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Bodo´s Power Systems®

Electronics in Motion and Conversion

October 2020

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With selected partners, we put all of our energy in the optimum distribution of power electronics components – delivered just-in-time and in superior quality. Benefit from our Distribution Power for your success!

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www.gva-leistungselektronik.de

GvA Power Electronics

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Bodo´s Power Systems®

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Bodo´s Power Systems®

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No Travel at All

With the cancellation of the in-person electronica and Semicon Europa, 2020 will end for me without a single business trip. Somehow, this feels strange - travel has been an important part of my job for the past few years. I have to adit that I do not miss the nights sitting in a hotel room alone, or the long days running around the halls heading from meeting to meeting and catching up on emails that came in over the day. And not to mention working on the next issue, which always needs to be done. Overall, working on the road is very demanding - I can remember that. But not one event in an entire year? That leaves me just a little sad and hoping for a better 2021. Business is still being carried out by people and the personal connection is often the foundation (excuse me, Zoom and Co…).

Anyway, it is what it is and we need to move on. Our digital event in December keeps us busy - we already have a good number of confirmed presenters. We are planning to split the presentations into blocks and have live discussions with the presenters after each block. As our audience is spread around the globe, we have decided to make the presentations available one day in advance to give everybody the opportunity to pick the topics of interest and also to prepare questions for the live Q&A session. This gives you the choice of either being prepared, or of reacting spontaneously to your opinions of the presentation. The program will soon be published on the website www.power-conference.com, and registration is open!

We still receive feedback from time to time that delivery of the magazine is being delayed. We have been working with a highly professional shipper for many years now and I am advised that delays are happening to all kinds of International publications. This may be caused by changes in transport procedures, changes in international transport

and/or changes in delivery procedures in the destination country due to quarantine or other protective measures due to the pandemic. Again, I want to refer you to our digital version, which is available on our website. Let's hope for a PCIM 2021 with all of this behind us. We are always carrying hundreds of copies to Nuremberg, even older ones, so PCIM 2021 could be a good opportunity to complete your printed collection.

Bodo's magazine is delivered by postal service to all places in the world. It is the only magazine that spreads technical information on power electronics globally. We have EETech as a partner serving North America efficiently. If you are using any kind of tablet or smartphone, you will find all our content optimized for mobile devices on the updated website www.bodospower.com. If you speak the language, or just want to have a look, don't miss our Chinese version: www.bodospowerchina.com

My Green (Power) Tip for the Month:
There were a lot of infection hotspots in or around meat factories, and not only in Germany. In part because of this, the share of plant-based meat and diet alternatives is growing massively. Maybe now is the time to try it out.

Best regards

Events

ESREF 2020
Online October 4-9
https://esref2020.sciencesconf.org

ECCE 2020
Online October 11-15
www.ieee-ecce.org

EV Tech Expo 2020
Online October 14-16
www.evtechexpo.com

GPECOM 2020
Online October 20-23
www.gpecom.org/2020

electronica 2020
Online November 10-13
www.electronica.de

PCIM Asia 2020
Shanghai, China November 16-18
www.pcimasia-expo.com

sps 2020
Online November 24-26
https://sps.mesago.com

Power Electronics Conference 2020
Online December 8-9
www.power-conference.com

IEEE IEDM 2020
Online December 12-16
www.ieee-iedm.org

Miniature current sensor

HMSR

Packaged as SO16 surface-mount device with a height of just 6 mm, HMSR current sensor is adapted to the power electronics world for a perfect integration thanks to its SMD automatic assembly and space saving. As a reinforced insulation level, cost effective and miniature solution for current sensing, HMSR provides solutions to photovoltaic, white goods, windows shutters, air-conditioning, high switching frequencies drives applications.

www.lem.com

- **6, 8, 10, 15, 20 or 30 A_{RMS} nominal current**
- **0.5% typical accuracy into the operating temperature range**
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- **2 µs response time**
- **Operating temperature range: -40°C to +125°C**
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- **Double overcurrent detection outputs**

LEM

Life Energy Motion

electronica 2020 to be Held Digitally

Messe München will organize the world's leading trade fair and conference for electronics as a virtual event this year. The current travel restrictions in Europe, which are becoming more stringent, have required a re-thinking of planning. The digital format for electronica in November will give exhibitors the opportunity to book digital trade fair booths. electronica virtual will also provide all customers additional ways to interact and network. A large portion of the conference and supporting program will also be available digitally. New developments related to the coronavirus pandemic prompted Messe München to decide to hold electronica as a virtual event this year. In light of travel restrictions that have been imposed by a large number of visitor and exhibitor countries, electronica would have lost its character as a world-leading trade fair if it had been held as an in-person event in November. Falk Senger, Managing Director of Messe München, said: "Even though an in-person trade fair could have been conducted with the help of our safety and hygiene concept, the latest developments related to travel restrictions in many countries forced us to rethink our plans. We are adapting these plans to this dynamic situation and are now focusing solely on our virtual format. International exhibitors and visitors are the heart of electronica. In light of current Covid-19 conditions, we would not have been able to meet the expectations with an in-person trade fair."

www.electronica.de

Isao Matsumoto Appointed as President and CEO

The Board of Directors of ROHM has appointed Mr. Isao Matsumoto as the new President and Chief Executive Officer of ROHM Co, Ltd. Isao Matsumoto has worked for ROHM since 1985. Most recently he was responsible for quality, safety and production as Director, Member of the Board and Managing Executive Officer. With his expertise across business segments, passion for innovation and his network with employees, customers and investors built up over many years, Mr. Matsumoto is the right leader to continue the company's successful strategy and providing new impulses for further growth.

"In recent years, issues related to the environment, resources, and energy have taken on greater urgency, impacting not only various markets but society as a whole. At the same time, major changes are taking place in the automotive industry, including the evolution of AI and technological innovation for achieving autonomous driving", explains Isao Matsumoto as the new President and CEO of ROHM Co, Ltd. "ROHM will accompany this transition with its unique technology and product portfolio. We are focusing in particular on the automotive and industrial equipment sectors along with overseas markets, while strengthening our development capabilities centered on power and analog – together with a manufacturing system to support it. In doing so, I will continue to foster a culture of innovation and team spirit. We will overcome future challenges as "One ROHM", as a unified ROHM Group working together with unwavering dedication." Isao Matsumoto graduated from department of metal engineering from Kyushu Institute of Technology.

www.rohm.com/eu

Reference Design for Electric Mobility Solutions

Renesas introduced a 48V Mobility Winning Combination Solution that helps customers accelerate the development of e-scooters, e-bikes, UPS and energy storage systems. This reference design uses a modular approach in both hardware and software to showcase core and optional functional blocks that can be adopted for many 24V-48V applications such as lawn mowers, electric carts, robot cleaners, power tools, power banks, and more. It also uses 15 Renesas ICs, including three key devices: the ISL94216 16-cell battery front end (BFE), robust HIP2211 100V MOSFET drivers, and RX23T 32-bit microcontroller (MCU) for motor control. The 48V mobility winning combination solution is powered from a 25 AHr Li-ion battery that drives a 1600W inverter to attain speeds up to 5000 rpm. "Micromobility options like e-scooters and e-bikes offer an attractive, low-carbon footprint vehicle for first-mile and last-mile travel. Rising demand for these applications is driving new battery management capabilities as cell balancing plays an increasingly critical role in recharging," said DK Singh, Director, Systems and Solutions Team at Renesas. "Our new 48V mobility winning combination solution combines Renesas'

advanced BFE, industry-leading MCUs, along with analog and power devices, and innovative motor control technology to help customers speed up the development of their high power and torque e-scooters and e-bikes."

www.renesas.com

Pete Malpas Appointed as President EMEA

RS Components has announced the promotion of Pete Malpas from President of Northern Europe to the role of President EMEA, reporting to Mike England, COO of Electrocomponents.

Pete will be responsible for accelerating performance across EMEA. He will lead the commercial operation and business transformation of the region, driving a more aligned and consistent go-to-market approach and value proposition. He will work closely with the Presidents of Asia Pacific and the Americas, sharing best practice and bringing consistency in the ways of working across the global business. Pete will continue to lead Northern Europe until his successor has been appointed.

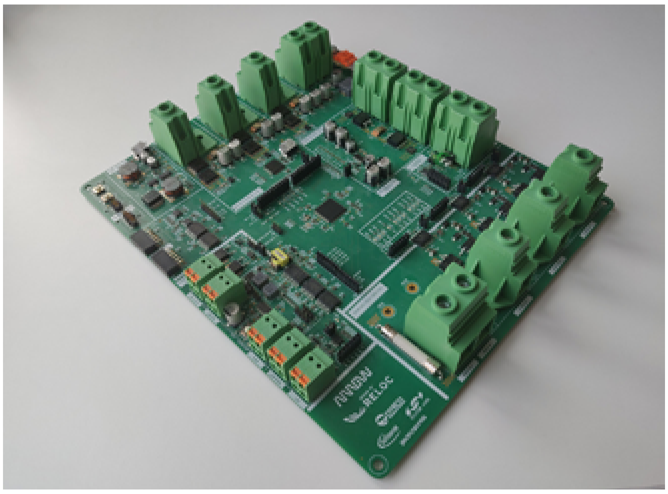
Mike England said: "Under Pete's leadership, I'm confident that we will continue to drive a high-performance culture whilst accelerating our EMEA growth and market share through the execution of a digitally powered and integrated go-to-market strategy. Our primary focus is to simplify our business, accelerate performance, deliver digital transformation, build scale and operate for less to become first choice for our customers, suppliers, people, communities and shareholders."

Pete joined RS in 2016 and has been instrumental in leading and transforming the approach to selling effectiveness and implementing the value-added solutions programme across Northern Europe.

www.uk.rs-online.com

Automotive High Voltage Evaluation Platform

Arrow Electronics has introduced the Automotive High Voltage Evaluation Platform (AHVEP), offering developers an extensive range of tools with which to explore the latest trends in electrification of vehicles. It provides a universal platform for applications and design challenges associated with a high voltage (48V/400V) power distribution network in cars. The Automotive High Voltage Evaluation Platform addresses a number of new challenges. As the transition from combustion engines to electric vehicles (EVs) and hybrid electric vehicles (HEVs) accelerates, designers face a large number of newly emerging requirements including: battery disconnect switches, cell balancing modules, battery junction boxes, battery management controllers, DC-DC conversion, on-board charging, superchargers, traction inverters, HVAC and supercapacitors. On top of these can be added challenges such as the isolation of communications, power management, motor control, load switches and current sensing; and ensuring safety and security in the new, electrically controlled environment.



Featuring a high-performance automotive microcontroller with Arm® Cortex®-M4F core, the platform employs a modular design that allows 12V, 48V and 400V circuits to be evaluated independently. It is suitable for applications including 48V BLDC motor control, 48V battery disconnect, 400V motor control, isolated current sensors and body applications up to ASIL-B.

www.arrow.com

SPS 2020 Goes All-Virtual

Due to the ongoing travel restrictions and other fundamental changes caused by the coronavirus pandemic, Mesago Messe Frankfurt has decided to hold the SPS 2020 in an all-virtual format.

"We're very disappointed to have to cancel this year's SPS event in Nuremberg," says Martin Roschkowski, President of Mesago Messe Frankfurt. "Early this summer, all signs were pointing in the right direction and we were all but certain that the exhibition would go ahead in November. The safety and hygiene concept we had put together at the time was well received and developed further by many people involved in the SPS. For us, it was another example of how well the SPS community works together, and our sincere thanks go out to all those who pitched in."

The main reasons behind the event's cancellation include the serious concerns many participants had expressed with regard to the very different surrounding conditions at hand and the well-being of their employees. The strict hygiene and social distancing rules that have been established, the travel restrictions in place, and the economic uncertainty resulting from the pandemic have made it clear that it would not be possible to hold the high-quality exhibition SPS attendees have come to expect.

www.sps.mesago.com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EMC Testing Laboratories in North America and Germany

Monolithic Power Systems announced that the company is poised to open EMC testing facilities in Livonia, Michigan and Ettenheim, Germany in 2020/2021 — adding to their lineup of new design services. These lab facilities will feature EMC chambers for Radiated Emissions and Immunity measurements, shielded chambers for Conducted Emissions, Immunity Measurements, and EMC Engineering and modern workplaces for pulse and electrical testing. MPS has been building on decades of experience in EMC-related topics to solve EMI problems during early design stages with their customers. These labs will allow anyone to gain access to fully compliant EMC testing equipment. “The further development of our EMC testing capabilities is a key milestone for MPS and a very important step to better serve automotive, consumer, and industrial customers in both the North American and European markets. With these two new laboratories, anyone can benefit from our flexible lab scheduling, which will enable engineers to quickly and easily develop new products that fit their EMC requirements and help shorten design cycles and save costs,” said Maurice Sciammas, Sr. VP, Sales & Marketing.

www.monolithicpower.com

Distribution Agreement for Japan

Yalcin Bulut

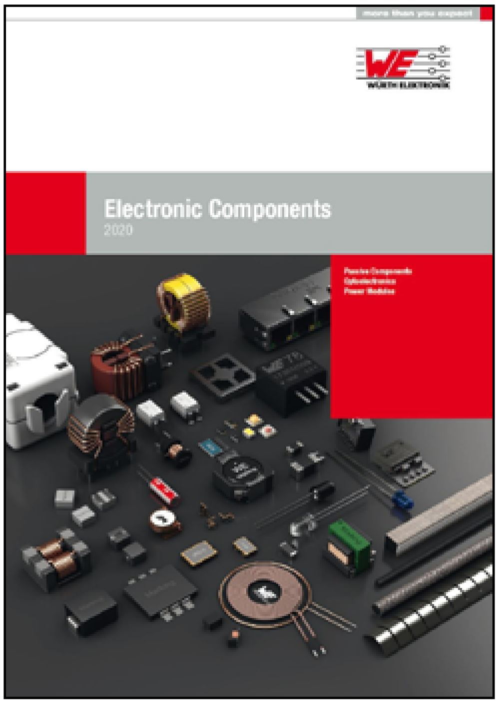
UnitedSiC has announced it has entered into a distribution agreement with Macnica, Inc., a major distributor of semiconductor products in Japan. Macnica will partner with UnitedSiC to distribute its product portfolio to Japanese customers in high-growth applications such as electric vehicles, battery charging, IT infrastructure, renewable energy and circuit protection. Yalcin Bulut, VP of Global Sales and Marketing at UnitedSiC, said, “This partnership focuses on selling and supporting the UnitedSiC product line to a wider group of Japanese power designers by leveraging Macnica’s highly regarded technical design-in expertise. This agreement will assure our customers will receive the best support as we grow our business in Japan.” Yusuke Kobayashi, President of Altima Company, a division company of Macnica said: “Macnica is pleased to be supporting and selling the UnitedSiC products in Japan. With continued pressure from the power engineers to deliver improved efficiency, performance and cost-effectiveness, we are confident we can deliver a value-add solution to the Japanese customers with the UnitedSiC products.”

www.unitedsic.com

Product Releases and Services

The “Electronic Components 2020” catalogue is now available, and can be ordered from Würth Elektronik in the print version or downloaded as a PDF. The 184-page catalogue presents products and services in the area of passive components, optoelectronics, and power modules. Separate special catalogues are available for many other product categories of Würth Elektronik. All products in the catalogue are available ex stock. Würth Elektronik is glad to supply free-of-charge samples to support developers in their projects: in connection with the design kits, which can be refilled at no extra charge, they can also be supplied to development labs over their entire product life.

Among the many highlights of the “Electronic Components 2020” catalogue are the high-current flat-wire inductors (WE-HCM), multilayer ceramic inductors (WE-MK), and current sense transformers of the WE-CST EE4.4 series. Thanks to an innovative manufacturing process, these transformers are smaller and better insulated than comparable products available on the market. In the optoelectronics field, the WL-OCPT optocoupler phototransistors and the extensions of the LED range by white LEDs with five different color temperatures deserve particular attention. The additions to the range of the MagI³C-FDSM family of particularly efficient power modules will surely also whet the appetites of developers and suppliers.



www.we-online.com

Industrialized process for pre-pasted Thermal Interface Material (TIM)

FEATURES

- Optimized for Fuji modules
- Increased lifetime of IGBT
- Advanced IGBT power density

- Thermal – Benefits
  - Higher thermal conductivity
  - Uniform thermal resistance
  - Increased reliability and lifetime

- Process – Benefits
  - Outsourcing of a “dirty” process
  - Stable quality level
  - Computer controlled automated process
  - Increased System reliability
  - Printing according customer specification
  - TIM upon customers preference possible

Intensifying Collaboration

Panasonic Industry Europe is proud to announce its Gold partner status under NXP Semiconductor’s Ecosystem member program. With the Gold partner status NXP recognizes market leaders and strengthens the bond for future product development. It also underlines a strong strategic positioning between the products of both companies and the shared mindset for offering solutions to customers which are one step ahead in the market. The close relationship between NXP Semiconductors and Panasonic Industry enables customers to utilize the features of NXP’s MCUXpresso software with integrated driver support for Panasonic Wi-Fi solutions like the PAN9026 module on the i.MX RT MCU series. This valuable advantage simplifies and accelerates the application development and speed-up the ready-to-market process. Furthermore the PAN9026 Wi-Fi Dual Band and Bluetooth module supports Linux Full GPL for NXP’s i.MX6 or i.MX8 and any other Linux based application processor.
Pascal Meier, Panasonic Industry Product Marketing Sensors & Wireless Connectivity states: „We are very proud to be awarded the Gold partner status within NXP’s member program because our customers profit from the knowledge and experience of Panasonic and NXP.

With the combination of NXP’s 88W8977 SoC on the PAN9026 module for example we were able to combine the most important short range wireless technologies in one chip. Engineered in Germany, manufactured in Slovakia we can provide our customers the flexibility for a wide range of wireless applications.”

https://industry.panasonic.eu

Taking Part at Power Electronics 2020

Proton-Electrotex will take part in International exhibition of power electronics components and modules - PowerElectronics 2020. The Power Electronics exhibition will be held in Crocus Expo, Moscow on 27-29 of October 2020. Power Electronics exhibition is in the only in Russia specialized exhibition of power electronics components and systems for various industries.
Proton-Electrotex traditionally presents its latest research and new products there. Besides, we showcase samples of existing portfolio already known to our customers. All visitors of the exhibition will have an opportunity to talk to representatives of the company's management, engineering team, customer support, purchasing, sales and marketing departments.
You can find Proton in Pavilion 1; Hall 1.

www.proton-electrotex.com

Acquisition to Drive LiDAR Solutions

Allegro MicroSystems announced the acquisition of Voxtel, Inc, a privately held company specializing in advanced photonic and 3D imaging technology including long-range, eye-safe Light Detection and Ranging (LiDAR). This acquisition brings together Voxtel’s significant laser and imaging expertise with Allegro’s automotive leadership and scale to enable the next generation of Advanced Driver Assistance Systems (ADAS). “Allegro is a market leader in magnetic sensors for the automotive market. Annually, we ship more than 1 billion devices into automotive systems – 100 million of which are shipped into advanced automotive safety systems, including semi-autonomous vehicle systems,” said Ravi Vig, CEO of Allegro. “Our experience, scale and design for quality uniquely position us to enhance the Voxtel LiDAR portfolio for ADAS applications, aiming to make LiDAR systems safer, cost-effective, and widely adopted features in the cars of the future.”

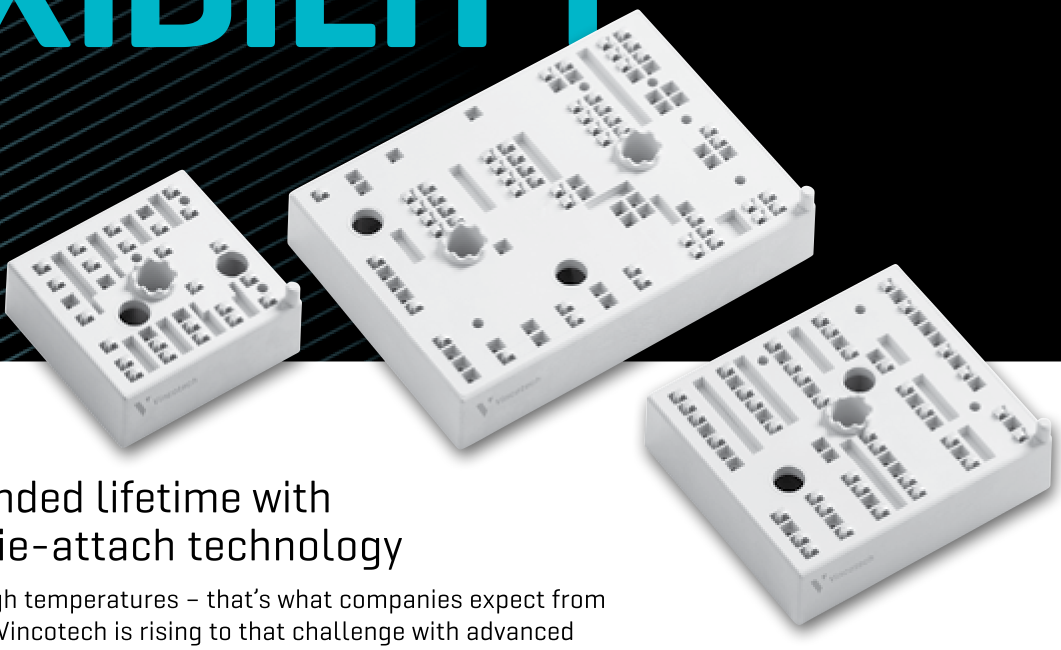
INNOVATION WITH PURPOSE
ALLEGRO
microsystems

“We are combining Voxtel’s proven LiDAR technology born out of an impressive history in ranging and space applications, with Allegro’s automotive expertise, world class IC design, proven quality systems, and high-volume manufacturing proficiency,” said Mike Doogue, Senior Vice President of Business Development. “Our OEM and Tier-1 customers will now have access to this advanced technology with Allegro’s assurance of world-class global support and the scale needed to support automotive manufacturing volumes.”

www.allegromicro.com

RELIABILITY MEETS FLEXIBILITY

Vincotech



MiniSKiiP®: Extended lifetime with NEW advanced die-attach technology

Longer operating time at high temperatures – that's what companies expect from power modules these days. Vincotech is rising to that challenge with advanced new die-attach technology to strengthen the bond between chips and DCBs all across the MiniSKiiP® line.

Featuring latest-generation **IGBT M7** and **IGBT7 chips**, Vincotech MiniSKiiP® products deliver the dual benefits of **superior performance** and **multiple sourcing** for flexible and scalable inverter designs with nominal currents ranging from 5 A up to 200 A.

Main benefits

/ More than ten times longer life at high operating temperatures

/ Latest-gen chips up efficiency and power density to help drive down system costs

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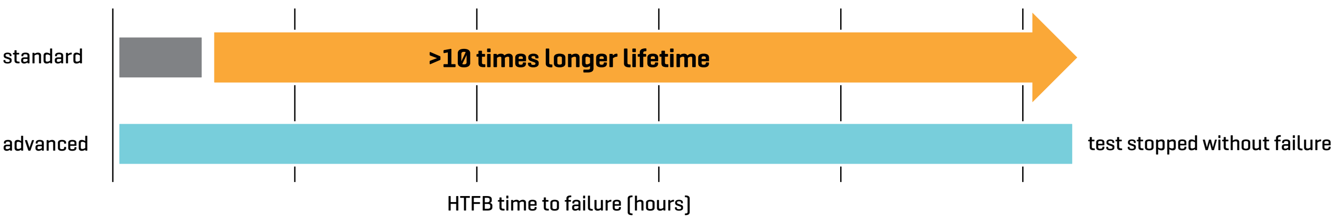
MiniSKiiP®: with advanced die-attach technology shows superiour lifetime at T_{vj}=150°C

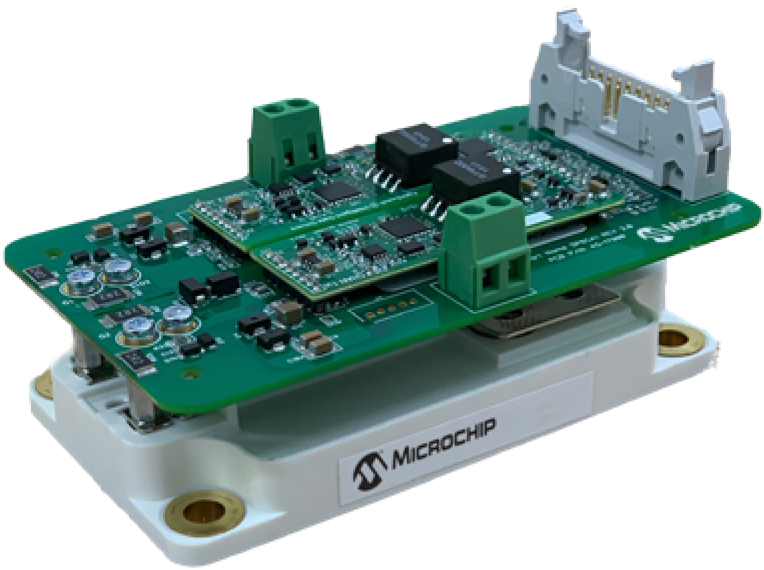


www.vincotech.com/MiniSKiiP-IGBTM7-7

EMPOWERING **YOUR IDEAS**

Power Module and Programmable Gate Driver Kit for Inverter Designers

Microchip's AgileSwitch® digital programmable gate driver and SP6LI SiC power module kit solution enables developers to proceed quickly from benchtop to production



The transformation to electrify transportation – from trains, trams, and trolleys to buses, automobiles and EV chargers – continues at a rapid pace, as countries shift toward improved modes of transit with greater efficiency and innovative technology. Microchip Technology announced its AgileSwitchÒ digital programmable gate driver and SP6LI SiC power module kit, a unified system solution to help designers quickly and effectively adopt disruptive Silicon Carbide (SiC) power devices – reducing time to market and ensuring confidence in field deployment.

Microchip's AgileSwitch digital programmable gate driver and SP6LI SiC power module kit speeds development from evaluation through production, eliminating the need to procure power modules and gate drivers separately – including gate drivers that are qualified for end-product production. With Microchip's AgileSwitch gate drivers and proven, high-performance SiC power modules, developers can avoid qualifying power modules and spending time to develop their own gate drivers, which can save months in development schedules. "We listened to developers in providing total system solutions for our microcontrollers and analog products," said Leon Gross, vice president of Microchip's Discrete Product Group business unit. "Now as SiC power modules increasingly enable the technologies transforming transportation and other industries, this complete product kit allows developers to focus on innovation and significantly reduce time to market."

