stage, GPS

There are many different, equally valid design philosophies for compensating switching regulators. For this article the technique used will be to evaluate the gain of the power stage at the desired crossover frequency and then set the gain of the compensator to the negative of the power stage gain, thus ensuring that the overall loop gain is zero at the desired frequency. For a conservative, stable bandwidth of 5 kHz the gain of G_{PS} is around 2 dB. R_P is fixed internally in the LM5001 at 5 kΩ, and in order to ensure that at least 1 mA flows through the TL431 (see excellent discussion in [1]) the value of R_A cannot go higher than 1,5 kΩ. Without R1 the minimum mid-band gain of the compensator would be:

$$G_{MID-MIN} = 20\log\left(\frac{R_P \times CTR}{R_A}\right) = 20\log\left(\frac{5k\Omega \times 1{,}5}{1{,}5k\Omega}\right) = 14dB \qquad \text{EQ.6}$$

The gain is simply too high - it pushes the overall loop bandwidth to around 25 kHz, where the phase margin would be almost zero owing to the load pole and right-half plane zero. The result would be an unstable regulator. Furthermore, without R1 the frequency of Pole 2 would be determined by EQ.3 and would be around 4,7 kHz. Such a low frequency would roll off the gain too soon, but more importantly would further reduce the phase margin - exactly the opposite of what is needed.

To lower the mid-band gain to the desired -2 dB and increase the frequency of Pole 2, R1 can be selected with the following equations:

$$G_{MID} = 10^{\frac{G_{PS-BW} \times -1}{20}} = 10^{\frac{-2}{20}} = 0{,}8V/V \qquad \text{EQ.7}$$

$$R1 = \frac{G_{MID} \times R_P \times R_A}{R_P \times CTR - G_{MID} \times R_A} = \frac{0{,}8 \times 5k\Omega \times 1{,}5k\Omega}{5k\Omega \times 1{,}6 - 0{,}8 \times 1{,}5k\Omega} = 944\Omega \qquad \text{EQ.8}$$

Replacing R1 with a standard value of 1 kΩ fixes the gain to perfection and pushes the Pole 2 frequency out to 28 kHz, giving the overall control loop plenty of phase margin. The remaining component to be selected is C1, using EQ.2 to set fZERO equal to the load pole.

The final compensator and overall control loop Bode plots are shown in Figures 4 and 5.

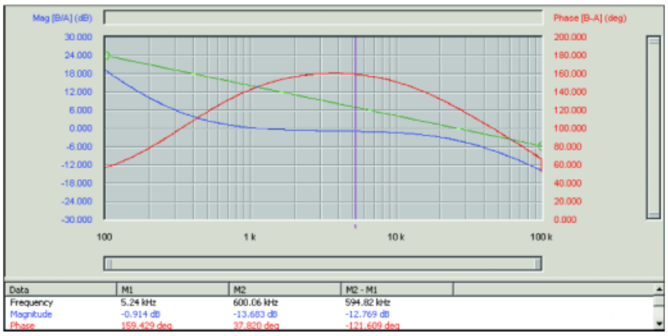

Figure 4: Gain (Blue) and Phase (Red) of the Compensator, GCOMP

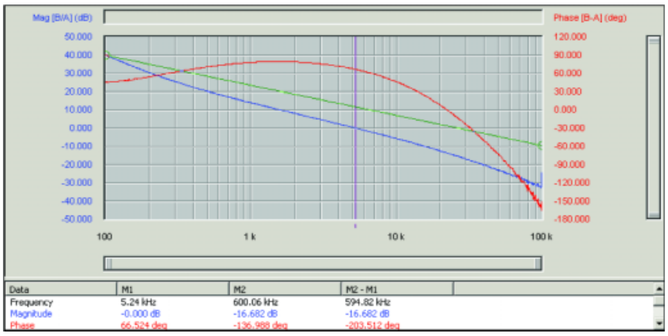

Figure 5: Gain (Blue) and Phase (Red) of the Control Loop, GLOOP = GPS x GCOMP

Conclusion

Figure 5 shows a stable control loop with a bandwidth of 5,24 kHz and 66º of phase margin. This simple technique to lower the compensator´s mid-band gain and also increase the frequency of Pole 2 is already employed in many designs, but may not be fully understood. With the design philosophy and equations stated explicitly circuit designers can now stabilize an isolated converter for the price of one MLC capacitor and one standard thick film resistor. This comes at a considerable savings of cost, component count and PCB area over the development of a regulated voltage independent of the output voltage to power the photodiode side of the optocoupler.

List of Changes to LM5001 Evaluation Board
1) R8 = 1 kΩ, R13 = R16 = zero, R18 = R18 = 10 kΩ,
2) R14 = R15 = 1,5 kΩ, C15 removed, C16 = 33 nF

References

Switch Mode Power Supplies, Christophe Basso, McGraw-Hill 2008
SNVA221B: AN-1588 LM5001 Evaluation Board, Texas Instruments 2013

About Power Induced Design

PID was formed in 2013 to provide power electronics design, consultation and training to customers in Spain, the European Union and beyond. Our goal is to provide rapid, efficient service, from ground-up design to technical training to stepping in and solving problems when capacitors are blowing up and MOSFETs are smoking. The name Power Induced Design and our "roller coaster" logo are tributes to the initials PID, the lead-lag compensator used in the control loops of many switching regulators.

info@powerinduced.com

IGBT Modules Benefit from Inverted Acoustic Inspection

When a high-current IGBT module experiences sudden electrical failure in service, the consequences are generally expensive and sometimes dangerous. Because they are used as high-speed switches for heavy power and current, IGBT modules play demanding roles in transportation (electric railways, electric autos), mining and other industries.

By Tom Adams, consultant, Sonoscan, Inc.

Makers of IGBT modules go to great lengths to build long-term reliability into their products, but during assembly of a module there is the opportunity for anomalies to be formed that are not easily detected by most test methods. The anomalies are collectively called gap-type defects. These defects include voids (in solder, for example), delaminations between materials, and cracks. They have two characteristics that can lead directly to a sudden failure during system operation:

1. they block heat being dissipated from the chip transistor. Because they handle varying loads of high current, IGBTs require very efficient heat dissipation.
2. they tend to become larger as a result of thermal excursions during service, and are then capable of blocking more heat flow.

Such defects can and do cause sudden field failures. The challenges for IGBT module makers are to avoid defects through good process control and to find and remove defects before they arrive in customers' hands. Gap-type defects are not detected by electrical tests, x-ray or other routine test methods. They are, however, made visible and characterized by acoustic micro imaging, which employs very high frequency ultrasound These defects reflect more than 99.99% of an ultrasonic pulse that strikes them as an echo signal. The echoes are used to create the acoustic image.

