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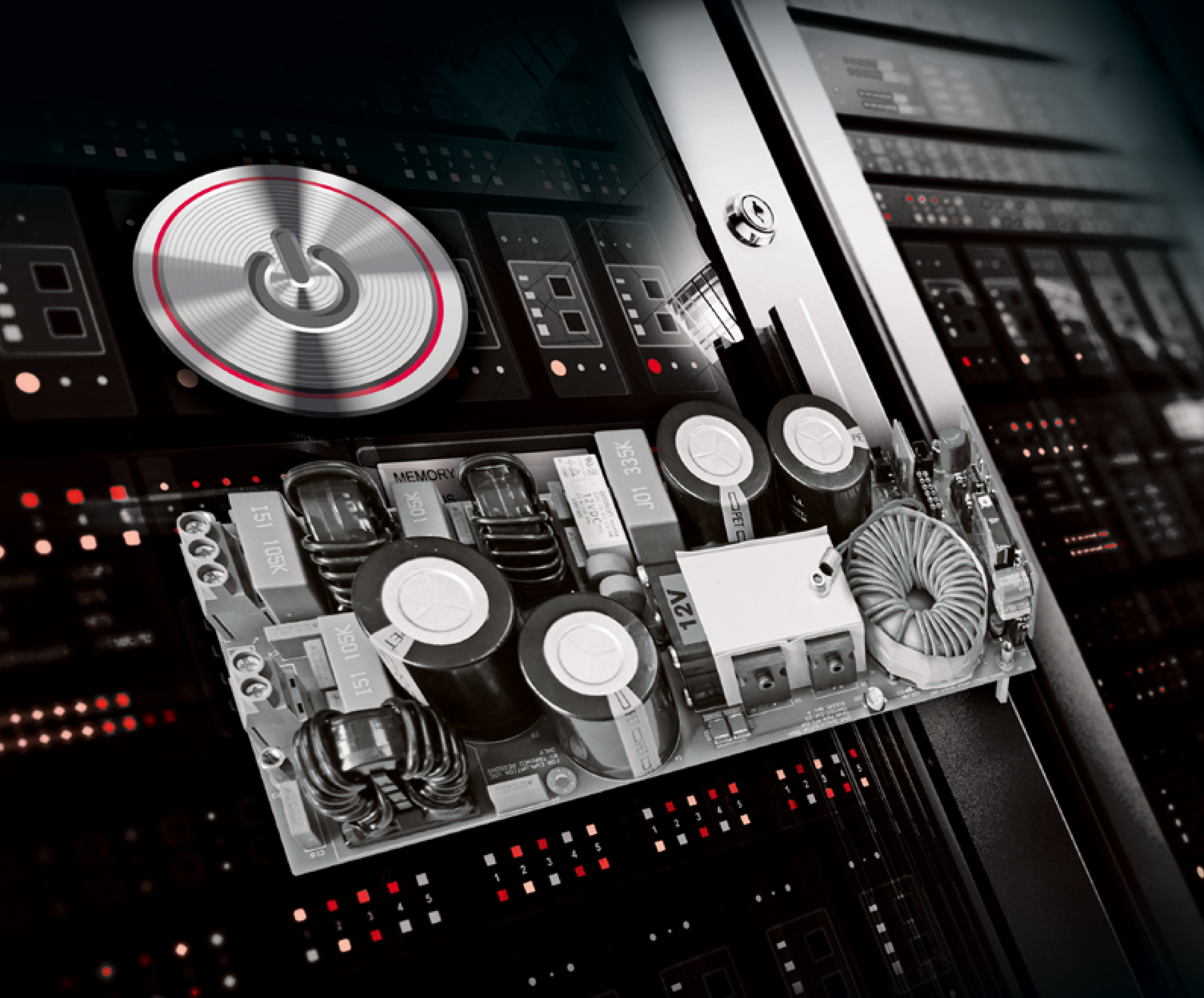
Bodo´s Power Systems®

Electronics in Motion and Conversion

October 2022



4th Generation SiC MOSFET in Totem Pole PFC for High-Performance SMPS

PULSED INDUCTANCE MEASUREMENT

POWER CHOKE TESTER DPG10/20 SERIES

Inductance measurement from 0.1 A to 10 kA

KEY FEATURES

Measurement of the

- **Incremental inductance** $L_{inc}(i)$ and $L_{inc}(\int Udt)$
- **Secant inductance** $L_{sec}(i)$ and $L_{sec}(\int Udt)$
- **Flux linkage** $\psi(i)$
- **Magnetic co-energy** $W_{co}(i)$
- **Flux density** B(i)
- **DC resistance**

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- **Lightweight, small and affordable price-point** despite of the high measuring current up to 10000A
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- **Development, research** and **quality inspection**
- **Routine tests** of small batch series and mass production

Technological leader in pulsed inductance measurement for 18 years

www.ed-k.de

Content

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Show Season has Begun

After two years without any live events, things are moving back towards normality in 2022. PCIM Europe and Embedded World were the tests for all of us and worked very well. I have to admit that I was very skeptical back in May when we packed our car and drove to Nuremberg. Of course, not everything is as it was before Covid, but my impression is that things are back on the right track. This was our experience last month, in Hannover, when we visited the EPE ECCE. By the way, this was one of the very few events in our area where we didn't need to take more than an 2 hour-long car ride. It was very well organised and the start of the trade fair season for us this autumn. Most of the established events are still alive and coming back, I recommend that you check out the extensive events calendar on our website to search for the ones that are of interest to you. To name but a few: ECCE, IEDM and WiPDA are in the US, and SEMICON Japan, PCIM Asia and a Wide Bandgap Forum by Bodo's Power China in Asia. Europe, which traditionally has some of the biggest trade fairs, will host SPS in Nuremberg and of course Electronica in November - the one I know that many of you have been waiting for over the last few years. In fact, so have I, and I'm really looking forward to Munich. And while there weren't too many Asian visitors at the earlier events, my recent visit to InnoTrans in Berlin showed that travel has become possible again from some areas in Asia. Of course, this can change from one day to the next and I really hope that this text is not obsolete after it has been published.

Speaking of events: Our Wide Bandgap event this year is developing fantastically. Most of last year's speakers have already confirmed their participation, and we also have many new companies presenting their technology approaches. If you haven't received an invitation to speak and

would like one, please get in touch. There are not many slots left, and I'm not saying this for marketing reasons or to sell you something, but to advise you to be quick if you're interested! If you need further information about our event, please go to www.bodoswbg.com where you can also find last year's presentations. You won't regret it!

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 our clients in North America. If you speak the language, or just want to have a look, don't miss our Chinese version at bodospowerchina.com.
An archive of my magazine with every single issue is available for free at my website bodospower.com.

My Green Power Tip for the Month:
Cold season is coming, and we all suffer from the increased cost for energy. Thoughtful use of heating is more important than ever. Turning off the systems completely is usually not economical; restarts may cause high consumption.