Microchip's flexible portfolio of 700, 1200 and 1700V SiC Schottky Barrier Diode (SBD)-based power modules utilizes its newest generation of SiC die. In addition, its dsPIC® Digital Signal Controllers deliver performance, low power consumption and flexible peripherals. Microchip's AgileSwitch family of digital programmable gate drivers further accelerates the process of moving from the design stage to production. Microchip's combination of SiC power module and software-configurable gate driver features Augmented Switching™ technology that enables designers to influence dynamic issues including voltage overshoot, switching losses and electromagnetic interference. Using a Windows®-based computer interface, this "configure-at-a-click" method may be used throughout the design process, from expediting early evaluation to simplifying final optimization using a computer mouse instead of a soldering iron.

www.microchip.com


Small. Efficient. Easy.
Enhanced HotRod™ QFN package helps shrink power supply footprint by 30% and improve thermal performance.
Texas Instruments
Texas Instruments
Texas Instruments

The Ascent of GaN: Redefining Power Conversion with GaN-on-Si Integrated Circuits

Discrete power transistors, whether silicon-based or GaN-on-silicon, are entering their final chapter. GaN-on-Si integrated circuits offer higher performance in a smaller footprint with significantly reduced cost and less engineering required. This article details how the ascent of GaN is redefining power conversion.

By Alex Lidow Ph.D., CEO and Co-founder, Efficient Power Conversion

Historical Perspective

In 1977, my colleague Tom Herman and I joined International Rectifier to start our professional careers in power conversion. Our initial project was to design a better power transistor compared with the power bipolar devices dominant in that era. After much evaluation and discussion, Tom and I settled on making a power transistor using a metal oxide (MOS) gate. Our first generation devices, with aluminum gate technology, launched in November 1978 and the second generation devices, based on silicon gate technology, launched in June 1979. Based upon their hexagonal structure, these second generation devices were dubbed the “HEXFET” and they started a massive redefinition of how power conversion was to be done.

IR's Eric and Alex Lidow: They believe they are two years ahead in technology

HEXFETs were faster, smaller, and eventually lower cost and more reliable than their bipolar ancestors. Designers needed to hone some of their engineering skills to take full advantage of the faster switching speed, which made power conversion systems, mostly AC/DC converters and motor drives at that time, smaller, more reliable and lower cost.

Tom and I recognized that designing with these new, higher-performing discrete devices would take precious time, and it was that design time that limited their rate of adoption. Our solution seemed simple: Develop integrated circuits that could be complete systems on a chip (SoC).

Our first attempt at creating a SoC was to build a monolithic triac using a recently invented device called TRIMOS [1]. Through this activity, we discovered some basic truths about integrating multiple power devices in silicon. By trying to put power devices that conduct vertically on the same chip, there was a significant increase in cost that prevented the SoC from being commercially viable. By making power devices lateral in design, the area consumed made the devices not commercially viable. Once this issue was known, Tom and a larger team, including Dan Kinzer and David Tam, pivoted and started developing driver ICs that could be used to switch power devices in half-bridge configurations. The first of these was the IR2110. To this day, discrete power MOSFETs (or their cousin, the IGBT) and driver ICs dominate the world of power conversion.

Gallium Nitride (GaN) Power Transistors

When I first heard about a team in Japan developing a method to grow device-grade gallium nitride (GaN) on a silicon wafer [2], I realized that the integration limitations of silicon in power conversion systems could be overcome with a new technology. GaN is naturally insulating, and the best way to make a GaN transistor is to have the three terminals, gate, drain, and source, on the top surface. There is no significant minority carrier conduction in GaN, so there would not be the problem of one power device polluting another with holes or electrons, as in lateral power MOSFET devices when they go into diode conduction.

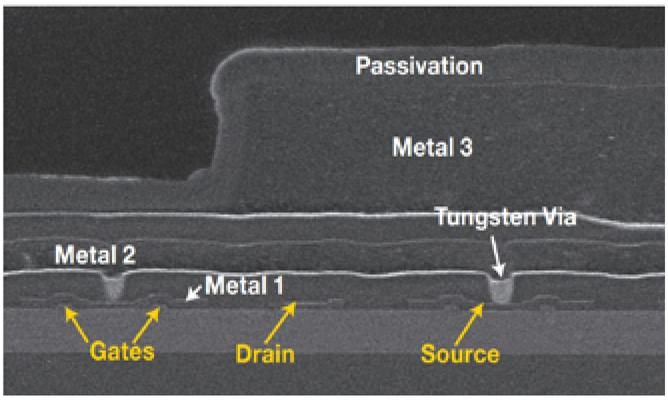


Figure 1: SEM micrograph of an eGaN FET circa 2009 [3.]

Based on this understanding, my two colleagues Joe Cao and Bob Beach, and I founded Efficient Power Conversion (EPC) in the fall of 2007. From the beginning, the goal was to make power devices that are both higher performing and are lower cost than their silicon ancestors. Initially we set our sights on developing discrete devices, but we knew that integration would be a way to redefine power conversion in a meaningful way, much like integration redefined digital electronics, and the adoption of the HEXFET, decades earlier.

In 2009, we delivered our first prototypes of 100 V discrete GaN-on-Si power transistors. They were put into production in March of 2010, along with a family of 40 V and 200 V transistors. As enhancement-mode devices, we named them eGaN® FETs. A scanning electron micrograph (SEM) image of these eGaN FETs is shown in figure 1.

These devices were fast – about five to ten times faster than silicon devices with the comparable voltage and on-resistance. This increased speed meant that circuit designers needed to be more careful with their layout, because added parasitic inductance would cause voltage and current overshoot. This overshoot increased power losses, increased EMI and EMC generation, and often led to designs that resulted in overvoltage of the gate or drain of the parts. The degree of difficulty designing with these parts seemed to be inversely proportional to the speed of adoption.

Within a year, we had established a second generation of products that were more stable with time and covered a wider range of applications including lidar, envelope tracking, vehicle headlamps, and DC-DC converters. This experience taught us that we had a challenge – we needed to make it easier for designers to harvest the full capability of these leading-edge devices.

GaN Integrated Circuits

Our first step forward in the integration of functions on a single chip came in September 2014, when EPC launched a family of monolithic half-bridge devices. By integrating two FETs onto a single chip that could be configured as a half bridge, the customer could (a) save a lot of board space, (b) cut the power loop inductance in half, and (c) reduce overshoot that leads to EMI and EMC. Figure 2 shows an example of one of these early half-bridge ICs, which was designed for a DC-DC converter in a buck configuration. The high-side transistor was designed to be smaller than the low-side transistor, and it was designed such that the inductance between the two power devices was near zero.

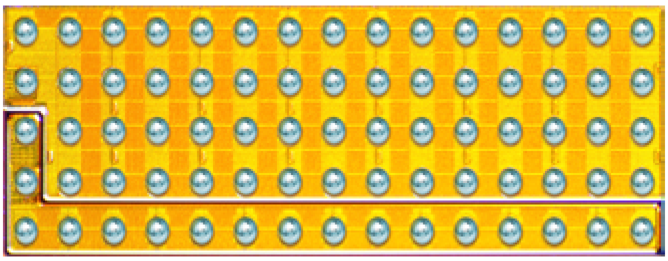


Figure 2: EPC first launched a monolithic half bridge in September 2014. (Shown is the EPC2100.)

In parallel, work started on adding drivers to power FETs on the same chip. The monolithic devices with drivers would reduce the need for an external silicon-based IC driver and would eliminate gate loop inductance. The first commercial products were launched in 2018. An example is shown in figure 3.

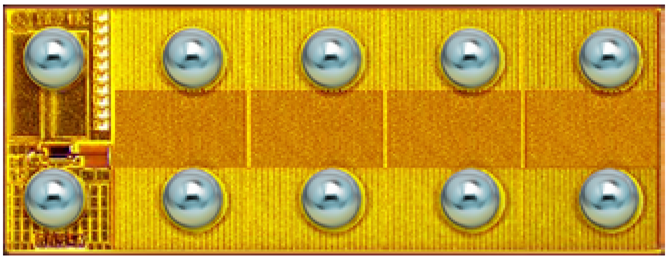


Figure 3: Using GaN-on-Si technology, the EPC2112 (shown here) integrated a driver and a power FET for the first time.

The ultimate goal, however, was to integrate all necessary functions for a complete power conversion solution on a single chip. As there are many types of power conversion topologies, there are many types of possible solutions. However, there is one building block that stands out as the most common, the half bridge. Half bridges are used in buck converters, boost converters, LLC converters, bus converters, motor drives, and many more converter topologies. It is therefore a worthwhile endeavor to create integration around a half bridge. Figure 4 shows how all the pieces fit together.

Since GaN is naturally insulating, high-side and low-side FETs can be located next to each other. By reducing the distance between the gate and drain terminals, tiny low voltage FETs can be made next to high voltage FETs. These small-signal devices can be used to make analog as well as digital functions. The high side and the low side can be connected with a high voltage level-shifting device shown in figure 4 on the far left.

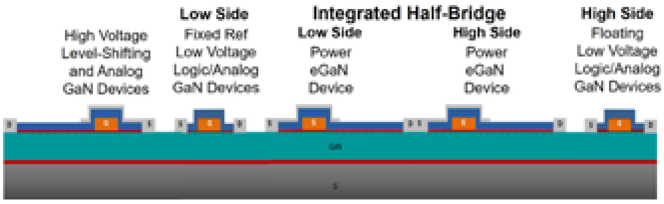


Figure 4: Illustration of how all the functions needed for a monolithic half bridge can be integrated on a single GaN-on-Si chip.

The first-generation EPC eGaN® ICs, such as shown in figure 3, were “handcrafted” based on trial-and-error and highly-educated guesses. To achieve the best and most reliable performance, technology platforms need to be translated into a rich set of models that scale, include parasitic interactions, are characterized over all temperature, voltage, and current conditions, and include realistic process variations. This is no small task, and it creates a natural tension with the simultaneous rapidly improving discrete FET performance. On one hand, it takes time and effort to fully characterize a technology platform; on the other hand, if the technology platform is changing faster than the characterization process, then the IC products lag their discrete counterparts in performance and cost effectiveness.

The initial output of this more formalized approach was first demonstrated in March 2020 with the introduction of a fully monolithic half bridge that integrated all the drive and level-shift functions, along with the bootstrap function. The simplified circuit diagram containing all the essential functions of a power stage is shown in figure 5, and the actual device photo is presented in figure 6.

Although simple in comparison to modern digital processors, this single-chip power stage provides a first demonstration of the integration of many important fundamental functions. It includes comparators, a central building-block for decision making in an integrated circuit,

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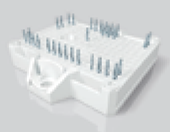

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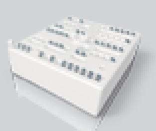

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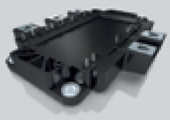

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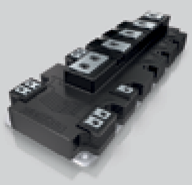

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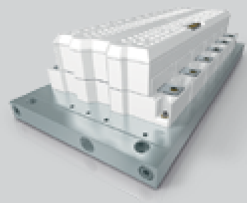

SKiiP® 3/4
100kW - 3MW

feedback for control of output action, latching for isolation of input and output, ESD immunity for assembly robustness, and voltage isolation between high-side and low-side devices on a single substrate.

Nearly any IC can be made using just this set of building blocks. Although design refinement and improvement will continue at a rapid pace, this first demonstration shows the immense opportunity available for creating GaN ICs and the bright future gallium nitride has for redefining power conversion. This product from EPC (the EPC2152) was designed for use in buck converter or motor drive topologies.

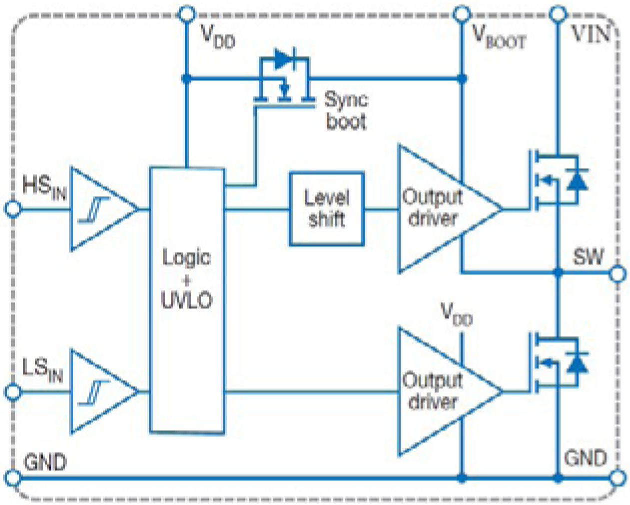

Figure 5: All the basic functions of a power stage are shown in this simplified circuit diagram, including output FETs, drivers for these FETs, level shifting for the high-side circuitry, input logic and protection, and a synchronous bootstrap function to generate the voltage needed to drive the high-side circuitry.

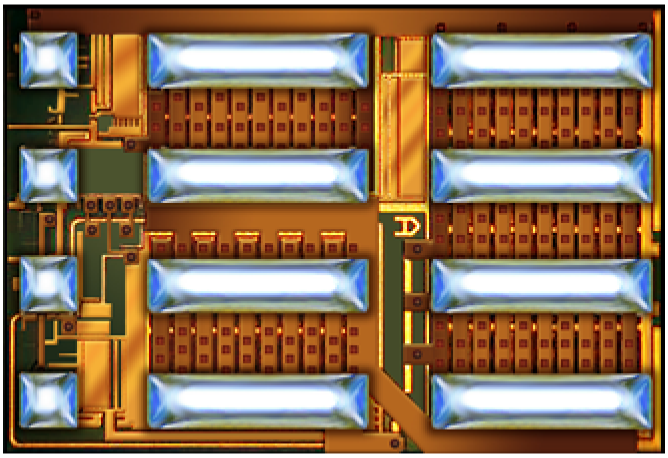

Figure 6: The EPC2152 is a monolithic implementation of the circuitry in figure 5. It was designed for operation as either a buck converter up to 2 MHz with an input up to 80 V and an output of 10 A, or as a stage in a three-phase brushless DC (BLDC) motor drive operating at 100 kHz or more. The chip measures 10 mm^2.

Shown in figure 7 is the system efficiency of the monolithic power stage (green line) when operated as a buck converter at 1 MHz with 48 V_{IN} and 12 V_{OUT} at 10 A. The black “X” in figure 7 shows the comparative performance of a state-of-the-art silicon solution at 1 MHz. The GaN monolithic power stage achieves a 50% reduction in power loss versus the silicon solution.

Also shown in figure 7, is the advantage gained by integrating the driver and the power FETs on the same chip. The blue line is the measured efficiency of the identical half bridge, but with discrete GaN FETs and the driver and level shift in a separate Si-based IC. The two main reasons for the significant improvement in efficiency are; (1) the reduced inductance in the gate loop when the driver and power devices are in intimate contact on the same chip, and (2) the monolithic integration of the two power FETs cuts in half the overall power loop inductance.

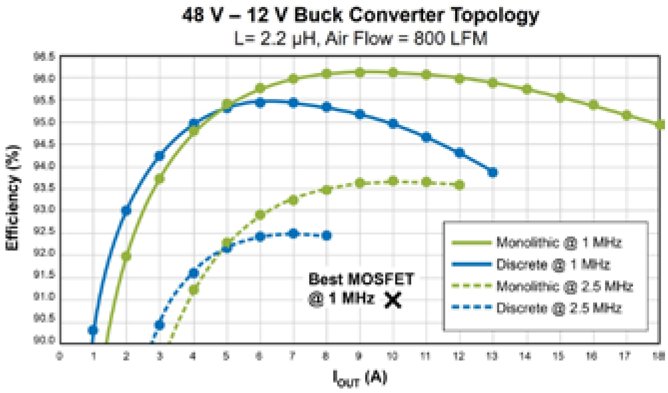

Figure 7: The EPC2152 power stage operating at 1 MHz (green line) has an overall power loss (including inductor and control IC) at 10 A that is 50% lower than the best Si MOSFET solution (black X) when operated with 48 V_{IN} and 12 V_{OUT}. The blue line shows the comparative performance when the power stage is fabricated with discrete GaN FETs driven by a silicon IC

In addition to a buck converter application, the EPC2152 was designed to be used in the primary side of an isolated DC-DC converter or for BLDC motor drives, as shown in figure 8.

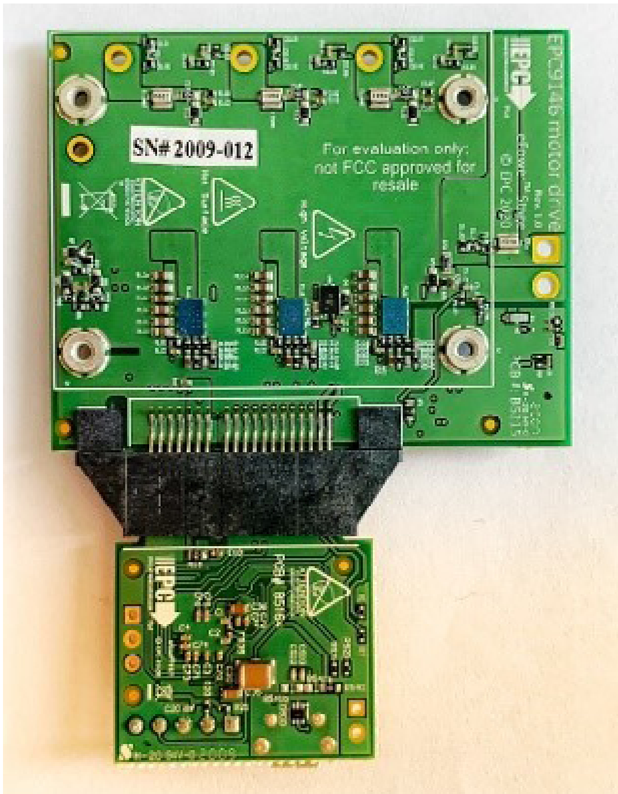

Figure 8: Three-phase BLDC motor drive using EPC2152 monolithic power stages.

The Future for GaN Integration

With a well-defined and rich set of scalable models based on the latest GaN technology platform, the challenge for further integration – the Ascent of GaN – shifts to adding even more functionality on a single chip [4]. The ultimate goal is to achieve a single component IC that merely requires a simple digital input from a microcontroller and produces a power output that drives a load efficiently, reliably under all conditions, in the smallest space possible, and economically.

To achieve this goal, sensors for current and temperature will need to be added to the chip. In addition, more digital control function will improve performance, lower cost, and reduce the overall engineering required of the power system designer. These added features and functions will become available over the next couple of years.

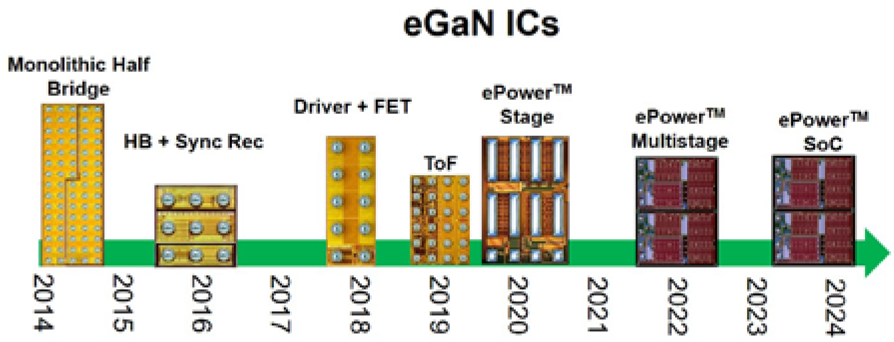

Figure 9: Efficient Power Conversion's journey towards a fully monolithic system on a chip.

Discrete power transistors, whether silicon-based or GaN-on-Si, are entering their final chapter. Integrated GaN-on-Si can offer higher performance in a smaller footprint with significantly reduced, at lower cost with less engineering required. Figure 9 shows the projected journey toward a fully monolithic system on a chip (SoC) starting with the first monolithic half bridges in 2014 and continuing with multistage and multiphase ICs for all power conversion applications.

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LV100: Smart Solution for 1500V$_{DC}$ 3-Level Central PV Inverters

In central PV inverter applications, 3-level neutral point clamp topologies based on 1200 V IGBTs are a popular approach. However, finding a suitable power module is often challenging considering the requirements of high current ratings, low stray inductance and standardized housing with widespread availability. Therefore a smart solution for the 1500V$_{DC}$ 3-level central PV inverters is needed.

By Thomas Radke, Narender Lakshmanan, Daniel He, Mitsubishi Electric Europe B.V

In general a problem occurs when 3-level NPC topologies are developed using several standard half bridge power modules. A series connection of IGBT modules results in high stray inductances which in combination with high switching di/dt cause high switching overvoltages [2]. IGBT modules with an integrated NPC topology phase-leg containing 4 IGBT and 6 diodes potentially have lower stray inductances but are not available for high current ratings and are more expensive due to the complex internal circuit [3]. The solution is the usage of the active neutral point clamp (A-NPC) topology in combination with a smart modulation scheme which enables the utilization of half bridge IGBT modules such as the new defacto standard (the LV100 modules) without the problem of switching overvoltages caused by high commutation inductances.

Due to a significant system cost reduction, an increased DC-voltage of 1500 V$_{DC}$ has recently become the standard for utility scale photovoltaic power plants Therefore, suitable circuit topologies and semiconductor devices capable of handling the 1500 V$_{DC}$ dc-link for central solar inverters have to be selected in order to fulfill the requirements pertaining to costs, efficiency, reliability and grid harmonics. A 2-level topology is not preferable since 1.7 kV IGBTs do not provide sufficient margin against failure considering the transient overvoltages. Additionally, under such operating conditions, the 1.7 kV IGBTs suffer high failure rates due to cosmic ray. Higher voltage devices such as the 3.3 kV IGBTs offer lower cosmic ray induced failure rates and also provide sufficient margin for transient overvoltage's. However, the 3.3 kV IGBTs' switching and conduction losses do not fulfill the system requirements pertaining to efficiency and switching frequency. An optimized intermediate voltage class IGBT blocking capability is commercially not available to support 1500 V$_{DC}$ applications. As a result a 3-level topology based on 1200 V IGBTs is the preferred topology nowadays for inverters with DC-link voltages of up to 1500 V$_{DC}$ [6] in the field of renewable energy applications. A half bridge circuit configuration is the prevalent circuit topology of high power 1200 V IGBT modules. One major reason is that the half bridge modules provide an internal layout which is optimized to reduce the commutation inductance loop and thereby, make it possible to utilize high current 1200 V modules with reasonable transient overvoltages during operation. By using those half bridge modules in a 3-level NPC topology, several modules are involved in the commutation loop and therefore, the benefit of low inductive internal module layout is not present. As a result, half bridge modules cannot be used unless the switching speed, especially the di/dt is significantly slowed down to reduce transient overvoltages. For the latest trench IGBT generation, the di/dt controllability via gate resistances at turn-off is limited, hence a significant slowdown of the switching speed is not possible. In addition the increase of switching energy due to such slowdown would negatively impact the system efficiency, power density and finally the inverter cost.

Commutation in 3-level NPC with half bridge / chopper modules
Classical 3-level NPC topology

To build a 3-level NPC topology, three modules (one half bridge module and two chopper modules) are required as shown in Figure 1. The modules A and C are the chopper modules and the module B has a half bridge configuration. The parasitic stray inductances of module A and B (Ls1p and Ls1n) to the DC-link is small due to the optimized low inductive IGBT module layout and the consideration of a proper laminated DC-link design. However, the stray inductances (Ls2p and Ls2n) during commutation over several modules is not optimized and therefore, relatively high in comparison.

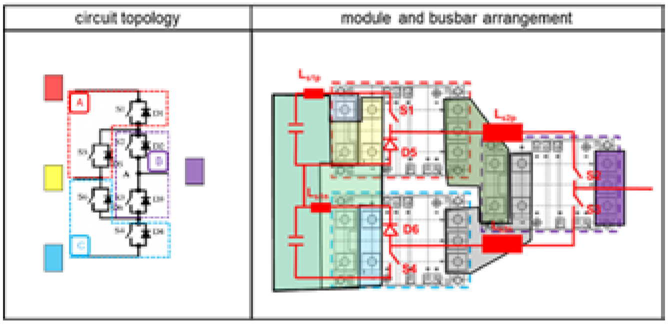

Figure 1: 3-level NPC topology based on three LV100 IGBT modules.

Depending on the operating mode which is related to phase shift of the output voltage and the output current as seen in Figure 2, different commutation inductances need to be considered. The different operating modes for the 3-level NPC topology are shown in Figure 3.

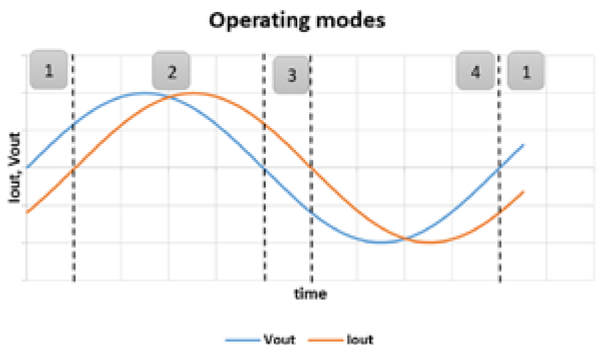

Figure 2: Operating modes of a 3-level inverter

In the operating modes 2 and 4, the effective commutation inductance is low since the commutation is within one power module (similar to a conventional 2-level operation). The IGBT module B is conducting the current but is not involved in the commutation loop. In the operating modes 1 and 3 the effective commutation inductance is high because all 3 modules are involved in the commutation event. As a result, overvoltages can occur which may exceed the blocking capability of the semiconductors and leads to the destruction of the IGBT modules.

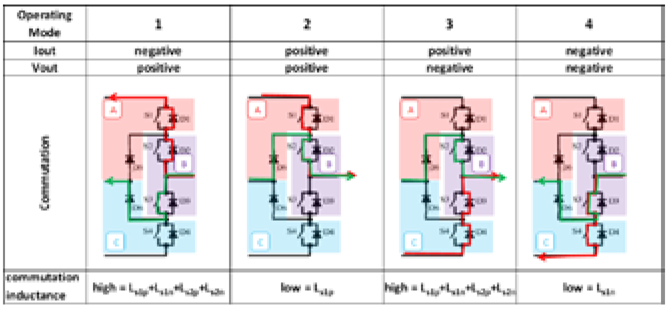

Figure 3: Operating modes for the 3-level NPC topology

Low inductive commutation by utilizing A-NPC topology

In the A-NPC 3-level topology, active switches (IGBTs) are added to the neutral point clamp diodes D5 and D6 of the NPC topology. By using these IGBTs, alternative commutation paths for the neutral voltage become available. Different control strategies are available which could lead to a more homogenous distribution [1] [5] of power losses among the different switching elements. Apart from such advantages, the A-NPC topology helps to realize low inductive commutation loops. Figure 4 shows the A-NPC topology being built by using three half bridge modules. For example, when the classical NPC topology is in operating mode 1, no low inductance path would be available since several modules are involved in the commutation event. However, when the A-NPC topology is in the operating mode 1, a new low inductive path over D2 and S5 is available. Additionally, in the operating mode 3, a new low inductive path over S6 and D3 also becomes available. Consequently, in all four operating modes, a low inductive commutation loop utilizing an active switch is present. No high inductive commutation path involving several modules is existing.