Many makers of IGBT modules, however, can't use acoustic micro imaging systems because the ultrasonic transducer must be coupled to the surface of the sample being inspected by water, and because to date all transducers have been designed to pulse downward. They must therefore scan the top side of the unencapsulated module, but for many modules putting the topside circuitry in contact with water is considered too risky.

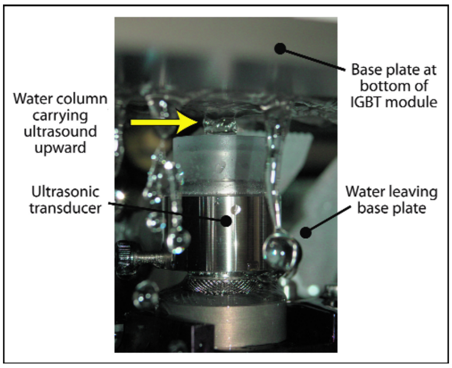

Figure 1: Pumping water upwards, the transducer assembly maintains a constant column of water as it scans the bottom surface of an IGBT module

This obstacle to long-term reliability has been removed by Sonoscan engineers, who have developed an acoustic micro imaging system that inverts the transducer [Figure 1] and places it under the IGBT module's base plate, where it scans the surface at speeds that can be >1m/s as it scans. The inverted transducer pulses ultrasound into the module and receives return echoes at thousands of x-y locations per second. It is coupled to the base plate surface by an inverted water jet that creates a constant column of upward-flowing water (arrow in Figure 1) that reaches the base plate surface but no other part of the module. For applications that require it, the inverted transducer can be moved to the top side and aimed downward to perform the same operations and collect data with the same speed and efficiency.

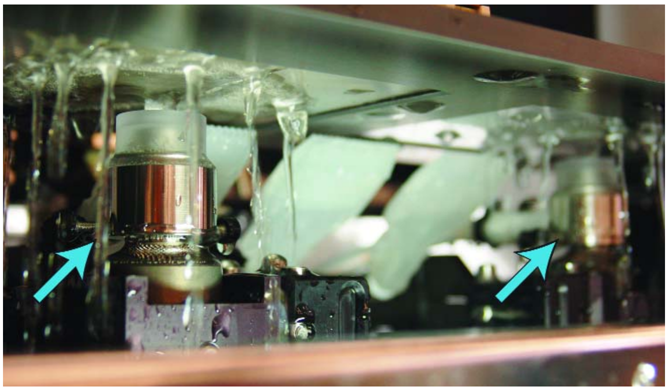

Figure 2: To boost throughput, the system can have two transducers, each scanning its own module

From its vantage point beneath the module the transducer can image internal features at any level, up to and including the IGBT transistors and their attachments. For higher throughput, the system can be equipped with two inverted transducers that image two IGBT modules at a time [Figure 2].

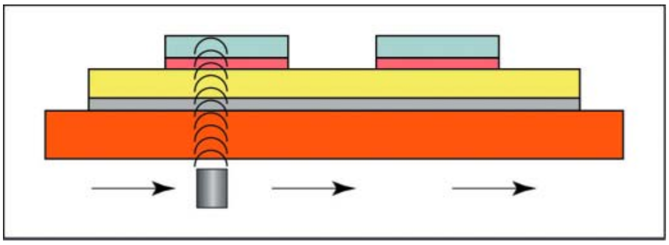

Figure 3: Simplified side view of a module. The scanning transducer sends thousands of pulses per second into the bottom of the module and collects echoes from material interfaces, including the interfaces associated with gap-type defects

Each transducer pulses ultrasound into the base plate of its module. The overall operation of one inverted transducer scanning the bottom side of one module is shown diagrammatically in Figure 3. As the ultrasound propagates upward, it is to some degree reflected by each material interface that it encounters. At the interface between the base plate and the ceramic plate or "raft" above it, a portion of the ultrasound will be reflected back to the transducer and a portion will cross the interface and travel upward. The percent of the ultrasound that will be reflected by striking this interface can be calculated from the density and acoustic velocity of the two materials. The portion of ultrasound that crosses this interface will travel upward and, barring interference from defects, will be in part reflected by the next material interface.

The exception to this pattern occurs when ultrasound strikes a gap-type defect, or more precisely the interface between the solid material it is traveling through and the air or vacuum in the gap. More than 99.99% of the ultrasound is reflected back toward the transducer for collection. In reflection-mode acoustic imaging, the brightness of a feature is determined by the intensity of the returning echoes. Echoes from gaps such as voids, delaminations and cracks are therefore bright white. Echoes from well bonded solid-to-solid interfaces are some shade of gray.

For IGBT modules, this means that the inverted ultrasonic transducer can display anomalies such as voids or cracks in the adhesive bonding the base plate to the raft, delaminations between any two elements, voids or delaminations in the die attach of the transistors, and other anomalies.

The echoes sent back from various levels within the IGBT module arrive at the transducer at different times. A single acoustic image is typically "gated" on a particular time interval representing the targeted depth in order to avoid using echoes from all depths and thereby creating a potentially confusing acoustic image. The gate may be as thin or as thick as desired. For example, when looking for voids or other defects in a solder layer bonding the base plate to the raft, the operator may gate on the top surface of the base plate and the bottom surface of the raft in order to image the whole thickness of the solder. Alternately, he may gate on a thinner portion of the solder region.

Figure 4 is the acoustic image made by the inverted transducer system of one of four units in an IGBT module. This image was gated on the interface between the base plate and the solder layer bonding the base plate to the ceramic raft. The image encompasses roughly half of the thickness of the solder. The material interface between the base plate and the solder is medium to dark gray. At the lower left the solder extends across an intended gap between this raft and the one to the left.

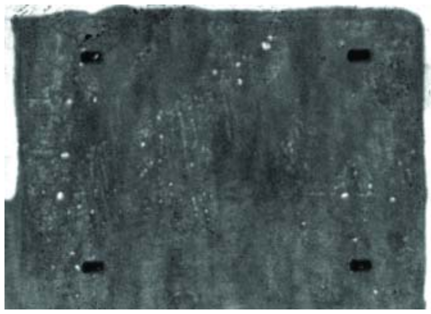

Figure 4: Acoustic image gated on the material interface between the base plate and the solder adhesive. The four dark objects join the base plate to the ceramic raft; the numerous white dots are voids in the solder

The four darker features, one near each corner, are posts that mechanically join the raft to the inner surface of the base plate. The numerous small white features are voids in the solder; these are probably air bubbles that were trapped in the fluid solder. Examination of the next level that was imaged - the second portion of the solder thickness - showed few additional voids and, more important, no large voids. Thus the voids seen in Figure 3 constitute most of the voids in the solder, and these voids lie close to the base plate. Although numerous, they are small, and may pose little risk to performance.