Best regards

Events

eMove 360° 2022
Berlin, Germany October 5 – 7
www.emove360.com

ECCE 2022
Detroit, MI, USA October 9 – 13
www.ieee-ecce.org/2022

Wide Bandgap Forum 2022
Shenzhen, China October 13
https://wbg.dldz360.com

ICECS 2022
Paris, France October 27 – 28
https://ogy.de/icecs

WiPDA 2022
Redondo Beach, CA, USA November 7 – 9
https://wipda.org

BEVA 2022
Munich, Germany November 8 – 9
www.beva-europe.com

sps 2022
Nuremberg, Germany November 8 – 10
www.sps-exhibition.com

electronica 2022
Munich, Germany November 15 – 18
https://electronica.de

SEMICON Europa 2022
Munich, Germany November 15 – 18
www.semiconeuropa.org

Motor Drive Center of Excellence Opened in Turin

EPC has opened a design application center near Turin, Italy, to focus on growing motor drive applications based on GaN technology in the e-mobility, robotics, drones, and industrial automation markets. The specialist team will support customers in accelerating their design cycles and define future Integrated Circuits for power management with state-of-the art equipment to test applications from 400 W to 10's of kW. Strategically located, Turin has a historical tradition in electric motors and motor drives enabling the company to draw on the wealth of local technical talent. EPC's engineers are helping customers reduce their design cycle times and adopt GaN for more efficient, smaller, lower-cost systems. Moreover, the center is exploring ways to exploit the potential of EPC's GaN technology in motor drive applications to enable a substantial increase in the efficiency of the motor, leading to higher power density designs than what has been possible with historically MOSFET-based designs.

Turin also features the Power Electronics Innovation Centre, a cross-department entity in the Politecnico di Torino - one of the most important technical Universities in Europe - and EPC is collaborating closely with PEIC by investing in shared research and development. The facility is headed by Marco Palma, EPC's Director of Motor Systems and Applications. Commenting on the opening he said, "Our new facility combines a comprehensive GaN product portfolio and design expertise offering customers a center of excellence that is unrivalled for motor drive applications. Its location is key too, as Europe is driving the green revolution in the e-mobility market, by using the Euro 7 standard in the short term and by banning internal combustion engines by 2035. This is definitely the right time to invest in higher power density motor solutions that avoid un-necessary energy waste."

www.epc-co.com

Green Light for Joined Company

SEMIKRON DANFOSS

SEMIKRON and Danfoss Silicon Power are joining forces to establish the ultimate partner in power electronics. On August 22, less than five months after it was first announced, Semikron Danfoss started doing business.

With an existing workforce of more than 3,500 dedicated power electronic specialists, Semikron Danfoss will provide technology expertise to its loyal customer base. The merger comes with a strong growth plan and a firm commitment to future investments, paving the way for green growth and a more sustainable, energy efficient, and decarbonized future.

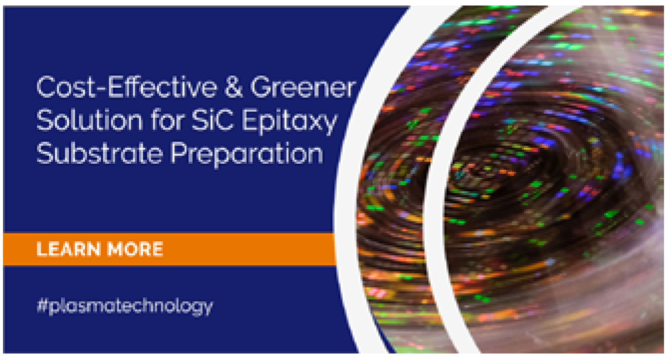
The newly formed Semikron Danfoss joint business will be owned by the current owner-families of SEMIKRON and the Danfoss Group, with Danfoss being the majority owner. Semikron Danfoss will retain the two main locations in Germany, Nuremberg and Flensburg. All global subsidiaries, production sites, as well as distribution channels will continue.

Claus A. Petersen, has been appointed CEO of Semikron Danfoss. "Semikron Danfoss will inspire the future. The timing of the new company is perfect. With strong growth in our key markets – automotive, industry and renewables – the merger is a great opportunity for customers, partners, and our employees. Also, with the emerging technology transition from Silicon to Silicon Carbide, we are set to become the strongest partner of our customers."

www.semikron.com

SiC Epitaxy Substrate Prep Solution

Oxford Instruments Plasma Technology announce an alternative method of preparing SiC substrates for epitaxy. Plasma polishing for SiC substrates has been demonstrated as a HVM compatible alternative to Chemical Mechanical Planarization (CMP), while alleviating significant technical, environmental and supply-chain issues associated with CMP.



The Oxford Instruments' Plasma Polish Dry Etch (PPDE) process is a direct plug and play replacement for CMP and easily integrates into existing process flows. CMP has been the process of record for SiC substrate preparation for many years, but suffers from undesirable operational issues and the industry as a whole is struggling to meet increasing demand for SiC substrates. Operating CMP in SiC substrate fabs has a large environmental footprint due to the semi-toxic slurry biproduct, and the heavy water usage that the process demands is wasteful. In addition, the polishing pads and speciality chemicals bring significant consumable cost in a challenging supply chain environment. Furthermore, the CMP process is inherently unstable as slurry chemicals and polishing pads are consumed, introducing drift into the process line. PPDE is a stable non-contact process, which reduces handling loss and allows for the processing of thinner wafers, producing more wafers per boule and enabling the progression to 200mm SiC substrates.

www.oxinst.com

Acquisition Completed

Allegro MicroSystems announced the completion of its previously-announced acquisition of Heyday Integrated Circuits (Heyday). Heyday is a privately held company specializing in compact, fully integrated isolated gate drivers that enable energy conversion in high-voltage gallium nitride (GaN) and silicon carbide (SiC) wide-bandgap (WBG) semiconductor designs. This acquisition brings together Heyday's isolated gate drivers and Allegro's isolated current sensors to enable some of the smallest high-voltage and high-efficiency power systems available on the market today. Additionally, this acquisition is expected to increase Allegro's addressable market for electric vehicles (xEV), solar inverters, datacenter and 5G power supplies, and broad-market industrial applications.

"The demand for simplified power management is increasing across the board, and high-voltage isolated gate drivers are fundamental for enabling technology for the future of high-efficiency power system designs" said Joe Duigan, Senior Director, Engineering and Business Development. "Together with Allegro's market leading current sensors and Heyday's isolated gate drivers we will be able to power the increasingly popular GaN and SiC MOSFET driven systems."

"We're thrilled to welcome Heyday to the Allegro family," said Vijay Mangtani, Vice President of Power ICs at Allegro. "This acquisition will greatly accelerate our efforts to deliver a market leading energy efficient technology platform for high-voltage designs in advanced mobility, clean energy, and motion control solutions."

www.allegromicro.com

Cell Phones with Inbuilt GaN Charging Protection

Innoscience Technology announced the Bi-GaN series of bi-directional GaN HEMT devices that save space and facilitate fast charging without suffering from reliability-limiting and potentially dangerous rises in temperature that can sometimes be seen in traditional silicon devices. Innoscience has also revealed that OPPO is using the BiGaN devices inside its phone handset to control the battery's charging and discharging currents. This is the first time that such protection, based on GaN technology, has been included in the phone itself – previously the circuitry had to be incorporated inside the charger. Until recently, silicon MOSFETs have been used as power switches in cell phones. However, these traditional devices not only occupy significant space on a cell phone's main PCB where every millimeter counts, they may also result in considerable temperature rises and power loss when fast-charging. InnoGaN has advantageous characteristics such as high frequency, high efficiency and low resistance, which are vital for efficient charging.