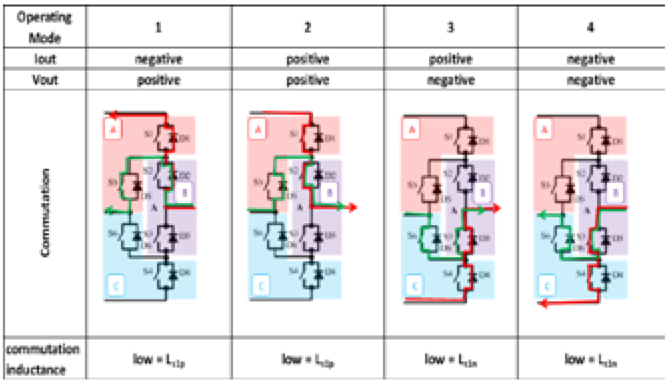

Figure 4: Operating modes for the 3-level A-NPC topology

3-level evaluations with LV100 IGBT modules

Test setup

Considering the fact that the LV100 package has been established as a new standard for high power applications such as renewable energy, industrial drives, railway converters and grid applications [7], a test setup with three industrial 1200 A IGBT half bridge modules has been constructed. The setup represents one 3-level A-NPC phase leg as shown in Figure 5. The classical NPC topology commutation has also been evaluated by keeping the IGBTs S5 and S6 turned off. The effective commutation inductances and the maximum current, which can be switched without exceeding 1200 V, has been evaluated. The conditions for this evaluation were T_j=25°C and V_{CC} = 1500 V (2 x 750 V).

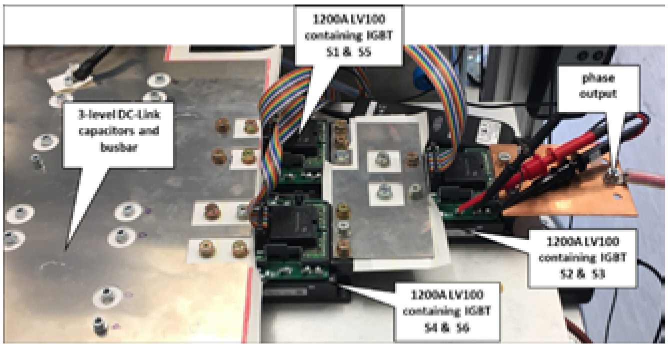

Figure 5: 3-level test setup based on three 1200 A LV100 IGBT half bridge modules

Evaluation results

The evaluation results shown in Figure 6 indicate that by utilizing the A-NPC topology, the stray inductance in all operating modes is less than 19 nH. In all operating modes the maximum current of 2400A (twice rated current) was not limited by transient overvoltages. The 2400A limitation indicated here pertains to the RBSOA limit as per datasheet for the 1200A IGBT module [8]. As shown in Figure 7, the maximum collector-emitter voltage (V_{CE}) while switching off a collector current I_C of 2400 A is less than 1100 V. However, by using the classical NPC topology, V_{CE} reaches 1200 V while turning off a 637 A collector current. The high overvoltage is caused by the high stray inductance of 118.2 nH.

Operating Mode	A-NPC		NPC	
	L_s [nH]	$I_{C(max)}$ [A]	L_s [nH]	$I_{C(max)}$ [A]
1	17.4	2400	113	634
2	18.7	2400	18.7	2400
3	17.8	2400	118.2	637
4	17	2400	17	2400

Figure 6: Evaluation results of operating modes: Commutation inductance and maximum collector current at 1200V for A-NPC and NPC topology

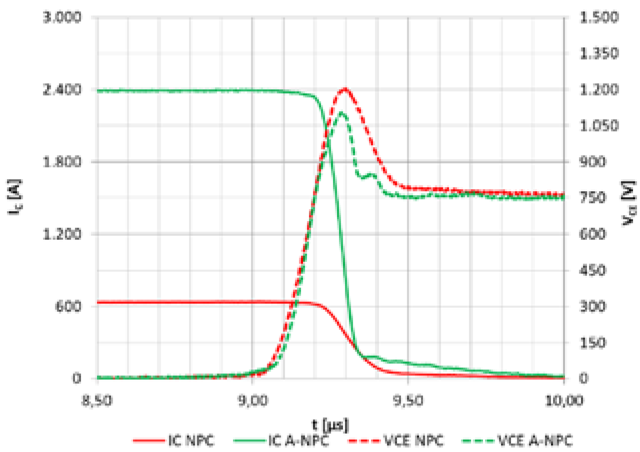

Figure 7: IGBT turn off waveform comparison: A-NPC vs. NPC in operating mode 3 at V_{CC}=2x750 V, T_j=25°C.

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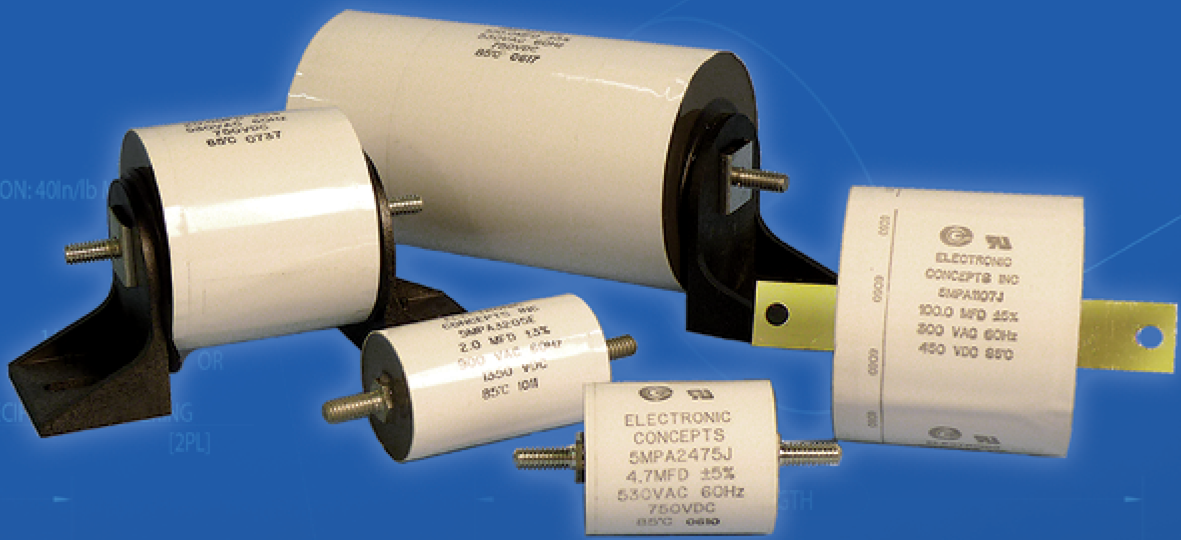

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Zero voltage crossing commutation in A-NPC topology

3-level voltage source PV-Inverters modulate sinusoidal voltages with a fundamental frequency of 50 Hz or 60 Hz. During the sinusoidal half waves (positive or negative) the A-NPC topology provide low inductive commutation paths. However, while changing the output voltage's polarity, for example changing from operation mode 2 to 3 or from 4 to 1, a high inductive commutation over several modules cannot be avoided. In case of a power factor for purely active power [3] [4] (cos(φ)=1/-1) the output current is zero and the higher commutation inductance cause no overvoltages. But in case the inverter has to provide reactive power, the current needs to commutate over the high inductance path. Since a maximum collector current limitation such as the evaluated 637 A would not be acceptable, a dedicated novel switching pattern is required to reduce the overvoltage. The example in Figure 8 shows the commutation during an output voltage polarity change from the negative to the positive half wave at negative output current condition. This represents the change from operating mode 4 to 1. During the negative half wave, the IGBTs S4 and S6 are switched alternatively. The current commutates between path 1 and 2. By changing to the positive voltage half wave, the current has to commutate from the half bridge IGBT module C to A, via the high inductance path of 118.2 nH. During the polarity change, the commutation path 2 and 3 can be switched on in parallel by turning on the IGBTs S2, S3, S5 and S6. As shown in the waveform in Figure 8, the current will naturally commutate partially via path 2 to 3. In the evaluations with the 1200 A LV100 IGBT modules, it can be observed that after 80µs about 40% of the current of path 2 (I_C S3) has commutated over to path 3 (I_C S2) without any overvoltage. After this partial commutation, path 2 can be switched off by turn off of IGBT S6 and S3. At this turn off the di/dt is reduced since the current is already reduced by 40% before turning off. As shown in Figure 9, when IGBT S3 is switched off, an overvoltage will occur caused by the turn-off di/dt and the corresponding commutation inductance. The resulting overvoltage measured at the IGBT is devoid of the magnitude of the DC-link voltage, since the path 3 (D2 and S5) are already conducting. The

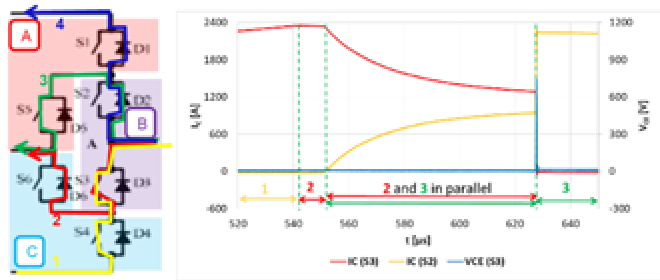


Figure 8: Novel commutation from operating mode 4 to 1 with reduced overvoltage

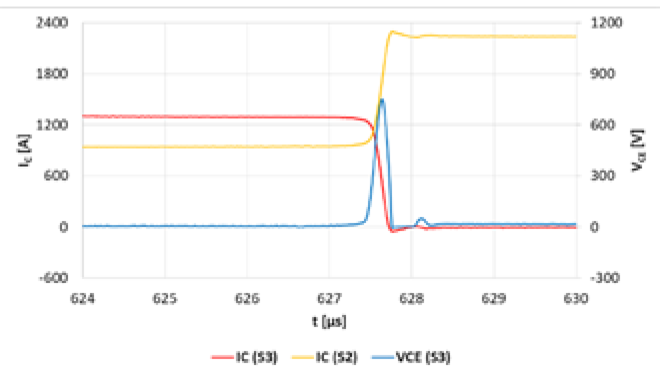


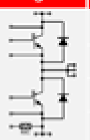
Figure 9: Waveform of IGBT S3's turn off during the novel commutation with reduced overvoltage

evaluation shows that at turn off of 2300 A, the resulting overvoltage is 750 V and thereby, well below the 1200 V limitation. The voltage polarity change to the positive sinusoidal half wave can herewith successfully be executed and the low inductive path 3 and 4 can be switched alternatively.

LV100 optimized for renewable and industrial applications

It has been demonstrated that half bridge IGBT modules can be used without the typical drawbacks related to the commutation inductances for the 3-level inverters. Additionally, considering the fact that central PV inverters require reliable, scalable and standardized power modules, the LV100 for industrial and renewable applications provide an optimized solution [7]. The LV100 housing is the new defacto standard for high power IGBT modules and therefore it has compatible outline to power modules from different suppliers. The line-up of the LV100 for indutrail applications covers the 1200V and 1700V blocking voltage ratings as shown in Figure 10.

The LV100 for indutrail applications is based on the SLC packaging technology which has been proven to be a thermal cycle failure free packaging technology [9]. The thermal cycling failure mode is absent since the SLC packaging technology utilizes interconnecting materials with matched thermal expansion coefficients and does not require a solder layer to connect the substrate to the baseplate. The 7th generation IGBT and diode chips' technology helps in achieving the highest possible inverter efficiency. A combination of these technologies with the advanced symmetrical low inductive internal layout delivers the highest possible power density [7] and a reliable operation.

I_C [A]	Circuit Diagram	V_{CES} [V]	
		1200	1700
800		CM800DW-24T	CM800DW-34T CM800DW-34TA*
1000		CM1000DW-24T**	
1200		CM1200DW-24T	CM1200DW-34T
1400		CM1400DW-24T**	

* Version with higher diode current rating optimized e.g. for wind generator side converter or AFE
** Under consideration

Figure 10: Line-up of LV100 for industrial and renewable applications

Summary

High power 3-level central PV inverters with low inductive commutation can be realized by using half bridge IGBT modules. It has been shown that by using LV100 IGBT modules in combination with the active neutral clamp (A-NPC) topology, a low inductive commutation path is available for all operating modes. During an output voltage polarity change, the novel commutation pattern described here can be applied to effectively reduce the switching overvoltage.

Conclusion: An excellent solution for high power 3-level inverters can be achieved by combining the high reliability offered by the SLC packaging technology, the power loss optimization offered by the 7th generation chip technology, the supply chain security available for the LV100 housing and the opportunity to establish low inductance switching schemes.

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The Advantages and Operation of Flying-Capacitor Boosters

This article describes the Flying Capacitor Booster solution, which increases the efficiency while still cost efficient without enormous three level DC-link capacitors and with only one choke on the input.

By Viktor Antoni, Development Engineer - Electronic Design, Vincotech, Hungary

Introduction

High-efficiency solar inverters are getting more and more in demand in the recent years. However, cost efficient solutions are also desirable. To achieve this, not only the inverter but also the booster stage have to be low cost and high efficient. Two- and three- level boosters are commonly used in solar inverters. The three-level solutions are able to decrease the voltage stress on the semiconductors and the output voltage ripple, and therefore the inductor size can be decreased. Due to three-level operation, switched voltage level is half of the DC-link voltage. Thus, one can use semiconductors with lower blocking voltage, which are faster and cheaper. For three-level operation an adequate DC-link capacitor (capacitive voltage divider) has to be utilized, which can then split the two-level DC voltage into three voltage levels. In this case the PWM signal needs to be corrected to ensure the symmetry of the neutral point of the divider. Usually two inductors are used in the input in three-level boosters.

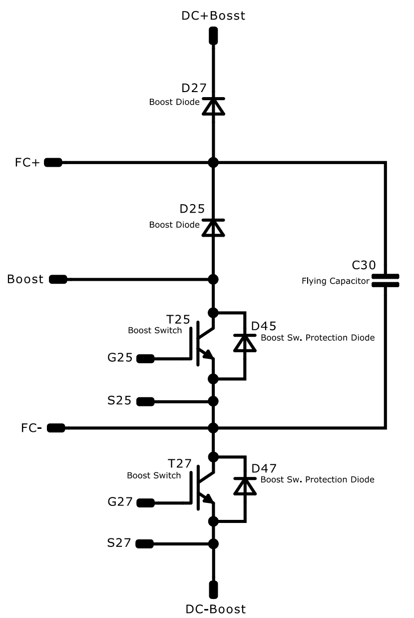

Figure 1: The three-level flying-capacitor booster

The Flying-Capacitor Booster

In this topology the additional voltage levels are synthetized by a capacitor, so-called flying-capacitor.

In a three-level case the voltage of the flying-capacitor is the half of the output voltage. The capacitor can offset the output voltage with V_DC/2 in positive and negative direction. The three-level flying-capacitor booster can be seen on Figure 1.

In the flying-capacitor booster due to the phase shift in the control of transistors, the input frequency is p times the switching frequency (p is the number of stages described later).

The Commutation Loops and Operation Modes of the Flying-Capacitor Booster

In a flying-capacitor booster the commutation loops include capacitors. A capacitor from the commutation point of view can be considered as zero impedance. Its main role in the commutation loop is to offset the two outer semiconductors from each other. With this offset the three-level flying-capacitor booster can be considered as two standalone boosters, in which the outer one's commutation loop includes the DC-link capacitor, the outer diode, the flying-capacitor and the outer switch. The inner commutation loop includes the flying-capacitor, the inner diode and the inner switch. The two commutation loops can be seen on Figure 2.

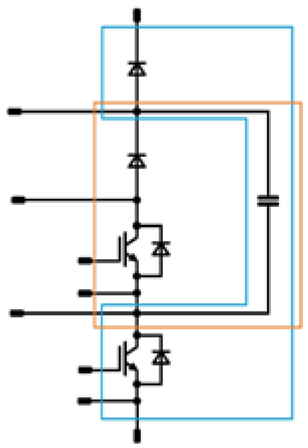

Figure 2: The two communication loops

In general the number of voltage levels are theoretically endless, but in practice three, four and five levels are used. The additional levels in n level solution can be realized by adding extra outer commutation loops to the three-level converter. Every added booster's commutation loop will be similar to the blue loop on Figure 2. The number of voltage levels can be calculated as the following:

$$n_{level} = p + 1$$

where p is number of the commutation loops (boosters). The voltage of the capacitor can be calculated:

$$V_{FC,i} = V_{DC} \cdot \left(1 - \frac{i-1}{p}\right)$$

where i is number of the given commutation cells. The first loop refers always the most outer loop.

This article describes the operation and behavior of the three-level flying-capacitor booster. All other solutions can be realized based on this article.

In the operation of the three-level flying-capacitor booster, four different modes can be derived. During normal operation the voltage of the flying-capacitor is the half of the output voltage and the inductor current is perpetual. In the first mode both two switches are off, the current goes through the two diodes, and they are working in bypass mode. In this mode the voltage of the flying-capacitor is not changing, the current of the choke is decreasing, and the output voltage is increasing. In the second mode, the lower switch (T27) is turned on. The current is charging the flying-capacitor resulting in its voltage to increase. In the third mode the inner switch is turned on (the outer switch is turned off), the current goes through the flying-capacitor, while its voltage is decreasing, and the output voltage will increase. In the last mode, both two switches are turned on. The voltage of the flying-capacitor will be stationary, while the current of the choke will be increasing. In the second and the third mode the inductor current change is dependent on the duty cycle (D). The operations and their effects can be seen on Figure 3 and Table 1.

The transfer function (y) of the flying-capacitor booster is the following:

$$y = \frac{V_{OUT}}{V_{IN}} = \frac{1}{1-D}$$

where is the duty cycle.

The used modes are dependent on the duty cycle. If , then. In this case Mode 4 is not used and the operation will be the following:

… → Mode 1 → Mode 2 → Mode 1 → Mode 3 → …

If > *0.5*, then *y > 2* , and the operation will be:

… → Mode 4 → Mode 2 → Mode 4 → Mode3 → …

In case of *D = 0.5*, *y > 2* ,the operation:

… → Mode 2 → Mode 3 → Mode 2 → Mode3 → …

The most commonly used operation is, when is less than 0.5.

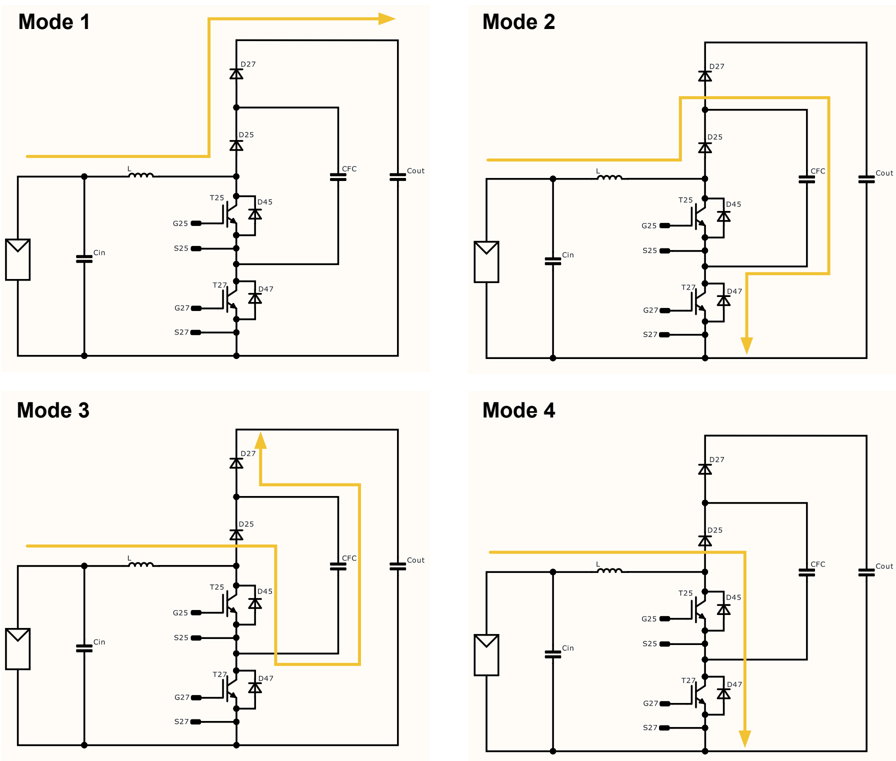

Figure 3: Operation modes of a flying-capacitor booster

Mode	Transistors	Inductor current	FC voltage	DC-link voltage		
	T25	T27	D<0.5	D>0.5		
Mode 1	OFF	OFF	decreasing	-	-	increasing
Mode 2	OFF	ON	increasing	decreasing	increasing	decreasing
Mode 3	ON	OFF	increasing	decreasing	decreasing	increasing
Mode 4	ON	ON	-	increasing	-	decreasing

Table 1: Output and FC voltage states

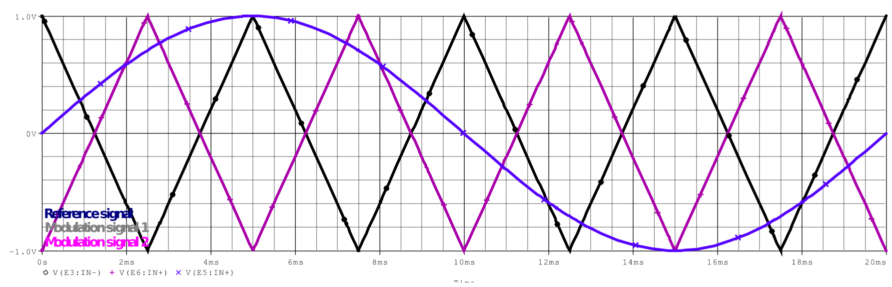

Figure 4: The reference and modulation signals for the PWM

The Operation of the Flying-Capacitor Booster

In the flying-capacitor booster topology the two transistors have to be controlled by 180° phase shifting (Figure 4).

This results that in case of *D = 0.5*, the operation modes will change between Mode 2 and Mode 3. The typical curves of the flying-capacitor booster can be seen on Figure 5 in case of *D = 0.2*.

The Advantages of the Flying-Capacitor Booster

The flying-capacitor booster topology compared to the booster topology has the following advantages:

- As the operation is three-leveled, the voltage stress on the semiconductor is decreased. This results in lower EMI, lower current and voltage ripple.

The flying-capacitor booster topology compared to the symmetrical booster topology has the following advantages:

- It has two-level input and output connection, while the third voltage level is synthetized by the flying-capacitor. This way the large three-level capacitors can be eliminated on the input and the output.
- Only one input choke is needed.

In both cases the input frequency is double of the switching frequency. This results in a lower input ripple current or the inductance can be decreased. Because of the double frequency, slower semiconductors can be used, which deceases the costs while the switching losses are also lower. This means for optimal behavior SiC MOSFETs are not needed, but Si IGBTs can be used.

For more detailed comparison of the topologies and component selection, please see Vincotech's benchmark "Boost your 1500 V string inverter".

Conclusion

The flying-capacitor booster is a high-efficient, low cost solution for solar inverter applications. The main advantages are the frequency multiplication, the lower semiconductor voltage, the lower voltage and current ripple, the lower switching losses, and the low EMI emission, while the enormous DC-link capacitor can be also eliminated. As every other topology the flying-capacitor booster topology has some challenges also. Those will be addressed in another article.

Stay tuned for our next article in Bodo’s November-issue: **“The Flying-Capacitor Boosters: Capacitor Sizing, Balancing and Pre-Charge”**

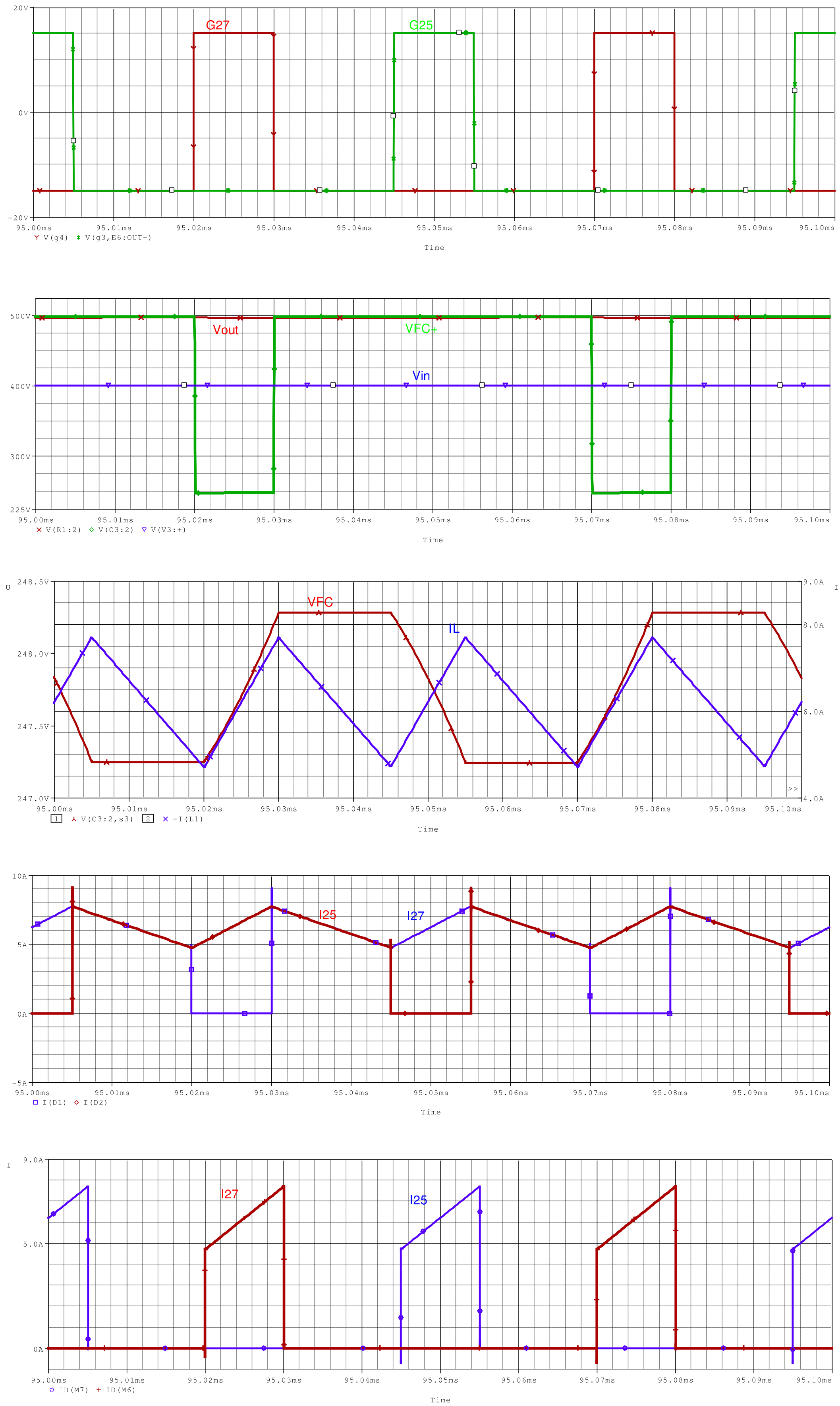

Figure 5: The typical curves

a, the gate signals
b, the output, the input and the FC+ voltage
c, the voltage of the Flying Capacitor and the inductor current
d, the Flying Capacitor current
e, the currents of the diodes
f, the current of the transistors

35kA Test Stand for Surge Current Tests

The close partnership between GvA Leistungselektronik GmbH in Mannheim and IRS Systemtechnik GmbH in Brennberg near Regensburg is currently producing very successful different versions of test benches for surge current tests.