Figure 5 was gated on the die attach below the components at the top of the module. Like Figure 4, Figure 5 was made by pulsing ultrasound into the base plate. In this case the ultrasound traveled through the base plate and rafts to the die attach. Gating selected only echoes from the die attach level for imaging.

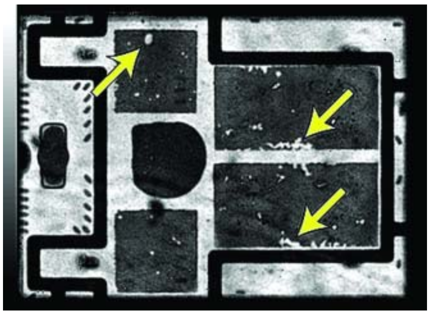

Figure 5: Scanning the bottom surface of the module gave this acoustic view of the die attach level. Arrows mark delaminations and voids that can cause field failures

The straight black lines are intentional gaps between the rafts. Because the echoes were gated on the die attach that is farther from the transducer than the raft, ultrasound returning from the die attach is blocked (reflected back toward the top of the module) by these gaps. The x-y coordinates corresponding to the gaps thus have no echoes, and appear black. The phenomenon is sometimes called an acoustic shadow.

The four rectangular features in Figure 5 are the medium gray tone resulting from the material interface between the die attach material and the die itself. Interrupting this medium gray tone are several much brighter areas that are voids or delaminations (marked by arrows in Figure 5). Although these defects are small, they pose some level of risk in an IGBT module, in part because they will probably be exposed to thermal variations that will cause them to expand. As their areas grow larger, the amount of heat they block will increase. All four of the rectangular components have such defects. The dark, nearly circular feature in Figure 5 is probably the outline of excess solder outflow from a small rectangular component.

IGBT modules are imaged acoustically at various stages of assembly. Rafts are sometimes imaged alone in order to look for internal defects, or to image the attach of components. Most frequently acoustic imaging is carried out on the completed module, with base plate attached, but before encapsulation. Defects found at this point can be remedied by rework. The module can also be imaged by the inverted transducer after encapsulation because the base plate is not encapsulated. Imaging after encapsulation may be helpful in diagnosing the cause of a failure, and is useful as a prelude to destructive physical analysis.

Summary

Overall, the inverted ultrasonic transducer gives the opportunity to inspect nondestructively the internal features of IGBT modules and to identify and rework those modules where anomalies capable of causing field failures are found. Because the inverted transducer can image features at any level, including the die attach and die at the top of the module, it makes possibly risky inspection from the top side unnecessary.

www.sonoscan.com

SiC at its Best…! or Customer Specific SiC Modules

While the speed of development for power electronics is increasing and possibilities of technology are exponentiating, today developers have various choice of which device to choose. The following article intends to get an overview for the various technologies and innovations in packaging technologies for customer specific SiC power modules.

By C. Rocneanu, Field Application Engineer, MEV Elektronik Service GmbH
And Co-Author: R. Dilsch, Application Engineer, CeramTec GmbH

The field of power electronics is aiming at three important goals: miniaturization of devices while increasing the power density and reducing the losses. In the past there have been different approaches to achieve those goals

One approach is the use of different materials. Silicon replaced Germanium very quick and has been hold as "philosopher's stone" for a long time. With the wide band gap materials the revolution in the power electronic industry starts again.

Due to the wide band gap as well as very good thermal conductivity SiC and GaN are ideal for high break down voltages, high frequencies and high temperature operation. Due to the structure of cost (yield and $/cm²) and the figure of merit for GaN-HEMTs (High Electron Mobility Transistor) the expected domain of GaN devices will be in application with break down voltages below 1200V, while the domain of SiC will be for break down voltages greater and equal to1200V. [1]

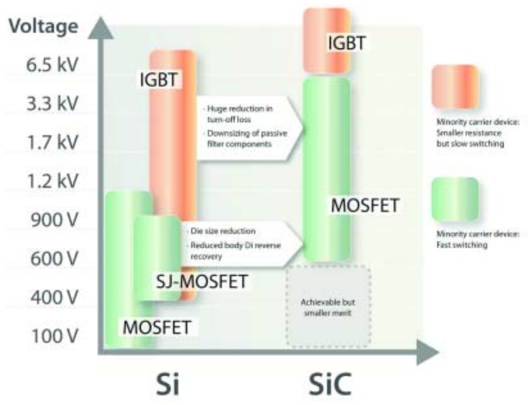

Figure 1: Overview of different power semiconductors in different voltage classes for Si and SiC SiC- und GaN-power devices

One further approach is the power device topology. Until the 1970s the bipolar Transistor has been state of the art. Due to its voltage dependent behavior, positive temperature coefficient and low conduction losses the MOSFET could replace the bipolar transistor.

With the introduction of the IGBT in the 80s advantages of the bipolar and FET structure could be combined. Nowadays both MOSFET and IGBT have their operating area dependent on the intended frequency and blocking voltage. While the IGBT is generally used for low frequencies (<30kHz) and high blocking voltages (>1000V) the MOSFET is used for higher frequencies (>=20kHz) and lower blocking voltages (<400V)

In the overlap segments where MOSFET and IGBT can be used it depends on the customer's application. Also special developed FETs like the SJFET are dominant in this market segment.

With introduction of SiC- and GaN-power devices the hunt for the best topology starts again. Today SiC-MOSFET, -JFET and -BJT are commercially available.

Due to the good adaption to Si devices a trend can be seen for the MOSFET. CREE and other mayor vendors are going for the normally-off MOSFET. Other companies go for the JFET (mostly normally-on) because of its higher current capacity. The problem with the normally-on structure with the GaN-HEMT or the SiC-JFET can be solved by a series connection of a Low-Voltage Si MOSFET (Cascode circuit). As another big player Fairchild is going with the BJT for the bipolar structure.

Although, the use of SiC-diodes and -transistors have made a big progress in some applications there are two more mayor problems to be solved before SiC can fully penetrate the market: pricing and package

Compared with Si-power devices on a discrete Level the price per device for SiC is multiples time higher.

At the discrete component level, the price per component part is higher compared to the Si power semiconductors due to the fact that the production is limited to 4" SiC wafers at the moment and SiC is a very expensive material. There will, however, be a significant improvement in terms of pricing in the medium term, because the surface of a SiC MOSFET is considerably smaller than an Si-IGBT and CREE e.g. can switch over to 6" wafers should the demand continue to increase.