Thanks to InnoGaN's low RDS(on), the fact that it does not have parasitic diodes, and the unique bidirectional feature of Innoscience's BiGaN technology, one BiGaN HEMT can be used to replace back-to-back connected NMOS MOSFETs in a common-source configuration to achieve bi-directional switching of the battery's charging and discharging currents. This reduces on-state resistance by 50%, chip size by 70%, and temperature rise by 40%.

www.innoscience.com

Silicon Carbide Materials Facility in North Carolina

Wolfspeed announced it will build a state-of-the-art, multi-billion-dollar Materials manufacturing facility in Chatham County, North Carolina. The investment is targeted to generate a more than 10 fold increase from Wolfspeed's current Silicon Carbide production capacity on its Durham campus, supporting the company's long-term growth strategy, accelerating the adoption of Silicon Carbide semiconductors across a wide array of end-markets and unlocking a new era of energy efficiency. The facility will primarily produce 200mm Silicon Carbide wafers, which axqre 1.7x larger than 150mm wafers, translating into more chips per wafer and ultimately, lower device costs. These wafers will be used to supply Wolfspeed's Mohawk Valley Fab, which opened earlier this year as the world's first, largest and only fully automated 200mm Silicon Carbide fabrication facility. Phase one construction is anticipated to be completed in 2024 and cost approximately $1.3 billion. Between 2024 and the end of the decade, the company will add additional capacity as needed, eventually occupying more than one million square feet on the 445-acre site.

"Wolfspeed is the industry leader in supplying the materials required to meet the accelerating demand for next generation semiconductors and creating a more sustainable future for all. Demand for our products continues to grow at a rapid pace, and the industry continues to be supply constrained. Expanding our Materials production will further our market leadership and allow us to better serve the growing needs of our customers," said Gregg Lowe, President and CEO of Wolfspeed.

www.wolfspeed.com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Go green +
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pdd.heu.eu

APEC 2023 Student Attendance Support Program Registration is Now Open

The joint sponsors of the Applied Power Electronics Conference (APEC) have announced the continuation of the popular Student Attendance Support Program for APEC 2023, scheduled to take place in Orlando, March 19-23. Chosen recipients of the program will receive reimbursement to cover qualified expenses for attending APEC 2023. Those eligible to apply for the program are power electronics students, undergraduate or graduate, who have been accepted to present papers at the upcoming conference in March. Once accepted, student presenters must apply for the Student Attendance Support Program by October 26, 2022.

In its 18th year, this popular program was initiated by the Power Sources Manufacturers Association (PSMA). It is now jointly underwritten by PSMA and the other co-sponsors of the APEC conference: the IEEE Power Electronics Society (PELS) and the IEEE Industry Applications Society (IAS).

The recipients of the Student Attendance Support Program will be chosen by the APEC 2023 Student Attendance Support Committee. As part of the application process, students must provide information about their educational institution, degree program, the name

of their faculty advisor, as well as a brief description of their career interest and reasons for attending APEC. The application also requires the title and ID number of their accepted APEC paper, including the name(s) of the co-author(s), if applicable.

www.apec-conf.org

PCIM Asia 2022: New Date

In light of recent developments concerning the pandemic in Shanghai, PCIM Asia will now be held from 26 – 28 October 2022 in Hall E1 at the Shanghai New International Expo Centre. The show will continue to provide a platform for exchanging ideas, showcasing technologies and expanding business networks. This will be achieved through gathering the latest power electronics suppliers at the fairground and by exploring the latest trends through the fair's concurrent programme.

On behalf of the organisers, Mr Louis Leung, Deputy General Manager of Guangzhou Guangya Messe Frankfurt Co Ltd expressed: "We are pleased to have confirmed suitable dates for the rescheduling of the fair, which meet the needs of our stakeholders. Meanwhile, we are in contact with our local and international exhibitors and supporters to provide them with the necessary support to facilitate their participation. We are also prepared to put the necessary measures in place to ensure the wellbeing of all fairgoers during the course of the October fair."

https://pcimasia-expo.cn.messefrankfurt.com

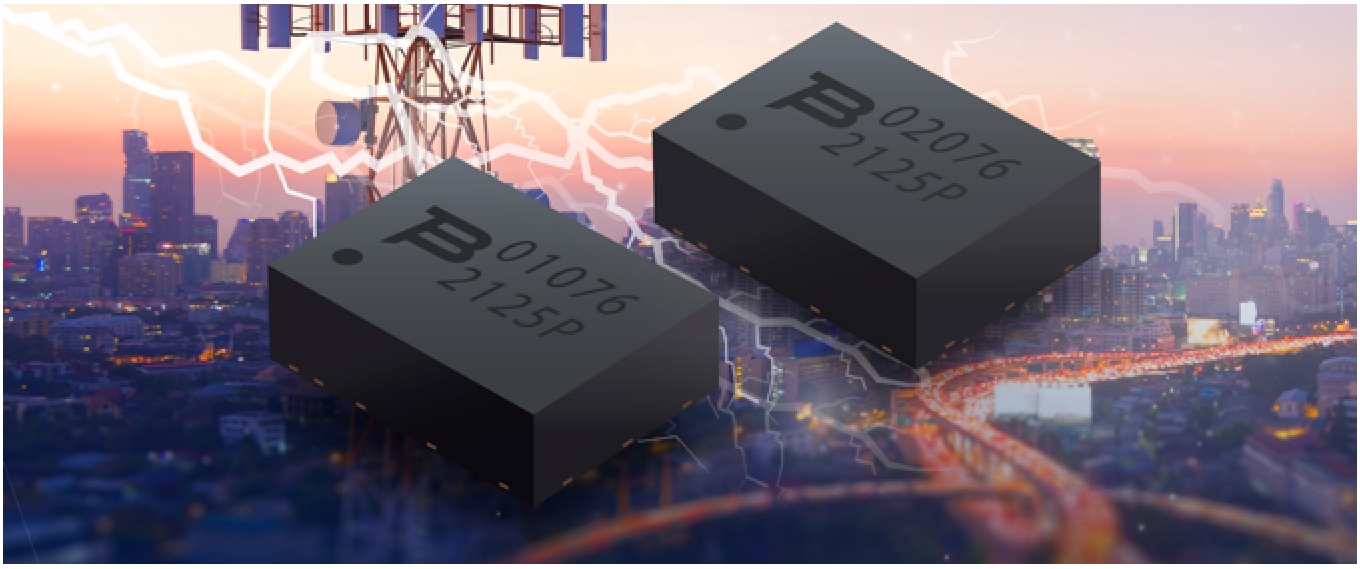
High Power next Core (HPnC)

with Fuji Electric‘s X series - 7G IGBT

MAIN FEATURES

- **Latest chip technology**
  - Fuji Electric‘s X series IGBT and FWD with low losses
- **High reliability**
  - CTI>600 for higher anti-tracking
  - High thermal cycling capability with ultra sonic welded terminals and MgSiC base plate
  - Improvement of delta T_j power cycle capability by using 7G Package Technology
- **RoHS compliance**
  - Ultrasonic welded terminals
  - RoHs compliant solder material
- **Over temperature protection**
  - Thermal sensor installed
- **Easy paralleling**
  - HPnC module has a minimized current imbalance
  - Easy scalability

PTVS Models Meet High Surge Current Protection Requirements in Smallest DFN Package



Bourns' recently announced Power Transient Voltage Suppressor (PTVS) diode devices in the industry's first SMT DFN packaging puts superior surge handling capability in a low-profile footprint that saves valuable design real estate. Measuring just 8mm x 6mm with a minimal height of 2.5mm, the Bourns PTVS1 and PTVS2 models allow designers the option of placing circuit protection on the back side of the PCB – a huge advantage compared to legacy PTVS solutions.