By Erik Rehmann, Manager Marketing & Quality, GvA Leistungselektronik

The latest joint development is a test stand for surge current tests up to 35kA for the IPH Institute "Prüffeld für elektrische Hochleistungstechnik" GmbH in Berlin. IPH is part of KEMA Labs, the Testing Inspection and Certification Division of CESI S.p.A., the worldwide leading service provider of independent tests of power components with headquarters in Milan.

Especially well-known automotive suppliers increasingly use IPH's test facilities with the surge current generator to test switching elements and fuses in vehicles with high currents for several milliseconds. GvA's scope of services included the design of all electrical components, the preparation of circuit diagrams, the construction of the switch cabinets and the assembly of the entire system. The development as well as the construction of the control system of the surge current system including the measurement value acquisition and the safety concept came from IRS.

Figure 1: Not quite commonplace: the new 35kA surge current system of IPH in Berlin.

"In the partnership with IRS, both contribute a great deal of know-how, which ideally complements each other," explains GvA Managing Director Thomas Schneider. "This is added value that our clients appreciate. And if, in addition, the personal chemistry between all those involved is right, then, as in our case, a very trusting cooperation develops, which is not commonplace these days".

Reinhard Schiegl, IRS Managing Director, confirms: "With GvA, we have gained a top developer for power electronics who can also take responsibility for large complete systems. Coupled with our many years of expertise in measurement and testing technology as well as control and software solutions, this is for me a real partnership with future potential".

IPH Managing Director and KEMA Labs Division Executive Vice President Domenico Villani is excited about his new test facility: "Surge current tests up to 35kA is an impressive rating. It cannot be offered by many. The new facility further expands the opportunities for our customers and partners at the Berlin location and consolidates our market position at the cutting edge of innovative technologies. We have decided in favour of GvA and IRS due to the great experience with such competences and we are more than satisfied with the project progress".

The surge current system in detail

The system consists of a total of 14 cabinets: a control cabinet with a bi-directional DC power supply unit for charging and discharging to a maximum of 1500Vdc, a capacitor bank consisting of 10 cabinets with a total capacity of 2.0F to provide the necessary energy for a "shot", an impulse current cabinet for switching the test voltage on and off, an disconnecting cabinet for system safety and a resistance cabinet for setting the target current.

The challenge of such a surge current system is to provide a high current (up to 35kA) at a constant voltage (up to 1500Vdc) for several milliseconds. A low internal resistance and a low inductance of the system play a major role in this. If a large part of the voltage already drops within the system, the target voltage would not be present on the device under test and high overvoltages would occur when the load current is switched off. With the internal resistance of <4mΩ achieved by GvA and the system inductance of <6µH, negative effects could be reduced as much as possible.

A special feature of this system was also the requirement to be able to switch the output current not only on but also off again in a reproducible manner. On the one hand, this was required for certain tests and, on the other hand, offers the advantage of being able to repeat current pulses in extremely short cycles. Thyristors are generally the preferred semiconductor element for switching such high currents. However, due to the physical properties of a thyristor, it is not possible to switch off the current again. With the IGBT switch developed by GvA for the new surge current system, IPH is able to switch the full current of 35kA on and off several times without completely discharging the capacitor bank and converting the entire energy of the capacitor bank into heat. When switching off, high switch-off voltages are generated above the IGBTs, which are reduced by a specially developed circuit network to such an extent that they cannot pose a danger to the IGBT modules.

Furthermore, it is quite possible that a test object may fail at some point during such tests of new components. In this case the entire energy of the capacitor bank must be able to be absorbed by the system, which is not exactly trivial due to the rather large capacitor bank. Therefore the resistor cabinet, which has resistor plates in different configurations for setting the target current, is designed to be able to absorb the complete energy in case of a failure.

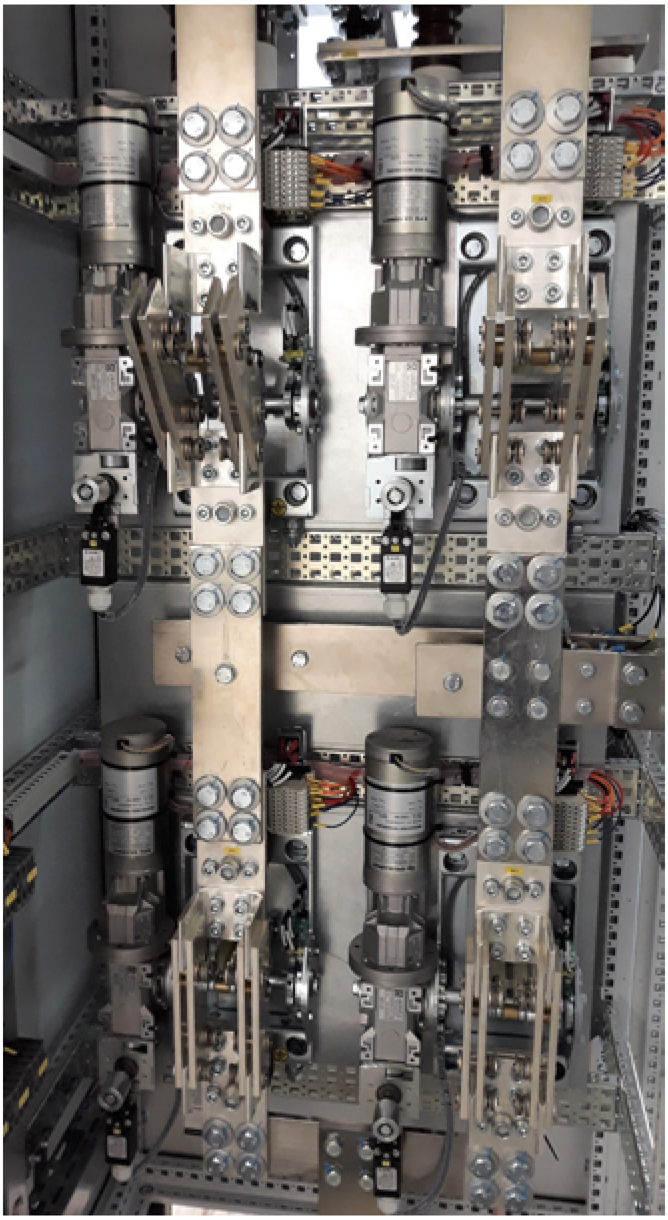

Figure 2: Four disconnectors are used for galvanic isolation of the system and grounding of the test object.

Due to the enormous energy content of the system of 2.25MWs, a special focus was placed on plant safety together with IRS. The software takes over the safety functions such as emergency discharges in case of malfunction or power failure, insulation monitoring, voltage and current monitoring as well as mechanical protection barriers and prevents incorrect operation by the operator.

This newly developed surge current test bench enables IPH and therefore the whole KEMA Labs Division of CESI SpA to contribute to further increasing the safety of future generations of electric vehicles by testing and qualifying components.

Earth Leakage Current in a Bi-directional Totem Pole Converter with Hybrid PWM Using Wide Band Gap Devices

A bi-directional totem pole converter with hybrid PWM using GaN (WBG) offers higher power density and higher efficiency as compared to other topologies. However, as a drawback, this converter draws leakage current, of line frequency. This article explains the generation mechanism of this leakage current along with its path through appropriate circuit diagrams.

By Milind Dighrasker, V. Thiagarajan, Kapil Bhise, Enstin Labs Pvt Ltd.

Introduction to Bi-directional Totem Pole

The bi-directional totem pole using only GaN is shown in Figure 1.1, includes two half-bridge legs. One half-bridge switches at high switching frequency and is denoted as the high frequency leg. The other half-bridge switches at the line frequency and is denoted as the low frequency leg [1]. In the PFC mode, the power is drawn from the grid and in the grid tie mode the power is fed to the grid with near to unity power factor.

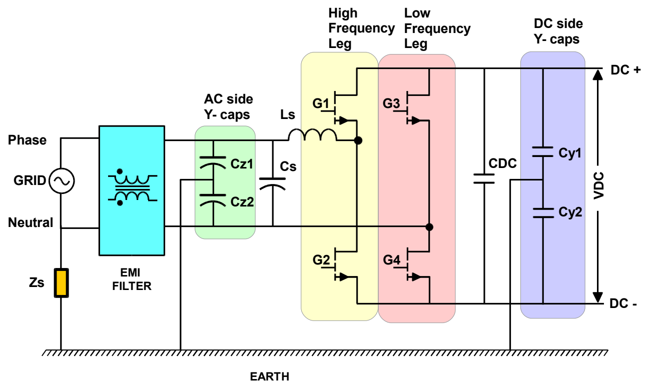

Figure 1.1: Bi-directional totem pole

The DC side Y-caps represents EMI filter or they can be a representation of parasitic capacitors of PV panel or load. The high-frequency switching devices are hard switched in this topology in both the modes, PFC as well as grid tie mode. This topology yields superior efficiency and power density. Newly emerging wide bandgap semiconductor devices can be a perfect match for this topology since they have almost zero reverse recovery charge. Relatively smaller switching loss in wide bandgap devices makes them particularly suitable for CCM operation in bi-directional totem-pole. Conduction loss in totem-pole converter is also reduced compared to conventional PFC, due to absence of line rectifier. A bi-directional totem-pole using all GaN devices is thus preferable for high efficiency and high-power density applications.

Application of bi-directional totem pole

- High efficiency servers and telecom power supply
- Bi-directional On-Board Battery Chargers (Bi-OBC)
- Solar inverters

Generation of Earth Leakage Current in Totem Pole

From the Figure 2.1 it is clear that the midpoint of the DC bus Y-caps "Cy1" and "Cy2" is connected to earth. This means "Cy2" is connected between the DC negative terminal and earth as shown in Figure 2.2. Any change in the voltage between DC negative and earth will charge or discharge "Cy2" [2]. The voltage between DC negative and earth will change because of switching of "G2" and "G4".

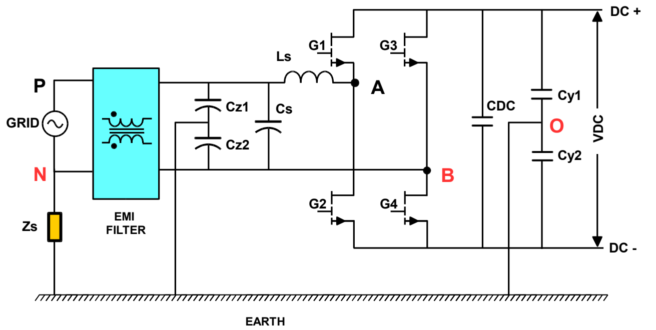

Figure 2.1: Bi-directional totem pole with Y-caps

Due to the low impedance path offered to current through "G4" the charge and discharge of "Cy2" is done through "G4" only. In hybrid PWM "G4" makes transition from ON to OFF or vice versa at the zero crossing only. For the entire positive or negative half cycle the voltage across "G4" is either VDC or zero. This means during the positive or negative half cycle, there is no abrupt change in drain to source voltage of "G4" and according to capacitor current equation in (1), "Cy2" will not charge or discharge resulting into no leakage current flow. At the zero crossing, due to the abrupt change in drain to source voltage of "G4", "Cy2" will see a sudden voltage change resulting into current spike to charge or discharge itself as per equation (1).

$$i_{CY2} = CY2 * \frac{dv_{CY2}}{dt} \quad (1)$$

This phenomenon give rise to leakage current only at the zero crossing. Leakage current increases the conducted and radiated electromagnetic emission. The leakage current will also be imposed on the line and neutral current and can increase or decrease depending on the direction of flow resulting into distortion near to zero crossing. The leakage current is directly proportional to the rate of change of voltage across the parasitic or Y-cap. The rate of change of voltage depends on the switching speed of “G4” and if “G4” is a GaN then the switching speed is faster than any other semiconductor devices. The selected GaN takes 9ns to turn ON and 15.5ns to turn OFF [3]. The voltage fluctuations will charge and discharge the parasitic or DC side Y-caps.

In case of PV panels – There exist a parasitic capacitance between the PV cell and the metal frame which is grounded. The ground voltage (potential between DC negative and earth) using hybrid PWM is same as the drain to source voltage of ‘G4” and it goes through sharp transition at the zero crossing which will charge and discharge the parasitic capacitance. If someone accidently touches the surface of the PV panel, a leakage current will flow through the body of the person (due to the absence of any other low impedance path). If the leakage current is excessively high, then it can give shock or personal injury.

In case of DC Bus capacitor – The Y-caps across DC Bus capacitor, generally placed as EMI filter in designs, will play the same role as the parasitic capacitance play in case of PV panel. The earth current of the DC supply will increase and if this current goes above the protection limit, the DC supply can randomly trip and disturb the entire operation of the bi-directional totem pole.

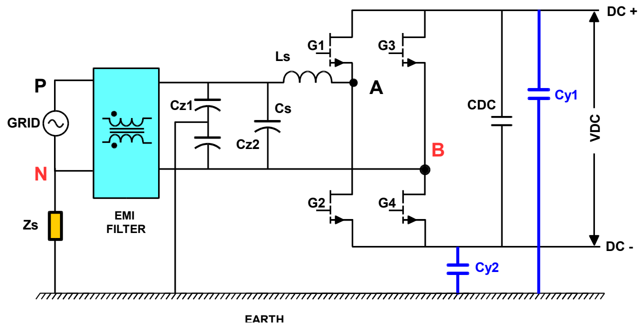

Figure 2.2: Bi-directional totem pole with Y-cap across G4

Bi-directional Totem Pole in PFC Mode

During positive half cycle (refer Figure 3.1) – G2 is the main switch and G1 conducts in the reverse direction with synchronous rectification and G4 being continuously ON for the entire half cycle. When G2 is ON, the differential current path is “P-Ls-A-G2-G4-B-N”. Energy is stored in inductor (Ls). Capacitor CDC supplies the load.

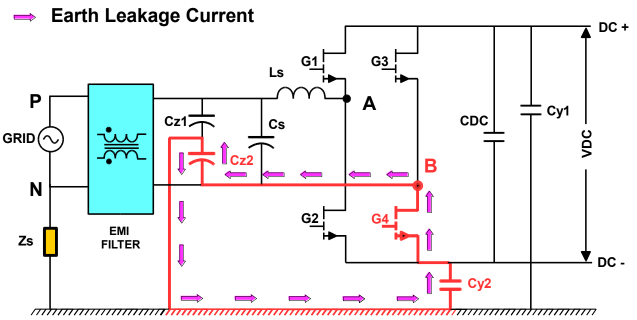

Figure 3.1: Bi-directional totem pole in PFC mode (during positive half)

When G1 is ON, the differential current path is “P-Ls-A-G1-CDC-G4-B-N”. Capacitor CDC is charged from the grid. Energy stored in the inductor and from grid is supplied to DC bus (CDC). The Y-cap “Cy2” which was charged during positive to negative transition (at the zero crossing) will get quickly discharged through G4 and the return path for the current is through earth and line side Y caps. The leakage current path is “Cy2-G4-B-Cz2-through earth”.

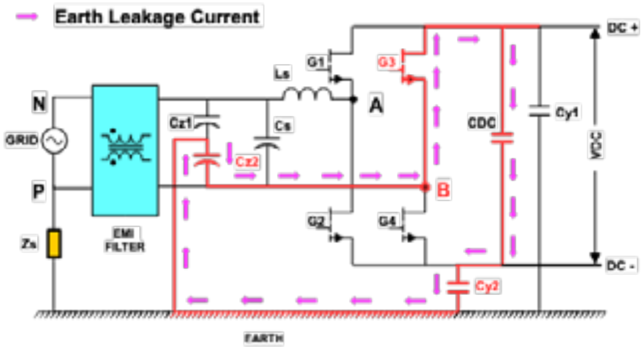

Figure 3.2: Bi-directional totem pole in PFC mode (during negative half)

During negative half cycle (refer Figure 3.2) – G1 is the main switch and G2 conducts in the reverse direction with synchronous rectification and G3 being continuously ON for entire half cycle. When G1 is ON, the differential current path is “P-B-G3-G1-A-Ls-N. Capacitor CDC supplies the load. Energy is stored in inductor (Ls). When G2 is ON, the differential current path is “P-B-G3-CDC-G2-A-Ls-N”. Capacitor CDC is charged. Energy stored in the inductor and from grid is supplied to DC bus. The Y-cap “Cy2” will quickly get charged during positive to negative transition (at the zero crossing) and the return path for the current is through earth. The leakage current path is “Cz2-B-G3-CDC-Cy2-through earth”.

Bi-directional Totem Pole in Grid Tie Mode

During positive half cycle (refer Figure 4.1) – G1 is the main switch and G2 conducts in the reverse direction using synchronous rectification and G4 being continuously ON for entire half cycle. When G1 is ON, the differential current path is “DC(+)-G1-A-Ls-P-N-B-G4-DC(-)”.

Capacitor CDC supplies to the grid. When G2 is ON, inductor energy freewheels through “Ls-P-N-B-G4-G2-A”. The leakage current path is similar to the PFC mode in the positive half cycle.

During negative half cycle (refer Figure 4.2) – G2 is the main switch and G1 conducts in the reverse direction using synchronous rectification and G3 being continuously ON for entire half cycle. When G2 is ON, the differential current path is “DC(+)-G3-B-P-N-Ls-A-G2-DC(-)”. Capacitor CDC supplies the grid. When G1 is ON, the inductor will free wheel through “Ls-A-G1-G3-B-P”. The leakage current path is similar to the PFC mode in the negative half cycle.

In the absence of the AC side Y-caps, the earth leakage current will continue to flow and find another path through the AC side neutral which is grounded to the earth and shown in Figures 4.3 and 4.4.

Simulation Results of Bi-directional Totem Pole in Grid Tie Mode

The circuit of Figure 1.1 is simulated in the grid tie mode to confirm the path of the earth leakage current. With reference to the grid voltage, it is seen that the earth leakage current is observed only at zero crossings.

From the simulation, it is clear that the current which flows through the AC side Y-cap “Cz2” is the same current that flows through the DC side Y-cap “Cy2”. The simulation result also shows the voltage across “Cy2” which changes state only when “G4” changes state from ON to OFF or vice versa and this voltage is same as the drain to source voltage of “G4”.

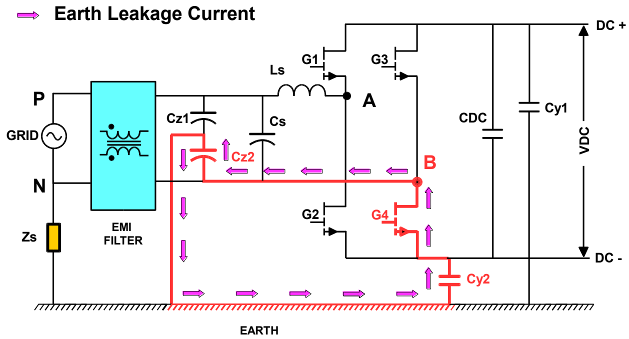

Figure 4.1: Bi-directional totem pole in grid tie mode (during positive half)

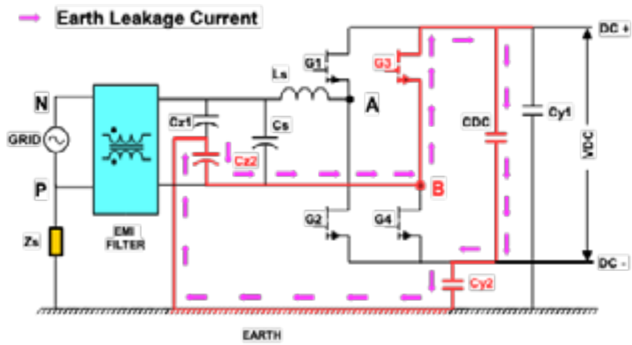

Figure 4.2: Bi-directional totem pole in grid tie mode (during negative half)

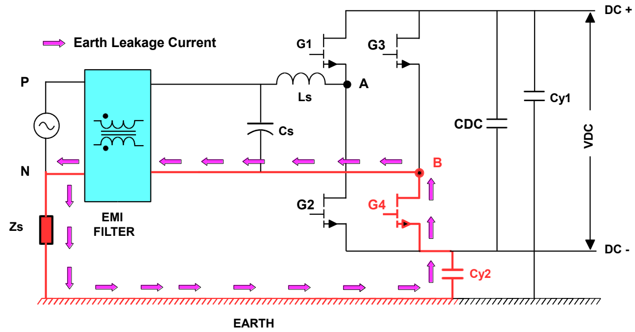

Figure 4.3: Earth leakage current path (negative to positive transition) in the absence of AC side Y-caps

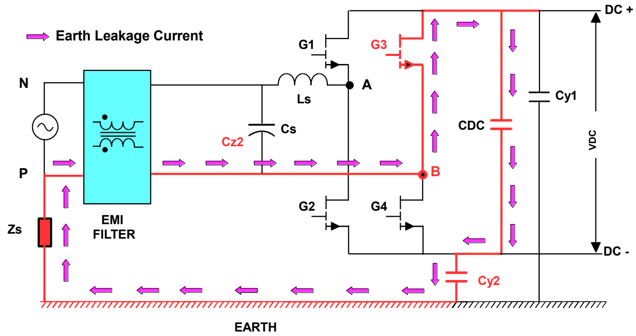

Figure 4.4: Earth leakage current path (positive to negative transition) in the absence of AC side Y-caps

Hardware Result of Bi-directional Totem Pole in Grid Tie Mode

The circuit in Figure 1.1 is built and run as a grid tie inverter to prove the simulation results. The sharp current pulse at the zero crossing is seen in Figure 6.1 similar to Figure 5.1. The sharp pulse is the result of abrupt change in the ground voltage which charge or discharge “Cy2” and matches with the simulation result.

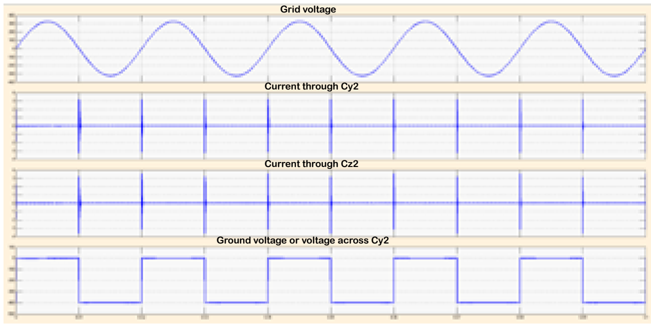

Figure 5.1: Simulation results using hybrid PWM in grid tie mode

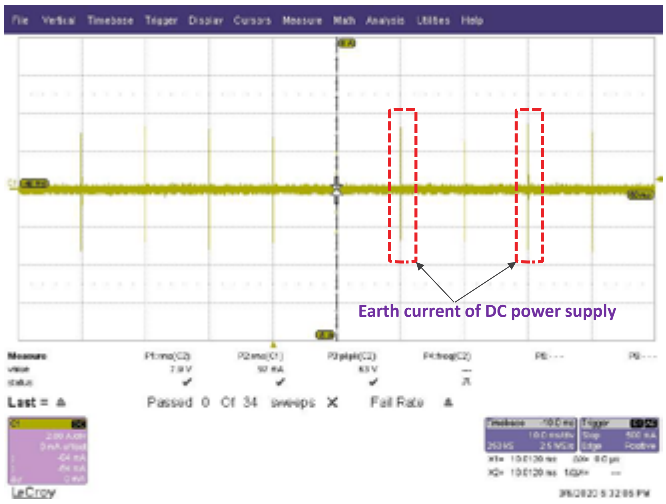

Figure 6.1: Experimental earth current of DC Power Supply

Conclusion

This article explained the root cause for the generation of leakage current having sharp edges at line frequency along with its path. Since the leakage current finds the return path through the earth, so it interferes with leakage current protection of the programmable DC source or load and results into malfunctioning of this equipment in addition to endangering the human safety.

Acknowledgement: The authors would like to thank VisIC Technologies, Israel for supporting this work.

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GaN Power Semiconductor Device Dynamic Characterization

As we've discussed in our last few articles, dynamic characterization of Silicon Carbide (SiC) power semiconductor devices poses a lot of design challenges to make repeatable and reliable double pulse test solutions. Gallium Nitride (GaN) power semiconductor field effect transistors (FET) present even more difficult challenges because of its higher frequency operation and multiple variations of technology. In this article, we discuss how we overcome the challenges associated with GaN FET dynamic characterization.

By Ryo Takeda, Bernhard Holzinger, Michael Zimmermann, and Mike Hawes, Keysight Technologies

Challenges for GaN FET dynamic testing

There are a few variations in GaN FETs. Typical types are listed below.

- GaN HEMT (Hi Electron Mobility Transistor)
- Gate Injection Transistor (GIT)
- Cascode GaN FET

Figure 1: GaN FET double pulse test results with oscillation.

They have different structures, behaviors, and properties. Therefore, each type requires different gate driving control, but all of them operate faster than their silicon or silicon carbide (SiC) counterparts, with typical transition times less than 10ns. Such an extremely fast speed brings about a lot of challenges for testing. Fast dv/dt and di/dt triggers ringing or oscillation and deteriorates measurement accuracy. Such oscillation sometimes destroys DUTs (Device Under Test) as shown in Figure 1.

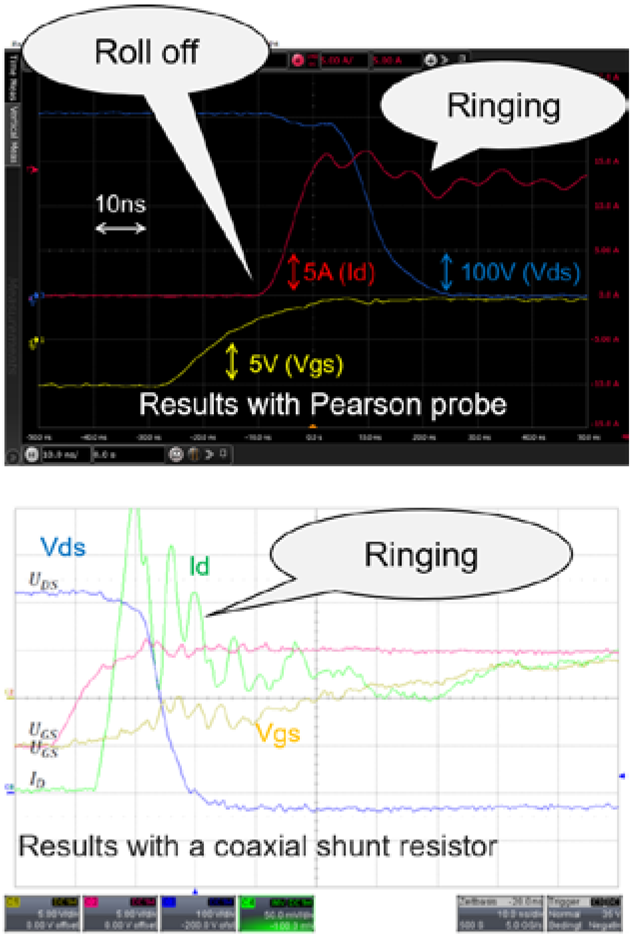

Figure 2: Distorted current measurement results on GaN FET.