Upon introduction of a 1700V, 1ohm SiC MOSFET (C2M1000170D), CREE can even offer a MOSFET which, in terms of price, is able to keep up with the Si-MOSFETs with a reverse voltage of more than 1200V - and has a significantly better performance. Furthermore, CREE, apart from the second generation of the 1200V, 80mohm

MOSFETs, has now also launched the second generation of the 1200V, 160mohm MOSFETs (C2M0160120D). In the second generation of SiC-MOSFETs, a considerably improved price could be achieved by a reduction of the chip area. Moreover, faster turn off and a better overall performance can be obtained by means of the expanded input voltage range (V_{GS}=-10V/ +25V) and the lower capacitance. All MOSFETs are available ex stock MEV Elektronik Service GmbH.

A comparison of the price in relation to the overall system costs shows a considerable reduction of switching losses and a reduction of costs in certain applications. The advantages offered by the characteristics of the SiC technology such as the higher switching speeds or extremely low losses can e.g. lead to cost savings with regard to inductor or heat sink.

Figure 3: Selection of several Powersem packages with different overall heights. SiC-EcoTM 1 and SiC-EcoTM 2 9mm and 17mm overall height, SOT-227 12mm overall height, Subassembly variable overall height, SiC-SlimTM 6mm overall height, Eco-SMPDTM 5.5mm overall height, Eco-227TM 12mm overall height without base plate, Chip-on-HeatsinkTM (CoH) variable overall height

Integrated circuit packaging

Apart from the price, another significant item is the housing or more precisely the integrated circuit packaging. On the one hand, the market requires the adaptation of standard packages, in order to reduce time and effort and the costs of a design-in. On the other hand, the available packages are hardly appropriate for the requirements and possibilities of SiC and GaN due to insufficient heat dissipation.

With identical RDS,on, a SiC-MOSFET has a 33 times, respectively 10 times smaller chip area than a Si-MOSFET or Si-SJFET. A reduction of the chip surface also leads to a reduced gate charge Qg and overall capacitance C, which are substantial factors for the losses. Fig. 2 shows the development of the chip surfaces in the past years.

Figure 2: Development of chip area with respect to junction temperature in power electronics [2]

Due to the fact that the ratio between power loss and available module surface steadily increases, the type of cooling (air, liquid) is another important element apart from the thermal transfer. Various packaging technologies and chip carrier substrates are now also available here.

Powersem packages

Since 2013, MEV Elektronik Service GmbH has been cooperating with Powersem GmbH, a German manufacturer and innovator of customized SiC modules.

"With the Eco-227*TM* , we have responded to the customers' needs without losing sight of the significantly improved characteristics of the SiC chips" says Mr Chadda, Managing Director of Powersem GmbH. "Due to the same housing and mounting dimensions as with the SOT-227, the customer is provided with optimum adaptability without being forced to convert his production. Consideration is given to the chip by mounting the Eco-227*TM* without additional base plate." Further examples are the SiC-Eco 1, SiC-Eco 2 and SiC-Eco 3 with a module overall height of 6mm, 9mm or 17mm. The SiC-Eco*TM* family is available both as solder able and as press-fit versions (Eco-Press-Fit*TM*). The Eco-SMPD*TM* (see figure 3) is also completely new and, compared to conventional TO-247 or TO-264 packages, it excels in low parasitic capacitances, low thermal resistance and high electrical voltage isolation.

Furthermore, Powersem is able to use the "Chip-on-Heatsink*TM*" technology in its module concepts. "Chip-on-Heatsink*TM*" is an innovation by CeramTec GmbH. As a manufacturer of high-performance ceramics, CeramTec is an important supplier for the power electronics industry. In the Chip-on-Heatsink technique, a copper layer is applied and sintered onto a ceramic base plate. These techniques are well known e.g. from thick-film technology. Thus, the ceramic material replaces the former base plates made of copper or AlSiC and provides the electrical isolation. The use of copper provides excellent electrical and thermal conductivity. The chip is directly soldered onto this copper layer. Due to this technique, a large number of thermal resistors can be omitted. Depending on the required ampacity and heat distribution, the copper layer may have a thickness of up to 400µm. Depending on the layout, the intimate bond between copper and ceramic material brings about a slightly convex bottom plate which is extremely beneficial for the heat-transmitting mounting on a heat sink.

Chip on Heatsink offers perfect preconditions for the reduction of the thermal resistance, in order to effectively distribute heat from the SiC chips. This feature as well as the thermal cycle-ability, which is about 10 times higher compared to the previous standard technologies, may lead to considerable improvements in power electronics.

The base plate cannot only be designed as a flat plate but also as a heat sink with integrated fins for convection cooling. Due to the fact that the base plate and the fins consist of one part, the normally necessary thermal heat sink paste or soldering can be omitted. If even higher losses are dissipated, the use of ceramic material enables the design of highly efficient liquid coolers. Here, the copper layer is directly applied, too, and represents the conductive paths, onto which the dies are directly soldered or sintered without any further interface.

Substrate chart

Nowadays, the three most commonly used substrates are AL2O3, AIN and Si3N4. Apart from the costs, the different physical properties such as thermal conductivity, thermal capacity, heat distribution and the coefficient of thermal expansion have to be taken into account. Table 1 shows an overview of the physical properties and a general cost overview for AL2O3, AIN and Si3N4.

expansion of the thick-film technology towards considerably higher currents and performances.

Summary

It has been stated that not only the appropriate package is vital for the selection of the right module but above all the right selection of substrates and technology. Usual distributors are dependent on the

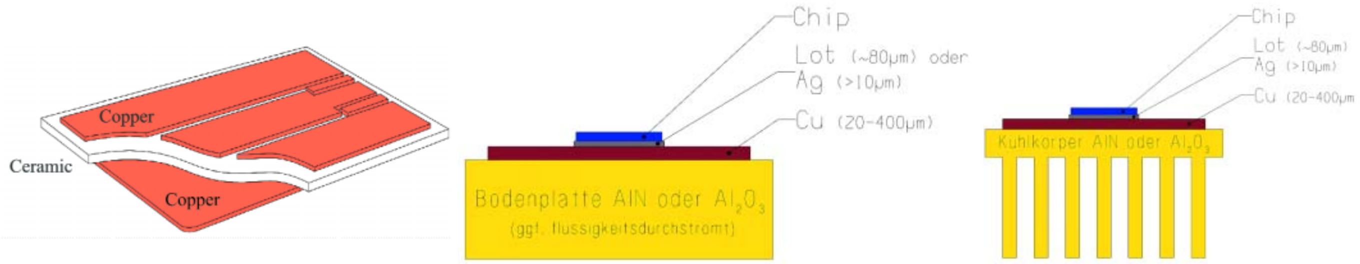

Figure 4: left-hand: DCB with double-sided copper [3], middle: cross section of SCT design with base plate or liquid cooler, right-hand: cross section of SCT design with liquid cooler

A high thermal conductivity value indicates a higher heat transmission per unit of time. The breakdown voltage specifies which maximum field strength an insulating material can withstand under certain conditions without losing its insulating properties. The coefficient of thermal expansion describes the relative change of length in case of a change of temperature.