Designed to provide enhanced protection against a wide range of ESD, lightning and induced switching transient threats, Bourns' PTVS devices are excellent circuit protection solutions particularly well-suited for highly exposed applications such as PoE and telecom baseband units (BBUs) and remote radio units (RRUs). Rated for handling 1 kA or 2 kA 8/20µs surge current (IEC 61000-4-5) with each current rating offered in eight voltages from 22V to 86V, designers can select the precise protection strategy for their applications. Although their small size might suggest these are crowbar technology, they're actually bidirectional voltage clamping devices. These new PTVS products are at home on either AC or DC lines delivering power or control signals.

The applications that can benefit from highly reliable, compact surge protection also include:

- 28 VAC control lines used in residential, commercial, and industrial HVAC systems
- PoE for kiosks, security cameras, and other remote systems
- Nominal 48 VDC systems in server applications, remote Wi-Fi, 5G radio systems, and industrial charging systems
- 24 VDC industrial controls where failures can lead to expensive down time

Many PTVS devices are known to exhibit a "fold-back" voltage characteristic where the voltage across the device drops with increasing current that can allow power to flow from the power supply to the protection component.

Bourns engineers used silicon design modeling to create a highly controlled fold-back feature that results in ultra-low peak clamping voltages that avoid follow-on current. Peak clamping voltages are maintained above the minimum rated breakdown voltage and, at most, just a few volts above the maximum rated breakdown voltage.

Low clamping voltage means the circuit designer can minimize the voltage ratings required for downstream components and still maintain healthy design margins. This may allow for lower cost components downstream.

The optimized fold-back feature helps ensure uniform breakdown that minimizes "current crowding" during the surge event. Such current crowding reduces the active area of silicon handling the surge power. Minimizing this effect has another benefit – the smaller silicon die required translates into the small area footprint of the package.

Qualified to JEDEC standards, the key design specifications for Bourns' industry-first DFN packaged PTVS1 and PTVS2 products are highlighted below:

PTVS1 - PTVS2	Rated Voltage	Breakdown Voltage		Peak Clamping Voltage
		Minimum	Maximum	
PTVSx-022C-H	22	24	27	28
PTVSx-026C-H	26	28	32	30
PTVSx-029C-H	29	32	35	34
PTVSx-043C-H	43	48	53	56
PTVSx-058C-H	58	64	70	67
PTVSx-066C-H	66	72	80	86
PTVSx-076C-H	76	85	95	91
PTVSx-086C-H	86	96	105	99

www.bourns.com

EMC Lab and Services for Europe

Monolithic Power Systems recently opened its European EMC Lab in Ettenheim, Germany.

I had the chance to interview Jan Spindler, who is the responsible manager for the laboratory, and Julian Meier, marketing manager for MPS in EMEA. They introduced the process of setting up this state-of-the-art facility and the idea behind this project.

By Holger Moscheik, Bodo's Power Systems

Moscheik: Please introduce yourselves briefly. What are your responsibilities at MPS and the EMC lab? How long have you been at MPS, and what did you do before?

Spindler: I am the head of the EMC lab in Germany, as well as the new MPS location in Ettenheim, Germany. I started at MPS in 2019 with this project, so I have been involved in every step of the project, from planning the building and the lab, to starting operations in June 2021. Previously, I worked for an automotive manufacturer in Stuttgart; in particular, I worked with antenna development and EMC. Overall, I have been involved with EMC since 2009.

Meier: I have been with MPS since April 2021 and, as marketing manager, I am responsible for all marketing activities in EMEA. This includes cooperation with publications and magazines, marketing activities with our distributors, and anything else that concerns marketing. I studied business administration and electrical engineering at the Technical University of Munich, and I most recently worked for a Dutch/Chinese semiconductor company before joining MPS.

Moscheik: What was the reason for building this facility in Germany, and what are the goals for this facility?

Spindler: MPS has been pursuing EMC strategies and how to build our own locations for different markets since 2018. It started with the construction of our laboratory in Hangzhou, China. For the US and European markets, we developed plans for Detroit, USA and Ettenheim, Germany. The goal in each case was to build state-of-the-art laboratories and boost our testing capacities.

Moscheik: What can you say about the equipment in Ettenheim? What tests and services are available?

Spindler: Currently, we have 10 people working at our lab, with 4 of them working purely in the laboratory. These individuals work on EMC measurements, but also conduct other electrical tests, such as those required for certain automotive and industrial standards. The remaining employees belong to the application, sales, and field teams.

We have about 600 square meters of available EMC and electronic laboratory space. This extra space means we can explore application engineering and have the capacity to support internal as well as external projects. The technical equipment includes 3 EMC chambers:

- SAC3 for emission and immunity testing for automotive, industrial, and consumer electronics.
- CISPR25 cabin for emissions and immunity testing for automotive electronics, specializing in the whole CISPR25 and ISO automotive field.
- Shielded chamber for conducted emissions and immunity testing for automotive, industrial, and consumer applications.

In addition, there are workplaces for pulse and electrical testing, which gives us a significant amount of flexibility and room for creativity. At the same time, there are still plenty of reserves in the building for further growth. Our management said right at the beginning, "You mustn't think so small. We have a vision. We have a goal."

Meier: It must be emphasized that the 600 square meters of laboratory space are supplemented by almost 1200 square meters of office space and seminar rooms. Both the EMC laboratory and the office space are designed to accommodate additional employees in the future. MPS as a company has grown significantly, especially in recent years, and we expect this trend to continue. We have already hosted some events and workshops with customers and distributors. The location in Ettenheim is perfect for us to train our customers and build strong relationships with our partners.

Moscheik: You have internal clients as well as external ones, so how do things look in terms of capacity and utilization at the moment?

Spindler: Normally, EMC problems are not mentioned in the project schedule. It is the same for our internal projects and for our customers. Our midterm planning is quite conservative, which allows us to have time slots for unexpected problems. Within this setting, we can work efficiently and still have the capacity to respond on short notice. If someone has a problem, we want to help quickly, not in 3 months. Right now, we can usually offer appointments within 2 weeks.

In addition, we support the entire European market from Ettenheim. Our product lines and field teams use our laboratory to analyze customer applications and support them in the event of questions and failure analysis.

Every market is somehow different, and even though we collaborate with the labs in China and the USA, the time difference can be a problem, especially with acute problems. Efficient communication and locality lead to faster solutions.

Moscheik: Your website says that you offer "independent lab services." What is meant by this?

Spindler: In addition to our internal orders and external customers, we offer companies that are not (or are not yet) MPS customers the opportunity to use our services and our expertise in the EMC field. In this way, we would like to demonstrate the importance that the market in Germany and Europe has for us. Products are becoming more and more complex and the time pressure in development is constantly increasing. Sometimes there is hardly any time left for the engineer to deal in-depth with the power tree, for example. The equipment required is also

becoming more extensive, and for some companies, it is simply uneconomical to keep all the necessary measuring equipment on hand. In this case, we would like to be the partner who supports and helps with solutions.

Moscheik: A full-service offer to everyone, so to speak?

Spindler: Exactly! We want to get away from pure product sales, which is often, "Buy this IC and then leave me alone." In principle, we really do offer a whole package behind it, as in, the whole solution. That means we don't just develop the IC — we develop within the application, and we support the customer throughout the entire development process. With the possibilities created here in Ettenheim, we can offer these solutions much more intensively. We talk to customers at eye-level and go beyond offering a product that works; rather, we are a partner for the project. It was very difficult to convey that with technical sales alone. Now I can invite customers to the lab and show the processes live. That is a very big advantage! We have also installed an MPS Now lab in Ettenheim, so our engineers can virtually support our customers in real time. More information can be found on our website.