Fast di/dt makes current measurement very difficult, because there is no commercially available current sensor which has both high bandwidth and low insertion inductance. Current sensors such as the Rogowski coil have less than 50MHz bandwidth, which is not enough for capturing current transitions less than 10ns. The Pearson probe can have up to 200MHz bandwidth, but its large size increases the test power loop inductance and therefore, deteriorates the measured waveform. Commercial coaxial shunt resistors have higher bandwidths, but their large insertion inductance causes ringing and voltage distortion (Figure 2). Because the parasitic inductance in the test circuit causes various issues such as ringing, it is common sense to solder the DUT to the test board to minimize the parasitic inductance. Unfortunately, it is very inconvenient if you need statistical results using multiple devices, because soldering/unsoldering devices quickly wears out the test board. Fixtures exist with spring type connectors, which allow solderless contact for SMD type devices. However, even such a tailor-made fixture has non-negligible parasitic inductance.

It would be ideal to have a one-size-fits-all test system for all GaN FETs. This goal is impractical for multiple reasons. Fast operating speeds of GaN FETs require the package of the device to be small to maximize the performance. However, there is little package standardization across the various GaN FET types. In addition, the different GaN FET types require different gate driver, components, layouts, and even different topology designs. Therefore, a test board must be made for each DUT, matching PCB contacts with the pad pattern of each DUT. Fortunately, most of the Double Pulse Test (DPT) system can remain standard.

Technologies to solve the challenges

As we've discussed in previous articles, the best method to minimize the test circuit parasitics is to reduce the test circuit area. Having smaller power loops and gate loops effectively reduces the associated parasitic inductance and therefore, reduces measurement waveform distortion such as ringing. In practice, reducing the power loop is not simple, because you must provide a method to measure current and voltage in this loop, as well as mechanism to connect the DUT.

Current measurement is a big problem as already shown in Figure 2. To solve this challenge, we developed a current sensor. Although a thorough analysis of the sensor's performance is still ongoing, double pulse test results indicate a much lower insertion inductance and superior bandwidth compared to other commercially available solutions.

As mentioned previously, soldering the DUT to minimize parasitic inductance is cumbersome and inefficient for double pulse test systems. A solderless contact with minimal parasitics is attainable. We've developed a solderless contact, minimizing contact inductance between the DUT and the PCB and achieved accurate mechanical aligning with a customizable DUT holder. (Figure 3). The parasitic inductance is much less than a typical DUT fixture with spring type connectors. The combination of designing a small circuit loop area, using a high bandwidth/low inductance current sensor, and attaching the DUT via a low inductance, solderless connection can provide you with very clean measurement waveforms. Clean waveforms allow more repeatable and reliable extractions of the desired switching parameters.

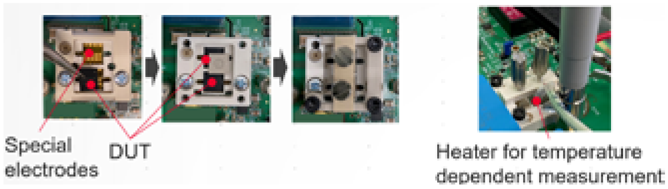

Figure 3: Newly developed solderless DUT interface.

In the last few articles, we discussed what we call the AUTOCAL function which calibrates various errors for voltage and current measurements and for timing misalignment. The same philosophy and technology can be applied for the GaN FET testing if the test board is designed right, enabling repeatable and reliable dynamic measurements even for GaN FETs.

For GaN FETs, dynamic R_{on} is a critical parameter to characterize the dynamic performance. So much in fact, that the JEDEC JC70.1 task group chose this parameter as their first defined test method, using a clamp circuit for V_{ds} measurements. [1] The idea is to clamp the voltage to a much lower value (e.g. 5V) than applied V_{ds} voltage (e.g. 400V). This allows the use of another channel of the oscilloscope to monitor the Vds voltage with much higher resolution (i.e. a standard low voltage probe can be used).

In summary, various advanced techniques/technologies shown below are necessary to make accurate dynamic characterization of GaN FET.

- Small size test circuit
- Low insertion inductance current sensor
- Non-solder contact technology
- AUTOCAL implementation for repeatable/reliable measurements
- Dynamic R_{on} measurement using clamp circuit

Keysight's solution for GaN power FET dynamic testing
Definition and development of a commercial double pulse test system for GaN FETs was a big challenge for Keysight. Not only the development of previously mentioned technologies, but also our approach to provide each customer with a tailored advanced solution, while keeping the modularity, comprehensiveness, and ease-of-use of our PD1500A Dynamic Power Device Analyzer/Double Pulse Tester.

Because the test board must be fabricated for each DUT type, our strategy is to have a tailored, add-on type board for the PD1500A as illustrated in Figure 4. Each tailored GaN test board has an EEPROM which stores unique DUT information such as maximum V_{gs}, V_{ds}, I_d, and clamp circuit voltage. This allows seamless integration of the GaN test board onto the PD1500A, so the software can use those values to avoid potentially dangerous test conditions and the user can perform tests safely and intuitively. Figure 5 shows an example of a tailored board for a GaN eHEMT device.

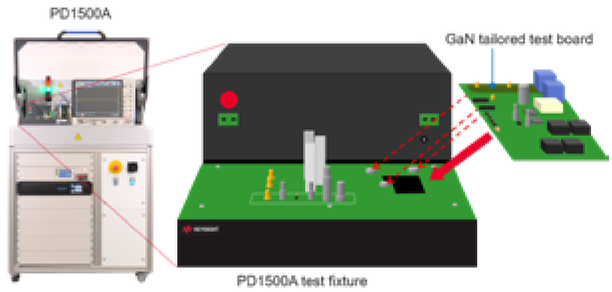

Figure 4: Tailored GaN test board for PD1500A.

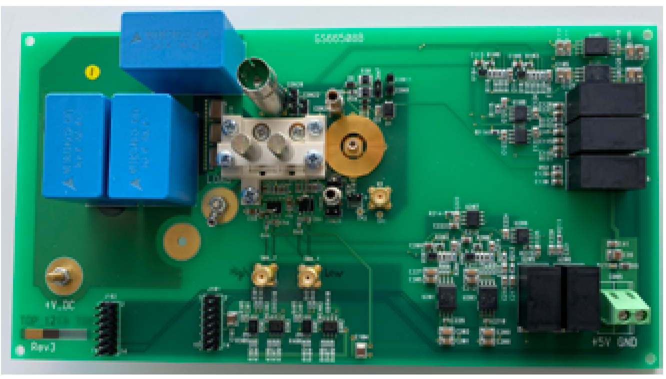

Figure 5: GaN tailored test board for eHEMT.

So how do these technologies impact the DPT waveforms of real GaN FETs? Figure 6 and 7 show measurement results for GIT and eHEMT. All the results show less than 5ns transition times (t_r and t_f) though relatively large gate resistance was used for GIT for this evaluation. Even for these fast transition times, the waveforms are clean with minimal amounts of ringing, allowing for repeatable and reliable switching parameter extractions.

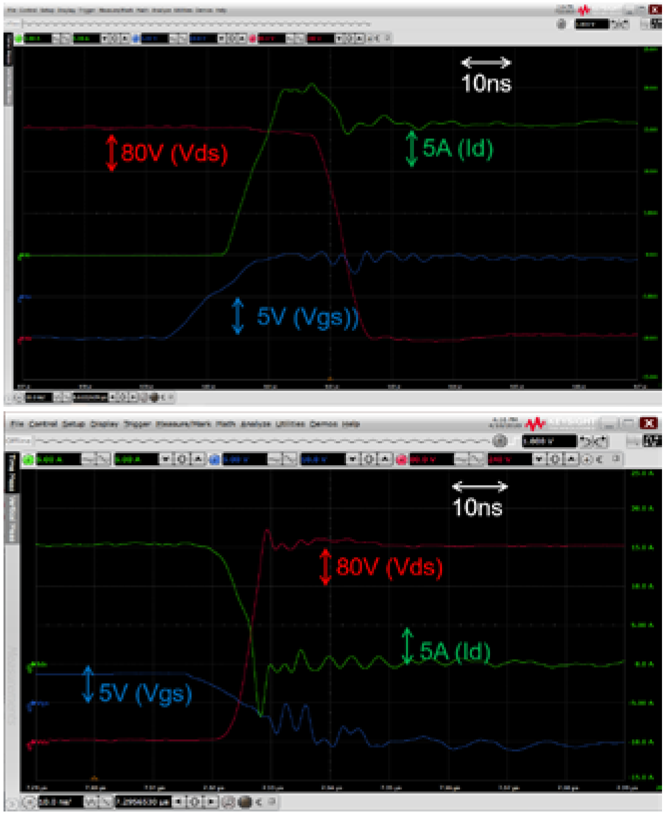

Figure 6: Test results (turn-on & turn-off) for GIT (DUT: PGA26E19BA (Panasonic)).

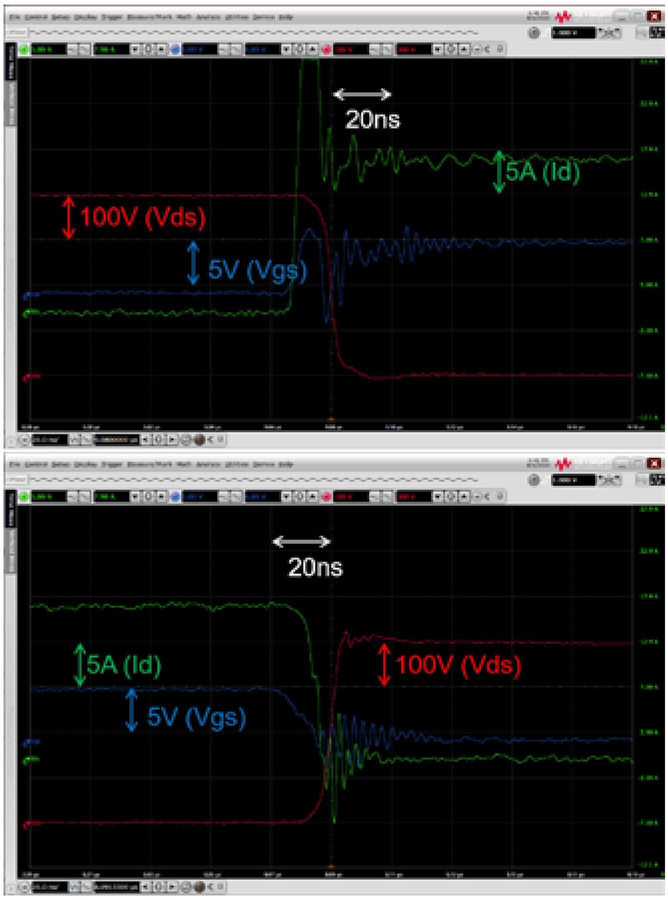

Figure 7: Test results (turn-on & turn-off) for eHEMT (GS66508B (GaN Systems)).

Figure 8 shows measurement results of dynamic R_{on} for GIT. The difference in resolutions between the clamped and unclamped V_{ds} waveforms (10X) significantly improves the resolution and accuracy of the R_{on} measurement.

The newly developed solderless DUT connection technology also allows for temperature measurement and control. This feature provides the capability for important temperature dependent measurement as shown in Figure 9.

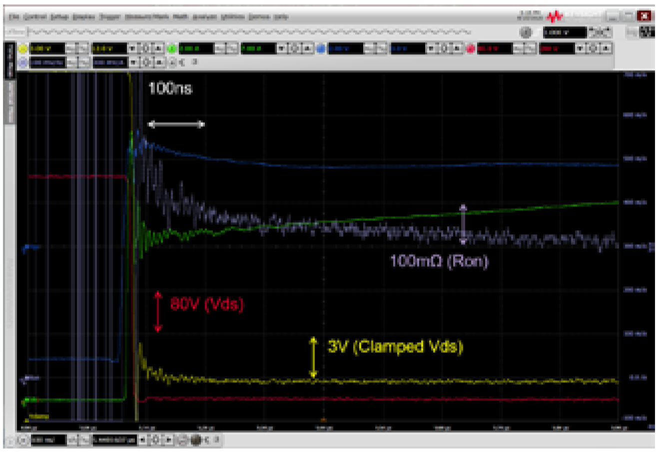

Figure 8: Dynamic R_{on} for GIT.

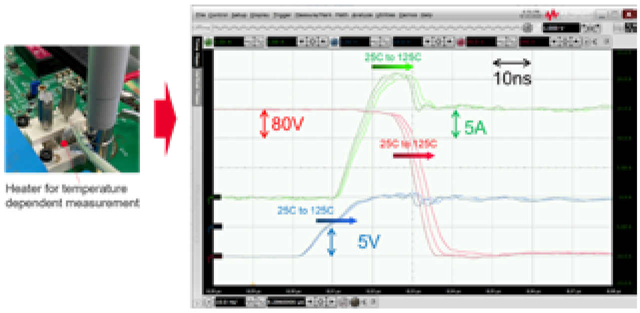

Figure 9: Temperature dependent measurement for GIT.

As mentioned previously, updated PD1500A software will automatically detect the GaN tailored test boards. Standard PD1500A software features such as waveform capture, switching parameter extraction, switching locus drawing, data saving, etc. are available (Figure 10).

Because GaN FETs have many variations, Keysight has a vision and strategy to accumulate knowledge and expertise in the format of schematic, board layout, and bill of materials (BOM). Our goal is to provide tailored solutions for each customer.

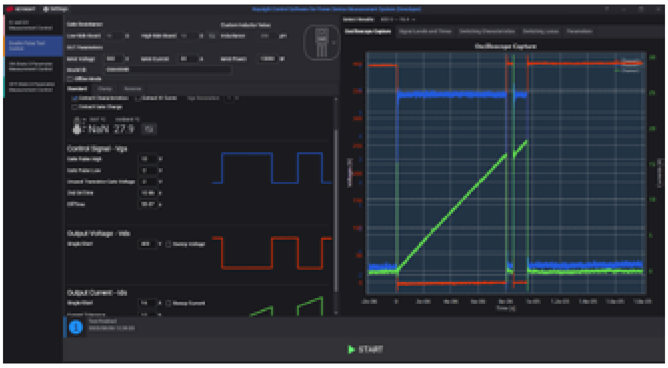

Figure 10: PD1500A user interface for GaN test.

Summary

GaN FET dynamic characterization is the most challenging of the newer power semiconductor devices. Using our measurement science experience and some key investments in industry leading technology, Keysight developed these technologies to enable repeatable, reliable, and accurate dynamic characterization of GaN FETs. The PD1500A Dynamic Power Device Analyzer/Double Pulse Tester now accepts tailor-made add-on GaN FET test boards to allow dynamic characterization of Si, IGBT, SiC and GaN power devices on a single test platform.

References

Dynamic ON-Resistance Test Method Guidelines for GaN HEMT based Power Conversion Devices, Version 1.0, JEP173.

www.keysight.com/find/pd1500a

Damp-Oscillation Solution for Validation of the Metal Alloyed Powder Core

The metal alloyed powder core is a kind of magnetic core, which is made from ferromagnetic alloy. After casting, it is pulverized, isolated with insulation layer compacted with inorganic binder under high pressure annealed in high temperature, and finally coated with epoxy coating to withstand high voltage stress.

By JC Sun, Bs&T Frankfurt am Main GmbH and Yi Dou, researcher of DTU

Introduction

FeAlSi, NiFe, NiFeMo composition have dominated second half of last century. Since the begin of 21st century diverse iron based alloy, casted and / or rapid solidified have been introduced to the market, where mostly iron based alloy with nearly zero magnetostriction enables relatively stable magnetic performance undergoing the long process chain.

Normally the permeability of alloyed particles performs as high as to several hundred thousand while after the mechanical process, the powdered bulky bodies` permeability can be managed to several of tens. These metal alloyed powder cores are mainly selected in power inductor applications, including inductance filters in grid-connection inverters, power factor correction (PFC) converters and output filters for middle-power switch-mode power supplies (SMPSs), where large flux linkage is required and at same time certain inductance needs to be guaranteed. A microscopic photo of the powder core is shown in Figure1, where internal structure are shown and the structure gives the cores unique physical and magnetic characters.

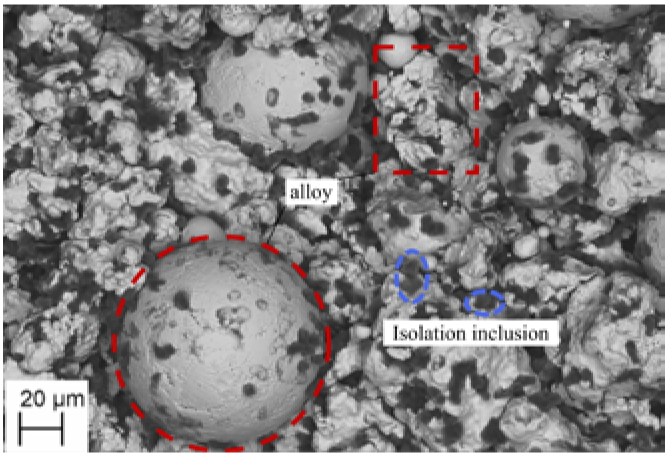

Figure 1: Microscope photo of a metal alloyed powder core

One of the unique characteristic of the metal alloyed powder core is the gradual soft-saturation behavior: the permeability of the core material is highly depended on the magnetic field strength on that thus no specific saturation condition can be defined, compared with ferrite materials or silicon steel sheets. Other notable characteristics of magnetics` powder core materials are high resistivity due to inorganic isolation surrounding the particle, those intra granular isolation is supposed to decrease volume eddy-current loss, and improve aging effect during the operation as wire wound components under harsh environment.

Even metal alloyed powder cores have been applied for decades, the standardization concerning material classification and measurement validation are still in begin i.e. IEC63299 and IEC63300. Actually the indeterminacy of standardization and measurement validation do bring challenges both for core designers and the application engineers: on the one hand, the expanding of standards for ferrite material IEC 60367 to enclose the metal alloyed powder core materials are still under negotiation, thus for core designers no consistent definition can be followed; on the other hand, several key parameters for the materials like Bsat and loss are missing on the datasheets of the materials, where the designers need for the components optimization [1].

In this article, the materials validation challenges for metal alloyed powder cores are introduced and the damping-oscillation solution are presented with detailed principle description and technical discussion. Case studies of the solution and results discussion are also presented to demonstrate the proposed measurement solution.

Validation Challenges of Powder Magnetic Cores

Due to the unique internal structure of metal alloyed powder cores and the corresponding performance, both the qualified definition and the core validation measurement meet significant challenges.

From the applications` perspective, how to compare powdered cores of different label and how to estimate the fundamentally inductance value are always the two primary concerns during the component design. Generally the inductance can be calculated with the permeability of the core material given by makers combining with the magnetic effective parameter of the core geometry, given by makers, nevertheless it is rather difficult to apply the conventional method on the metal alloyed powder core due to the unclear definition between the alloyed materials and the shaped cores. Typically, the initial permeability of the alloyed particle can be as high as some hundred thousand while the powdered bulky body is normally managed as several of tens. Thus, in the beginning the effective permeability must be distinguished when manufacture providing the reference. Besides, though the cores owns the unique structure with distributed air-gap, the structure should still be regarded as a closed magnetic circuit, thus

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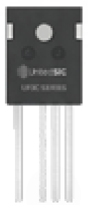

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the length of magnetic flux`s path can be define then the magnetic field strength should be selected as the argument when depicting the permeability`s non-linearity. Under this circumstance, the given effective permeability as a constant has already lose its function as validated reference. Besides of undefined effective permeability, the A_L value is another parameter provided by makers to the application engineers as only key reference with limit specification during the design. And the A_L value suggested that a normalized inductance value with single turn for closed magnetic circuit, which may be misleading.

The uncertainty of the A_L comes not only from the non-linear effective permeability, but also from the error from undefined measurement standard. First of all, the measurement for metal alloyed powder cores is still under negotiation but normally following the standard of magnetic components with rated current less than 22 A as in standard IEC 62024 ed 2, where the small-signal LCR meter with DC bias source is recommended as the validation solution. In addition, the limitation from the validation solution, including the measurement range of the excitation source and the inconsistent small-signal condition etc. make it difficult to distinguish the cores/materials and to make a fair comparison [2].

On the other hand, the measurement validation as a standard itself is worth to be further discussed. The small-signal LCR meter measurement as in IEC62044-2 is regarded as a established method to evaluate the metal alloyed powder cores, with benefit of convincing data sampling method and controllable excitation. However, the conventional small signal measurement with LCR meter is normally subject to its lower excitation capability on some conditions. Generally speaking, the distinguish between small-signal excitation and large-signal excitation locates on whether the driving source break the coercivity [3]. However, in terms of typical metal alloyed powder cores, the coercively is usually between some hundreds to thousands A/m, almost semi hard magnetic materials, it means the Rayleigh area of metal alloyed powder core is significantly large compared to other soft magnetic materials like ferrite, which the small-signal LCR meter measurement is not able to reach. Thus, a large-signal excitation would be a must to provide enough magnetizing condition to fully depict metal alloyed powder cores` performance.

With the modification of applying a DC current bias of to exciting the materials, the performance with H-bias can also be depicted in this straightforward way. Nevertheless, some drawbacks still limit the further expanding the application on metal alloyed powder cores: first of all, the controlled current source which mainly providing the bias current for the cores is limited by its output precision, especially when no bias is implemented during the measurement; secondly, when a relatively large current bias needed for magnetizing the metal alloyed powder cores with intrinsic distributed air-gap, the current output capability and precision will also bring extra system error during the hardware implementation. And the disadvantage to validate ferrite cored component is well described in standard IEC62024-2, Thus, it is necessary to introduce another "large-signal" validation solution combining with the small-signal LCR meter measurement to provide convincing validation for metal alloyed powder cores.

Powder cores validation solution with Bs&T-Pulse

Damped oscillation method compliant modified IEEE 389 is a magnetic validation solution with transient high current amplitude, which enables large excitation and its full reversal current enables further completion of re-magnetization path and Bs&T pulse micro is an integration hardware/ software solution with the damped oscillation method. The fundamental operational principle of Bs&T Pulse has been presented in [2]. During the damped oscillation, the initial stored energy in the capacitor can be fully discharged to magnetize the D.U.T. like a powder core to provide large excitation due to fast switching speed of thyristor, which is able guarantee adequate magnetization for the powder core materials. An illustration of the initial measurement data is shown in Figure 2 (a), which demonstrates the energy charging stage and the following damping oscillation process. In Figure 2 (b), the very-initial measured waveform is plotted, where the voltage waveform does not perform as a typical damping oscillation. In fact, in this period, the shape of the waveform is highly depended on the type of cores (such as hard or soft materials, open or close magnetic circuit etc.) as well as the performance of the energy-storage capacitor. In Bs&T pulse solution, all the waveform can be traced as raw data for analysis afterwards.

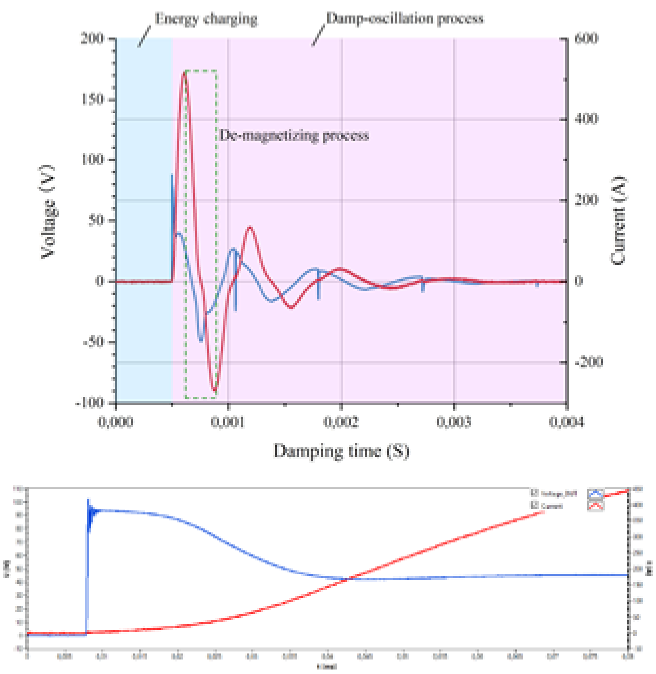


Figure 2: Demonstrated measurement results from Bs&T pulse:

a) Total measurement process (b) Expanding plot for the very-beginning damping period; (Sample: T106, 24 turns)

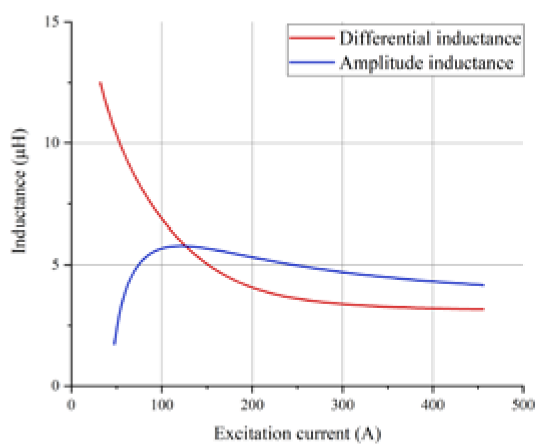


Figure 3: Measurement of differential and amplitude inductance with damp-oscillation method

The differential inductance and amplitude inductance regarded as two fundamental parameter of a component can be directed measured by the method, as shown in Figure 3. The tested sample is a toroidal core with T106 shape and 24 turns of winding and the material composite is FeSiAl. In order to remove the error from residual magnetism, the second de-magnetizing process is selected to depict the performance. Generally from the aspect of application, the amplitude inductance always catch more attention because before saturation occurs for the cores, the amplitude inductance is normally regarded as a constant for induced operation analysis. However, as for a components with metal alloyed powder, amplitude normally performs as a function if excitation current, which is usually called "soft-saturation" character. This unique character definitely cannot be observed only by small-signal measurement, due to the relative small excitation range, neither by the modified small-signal method with DC bias because the un-continuous driving bias. As a comparison the damping-oscillation method is a good alternative to directly find the amplitude and differential inductance owing to its oscillation process. As shown in Figure 3, the differential and amplitude inductance was measured with the current oscillating to be higher than 400 A and the "soft-saturation" character is depicted with its non-linearity inductance to adapt switch-inductor/ resonant applications.