	AL_2O_3	AIN	Si_3N_4
Thermal conductivity @20°C [W/mK]	24	180	90
Breakdown voltage [KV/mm]	10	20	18
Coefficint of thermal expansion @20°C - 300°C [ppm/K]	6.8	4.7	2.5
Costs Nov 2013	low	high	very high

Table 1: Physical properties and cost appraisal of different substrates [2]

While the cost appraisal in general clearly speaks in favor of AL_2O_3, AIN and Si_3N_4 have obvious technical advantages compared to AL_2O_3. The better thermal conductivity of AIN compared to Si_3N_4 may be put into perspective taking into consideration that with Si_3N_4 only substrate layers which are half as thick can be used. Another big advantage of Si_3N_4 is the higher thermal stability against alternating loads. The thermal stability against alternating loads depends to a great extent on the technology applied.

DCB, AMB and SCT

Direct copper bonded (DCB) or Direct Bond Copper (DBC) comprises the application of copper onto insulation (ceramic material) by means of a high-temperature process, which very firmly bonds the copper to the ceramic material. The copper layers normally have a thickness of 200 or 300µm which makes fine structures impossible.

Similar applies to AMB, where a copper film is firmly bonded to a ceramic plate by means of a high-temperature soldering process across the entire surface. Then the insulation trenches are etched in both processes.

With SCT, the process is different. Here, the copper layer is applied onto a ceramic plate up to a thickness of 400µm, namely only where it is desired. Due to the processes applied, almost any thicknesses can be produced. Furthermore, not only ranges with thin and very fine structures (100µm pitch) but also ranges with thick copper with a high ampacity are possible on a substrate. Thus, SCT represents an

existing technologies of their suppliers and have to sell their available product portfolio to the customers. As a design-in distributor, MEV, however, strongly focuses on technical competence. Accordingly, well-known manufacturers are working on customized projects together with MEV, thus guaranteeing that the customer is able to decisively contribute to the development of the desired module.

	AL_2O_3	AIN	Si_3N_4
DCB [cycles]	Medium (can be improved by Dimple)	Poor (can be improved by Dimple)	Very good
AMB [cycles]	Medium (can be improved by Dimple)	Poor (can be improved by Dimple)	Very good
SCT [cycles]	Very good	good	Very good

Table 2: Thermal stability against alternating loads with different substrates and technologies

CREE Inc., Powersem GmbH and CeramTec GmbH are strong and innovative partners of MEV Elektronik GmbH who perfectly match the customized design-in strategy of MEV Elektronik due to their experience and know-how. Should further information about this topic be desired, please do not hesitate to contact one of the following persons:

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Sources:

[1] Michael A. Briere, The Status of GaN-on-Si based Power Device Development at International Rectifier, ACOO Enterprises LLC under contract to International Rectifier, APEC Exhibitor Presentation, March 19, 2013
[2] http://www.CeramTec.de
[3] DCB image from www.wikipedia.de

The Revolutionary New Impedance Analyzer

Originally conceived as a time domain analysis device the HIL is now entering the frequency domain which will revolutionize the way power electronics controllers are developed, tuned and tested.

By Elaina Chai Massachusetts Institute of Technology and Adrien Genic Typhoon HIL Inc.

Introduction

As the applications and complexity of power electronics systems continue to grow, there is an increasing demand for fast and accurate tools for improving power electronics controls design, test, and verification. Hardware-in-the-loop (HIL) is receiving increased attention as an indispensable tool for designing and validating complex controls systems. It enables control engineers to test real controller systems by directly interfacing them with a real-time emulation of a converter power stage. Since engineers are able to quickly test controllers under a wide range of operating and fault conditions without a high-power lab, the amount of time and resources required for the design, testing, and validation of these systems can be drastically reduced.

The HIL configuration enables repeatable, formalized testing for a wide selection of operating conditions (including faults), that are often impossible or too expensive to test with real hardware. The high power when digitized in the HIL opens a world of new possibilities.

Challenges of Power Electronics impedance analysis

In the design, integration and analysis of complex power electronics systems, it is often necessary to obtain the small-signal impedance characteristics of an existing power electronics component or subsystem at a given operating point. Stability analysis in power electronics power systems is a crucial task due to the nearly ideal control capability of many modern power converters. The excellent load regulation capability of converters is a desirable feature in many applications, but it also makes converters a constant-power load device, which is a potential cause of negative impedance instability.

In order to obtain the frequency-dependent characteristics through experiment, there are significant obstacles that have to be solved. First of all, the system has to be running in the laboratory. Secondly, periodic voltage or current disturbances have to be injected into the system while it is running. The magnitude of the disturbances at a specific frequency has to be large enough to be able to measure it which can be challenging. Measurements of the disturbed system are then taken and post-processed to determine the impedances at specific frequencies. These measurements, when done in high power systems, are dangerous and require expensive equipment.

Figure 1 illustrates a typical stand for developing and testing power electronics controls in a conventional way.

Impedance analyzing the HIL way Thanks to the ultra high fidelity of HIL emulators, impedance and stability analysis of power electronics converters is made simple. Since the power stage is digitalized inside the HIL device, there is no high power in the loop anymore. A very intuitive interface allows the user to easily inject any kind of disturbances into the emulated power stage, measure them and process them automatically in order to get the desired impedances or transfer functions. All these tests and measurements are done on a HIL device, within the comfort of an office desk, shown in Figure 2.

Various types of automated tests and analysis can be done automatically using scripting.

Figure 1 Power electronics test stand, the conventional way; 1 - digital controllers; 2 - high power systems; 3 - measurement and testing equipment

Figure 2 Power Electronics test stand, the Typhoon HIL way

The compound of a digitalized power stage and advanced signal processing capabilities of the HIL gives its impedance analyzer limitless usage of known impedance analyzing methods in a completely new fashion.