Meier: I would like to mention that at this point, when the lab is still very new, our focus is on our existing internal and external customers. But for sure the EMC lab will help us make a good name for ourselves when building up new customers.

Moscheik: Did these possibilities influence the decision for Ettenheim?

Spindler: In the past, MPS started with a sales structure in Germany. We then reached a point where we said, "We now must do more." We need more technical capabilities — simply because the demand is much greater — and we want to be more efficient. That's when the question came up: where do we go? In Munich, we already have a location/sales office, but we could also go somewhere else. Being an international company means we are not necessarily tied to Munich.

Ettenheim is located between Basel and Karlsruhe, near to the autobahn A5, Switzerland, and France, and you can reach international airports within 2 hours via train. Within the city of Ettenheim, we found an excellent infrastructure and the land to fit our overall concept. As a starting point, we already had a good customer base and network in this region. It is a very green region a great foundation as we grow.

Moscheik: Thank you both for the insightful talk. I wish you much success for Ettenheim, and will definitely visit you once I'm in the area.

www.monolithicpower.com

4th Generation SiC MOSFET in Totem Pole PFC for High-Performance SMPS

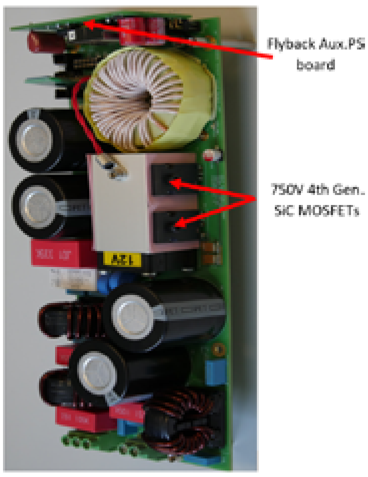
This article introduces a compact evaluation kit to demonstrate the high performance of ROHM's 4th generation SiC MOSFETs in a state-of-the-art Totem Pole PFC. In addition to showing key performance metrics such as efficiency measurements the paper describes some design challenges of the topology at hand and how they were addressed in order to obtain a PFC with universal input.

By Abdelmouneim Charkaoui, Christian Felgemacher, Felipe Filsecker and Jochen Hüskens, ROHM Semiconductor

The Totem Pole PFC (TP-PFC) topology as such has been discussed in multiple articles in the past, e.g. in this magazine in [1]. With the availability of WBG semiconductors that feature high performant body diodes it is becoming very attractive. Its key advantage over the traditional boost PFC is that it eliminates low frequency rectification and the power loss associated with the forward drop of a 50 Hz rectifier. Thus, efficiencies above 98% can be achieved and, if a suitable secondary stage with a similar efficiency is used, the 80+ Titanium target efficiency can be reached.

In Figure 1, a picture of the featured evaluation kit (EVK) that implements the TP-PFC with rated input current of 16A is provided alongside some of the design specifications. The key devices in use in this board are highlighted in Figure 1. In addition to 4th Generation SiC MOSFETs this design uses ROHM Si SJ MOSFETs, as well as the gate drivers BM61S41/BM61M41 and other components from ROHM, such as the shunt resistor and the flyback switching regulator IC in the auxiliary power supply.

The performance of the developed EVK is illustrated in the following plots showing the measured efficiency and the achieved input power factor at both 230V and 115V AC input. Regarding the efficiency, it should be noted that this includes all on-board power consumption of the auxiliary power supplies for the gate drivers, the low voltage electronics, and the cooling fan. It can be seen that the requirement of a power factor > 0.95 at 20% load is reached. If the PFC circuit is combined with a DC/DC stage of suitably high efficiency the design can also meet the efficiency requirements of 80+ Titanium.



a) TP-PFC EVK

Parameter	Specification
Input voltage (freq.)	85 – 265 V_{AC} (50±3 Hz or 60±3 Hz)
Output voltage	400V (+/- 5% ripple voltage)
Output power	3.6 kW @ 230V_{AC}
Switching frequency	100 kHz
Efficiency @ 50% load, V_{AC} = 230V	≥ 98.5%
Cooling	Forced air, small fan
Topology	Totem Pole
HF Switch (Q2, Q4)	4th Gen SiC MOSFET SCT4045DR (TO-247-4L)
LF Switch (Q1, Q3)	Si SJ MOSFET R6076ENZ4
Flyback Switching Regulator	BM2P101FK-LBZ
Form factor	233 x 89 x ca.40/45 mm

b) Specifications

Figure 1: TP-PFC EVK and specifications

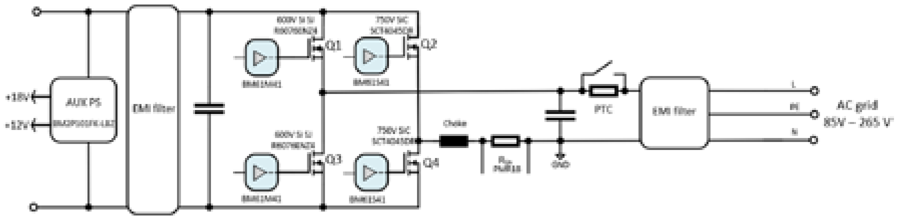
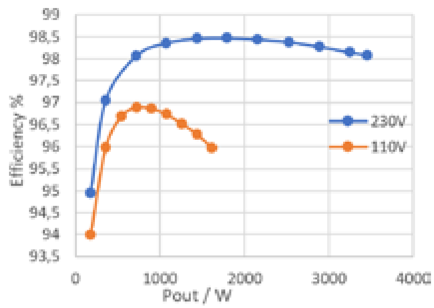
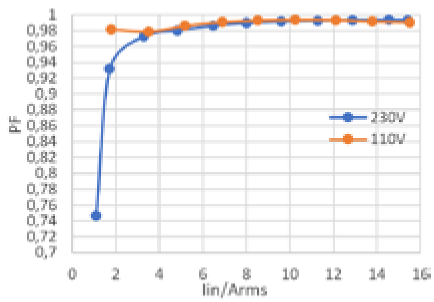


Figure 2: TP-PFC circuit diagram



a) Measured efficiency



b) Measured power factor

Figure 3: Measured efficiency and power factor

The following paragraphs discuss how this design has been developed and how certain challenging aspects of this topology were addressed. Amongst these challenges are:

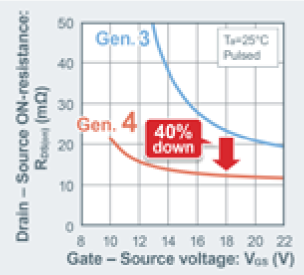
- Finding the correct settings for blanking and deadtime.
- Safe automatic start-up on the grid's universal input voltage.
- Soft start around the AC zero-crossing to minimize current spikes.

Beforehand, the benefits of ROHM's 4th generation SiC MOSFETs are going to be highlighted.

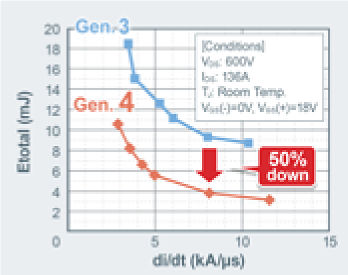
ROHM 4th Generation SiC MOSFET

The new SiC MOSFETs realize a substantial reduction of 40% in the on-state resistance per unit area compared to the 3rd generation SiC MOSFETs. This reduction is achieved without sacrificing short circuit robustness – making the new devices extremely high performing and robust.