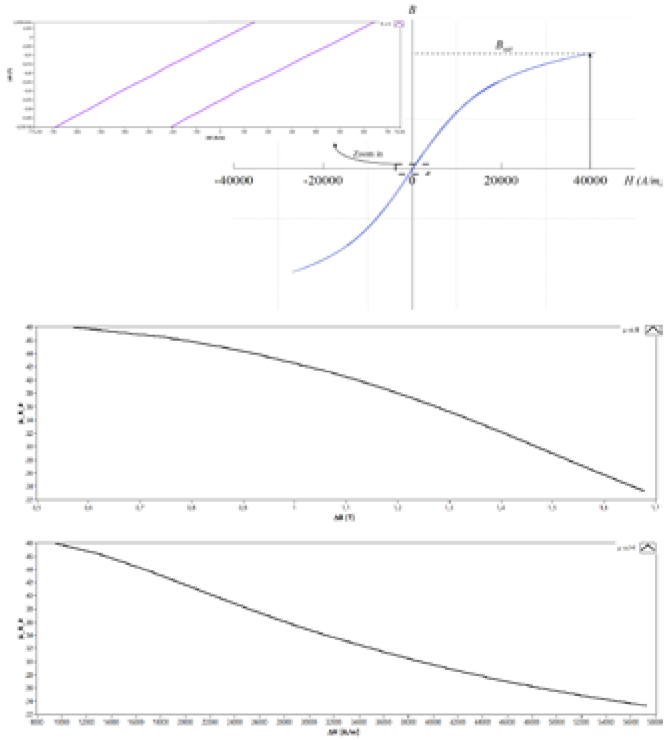


Figure 4: B-H loop depiction and relative permeability as a function of excitation magnetic field strength (Core shape 2x E65 Xflux 040 with 139 turns)

Correspondingly, the performance of the powder core material can be evaluated. Particularly, here a testing sample is selected as demonstration: the core consists of two EE65 core in stacking from Fuss-emv and its DC and AC ESRs are measured as 294.5 and 320.0 mΩ [3]. In Figure 4 (a), a commutation curve depiction is shown by plotting the B-H data through the whole damp-oscillation period, then further investigation with anisotropy distribution to articulate the linearity of diverse magnetic material is possible. As given in the core`s datasheet, only the $A_L$ value is given as a function of DC bias but no definition of measurement condition or the inductance evaluation is clarified, leading to much uncertainty of the parameters` precision. As the comparison, in the commutation curve, the B-H plot is able to give transparent measured performance evaluation for the core. For example, in the zoom-in plot the coercivity can be read for the core and the saturation flux density (Bsat) may be defined as when excitation H= 40000 A/m and also can be read directly from the first demagnetization path, (without disturbance of uncertain of remanence of DUT) . In addition, from the commutation curve, the saturation phenomenon, the coercivity and the relative permeability can work as curve-fitting reference in the future design guideline, such as building piece-wise core model and as training data group in the AI-based converters` optimization.

	1	2	3	4	5	6	7	8
Material	FeAlSi	FeAlSi	FeSi	FeSi	FeAlSi	FeAlSi	FeSi	FeSi
Permeability	60	90	60	90	60	90	90	60
Size	T106	T106	T106	T106	T184	T184	T184	T184
Weight (g)	25.72	26.30	29.74	29.45	129.28	134.68	155.12	148.81

Table 1: Samples description for the case-study

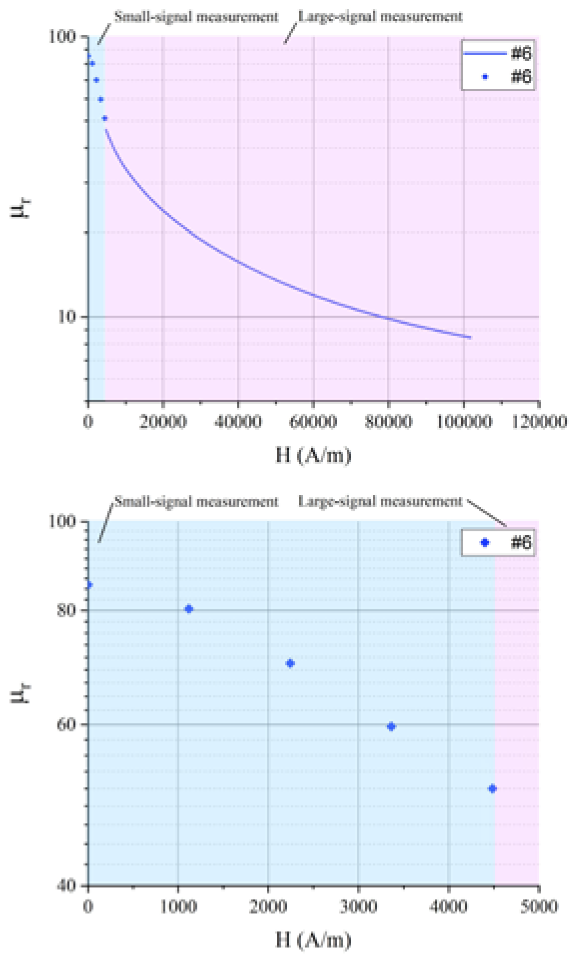
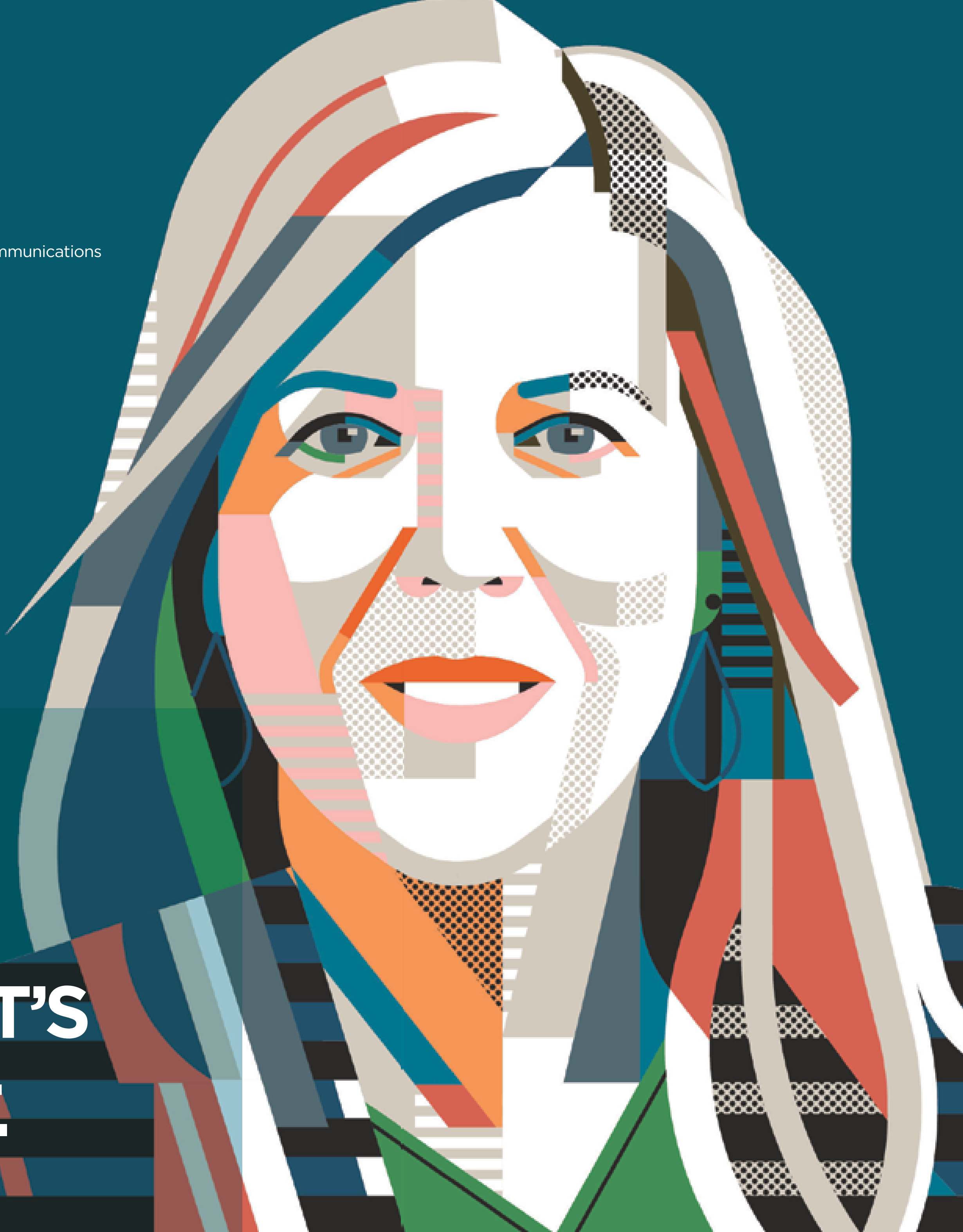


Figure 5: Combining validation for the inductors with metal alloyed powder cores

In Figures 4 (b) and 4(c), the relative permeability of the material can be calculated as the function of the excitation magnetic field strength or the magnetic flux density. Obviously, the soft-saturation phenomenon, whereas the relative permeability of the powder core material de-



creases with increase of the excitation, is precisely measured for the specific set-up condition, including the core shape, number of turns, temperature, particularly, a high excitation current can be provided by the Bs&T pulse solution was provided to guarantee a full-map depiction of the permeability shifting. Compared with the effective permeability from the datasheet, the measured relative permeability is able to provide much more information and as a reference for the component designers.

Combining validation of small- and large-signal measurement for the powder core

In this article, we demonstrate a combining validation for selected metal alloyed powder cores with large- and small-signal measurement to verify the full-map measurement concept. Firstly, Table 1 presents the parameters of the selected cores including the material composition, the initial permeability, the cores` shape and the weight of the cores. It is noticed that only two types of core shape, the T106 shape and the T184, are selected as the testing samples while different filling factors were implemented for the cores to construct the distributed air-gaps with different material performance. Correspondingly, the selected cores owns different weight/ density, which can be calculated the filling factor backwards.

An example measurement results for #6 sample with the combining validation are illustrated in Figure 5, along with a zoom-in figure to highlight the measurement by small-signal method. The measurement range of the small-signal and large-signal method are marked in different color in the figure and obviously the large-signal measurement has larger range however, the large signal cannot replace the small-signal testing but only serve as supplementary methods. Besides, it can be found that the small-signal measurement can only provide dis-continuous measurement with discrete results while the damp-oscillation method is able to conduct a continuous measurement in terms of the excitation.

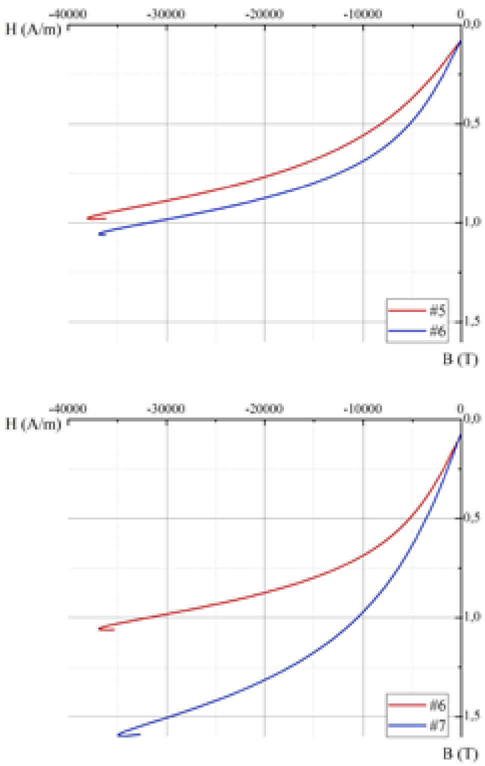


Figure 6: Performance comparison between cores with single variables for cores

In particular, several comparison analysis are conducted on the measurement from Bs&T pulse solution: firstly, as shown in Figure 6 (a), a pair of cores (#5 and #6) with same raw material/ shape but different effective permeability are evaluated with B-H loop, which indicates the material filling-factor does influence the performance of the core; In Figure 6 (b), the comparison between cores (#6 and #7) with same shape/ permeability but built with different materials is made: when the magnetic field strength is increase from zero, the two core perform similarly based on the observation while, the permeability of the core with FeAlSi material start to decrease earlier than that with FeSi material. In this case, the performance comparison is clearly presented and the performance can be qualified as well. For the evaluation, the demagnetization process is selected to remove the error from the remanence.

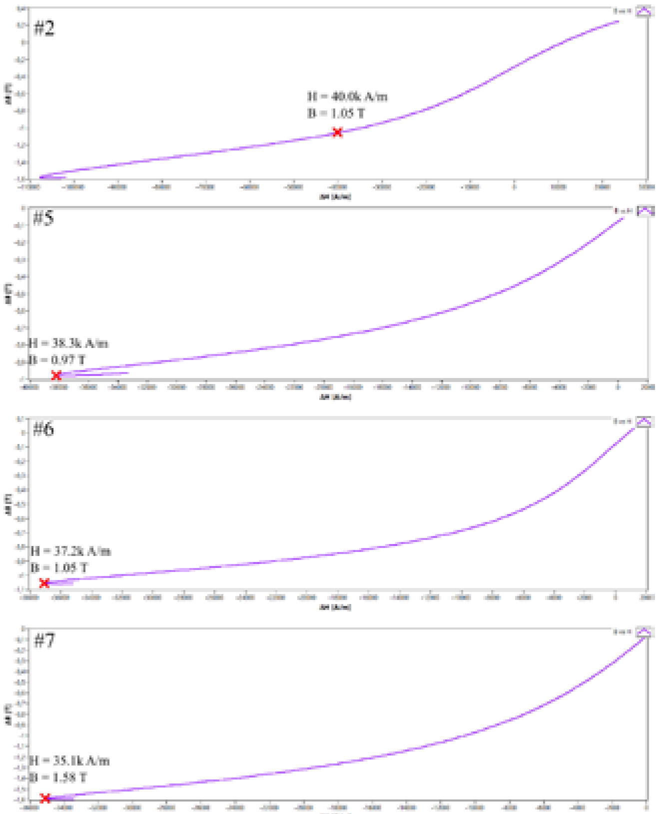


Figure 7: Performance comparison between cores with single variables for cores in Table 1

In addition, the saturation performance are depicted for the samples, as shown in Figure 7: Theoretically, at 40,000 A/m of the magnetic field strength, the material should perform with 1.05 T for the magnetic flux density. In the measured data, all the measurement of the magnetic flux density are tested as 1.05 T, which can verify the theoretical results. Besides, the shape of B-H curve shows different among cores, which means an independent measurement is a must to depict the performance among cores, rather than mathematical calculation from a constant permeability; Particularly, the #7 sample with FeSi material and 90 of the permeability theoretically should meet 1.7 T at 40,000 A/m for the magnetic field strength, which can also be verified by the measured result. Finally, the calculated Q-factor of the selected cores are plotted in Figure 8. The power loss measurement is always regarded as a challenge due to the intrinsic error from two separate measurement channel, especially on higher operation frequency. Though one solution with impedance compensation method was proposed to reduce the phase-angle error especially for high-frequency applications, the system error coming from propagation delay of sampling channels is always difficult to be totally corrected by during the hardware implement [4].

Thus, the data sampling method within single channel shows more potential than the conventional solution. In the Bs&T pulse solution, the issue is minimized by measure the voltage and the current within the same sampling channel and the power loss can be identified by Q-factor.

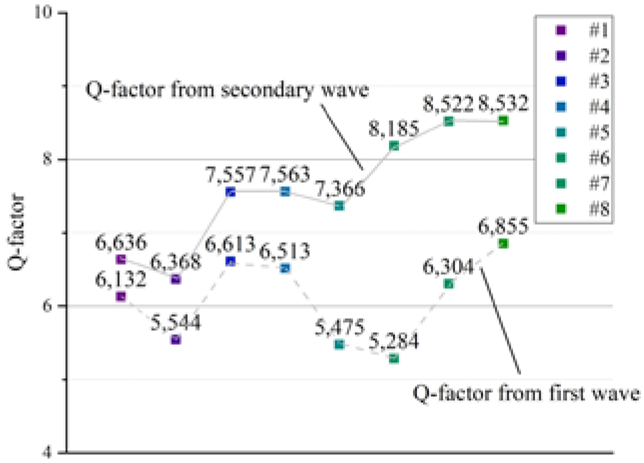


Figure 8: Q-factor measurement results from Bs&T pulse solution

It must be clarified that the Q-facotr measurment by damp-oscillating method. Refer to the system structure, the LC resonant circuit actually consists of the capacitor, which works as the energy source for oscillation, and the D.U.T, whose series resistance is the measured target. With a fixed capacitance value, the resistance can be calculted by using the current divided by the voltage when equals zero. Actually, this calculated value depends on the resonance frequency and also includes the equavalend-series-resistance (ESR) of the capacitance. Especially under hundreds of frequency conditions, this uncertainty is very hard to be deduced but anyway, a relative comparison can be made among tested components as long as keeping the same testing parameters.

Conclusion

The increasingly use of powder brings both benefits and challenges for the application and the core validation. However the conventional small-signal measurement cannot meet the requirement for the powder core manufacturers and application engineers. Bs&T pulse is offering a convincing validation solution for the components with powder cores and combining with the small-signal measurement, a full-map performance of the cores even the components can be unearthed maximally.

Reference

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[2] "Hanna Curve Reloaded" by JC Sun, Bs&T Frankfurt am Main GmbH & Yi Dou, DTU Kopenhagen
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[3] https://www.mag-inc.com/Media/Magnetics/Datasheets/00X6527E040.pdf

[4] Stolzke, Tobias, et al. "Comprehensive Accuracy Examination of Electrical Power Loss Measurements of Inductive Components for Frequencies up to 1 MHz." Journal of Magnetism and Magnetic Materials, vol. 497, Elsevier B.V., 2020, p. 166022.

A Perfect Match: Power Losses in Buck Converters and How to Increase Efficiency

Today's highly developed power ICs require superior power inductors. Building a standard power supply with common footprints can help reduce design time and production costs. Determining the best match between an inductor and an IC is paramount to achieving the best performance in terms of PCB space, as well as thermal and cost efficiency.

By Samuel Babijak, Field Applications Engineer at Monolithic Power Systems

Let's explore which parameters are most important when designing a buck (step-down) converter, and how to pair it with the best inductor available. We will also learn how to calculate basic parameters and explain some of the requirements for both switch-mode power ICs and inductors, including ripple current, inductance (L), saturation current (I_{SAT}), and rated current (I_R).

Today's Electronics Landscape

Over the past 10 years, consumers have grown to expect that technology will make their lives easier. At the same time, the amount of electronic items in the average home has increased. Ever-increasing options for connectivity and electronics mean these devices must become more efficient to remain competitive. For power supply designers, the best way to support this consumer shift in electronics usage is to convert voltages from the input to the necessary supply rails with a step-down converter utilizing high-performance parts.

The most common power supply topology is the buck or step-down converter. The main components for these topologies are input and output capacitors, switches (e.g. MOSFETs), and an inductor. The goal of these devices is to regulate the output voltage. High-side and low-side MOSFETs come in handy when they are combined with a regulator, and form an integrated step-down regulator IC.

Selecting a suitable IC with the best inductor does not have to be a significant challenge. Taking care of a few design parameters is the key to successfully choosing an inductor that works well with a buck converter, and to avoiding power losses and increasing efficiency.

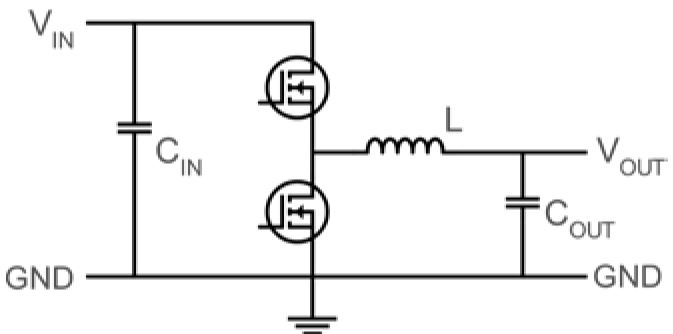

Figure 1: Basic Buck Converter Schematic

Fundamentals of Buck Converter Power Losses and Efficiency

A block diagram of a buck converter and its basic parts makes it apparent which components contribute to efficiency, and which parameters should be considered (see Figure 1).

When breaking down the efficiency and power loss of a buck converter, we can see that the biggest impacts on power loss and efficiency are the MOSFETs and the inductor. The quiescent current and programming resistors are not notable contributors (see Figure 2).

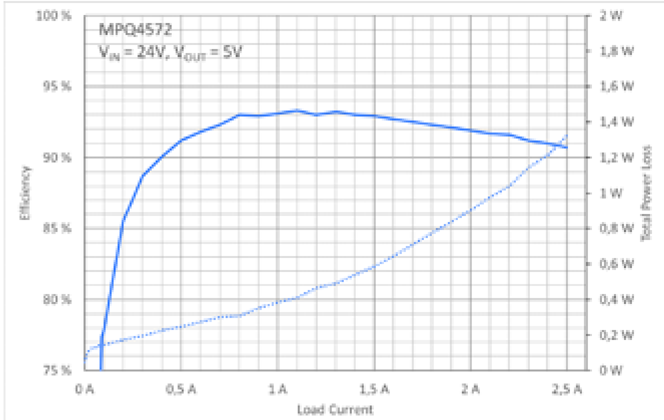

Figure 2: Efficiency Chart of the MPQ4572 Buck Converter with the MPL-AL6060-150 15µH Inductor

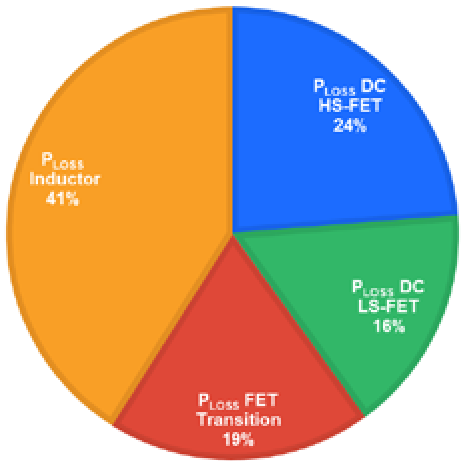

Figure 3: Efficiency Breakdown of a Buck Regulator

Figure 3 shows an efficiency breakdown of a 24V to 5V buck converter with a 2A load. While the inductor and MOSFETs have 870mW of power loss, quiescent power consumption adds just 900µW to the total sum. To achieve the highest efficiency and avoid wasting energy, we must ensure that state-of-the-art switching elements are coupled with high-performance inductors.

Inductance (L)

As a rule of thumb, it is usually recommended to start a converter design with a 30% to 40% ripple current. This leads to a nominal inductance (L), calculated with Equation (1):

$$L = (1 - DC)\,x \left(\frac{V_{OUT}}{f_{sw} \times \Delta I_L} \right) \qquad (1)$$

Where DC is the duty cycle of the converter, V_{OUT} is the output voltage, f_{SW} is the switching frequency, and ΔI_L is the ripple current.

For this example, the input voltage is 24V, the output voltage is 5V, the ripple current is 800mA (average 2A load), and the switching frequency is 500kHz. With these numbers, we can calculate the typical inductance to be 9.89µH.

Ripple Current (ΔIL)

Ripple current (ΔI_L) is the amount of low-frequency AC current that is superimposed onto the average load current and flows through the main power inductor to charge the output capacitor (C_{OUT}). The ripple current can be estimated with Equation (2):

$$\Delta I_L = (1 - DC)\frac{V_{OUT}}{f_{SW}\, x\, L} \qquad (2)$$

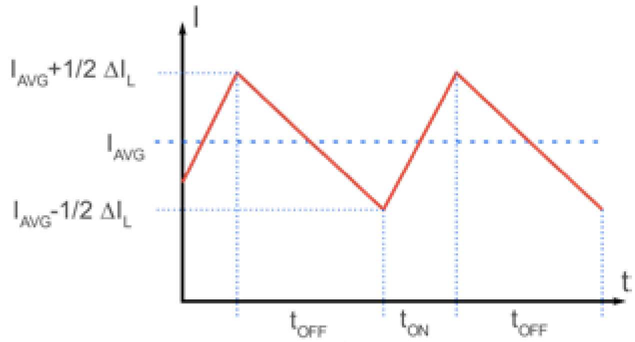

Figure 4: Ripple Current on Average Load Current

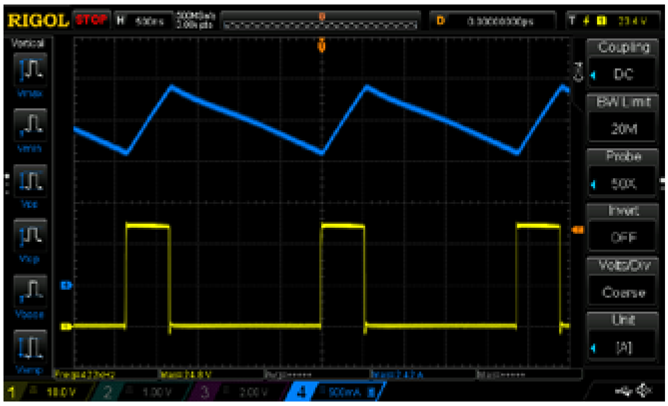

Figure 5: Inductor Current (Blue) and Switch Node Voltage (Yellow) of a 24V Buck Converter

Figure 4 shows important design parameters, including peak current (I_{PEAK}) and average current (I_{AVG}). This average current is the intended load current of our system, and is connected to the buck converter's output. Half the ripple current (ΔI_L) is added to the average load current, forming the peak current. For a successful and highly efficient buck converter design, it is essential that the inductor's saturation current (I_{SAT}) exceeds the peak current.

Figure 5 shows an example of an optimized 24V to 5V step-down converter, utilizing the MPQ4572 from MPS together with a 15µH inductor (MPL-AL6060-150). The ripple current oscillates around a 2A load current with a perfect triangular waveform.

Saturation Current (I_{SAT})

Due to the physical properties of the ferromagnetic material used in modern inductors, a higher number of turns and inductance (L) results in a lower the saturation current (I_{SAT}). Figure 6 shows a typical I_{SAT} graph. From this graph, we can expect an effective inductance of 13µH at a 2A load current.

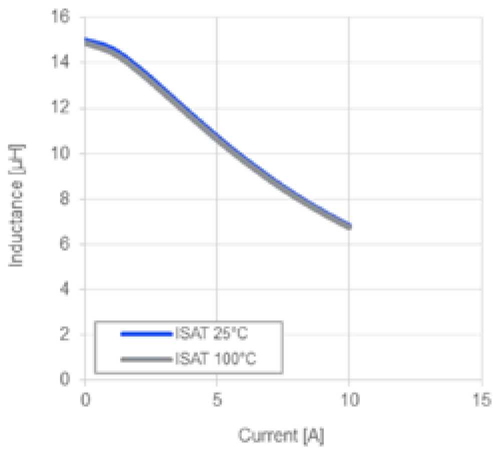

Figure 6: Saturation Current (I_{SAT}) as a Function of the Inductor Current (IL)

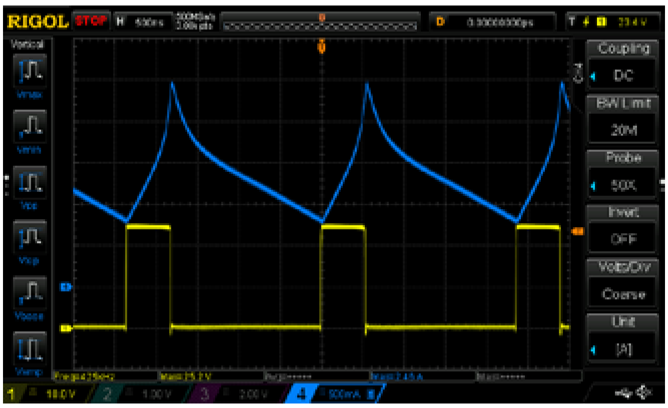

Figure 7: Inductor Current (Blue) and Switch-Node Voltage (Yellow) with Too Low Saturation Current

As power supply designers, it is critical to keep in mind that inductance decreases when the current flowing through the inductor increases. Increasing temperatures decrease the effective inductance. Depending on the technology, structure, and materials used in the inductor, the curve of the saturation current can be stable up to several amperes.