Using HIL's powerful oscilloscope and its capture function capabilities with storage space of up to 32 Mpts, a detailed and accurate time and frequency domain analysis can be obtained.

Figure 3 represents a block diagram of HIL impedance analyzer interaction paths with the power stage model and the controller. Disturbances can be injected anywhere in the power stage by adding disturbance voltage or current sources. Additionally, any measurement can be fed back into the embedded impedance analyzer. Frequency range and/or the exact frequencies of interest can be defined and the step of the frequency sweep as well. Disturbances can also be fed directly into the controller in order to obtain the control to output transfer function.

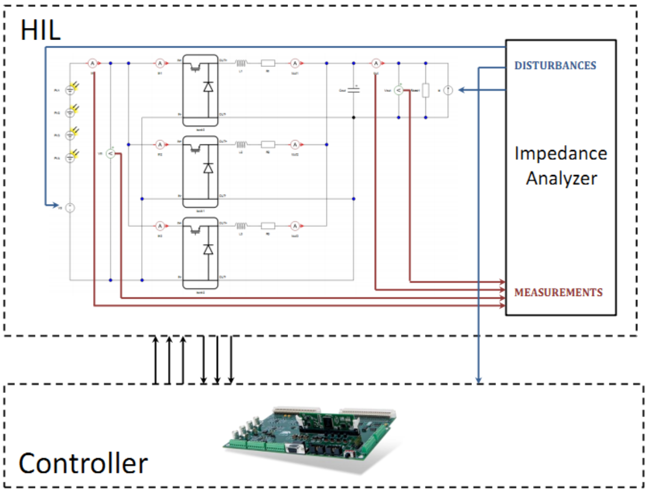


Figure 3 Impedance analyzing, the HIL way

The work flow of the impedance analyzer is shown in Figure 4. Disturbance sources and required measurements are included in the model. The controller is started up, and set to the required operating point. The impedance analyzer starts to inject disturbances at specified frequencies in the operating model. Measurements are collected for each disturbance frequency and plotted. Post-processing will obtain the discrete Fourier transform (DFT) of the collected data. In order to get the specified impedance characteristic or transfer function, measured variables are compared.

The time needed for completing the impedance analyzing process depends on the level of details specified by user. On TFS (frequency sweep time), shown in Figure 4, the number of swept frequencies has the biggest impact, while on data acquisition time (TAC) the amount of data captured for each disturbance frequency has the biggest impact. The overall time needed for the complete process can vary from a few seconds to few minutes, if high requirements are specified.

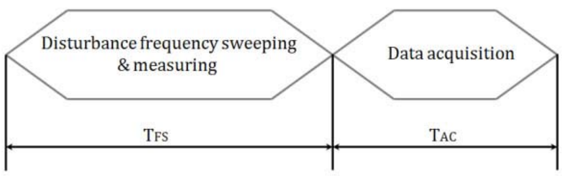


Figure 4 Timeline of the HIL Impedance Analyzer

The input impedance is measured by injecting a disturbance into the input voltage, while measuring its effect on the input current. The disturbance is modeled as a small sinusoidal voltage source in series with the input voltage. Indeed, this proves the benefits of using a HIL emulator, there is no need for an isolation transformer or impedance matching in order to successfully inject disturbances into the power stage. Input impedance magnitude and phase characteristics are shown with green dots in Figure 5.

The output impedance of buck converter is measured by injecting a current disturbance into the output of the converter. The resulting current and voltage across the load is measured to calculate the frequency response. Characteristics shown with red dots in Figure 5 represent the magnitude and phase of output impedance.

Line-to-output transfer function is measured by injecting disturbances into the input voltage and measuring the resulting output voltage. Input and output voltages are processed to get the line-to-output transfer function. Line-to-output transfer function is represented with blue dots in Figure 5.

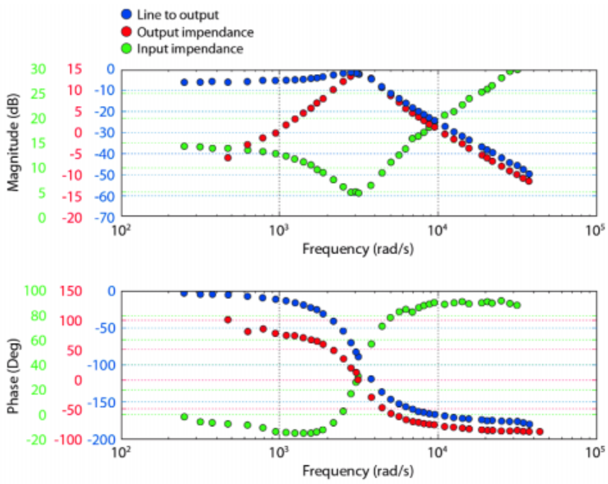
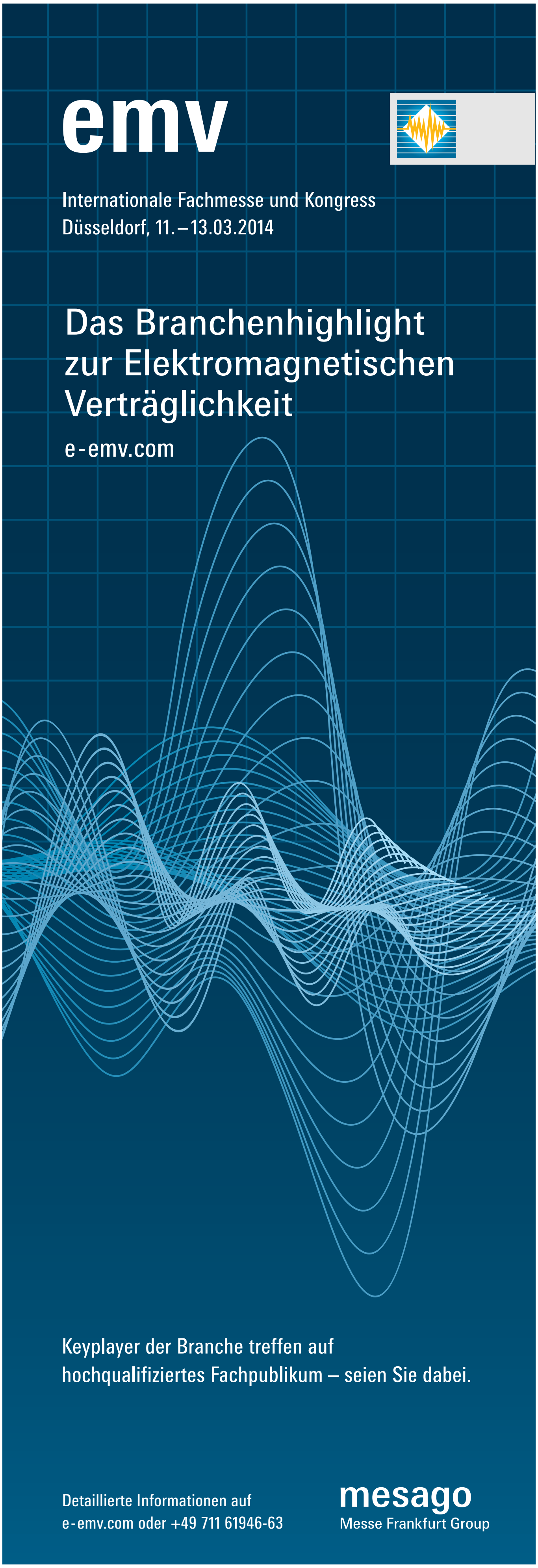