In addition, the switching losses in the 4th generation SiC MOSFETs are 50% less than in the 3rd generation thanks to a drastically reduced gate-drain parasitic capacitance "C_{GD}". This translates to a higher conversion efficiency.



a) On state resistance reduction in 4th generation SiC MOSFETs.



b) Switching loss comparison 3rd vs 4th generation SiC MOSFETs.

Figure 4: On-state resistance and switching loss reduction in ROHM's 4th generation SiC MOSFETs

For driving the gate, in contrast to the 18V gate-source voltage "V_{GS}" required in the 3rd generation and earlier SiC MOSFETs, the new products support a more flexible gate voltage range (15-18V). In addition, due to the reduction in the "C_{GD}" parasitic capacitance and hence the "C_{GS}" to "C_{GD}" ratio, the 4th generation SiC MOSFETs can be safely turned off with just 0V without parasitic turn-on that may be caused by a high dV_{DS}/dt. As a result, the gate driver circuit can be simplified by eliminating the need for a negative bias for turn off.

Table 1 shows ROHM's 750V and 1200V 4th generation SiC MOSFET line up. The devices are available in THD-through hole TO-247N and TO-247-4L as well as in the SMD version TO-263-7L. The automotive qualification is planned for all devices marked with an asterisk (*).

Part No.	RDS(on)_typ (mΩ)	ID (A)	Package
SCT4045DE (*)	45	34	TO-247N
SCT4026DE (*)	26	56	
SCT4013DE	13	105	
SCT4045DR (*)	45	34	TO-247-4L
SCT4026DR (*)	26	56	
SCT4013DR	13	105	
SCT4045DW7 (*)	45	31	TO-263-7L
SCT4026DW7 (*)	26	51	
SCT4013DW7	13	98	

a) 750V MOSFET line up

Part No.	RDS(on)_typ (mΩ)	ID (A)	Package
SCT4062KE (*)	62	26	TO-247N
SCT4036KE (*)	36	43	
SCT4018KE	18	81	
SCT4062KR (*)	62	26	TO-247-4L
SCT4036KR (*)	36	43	
SCT4018KR	18	81	
SCT4062KW7 (*)	62	24	TO-263-7L
SCT4036KW7 (*)	36	40	
SCT4018KW7	18	75	

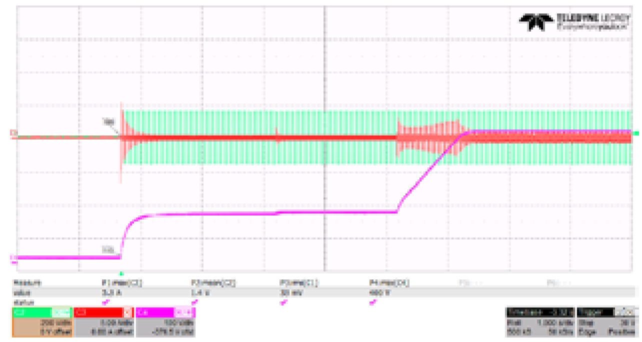
b) 1200 V MOSFET line up

Table 1: ROHM's 4th generation SiC MOSFETs line up

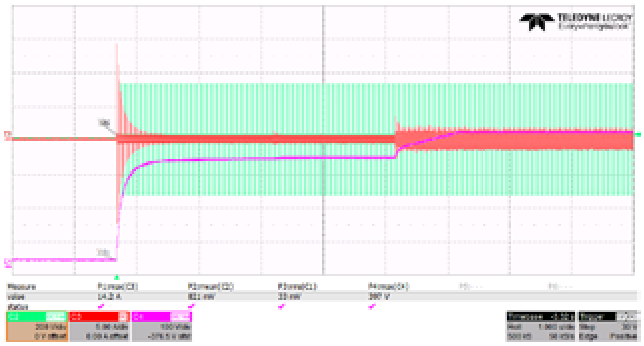
Blanking and dead time setting
The errors associated with the AC zero-crossing detection as well as the parasitic elements of the MOSFETs must be taken into consideration when setting the PWM control. In this TP-PFC EVK, a 50µs blanking time has been inserted around the AC zero-crossing. During which, the four switches are turned OFF shortly before the zero-crossing, either from positive to negative or from negative to positive, to prevent shoot-through. The control loop is frozen during this time to prevent the integrator build-up from causing an unwanted high current spike by applying a large PWM pulse in the next turn on. A short blank time enables higher controllability over the current waveform, lower THD and relatively higher efficiency. However, the minimum blanking time is limited by the controller sampling rate and the line frequency.

In addition to the blanking time around the AC zero-crossing, a suitable dead time must be set between the control commands of the complementary SiC MOSFETs. From the BM61S41 gate driver datasheet, the propagation delay has a maximum value of 65ns. Adding another 10ns max for the PWM propagation mismatch results in an absolute minimum dead time of 75ns. To account for the turn-off and turn-on delays of the SiC MOSFETs and to have some margin, the dead time for this board was set to 150ns. Of course this needs to be evaluated for each design and is also impacted by the selection of turn-on and turn-off gate resistances.

Automatic start-up on a universal grid input
The TP-PFC EVK is equipped with a PTC thermistor for pre-charge in parallel with a bypass relay. At start-up, the relay is turned off and the bulk capacitors are pre-charged through the PTC to a safe threshold before turning on the relay and operating the converter.



a) Automatic start-up 110Vac, 400Vdc



b) Automatic start-up 230Vac, 400Vdc

Figure 5: PFC automatic start-up vs AC input voltage

This prevents a circuit damage due to high inrush currents. The EVK was tested over the full universal input range [85Vac-265Vac] and has been proven to be safe for an automatic start up even at 265Vac. Thanks to the implemented Second Order Generalized Integrator - Frequency Locked Loop (SOGI-FLL), this EVK is also able to track and detect drifts in the grid's frequency of 50±3 Hz or 60±3 Hz.