Because high-efficiency inductors have a soft saturation and buck converter, ICs have protection features such as peak current limiting. This means there is no way to choose the wrong inductor. Even with an exceedingly high or low inductance, we will still see reasonable results. However, it is important to have enough margin on the saturation current, as an insufficient margin can lead to a low-efficiency system. A lower saturation current can contribute to sharp spikes on the inductor current (see Figure 7).

Rated Current (I_R) and DC Resistance (R_{DC})

Another important parameter to consider is the rated current (I_R). Remember, as inductance increases, the rated current (I_R) decreases. Moving forward, we can directly use the average load current as an estimate for the effective temperature rise (ΔT).

The temperature rise is directly related to self-heating because of DC losses inside the copper windings. This means that the lower the DC resistance, the better the self-heating, and the higher the inductor's rated current (I_R).

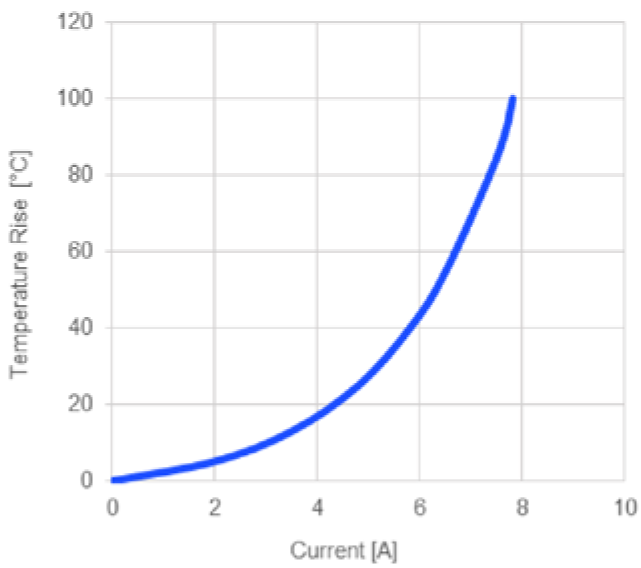

Figure 8: Rated Current Chart

The diameter of the enameled copper wire, which forms the coil of an inductor, is smaller in smaller package sizes. This leads to higher DC resistance, DC loss, and lower I_R. Choosing a good compromise between the package size and rated current is important for a successful buck converter design. As a rule of thumb, a temperature rise of 20°C to 30°C for average operating conditions is a solid starting point (see Figure 8). Having exceptionally small components on the PCB is also important in terms of EMC, as hot loops can become smaller.

Matching the Inductor and Buck Regulator for Optimal Efficiency

Now that we have gone through the fundamentals, finding the optimal efficiency of a buck converter means that we need to choose a regulator IC and an inductor that match one another's performance. If we disregard the inductor's AC losses and the MOSFETs' transition losses, we can focus on DC power losses.

The power loss (P_{LOSS}) of any conductor can be calculated with Equation (3):

$$P_{Loss} = I^2 \, x \, R_{DC} \qquad (3)$$

The conduction losses from our switching MOSFETs don't always add up for the whole switching period since MOSFETs have an on and off time. While the high-side MOSFET (HS-FET) is on, it gives us a power loss multiplied with the duty cycle (DC). By comparing the DC resistance (R_{DC}) of the inductor with the $R_{DS(ON)}$ of our MOSFETs, we can use the fraction of the RDS(ON) for matching. Both terms (R_{DC}) and (DC x $R_{DS(ON)}$) should be close to one another. They don't need to be perfectly equal, but we can see the optimal efficiency with close terms (within mΩ).

For example, for a 24V to 5V conversion, there is a duty cycle of V_{OUT} / V_{IN} = 0.208, meaning the HS-FET conducts the inductor current only 20.8% of the time. This means the conduction loss only adds up to 20.8% of the total conduction losses. However, the low-side MOSFET (LS-FET) is conducting the inductor current at 79.2%, which is on most of the time. This why most modern buck regulators have differently scaled MOSFET switches.

To minimize losses and achieve an efficient compromise between size, performance, and cost, first match the DC resistance of the inductor with the ratio of the MOSFETs' $R_{DS(ON)}$.

Since modern buck converters have switch on resistances that range from tens to hundreds of mΩ, the best performance can be matched with small and highly conductive power inductors that utilize round or flat copper wires together with a molded ferrite compound.

Conclusion

Matching the right inductor and buck converter can be a challenge with the vast number of different inductors on the market. Even if we make compromises between size, efficiency, and cost, there is always a best choice of inductors that meet the technical and environmental requirements of our final application.

Both modern buck regulator ICs and molded power inductors are available with DC and conduction resistances in the tens of mΩ range. Making sure that all of the resistances are in the same range helps achieve an optimal compromise between size and efficiency. Larger package inductors and MOSFETs typically help reduce power loss. However, at a certain size, cost and PCB space increase rapidly with no significant performance boost toward this goal. Therefore, aiming at the necessary saturation current (I_{SAT}), rated current (I_R), resistance (R_{DC}), and on resistance ($R_{DS(ON)}$) is a fast and easy way to achieve outstanding performance with a reasonable effort to create a perfect match of power inductors with buck (step-down) converters.

www.monolithicpower.com

When a Modular Power Supply is the Best Solution

There are many ways to generate all of the DC supply rail voltages required for a given electronic design. Often a single, off-the-shelf, mains-connected converter provides the internal power system with a single DC voltage, isolated from the hazardous line from which additional rails can be generated with internal DC/DC converters.

By Dylan Howes, Engineering Manager, TT Electronics

These DC/DC converters can either be designed and built with discrete components or purchased as pre-designed modules that mount directly onto the PCB or somewhere else within the chassis. Designing in a single, off-the-shelf, mains-connected converter with multiple outputs is also an option. In rarer cases, a designer may elect to utilize multiple mains-connected converters to generate some or all the required system voltages. When no readily implementable arrangement of these options adequately meets the design requirements, the designer may seek out the design of a custom power supply.

As a device's power system becomes more complex, any of these approaches can be fraught with design and commercial challenges, particularly for OEMs without a dedicated power supply team. In this landscape, modular configurable power is a viable option and often a factor in applications such as medical systems (i.e., surgical robotics, imaging devices, and laser apparatus) as well as industrial automation equipment. Faster and more cost effective than designing a custom solution from the ground up, these devices reduce the time and resources required for development, compliance, and achieving high power density performance.

Figure 1: Modular configurable power is a viable option

What is modular configurable power?

A simple way to think of a modular configurable power supply is as a custom power supply without any of the common major disadvantages – no NRE costs and agency submission fees, no MOQs and long development cycles. In many cases a configurable power supply can also provide a custom power conversion solution, agency approved and ready to use, overnight. These conveniences likely do come at a higher unit cost, but the diverse advantages of modular configurable power are such that higher costs are often justifiable. In many low volume applications, there could even be a strong cost advantage to using a modular configurable solution, particularly when development and agency submissions costs are considered.

Generally, a modular power converter consists of a mains-connected front end and some number of independent DC modules. The front end itself houses the EMC filtering, power factor correction and the isolation transformer. Power is transferred from the front end to each of the DC modules which then process that power and provide a regulated DC output. Modular power supply manufacturers typically offer a handful of different modules that can be populated into the DC slots, each covering a different range of output voltages. Output voltage adjustability on each module is often quite wide for maximum versatility.

There are many modular configurable solutions on the market that also present some degree of remote programmability of the I-V characteristic on each module, as well as remote sensing features and independent inhibit signals. Some modular converters offer an additional level of versatility and convenience in being field-configurable, meaning that the OEM can populate and depopulate the modules themselves.

Versatility and development flexibility

The most obvious advantage of a modular configurable power supply is its extreme versatility. The same set of elements can be adjusted and/or arranged to exhibit a wide assortment of I-V characteristics. A well-designed modular platform should have very few gaps, or holes, in the achievable I-V permutations whose products lie under the rated throughput of the converter. For instance, a versatile 600W modular platform should be able to offer 5VDC at 120A, 120VDC at 5A, or any other I-V permutation between these extremes when configured as a single output device. That same platform could be reconfigured to provide several different voltage rails, each with a similar degree of flexibility. If each of the modules are inherently isolated, another degree of flexibility is realized in the availability of negative voltages. Unlike many non-configurable multi-output power converters, a well-designed modular solution will mitigate interactions between individual outputs. Each output module is independently regulated with its own feedback loop. As a result, there are no minimum currents to maintain cross regulation and perturbances on one rail won't propagate to other rails.

As today's electronic devices become increasingly feature-dense and cost constrained, system power requirements (and their associated allocations for physical space) must be considered much earlier in the design process. This can lead to an underutilized converter or a constricted design process if concept phase assumptions about power requirements do not pan out. With a modular solution, the power converter can be made to adapt with the design throughout the entire development cycle without ever changing the mechanical design, power supply vendor, or compliance considerations. If a sub-circuit's supply voltage changes in the middle of the development cycle, the designer can simply adjust the module's set-point. If a network ultimately needs a good deal more power than estimated, the designer can simply populate another module. And if a feature gets scrapped by marketing, the designer can depopulate a module and achieve cost savings. All of these changes can be made immediately, without scouring the market for a new part or redesigning an internal power distribution network.

Figure 2: Modular configurable power supplies are extremely versatile

Modular power facilitates a modular product

It is not uncommon for a product to be offered with options or varied tiers of performance and features. Model XYZ+ does a few extra things over model XYZ, and model XYZ- comes in at a more affordable price point. Modular power converters allow for a single power platform to serve an array of product options via the population or depopulation of individual modules. Often, economies of scale can be realized on the AC front-end (where the bulk of the cost lies) and system mechanical design is simplified by having a single power supply footprint for each product version. Wiring and safety/EMC compliance characteristics associated with the mains connections are common across the different product versions, as is general power system performance.

Modular power simplifies compliance

Many regulatory compliance items are strongly influenced by power conversion design choices. Acting as safety barrier between the hazardous high voltage mains and the SELV electronic networks, a power converter falls under great scrutiny during safety agency submissions. Further, as our world continues to strive for greater and greater energy efficiency, the ubiquitous implementation of switch mode power conversion in both our AC/DC and DC/DC converters means that the power supply can be one of the noisiest elements in a given electronic assembly from an electromagnetic standpoint. In contrast to a system comprised of a number of different off-the-shelf converters, or even an internally designed power distribution system, a modular solution's entire power system has already been specifically designed and tested for compliance with stringent safety and EMC mandates. If a system contains several switch mode power converters, all marching to the beat of their own drums, it can be easy to stumble into an emissions nightmare as broadband noise from each of the converters sums unpredictably. A well-designed modular power supply affords a holistic approach to mitigating emission for the entire power system.

Some OEMs without dedicated hardware teams may be tempted to utilize several mains-connected, off-the-shelf power supplies for different subsystems within their device. This approach can very quickly lead to safety non-compliances as leakage currents from each of the mains-connected devices sum. Many off-the-shelf AC/DC converters are designed with the intention of being the only mains-connected elements in the system, and leakage current margins may not be sufficient for the connection of additional elements across the mains.

When a designer elects to use a modular configurable power supply as their power system, they have the reassurance that the power system itself will not be a direct cause of a regulatory non-compliance. This offers peace of mind, reduces agency testing costs, and can greatly improve the product's time to market through a much more efficient regulatory review process. Further, in the event that the power system does indeed contribute to a system level non-compliance, the OEM has a single vendor with whom to work toward resolution as opposed to an assortment of switch mode power supply providers.

Power denisty

Modular power supplies tend to achieve greater power densities than non-modular solutions. The total conversion efficiency of the power system as a whole can be optimized, allowing for a smaller package size as less heat needs to be dissipated. Also, a single mains-connected supply will always yield a greater power density than multiple mains-connected devices as primary side functions are consolidated.

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Product Value Maximization: A New Dawn for Business Development

Global challenges (i.e. climate change, limitation of resources, wasted energy) put extra challenges on the engineering community. All companies face the challenge to bring their product to market with limited resources. Foxy Power GmbH developed a unique concept called "Product Value Maximization" which is a product and application centric approach.

By Christopher Rocneanu, CEO and Founder, Foxy Power GmbH, and Michael Doktor, CCO and Founder, Foxy Power GmbH

Companies that implement Product Value Maximization (PVM) have an advantage among their peers as it helps them to successfully launch innovative, cutting edge technology products by optimizing resource allocation to gain a competitive advantage. Broad industry changes are driving the need for PVM. As an example, the automotive industry is in flux. The transition to renewable energy and EV's is happening in a perpetually evolving and politically driven globalization, which translates to pressure on prices and quality. The reinvention of an entire industry, as we are seeing in the automotive sector, is challenging in many ways: It is very cost and labor intensive, has complex logistical structures, and existing supply chains which cannot be easily and quickly modified without endangering the societal harmony. Additionally, this reinvention requires highly qualified human resources (especially electrical engineers), which will make the ongoing fight for qualified employees even more pronounced.

Often, at the working level, the scope of tasks increases and will continue to do so. Together with faster design cycles, this can lead to less time for innovation. A simple example from the author's past experience in business development within the SiC industry: About 10 years ago, electrical engineers were more focused on technical issues and had time to read datasheets properly, while today the initial questions being asked are about pricing, second sourcing, and lead times; if you can make it past the receptionist and get to discuss with the engineering department in the first place.

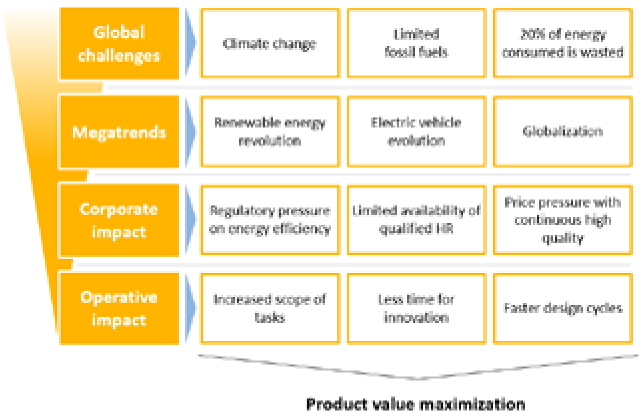


Figure 1: Global Challenges, Megatrends and impact on Corporation and Operatives

Within the semiconductor manufacturing community, the EV evolution is a challenge and an opportunity at the same time. The increase in semiconductors used has led to a significantly increased lead time for key components, as well as for low-cost components. Recently, billions of dollars have been invested into new fabs for semiconductor manufacturing, packaging, and wafer production especially for wide bandgap semiconductors. While the established players can grow their revenues and continuously expand their market position, a lot of new players and previously purely industrial focused players want to move – regardless of suitability – towards the automotive industry.

In Figure 1 we summarized the global challenges and trends, and the impact they have on corporate and operative levels.

Foxy Power GmbH has been founded to assist startups and manufacturers of disruptive technologies in navigating these transitions, in basing their decisions on customer and market feedback, and bringing their products faster and more efficiently into the market. Foxy Power differentiates itself from distributors and classic representatives with the concept of Product Value Maximization, which we will elaborate in detail. The idea is to add the Product Value Maximization component to the classical Sales and Representative model and create a Rep+ model, which is first of its kind.

The core competence of Foxy Power is business development, sales and strategy, and is reflected in three main business pillars:

1. Innovation: includes partnerships with startup companies with new products, but also with established players launching new products and tackling new markets and applications
2. Systems and Engineering Services: includes partnerships with companies offering customized subsystem or total system solutions.
3. Logistics and others: includes partnership with design in distributors to offer various components and holistic logistic solutions.

A manufacturer will at some point in time, decide that distributors and representatives should be added, to multiply the sales effort without multiplying the sales costs and carrying the risk of stocking. A classic mistake that startups can fall for is signing with large distributors. Big names do not necessarily mean big return for your company. Adding your new, unknown, and potentially in need of detailed technical explanation product line to the existing 999+ product lines will not bring you to the Top 3 lines which need to be sold daily. Even though the CEO may think that you have the greatest, most unique product in the world!

After choosing a suitable distribution partner the standard process typically starts with signing a sales agreement that is often limited to a territory. If the sales team is lucky, they might receive a reasonably sophisticated product training. Afterwards, the sales team is sent into the world to engage with customers. This approach is usually followed by disappointment on both sides of the agreement, since the results tend to be underwhelming.

PVM picks up right after the first training. Products are individually analyzed in order to determine additional value and features in certain applications. This individual analysis leads to Unique Selling Propositions (USPs). Afterwards, we identify the right applications, partners, and customers. This can be the EV market; but it can also be industrial. Ultimately, the targets will depend on the product features, the status of the product's life cycle, and application. Manufacturers can profit from the EV evolution without going into financial and contractual risks from the automotive industry, and focus initially on industrial applications e.g. forklift chargers or DC fast chargers.

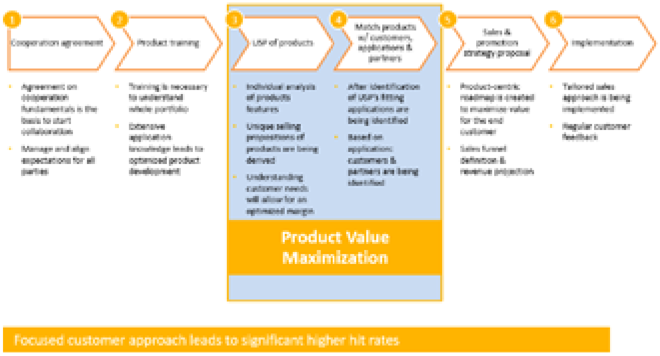


Figure 2: Sales Approach including Product Value Maximization

Foxy Power is not limited by territory; we focus on applications to ensure an application-centric product roadmap and market approach. This secures an efficient and effective customer consulting and maximizes the end customer's value. Additionally, if you understand the value of your product to the application on a system level you can optimize its pricing!

Finally, the sales funnel is defined, and revenue will be projected, and a custom-tailored sales approach is implemented, including regular customer feedback sessions, which lead to significant higher hit rates.

Business development and generating revenue in the market are Foxy Power's key assignments. Sometimes you don't have to look far to create partnership and create something great. Foxy Power's partners can profit from a highly innovative network, as written below.

One of Foxy Power's first partners is Converdan A/S. Converdan is a Danish company founded in 2013 and with more than 150 years of combined power electronics experience. As a trustworthy, agile, professional, and dedicated engineering & manufacturing partner they enjoy an extraordinary customer retention rate. They differentiate themselves via their modular technology platform that is based on generic hardware, converter control algorithms and software which allows for a very short time to market, while simultaneously reducing losses, size, materials and hence costs. Converdan covers the whole range from AC/DC inverters to DC/DC converters typically used in power suppliers, battery chargers, grid inverters, Variable Frequency Drives and many more. Foxy Power supports Converdan with sales and business development, but it was also tasked to support their determination to innovate and keep a competitive edge with the AFE333KLQ and AFE333KAC; liquid or air cooled 3 phase Active Front End module building blocks (see Figure 3).

Figure 3: 3-Phase Active Front End Module AFE333KLQ designed by Converdan A/S

One of the key challenges for Active Front Ends is reducing the transistor's losses, specifically during switching. Despite using state-of-the-art wide bandgap FETs and by increasing switching frequencies, switching losses usually still account for roughly 50%-70% of the total (active component) losses. In DC/DC converters, reduction of switching losses has been successfully implemented by using one of the soft switching topologies e.g. LLC, Phase shifted Full Bridge and others. Even though a lot of R&D resources have been spent in the last decades on various approaches (e.g. high-Speed DSPs, look up Tables, voltage and current comparators) soft-switching in DC/AC inverters with varying input voltages, temperature and load conditions, has been unsuccessful until today.

Pre-Switch Inc. was founded in 2016 with the sole purpose of bringing soft-switching into the world of DC/AC and AC/DC inverters. Pre-Switch has overcome this challenge by using Artificial Intelligence (AI) to constantly adjust the relative timing of elements within the switching system required to force a resonance to offset the current and voltage wave forms – thereby minimizing switching losses. Pre-Switch is enabling customers to build IGBT systems with switching frequencies 4x-5x faster than their hard-switched IGBT systems and SiC systems up to 35x faster than their hard-switched SiC systems. This offers engineers a considerable new design freedom (Figure 4). In case of a SiC based EV inverter, using Pre-Switch technology enables engineers to increase Fsw from the ubiquitous 10kHz up to 100kHz and can reduce dimension, weight, and system cost in the inverter. More importantly, by increasing the switching frequencies, Pre-Switch technology helps in creating a near perfect sine wave without any output filter, which can lead to an increased battery range.

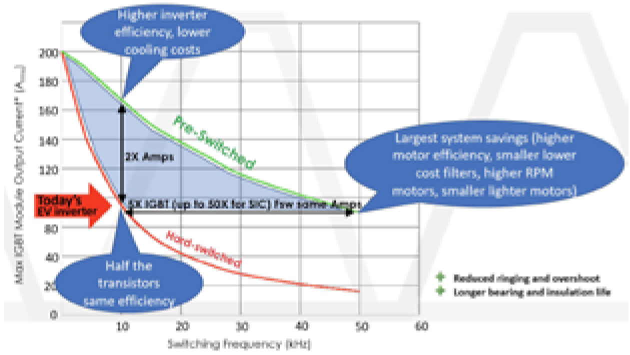


Figure 4: Pre-Switch allows new design freedom for engineers (Output current vs switching frequency for an IGBT EconoDual 2 Module)

Foxy Power was appointed as Pre-Switch's global and exclusive partner, and successfully approached various global automotive OEM and Tier 1 suppliers. More importantly, the technologies have been successfully designed into other (industrial) applications. Foxy Power creates value for its customers and network partners via partnerships or joint projects with public entities. In the coming months more details and disruptive technologies and projects will be disclosed.

sales@foxypower.com

Inductive Energy Harvesting

By bringing together TCT's engineering expertise in ferromagnetic cores with e-peas' popular AEMS series of ultra-low power PMICs, the two companies have been able to develop an innovative energy harvesting platform that is based on induction. The demonstration

will consist of a compact TCT current generator accompanied by an e-peas AEM30940 PMIC. This current generator will be placed onto an electricity cable (carrying a few amps of AC current). Through induction it will be able to harvest energy from the AC current passing through the cable, with the AEM30940 (in combination with a semi-active rectifier) converting and managing the current delivered. The DC current will subsequently be used to power a connected hardware device comprising multiple sensors and Bluetooth Low Energy (BLE) beacon connectivity. An LED indicator is included to show that this is in operation. The 3µW cold start power of the AEM30940, which is much lower than competing solutions, will prove pivotal in allowing energy to be efficiently harvested from the AC source. Also, thanks to low internal leakage exhibited by this PMIC, it will be able to take care of the storage of extracted energy and provide a regulated voltage to the connected low-power hardware. The AEM30940's linear converters provide two independents regulated voltages, which thereby eliminates the need of any additional converters.

www.e-peas.com

Capacitors Pulsed Power Applications

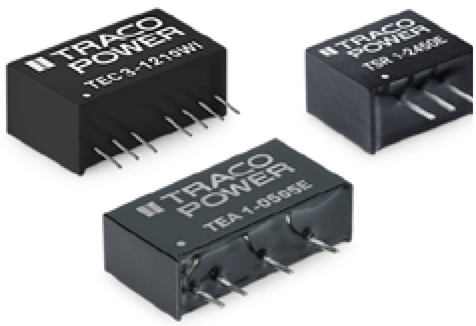
Cornell Dubilier Electronics announces a major product expansion of standard and custom high energy storage, pulse-discharge capacitors. These are specialized devices, designed for applications requiring repetitive high energy and high voltage charge/discharge cycles.

The capacitor technology is based on film dielectric with self-healing metallized or high current discrete foil electrodes, depending upon application requirements. There are both dry and oil-impregnated types, offered with a broad range of plastic or metal packaging configurations and a variety of terminal options.
Designed to deliver large amounts of energy in short bursts, these devices are aimed at end-product applications in external defibrillators, industrial lasers, critical military applications, pulse forming networks and more. These specialized markets are growing more rapidly than many others in power electronics, and often require custom products. Reliability of these capacitors is paramount, and must therefore be designed, constructed, and tested to deliver consistent performance over the life of the application. Due to the critical nature of their applications, CDE stresses the need to gain a thorough understanding of the performance requirements and will work collaboratively with customers to develop an optimal solution. Designs are typically qualified after considerable testing by CDE and in the customers' own testing programs. Cornell Dubilier's high energy storage, pulse-discharge capacitors are designed and built in the USA, with voltage ratings up to 100 kV and peak discharge current ratings of up to 250 kA.

www.cde.com

"Low-Cost" DC-DC Converter

The TSR-E, TEA, TBA and TEC series from Traco Power are available from 1 to 3 watts covering 12 new product families. They all focus on a simple and effective design approach which is unique to those Traco Power Products. By innovative engineering we have come up with an electrical design which minimizes component and labor costs. Key focus of those designs was to maximize the amount of automatization of the manufacturing process. With this innovative product design, we optimized the automation of the manufacturing process to the maximum. This enabled us to launch cost and quality optimized, low power dc- dc converters which are ideal for your high volume IoT projects. Key specifications of the TSR-E, TEA, TBA, TEC DC-DC converters are standard I/O isolation of 1500VDC with optional 4000VDC, -40°C to +86°C operating temperature range without derating, Available input ranges +/-10%, 2:1 and 4:1, Industry-standard SIP-4, SIP-7 and SIP-8 packages.



www.tracopower.com

Glass Reinforced Thermoset Multi-Thickness Bondply

Rogers Corporation's RO4450T™ bondply offers designers a spread glass reinforced bonding material in seven thickness options ranging between 0.0025” (0.064mm) and 0.006” (0.152mm), improving flexibility for high multilayer board count designs.