Figure 5 HIL impedance analyzer results for a buck converter; the upper diagram shows the magnitude while the bottom is the phase diagram; green dots represent the input impedance characteristics; red dots are output impedance characteristics; blue dots are the line-to-output transfer function

Conclusion

By removing high power from the loop and replacing it with digital HIL devices, completely new possibilities for developing and testing power electronics systems are unfolded. From the comfort of his office, an engineer is able to develop and test power electronics systems in such detail that cannot be done in a high power lab. HIL devices provide vastly improved test coverage and reduced time to market. With HIL digitalized power, testing is made simple.

www.typhoon-hil.com



Three-Phase Inverter with Integrated PFC Shrinks and Simplifies Appliance Motor Drive Design

International Rectifier, IR introduced the IRAM630-1562F intelligent power module (IPM) featuring Power Factor Correction (PFC) and inverter stage. The new IPM shrinks and simplifies design of energy-efficient appliance and light industrial motor drive applications including air conditioners and washing machines.

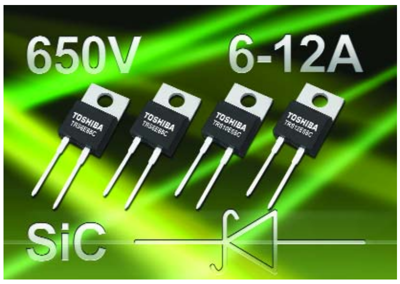
The IRAM630-1562F combines IR's low loss, Trench IGBTs with a three-phase, high-voltage gate drive IC and PFC input stage, integrating more than 30 components into a single compact isolated package. Built-in over-temperature/over-current protection, along with an integrated under-voltage lockout function, and built-in temperature monitor provide for a high level of protection and fail-safe operation. Other integrated features such as bootstrap diodes for the high-side drive function and single polarity power supply simplify the system design while reducing overall cost.

The IRAM630-1562F's open emitter configuration enables multi-shunt current feedback for a sophisticated vector control loop, in V/Hz control loop, with no circuit layout limitation. Over-temperature is detected internally and triggers a fault condition. EMI emissions are minimized due to shorter connection routing, optimized component layout and internal shielding.

www.irf.com

Family of 650V SiC Power Devices

Toshiba Electronics Europe (TEE) has extended its family of 650V silicon carbide (SiC) Schottky Barrier Diodes (SBD). 6, 8 and 10A devices are now available in addition to the 12A SBD that entered volume production earlier in 2013. Analysts are predicting significant growth in the SiC power device market and Toshiba is aiming to address this with its new offerings.



The SBD is suited to applications including power conditioners for photovoltaic power generation systems. SBDs can also act as replacements for silicon diodes in switching power supplies, where they are 50% more efficient.

SiC power devices offer more stable operation than current silicon devices - even at high voltages and currents - as they significantly reduce heat dissipation during operation. They meet diverse industry needs for smaller, more effective communications devices and suit industrial applications ranging from servers to inverters and trains to automotive systems.

The Toshiba SBD range features a maximum reverse recovery current (IRRM) of 90µA @ 650V. All devices are housed in TO-220 packages; other packages are planned.

www.toshiba-components.com

Ultra-Low Profile 100 W Baseplate-Cooled AC-DC Power Supply

CUI Inc has announced a 100 W baseplate-cooled, high performance ac-dc power supply series with an ultra-low profile (17mm) in an encapsulated board mount package.

The addition of the VBM-100 series ac-dc power supply to the company's power product group is intended to meet the specific needs of ITE, telecommunications and industrial applications were space limitations and / or noise restrictions limit the use of fans for cooling.
In addition to outputting up to 100 W, the compact ac-dc series comes with a choice of six tightly regulated output voltages (12, 15, 24, 28, 36 and 48 Vdc) and a voltage accuracy of ±1% at 25°C. Custom voltages are also available on request.
Measuring 4.5 x 2.4 x 0.6 in. (117 x 61 x 17 mm), the VBM-100 series provides a universal input range of 90~264 Vac and features active power factor correction meeting EN61000-3-2 Class D standards.
The encapsulated units offer a no load power consumption of less than 0.5 W and run at efficiencies of up to 92%. The VBM-100 ac-dc supply operates at temperatures between -20°~85°C and incorporates several protections, including over voltage, short circuit, and over temperature.
All models carry UL/cUL and TUV 60950-1 safety certifications for ITE, commercial and industrial equipment, and are compliant with the EN 55022 Class B standard without the need for external filtering.
The VBM-100 series is now available through distribution with prices starting at $113.90 for 100 pieces with OEM pricing available on request.

www.cui.com

AC/DC Converters: 5 W in a Small SIP Packaging

PEAK electronics has expanded its proven PPM SIP series AC/DC converters with a 5 W PPM5-SB-xxELF module. The high-efficient products are available in a 42 x 27 x 11 mm ultra-miniature SIP12 packaging. In the past, the small SIP converter family only provides 1.65 W to 3 W.

The wide input voltage range is from 100 to 400 V DC and 85 to 264 V AC, respectively. The output voltage depends on the module type and ranges from 5 to 24 V DC. The series is featured by a typical ripple & noise of 50 mV and a max standby power of 0.5 W. The maximal efficiency is 75 %.
The PPM SIP converters are characterized by an over voltage, a short-circuit protection and an over loading protection. The input / output security isolation is 3 000 VAC. The converters are widely used in industrial, official and consumer equipments.

www.peak-electronics.de

ICW Announces Sales Agreement with ICEL

Wrexham-based, metallised film capacitor manufacturer ICW is pleased to announce a new joint sales agreement with and the Milan-based, film capacitor manufacturer ICEL S.R.L. Established in 1960, ICEL manufactures a comprehensive range of box radial polypropylene and polyester capacitors for snubber, pulse power, DC link and AC filtering applications. This new agreement means that both companies will be able to offer one another's products in their respective home markets.