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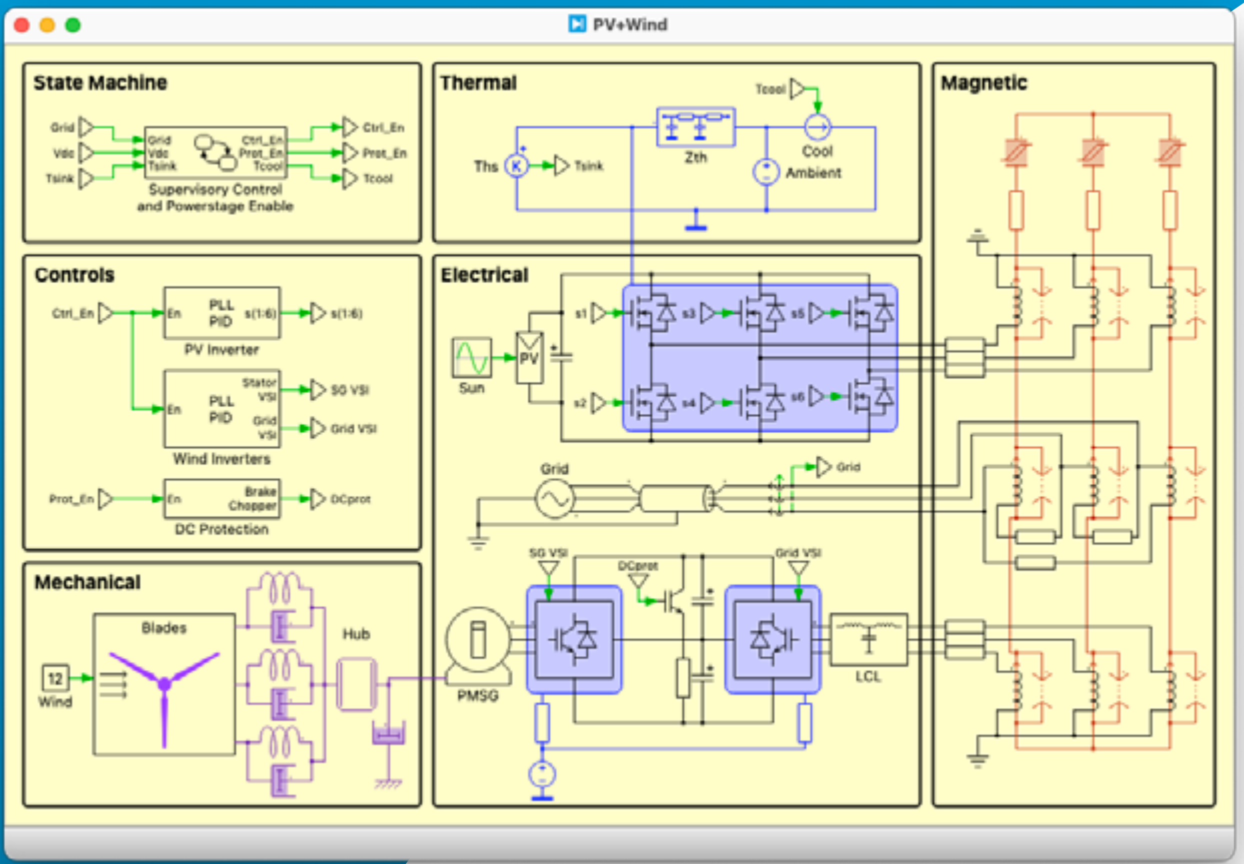

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Measures to minimize current spikes following AC: zero-crossing

In the TP-PFC topology, the MOSFET's switching sequence is of the essence. A failure to understand and observe the control challenges in a TP-PFC can lead to improper operation, unexpected EMI issues or even failure of the power devices. The most common challenge that is inherent to this topology is the occurrence of current spikes at the AC zero-crossing [2],[3]. These are mainly caused by the output parasitic capacitor "C_{OSS}" and the associated reverse recovery charge "Q_{rr}" of the line frequency switched MOSFETs, which are only changing state on the AC zero-crossing. A detailed analysis of the AC current spikes and waveforms in a TP-PFC topology is presented in [2].

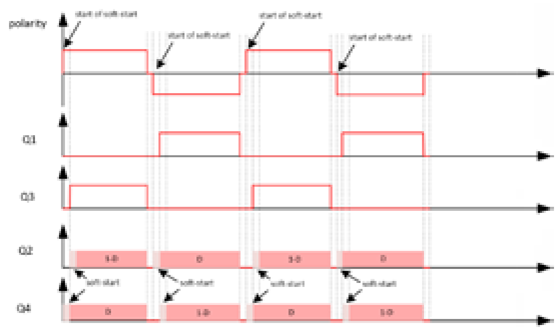


Figure 6: MOSFETs soft start in TP-PFC

In ROHM's TP-PFC EVK a soft-start sequence is implemented after every AC zero crossing. This involves a ramping of the duty cycles applied to the high frequency SiC MOSFETs (Q_2, Q_4) and fine control over the turn-on of the low frequency Si SJ MOSFETs. The implementation of this soft start achieved significantly reduced current spikes. The implemented MOSFET's switching sequence is shown in Figure 6.

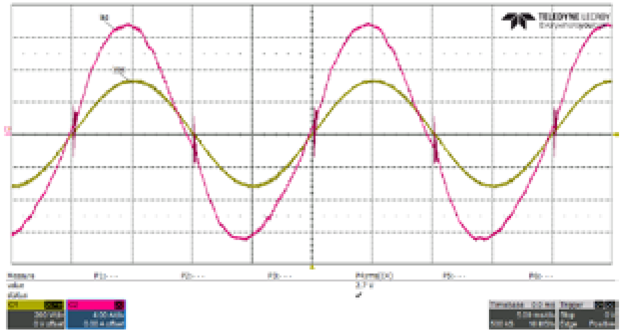
The MOSFETs Q_2 and Q_4 are complementary switched. During the negative half cycle, the Q_2 MOSFET is the active switch which is controlled by the calculated duty cycle "D". During this time, the Q_4 MOSFET is operating in synchronous rectification mode at "1-D" duty cycle. Note that the Q_1 MOSFET is only switched at the grid's frequency and stays on during the full negative half cycle to provide a low impedance return path to the mains. The operation reverses again during the positive half cycle and the high side and low side MOSFETs of each leg interchange their function.

As the input voltage changes polarity from negative to positive half cycle, and right after the AC zero crossing, the soft start sequence of the Q_4 MOSFET kicks in. This sequence consists of applying an increasing factor to the pulse width in a way that gradually increases the on time of this MOSFET from 0% to 100% of the calculated "D"-cycle. While doing this, the Q_1 MOSFET completely reverse recovers and the "V_{DS}" of Q_3 reduces to ground. Thus, the positive current spike, caused by the slow recovery of Q_1 and the high "V_{DS}" voltage across the Q_3 MOSFET, is eliminated.

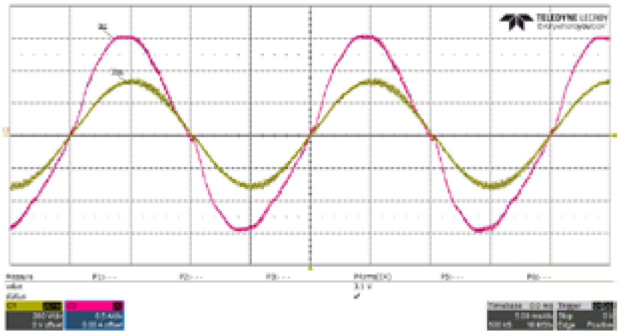
Knowing that the AC voltage is very low right after the zero crossing and since the inductor is already charged to the DC bus voltage, a large negative reverse current will flow through the inductor back to the mains. This leads to a high negative current spike when turning on the Q_2 synchronous MOSFET even at "1-D" duty cycle. Therefore, once Q_4 reaches the full "D"-cycle, the soft start is also applied to the Q_2 synchronous MOSFET to reduce this negative spike to near zero. Simultaneously, as Q_2 softly starts, Q_3 must be turned on to provide the current path back to the mains.
A large negative current spike will also appear at the AC zero-crossing if the Q_3 MOSFET is turned on too late after the soft start of Q_2 is completed as detailed in [2].

Experiment results

Figure 7 shows the input current waveform around the AC zero-crossing with and without the soft start.



a) Traditional control without soft start



b) With soft start method

Figure 7: Input current spikes at AC zero crossing with and without soft start method (red: I_{AC}, green: V_{AC})

Note that, since the "1-D" is very small when Q_2 first turns on, it becomes even smaller and tends to zero when multiplied by the soft start factors. Depending on the used gate driver, Q_2 may stay off for a couple of PWM cycles until the "1-D" term becomes larger than the gate driver's minimum PWM on time. This results in a remaining, but very small, positive, and negative current spike at each AC zero crossing.
The MOSFETs' control sequence explained in the previous section was implemented and tested in the 3.6 kW TP-PFC EVK. From the test results, without this control method, both negative and positive current spikes are present. The application of the soft start to both active and synchronous MOSFETs, as well as turning on the low frequency MOSFETs at the right moment, has shown better current waveforms and helped achieved much lower THD.