RO4450T glass reinforced thermoset bondplies were developed for wireless circuit designers looking for a better performing and more reliable alternative to FR-4 materials. The thermosetting hydrocarbon ceramic resin system facilitates a high post cure Tg, making these materials an excellent choice for multilayers requiring sequential laminations as fully cured RO4400 bondplys are capable of handling multiple lamination cycles.
In addition, FR-4 compatible bond requirements permit RO4450T bondply and low flow FR-4 bondply to be combined into non-homogeneous multilayer constructions using a single bond cycle. RO4450T bondplys are recognized by Underwriter Laboratories with the UL 94 V-0 flame rating, and are compatible with lead-free processes.

www.rogerscorp.com

10kw SMPS Transformer

Payton Planar introduces a High Voltage Planar Transformer with PARTIAL DISCHARGE extinction voltage (<10pC) of 10kV between primary, secondary and core. The total output power is 10kW at 250kHz and 400V input voltage. The output is 95V at 100Amps. The topology is full bridge with -55°C to 150°C operation. Power dissipation is 80Watts at 99.2% efficiency. The size is L:100mm, W:80mm, H:40mm. The weight is less than 600grams.

www.paytongroup.com

Real-time Spectrum Analyzers

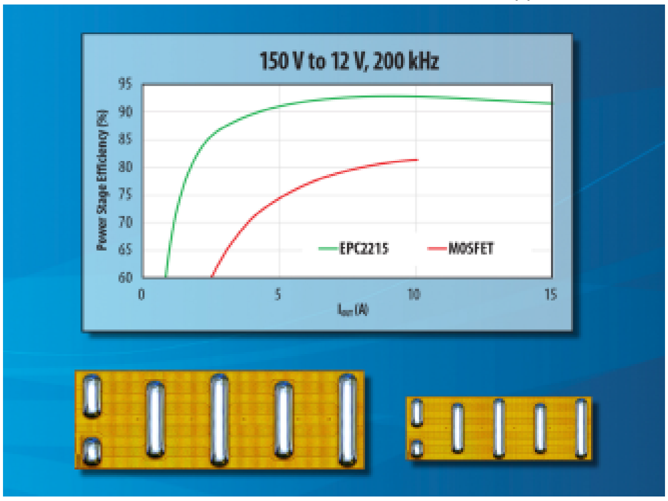
RIGOL Technologies is expanding its real-time spectrum analyzers series RSA5000 and RSA3000 with a VNA option (Vector Network Analyzer). The devices are based on the UltraReal technology developed by Rigol. This platform allows real-time measurements and more. The RSA5000N and RSA3000N series now have the integrated VNA function as standard and are characterized by their compact and elegant design and operation via touchscreen for even more diverse applications. The instruments are available in different bandwidths from 9 kHz to 1.5 GHz or even up to 6.5 GHz. The RSA5000N and RSA3000N series have a modular structure and, in addition to the new VNA function, also include the four well-known function modules RTSA (real-time spectrum analyzer up to a maximum bandwidth of 40 MHz), GPSA (sweep-based spectrum analyzer with outstanding performance), EMI (pre-compliance tests according to CISPR specifications) and VSA (vector signal analysis for different digital demodulation and bit error measurement, only RSA5000N).

Real-time spectrum analyzers are executing important functions in many test laboratories and they are often equated to high costs. The extended basic performance series RSA5000N or RSA3000N is a cost-effective alternative for users with demanding analysis tasks and at the same time limited budgets. This fully equipped instrument features fully digital IF technology (Intermediate Frequency) for accurate and high-resolution measurements across the entire frequency range from 9 kHz to 6.5 GHz.

www.rigol.com

Performance of FET Family Doubled

EPC advances the performance capability while lowering the cost of off-the-shelf gallium nitride transistors with the introduction of the EPC2215 and EPC2207 200 V eGaN FETs. The applications



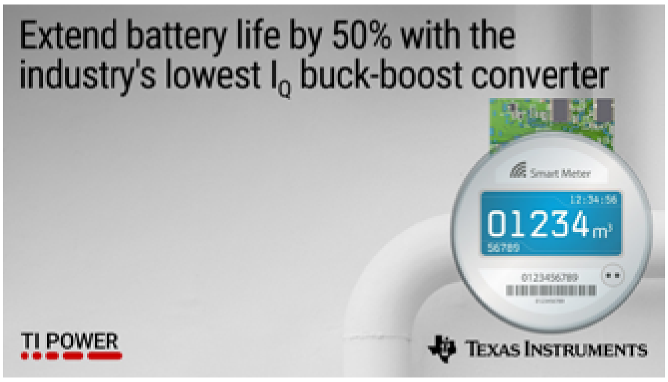
for these devices include class-D-audio, synchronous rectification, solar MPPTs (maximum power point tracker), DC-DC converters (hard-switched and resonant), and multilevel high voltage converters. The EPC2215 (8 mΩ, 162 Apulsed) and the EPC2207 (22 mΩ, 54 Apulsed) are about half the size of the prior generation 200 V eGaN devices and double the performance. The performance advantage over a benchmark silicon device is even higher. The EPC2215 has 33% lower on-resistance, yet is 15 times smaller in size. Gate charge (QG) is ten times smaller than the silicon MOSFET benchmark with the new technology, and like all eGaN FETs, there is no reverse recovery charge (QRR) enabling lower distortion class D audio amplifiers as well as more efficient synchronous rectifiers and motor drives. According to Alex Lidow, EPC's co-founder and CEO, "This latest generation of eGaN FETs achieve higher performance in a smaller, more thermally efficient size, and at a comparable cost to traditional MOSFETs. The inevitable displacement of the aging power MOSFET with GaN devices is becoming clearer every day."

www.epc-co.com

DC/DC Buck-Boost Converter Extends Battery Life

Texas Instruments introduced a DC/DC buck-boost converter to combine programmable input current limit and integrated dynamic voltage scaling to extend battery life by at least 50%. The TPS63900 maintains the low quiescent current (IQ), 75 nA, with 92% efficiency at 10 µA and delivers up to three times more output current than competing devices to help engineers extend the life span of battery-powered industrial and personal electronics applications.

It is a common challenge for engineers to design for low IQ while providing enough output current to send signals between connected smart grid applications and a network via commonly used radio-frequency standards, such as narrowband Internet of Things (IoT), Bluetooth® Low Energy, and long-range and wireless M-Bus. The TPS63900 helps engineers conserve energy in wirelessly connected applications that run on batteries. It integrates dynamic voltage scaling to deliver power while keeping the system at the minimum voltage required to operate efficiently, maximizing battery life and reducing required maintenance for industrial applications. This feature enables design engineers to optimize power architectures for ultra-low-power sensors and wireless connectivity integrated circuits, supporting



applications that can operate for at least 10 years using the primary battery. For example, the buck-boost converter can be paired with TI's MSP430FR2155 in security sensors or wireless IoT sensors to monitor the vibration of water pumps for predictive maintenance and help drive down costs.

www.ti.com

High-Voltage Home Storage System

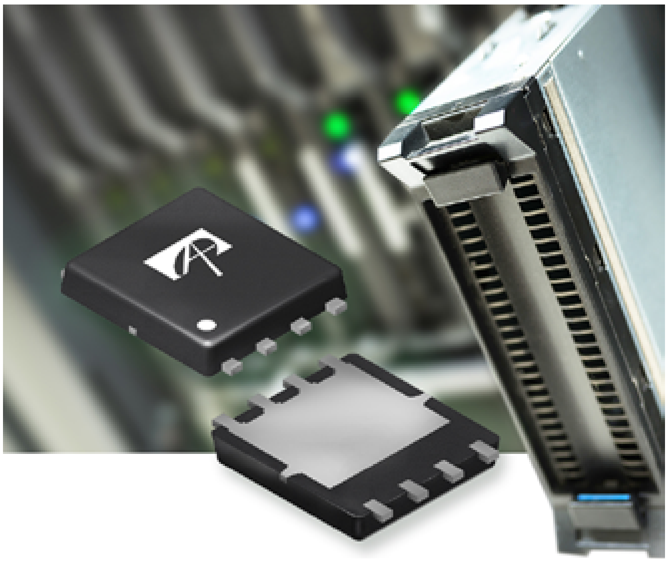
The BMZ Group is starting the delivery of HYPERION home storage systems and is completing its product range in the "Green Energy" area with the innovative high-voltage home storage system - a modular, expandable system for the residential market on a 300 volt basis. The modular structure enables the installer to assemble quickly and easily and the operator a high degree of flexibility and cost security, since the system can be subsequently expanded with the modules without great effort. The HELIOS modules deliver 2.5 kWh and can therefore range from a basic configuration of 7.5 to max. 15 kWh usable energy content can be expanded in one housing. This has now resulted in a storage system that can not only be integrated into today's design, but above all maximizes the yields over the entire service life. Our Green Energy products, especially of course the flagship HYPERION, are developed in Germany and are also built here. Caption: High-Voltage-System Hyperion, modular structure and primarily located in the home storage area. "After an intensive dialogue with installers and end users, the HYPERION system was developed, which is one of the top devices in today's solar storage market. Not only the price of the hardware is relevant for us, but above all the manageable acquisi-

tion and installation costs as well as low maintenance and follow-up costs have been given to the engineers of the BMZ Group as a guideline. "Sven Bauer, CEO and founder of the BMZ Group, sums up.

www.bmz-group.com

SOA MOSFET for 12V Hot Swap Applications

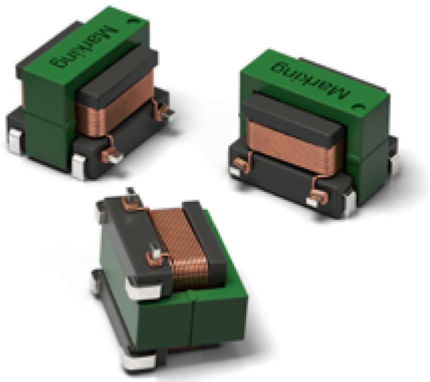
Alpha and Omega Semiconductor announced the release of, AONS32310, a 30V MOSFET with low on-resistance and a high Safe Operating Area (SOA) capability which is ideally suited for demanding applications such as hot swap and e-fuse. A high SOA is essential in server hot swap applications where the MOSFET needs to be robust to manage the high inrush current effectively. AONS32310 delivers high robustness with a 30V MOSFET in a DFN 5x6 package. The AONS32310 has a maximum Rds(on) of 1.05mΩ at an applied Gate-Source Voltage equal to 10VGS. "High reliability is an essential metric in datacenter infrastructure. The Hot Swap MOSFET is one of the critical components that must be robust and reliable to meet server demands. AONS32310 has high SOA with low on-resistance to meet these demanding application requirements," said Peter H. Wilson. The AONS32310 is immediately available in production quantities with a lead-time of 16 weeks.



www.aosmd.com

Current Sense Transformers

Würth Elektronik expands the product family of WE-CST current sense transformers with the new WE-CST EE4.4 series. An innovative manufacturing process not only makes these current sense transformers extremely small (4.7 x 4.65, 3.55 mm), but also provides better insulation. Their insulation voltage of 750 VAC, is 50 percent higher than that of market competitors. The WE-CST series type EE4.4 is suitable for a broad range of high frequency applications up to 1 MHz with currents up to 7 A. Applications for the minute SMT-mountable current sense transformers include AC current measurement, switched mode power supplies, overload detection, load shedding and disconnect detection, metering, load measurement and high frequency current sensing. The current sense transformer displays excellent temperature behavior and is approved for the operating temperature range of -40 to +125°C. WE-CST EE4.4 is available from stock in four different winding ratios from 1:20 to 1:150. Five further variants are set to be added in August. Developers can receive free samples on request. Würth Elektronik does not specify a minimum order quantity.



www.we-online.com

Silicon Carbide MADK Board for Servo Drives

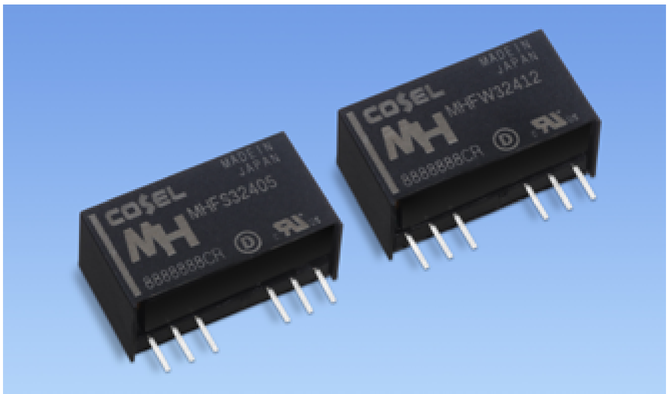
In power electronics motor drives take up a major share in the market. With its CoolSiC™ MOSFET Modular Application Design Kit (MADK) boards Infineon Technologies helps in further shortening time to market in this relevant segment. As part of the MADK platform for motors of up to 7.5 kW, the evaluation board EVAL-M5-IMZ120R-SIC is a 3-phase inverter board aiming at servo drive applications. As a true first, Infineon offers details about schematics (PDF), parts (Excel), layout (Gerber), and design package (Altium) as download package on the company's website. In this way, the board can also serve as a reference design facilitating the design process.

For servo drive applications, silicon carbide reduces semiconductor power losses by up to 80 percent. Making use of this technology can lead to zero maintenance of drives since fans might not be needed for cooling. Additionally, it allows the integration of motor and drive with less complex cabling making inverter cabinets redundant. The evaluation board was developed to support customers during their first steps designing applications with the CoolSiC™ MOSFET 1200 V in discrete packages (IMW120R045M1) and EiceDRIVER™ 1200 V isolated gate driver (1EDI20H12AH). The assembled discrete has a rated blocking voltage of 1200 V at a typical on-state resistance of 45 mΩ, the board supports all CoolSiC™ MOSFETs in 3pin and 4pin TO247 packages.

www.infineon.com

3W High Isolation DC/DC Converters

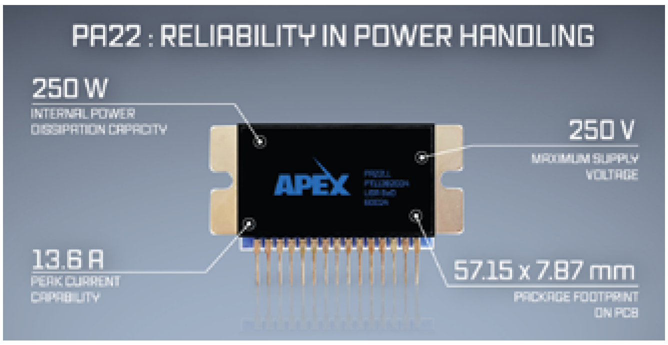
COSEL announced the addition of a series of high isolation 3W DC/DC converters for medical and industrial applications. Packaged in a Single In Line (SIP) type 8, the COSEL MH3 series has a reinforce isolation of 3kVAC, 4.2KVDC, complies with medical isolation standard (2MOOP (250VAC)) and ruggedized for industrial applications that might implies differential In/OUT voltage. Three input voltages (4.5V-18V ; 9V – 36V and 18V -76V) and a large variety of single (MHFS3) and dual output (MHFW3) cover a large range of applications. Designed for performances, the MH3 has only 20pF max insulation capacitance reducing noise transfer. The COSEL MH3 is a unique design from COSEL, manufactured in Japan and covers by a 5 years warranty. Designed with high reliability in mind, the COSEL MH3 series has a reinforced insulation, sustains 3kVAC and 4.2kVAC isolation test in accordance to safety standards and its transformer designed to sustain differential voltage that might happen in industrial applications. With long expertize in designing power supplies for equipment using IGBT drivers, COSEL designers applied high-power high-isolation best practice to the low power 3W MH3 series to reduce isolation fatigue resulting from differential high voltage happening in motor control or IGBT driver.



www.coseleurope.eu

High Precision Linear Power Amplifier

The PA22 from Apex Microtechnology offers exceptional power handling capability by meeting high supply voltage demands, driving substantial current levels, and providing a remarkable internal power dissipation capacity. The PA22 delivers these features in a space-saving SIP package, providing users with a new standard of linear power amplifier for high pulse current applications. The device provides a peak current capability of 13.6 amps, can handle a maximum supply voltage of 250 volts, and offers an internal power dissipation of 250 watts. Its novel design allows for easy and reliable mechanical mounting and thermal interfacing with industry standard heat sink techniques, also enabling strong performance even when socketed. This amplifier is equipped with output temperature sensing and current limit, providing users further control in its operation and system integration.

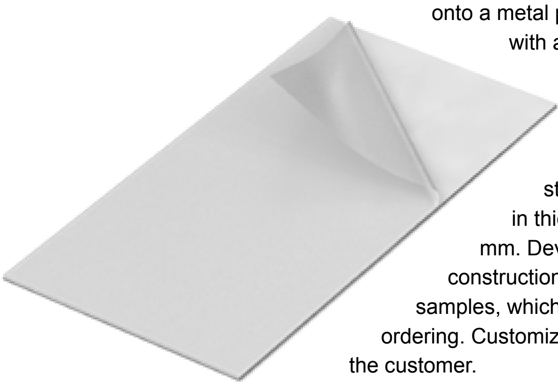


"PA22 is designed to withstand fault conditions on system side for a certain time without catastrophic impact on its functionality.", says Director of Business Development, Jens Eltze. "The device underlines again our commitment to supporting our markets and customers with products that solve difficult analog power challenges".

www.apexanalog.com

Thermoconductive Gap Filler

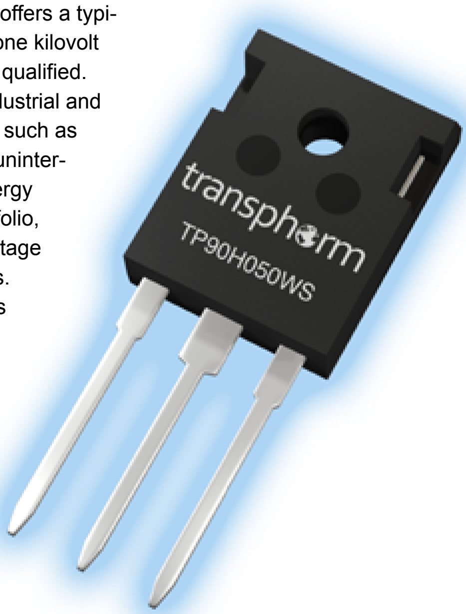
With its WE-TGF (Thermal Gap Filler) Würth Elektronik now offers a solution for heat dissipation. The outstanding feature of the self-adhesive gap-filler material: The non-conductive barrier with a high dielectric strength has a high thermoconductivity index of 1 W/(m*K). The material easily adapts to the differing thicknesses of components on the PCB and fills the gaps between hot electronic components and metal casings or cooling components. WE-TGF is made of silicone incorporating ceramic particles. For applications in which the PCB is screwed onto a metal plate, the material is also reinforced with a glass-fibre mesh. The thermoconductive gap filler is suited for use e.g. in power electronics, entertainment technology, or in networking devices. WE-TGF is available ex stock in a variety of dimensions and in thicknesses ranging from 0.23 to 5 mm. Developers working in the prototype construction area can request individually cut samples, which are shipped within 48 hours of ordering. Customization comes at no extra charge for the customer.



www.we-online.com

900 V GaN FET is Now in Production

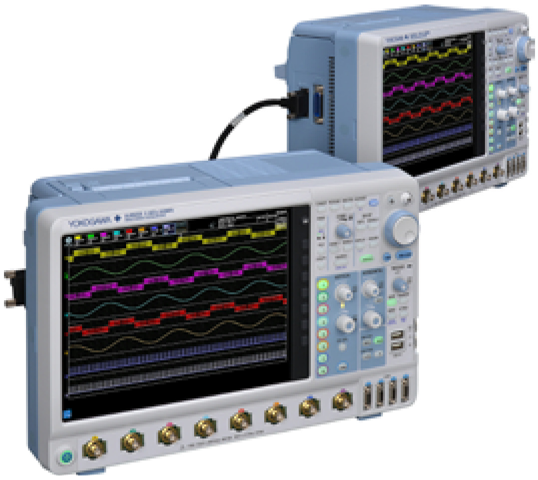
Transphorm Inc. announced its second 900 V GaN FET is now in production. The TP90H050WS offers a typical on-resistance of 50 milliohms with a one kilovolt transient spike rating and is now JEDEC qualified. The primary target markets are broad industrial and renewable energy, including applications such as photovoltaic inverters, battery charging, uninterruptable power supplies, lighting and energy storage. Additionally, with the 900 V portfolio, Transphorm is working its way up the voltage range to include three phase applications. Introduced last year, the TP90H050WS is the company's second 900 V device following the TP90H180PS. The two-chip normally-off power transistor delivers a ±20 V gate robustness in a standard TO-247 package, increasing its reliability and designability for power systems. The combination of Transphorm's high-speed GaN and the thermally robust TO-247 package enables systems to reach greater than 99 percent efficiency while generating up to 10 kW of power in typical half bridge configurations with bridgeless totem-pole power factor correction (PFC). "Transphorm's work on its 900 V platform illustrates the capability of high voltage gallium nitride power transistors," said Philip Zuk, VP of Technical Marketing and NA Sales, Transphorm. "This device gives us the ability to support applications that were not previously accessible to us. We have received strong interest when sampling these 50 milliohm FETs. We're proud to say that their availability status has shifted now to high-volume production to meet customer demand."



www.transphormusa.com

Mixed Signal Oscilloscopes for Automotive, Mechatronics, and Electronics

The DLM5000 oscilloscopes from Yokogawa are successors to the eight-channel DLM4000 series mixed signal oscilloscopes, and feature a number of improved functions and enhanced operability. In addition, a DLMsync option is planned to be released by next spring

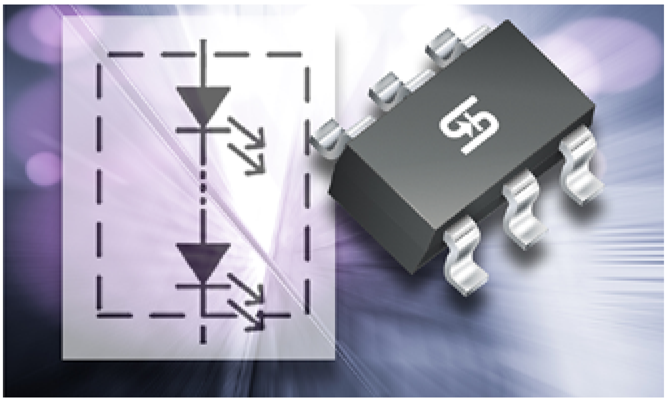


that will enable measurements to be taken simultaneously by two connected DLM5000 oscilloscopes. The DLM5000 series is targeted at developers of new automotive, mechatronics, and electronics products, and may be used in combination with Yokogawa Scope-Corders, power analyzers, and other products. The DLM5000 series models have either four or eight analog input channels. With a single DLM5000 oscilloscope, it is possible to simultaneously view signals and inputs from up to eight analog signals and a 16 bit logic channel (32 bit logic channel available as an option). When simultaneously measuring inputs from all analog channels, each of the two models can maintain a maximum sampling rate of 2.5 GS/s (giga sampling/second), twice the speed of the DLM4000 series. With the optional DLMsync function that is planned to be released by next spring, it will be possible to simultaneously and accurately measure signals from up to 16 analog channels and two 32 bit logic channels (with the optional function enabled) by connecting two DLM5000 oscilloscopes. This is sufficient for and offers great flexibility with the debugging of embedded systems.

www.yokogawa.com

Linear Constant-Current CMOS Driver IC

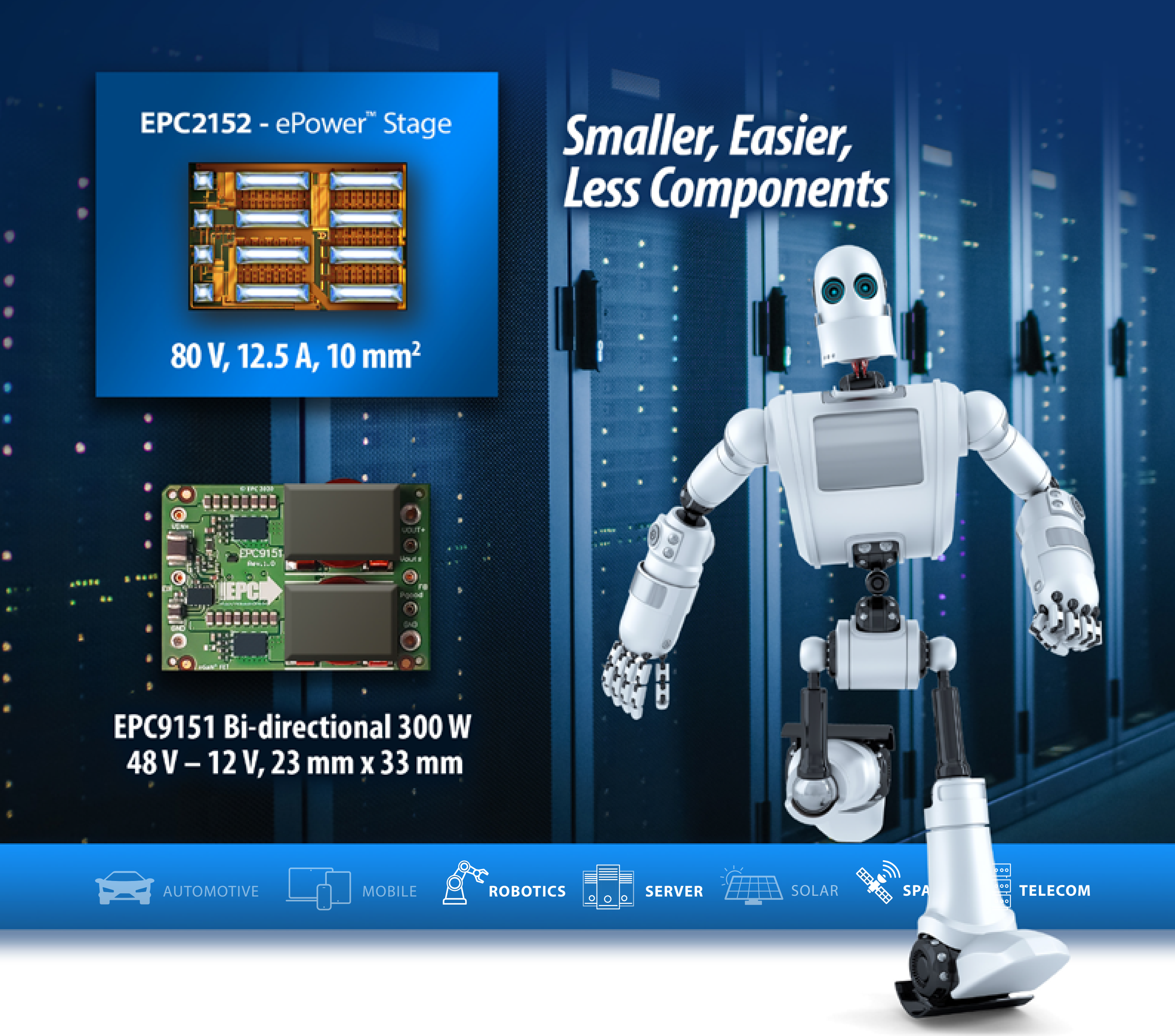
Taiwan Semiconductor announces the availability of the TSCR4 family of linear CMOS LED driver ICs, providing a much improved performance drop-in replacement for legacy bipolar drivers. These constant current drivers provide stable LED current over a wide range



of conditions including source voltage variations, changes in load or temperature variations. Compared to legacy bipolar LED drivers, the TSCR4 family offers higher current setpoint accuracy and stability, lower quiescent current, tighter output compliance voltage and improved temperature coefficient. These ICs enable upgrades of existing designs for higher performance with no re-design effort required. “The TSCR4 family of LED driver ICs is the perfect part to upgrade a legacy design,” reported Sam Wang, Vice President, TSC Products. “The features and performance of these devices at an affordable price point make them an excellent candidate for new designs, as well.” Applications include automobile, truck and bus interior and exterior lighting, architectural lighting, signage, advertising and decorative lighting, lighting in refrigerators, freezer cases, kiosks and vending machines, emergency lighting (EXIT signs, stairstep and emergency exit pathway lighting systems).

www.taiwansemi.com

Advertising Index



EPC2152 - ePower™ Stage
80 V, 12.5 A, 10 mm²
Smaller, Easier,
Less Components
EPC9151 Bi-directional 300 W
48 V – 12 V, 23 mm x 33 mm
AUTOMOTIVE
MOBILE
ROBOTICS
SERVER
SOLAR
TELECOM