David Thomson, managing director of ICW, said: "The product lines of ICW and ICEL complement one another perfectly, allowing ICW to offer a complete film capacitor solution in the UK market.

"In addition to supplying high quality, cost effective capacitors, both ICW and ICEL offer customers complete technical and development support. "Our common approach to customers and complementary product ranges can only result in a better film capacitor solution for our customers."

A comprehensive industry cross reference to ICEL products can be found at:

www.icwltd.co.uk

Industry's First 1700V SiC MOSFET

Richardson RFPD, Inc. announced the availability of the industry's first 1?, 1700V Silicon Carbide (SiC) metal oxide semiconductor (MOSFET) from Cree, Inc. (Cree).

The C2M1000170D Z-FET™ offers high speed switching with low capacitances and high blocking voltage with low RDS(on). It is easy to parallel, simple to drive and resistant to latch-up. The C2M1000170D is ideal for power supplies to 200W operating from DC inputs from 200V to 1000V, and it replaces silicon MOSFETs in auxiliary power supplies where reliable, efficient power conversion from high voltage buses is required to operate system logic, displays and cooling fans. This new SiC MOSFET beats silicon MOSFETs on switching efficiency, operating frequency, blocking voltage characteristics and reliability, while lowering system implementation costs.

www.richardsonrfpd.com

Three Optimized Higher Current 1.8kV Thyristors

IXYS Corporation announced that its wholly owned UK subsidiary, IXYS UK Westcode Ltd., introduced three new 1.8kV pressure contact phase control thyristors with increased power density.

The new improved designs offer more than 40% increase in current rating over existing designs, while retaining the overall same package footprint. The improvement in performance is achieved by maximising the die size and an improved package design. The new silicon dice are bonded and encapsulated in fully hermetic ceramic packages with a novel design that have reduced thermal resistance, and the dice have enhanced electrical performance.

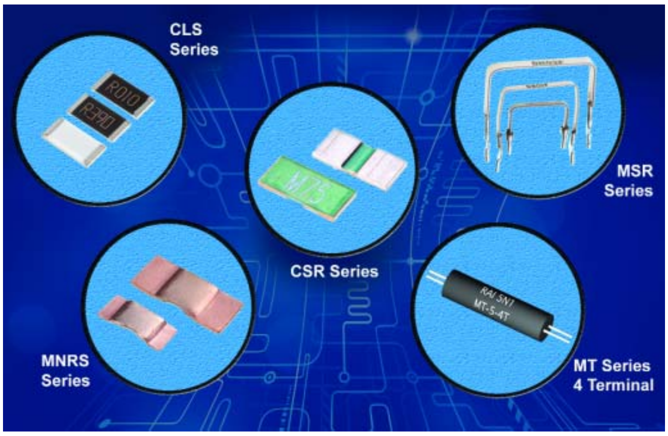
The new 2.2 inch (56mm) die device has an average current rating of 2600A and the package has a 2 inch (50mm) electrode contact diameter, with an industry standard overall diameter of 3 inches (74mm). The new 2.7 inch (69mm) die devices have average current ratings of 3175A to 3565A and the packages have a 2.6 inch (66mm) electrode contact diameter, with industry standard overall diameters of 4 inches (101.5mm).

Typical applications include soft starters, DC drives, and all controlled rectifier applications requiring devices in this power rating.

www.ixysuk.com

Low Cost Current Sensing Applications with a Full Line up of Low Ohmic Resistors

Riedon, a specialist manufacturer of cutting-edge resistive solutions, is targeting the demanding requirements of current sensing and shunt applications with its comprehensive portfolio of low ohmic value resistors, ranging from the economical bare metal element MSR series through to its CLSA series chip resistors that provide AEC-Q200 compliance for use in harsh automotive environments. Utilizing various technologies, Riedon offers ±1% tolerance resistances from 0.5 milliohms up to 1 ohm in various package formats with TCRs as low as ±20ppm/oC and power ratings up to 5 Watts. For tolerances down to ±0.1%, Riedon is also able to supply four terminal versions of its axial lead low ohm power resistor.



Riedon's MSR series uses a bare metal element in an all-welded construction for through-hole circuit board mounting to provide resistance values from 5m? to 100m?, while also achieving low inductance (<10nH) and low TCR (±20ppm/oC). MSR resistors are available in 1, 3 and 5-Watt power ratings with tolerances of ±1% or ±5%. For surface mount applications, Riedon has several chip resistor solutions: its MNRS chip shunt resistors offer excellent long-term stability and low inductance with 4- and 6-Watt ratings and resistances from 1m? to 4m?; the CSR family of ultra low ohm metal strip chip resistors come in three sizes (1206 / 2010 / 2512) for power ratings from 1 to 3 Watts, with standard and customized resistance values from 0.5 m? to 15m?; and featuring an alumina substrate for high power dissipation the CLS/CLSA series of chip resistors operate over -55oC to +155oC, with the CLSA parts meeting the Automotive Engineering Council's AEC-Q200 stress test qualification.

www.riedon.com

Ultra-Compact 50 W Dc-Dc Converter Cuts Board Space

CUI Inc has announced one of the industries smallest 50 W dc-dc converters, the PQA50-D. The series' feature set makes it ideally suited for IT equipment, telecom and industrial systems.

The dc-dc converter series is a low cost, high performance family with a 2 x 1 inch (50.8 x 25.4 mm) footprint - an industry standard size for less powerful devices. It incorporates six sided metal shielding for improved EMC performance and efficiency up to 93%.

The converters maintain high efficiency figures across the entire input voltage range - including under light loads, making the PQA50-D series ideal for designs where minimizing power consumption at various

operating conditions is a priority.

The single output isolated dc-dc converter modules feature a 2:1 input range and are available with an 18~36 Vdc or 36~75 Vdc input voltage range and 3.3, 5, 12, 15 or 24 Vdc output voltages.

The series has 1500 Vdc input-to-output isolation and protections for output over voltage, short circuit, over load, and input under voltage.

The series offers precise voltage regulation, featuring load regulation of +/- 1% max. from 10% to 100% load and line regulation of +/- 0.5% max. Additional features of the new PQA50-D series include an operating temperature range of -40~85 °C, remote on/off control, and voltage adjustability of +/- 10%.

The PQA50-D series is now available through distribution with prices starting at $85.12 for 100 pieces OEM pricing is available upon request.

www.cui.com

ADVERTISING INDEX