Summary

The presented TP-PFC EVK shows a high performance in major design aspects, including control features and a high efficiency, reaching 98.5% while including all on-board power consumption of the auxiliary power supplies and the cooling fan. Both low on-state resistance and low switching loss of the 4th generation SiC MOSFETs helped in the achievement of such performance. The results demonstrate how suitable these new products are for many power conversion applications such as for example server and data center power supplies, telecommunication, industrial power supplies (SMPS), energy storage systems as well as inside electric vehicles (e.g., OBC) where high power density, efficiency, simple gate circuit and short circuit robustness are required.

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Chasing the Speed of Light

As the level of automation increases in machines, detailed awareness of the surroundings becomes necessary. Time-of-flight based 3D imaging systems have become the eyes of machines. eGaN® technology has been the workhorse of laser drivers for these systems, enabling the resolution to make intelligent decisions.

By Stephen Colino, VP, Strategic Technical Sales, Efficient Power Conversion Corporation

When you are chasing the speed of light, at 10s to 100s of amps, from 10s to 100s of volts, there is little room for parasitic capacitance and inductance. This article explains the detailed mechanisms for driving lasers, and why eGaN FETs and eToF™ ICs have been and will continue to be the best choice for these demanding applications. It should be noted that the concepts presented in this article can be applied to most power switching applications.

Fundamentally, the circuit for driving a pulsed laser for time-of-flight lidar is simple, as shown in Figure 1. While other circuits are possible, they need more and larger components and have higher cost. With optical power being related to laser current, the electrical objective is to achieve the required peak current in a time on the order of the speed of light relative to the required resolution. Considering light travels 0.3 m in 1 ns, inductance must be kept on the order of hundreds of pH in order to keep the driving voltage at a practical level, and the driving voltage must be applied in hundreds of ps.

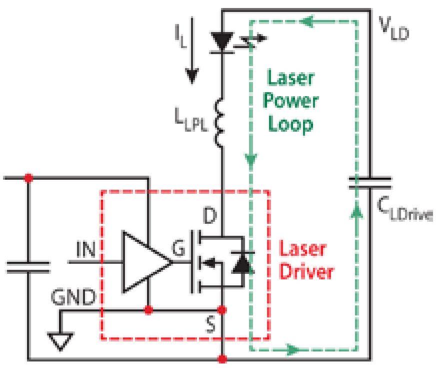

Figure 1: Basic laser driver circuit

Much has been written of techniques to reduce inductance to hundreds of pH using short, wide traces and inductance cancellation [1], [2], [3]. The focus is on the laser driver, which must apply the voltage to the power loop inductance fast enough to achieve the required peak current. In the sub nanosecond timeframe, at the currents required to achieve the distance and field of view needed by the system, the charging and discharging of the multiple capacitances, and their overlapping loops must be considered in detail as shown in Figure 2.

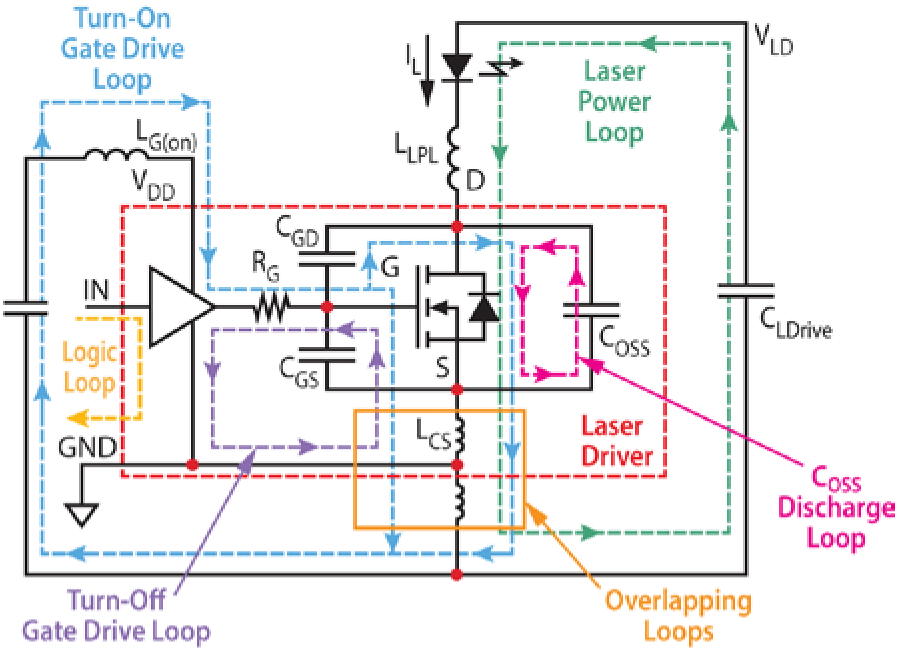

Figure 2: Detail of laser driver loops and stray elements

Figure 3 shows an approximation of key waveforms for a turn-on event for the circuit of Fig. 2. Turn-on starts with the logic input going high. After some propagation delay, the gate voltage starts to rise with C_{GS} charging through the various impedances of the turn-on gate drive loop as shown by Stage 1. Even with the gate voltage rising, there is negligible impact on the laser power loop until V_{GS} reaches a value where the output FET begins to conduct. With the extreme di/dt and dv/dt of a laser driver, the input loop must be decoupled from all other loops through layout and/or filter to prevent false triggering. It should be noted that that the return to the gate drive capacitor in the turn-on gate drive current loop comes from the power FET source and not the gate driver as shown in Figure 2. Figure 4 shows the transfer characteristics of the EPC2204 [4]. This curve defines the V_{GS} necessary to begin conduction as well as the V_{GS} necessary to drive required current. In this example, 1.75 V is necessary to begin conduction. This is where stage 2 of Figure 3 begins.

With the FET channel beginning to conduct current, C_{OSS} starts to discharge and V_{DS} begins to fall. Driven as a step pulse, V_{DS} must collapse rapidly to present a high voltage across the power loop inductance that drives the di/dt of the resonant circuit that determines the magnitude and duration of the pulse for the application. Since channel current, hence dv/dt, is controlled by the transfer characteristics curve, V_{GS} must

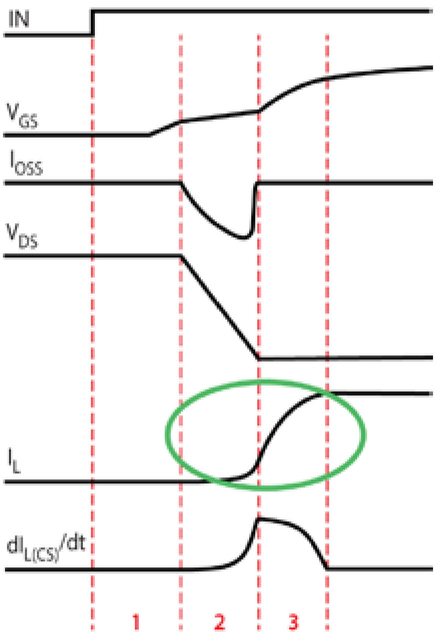

Figure 3: Theoretical waveforms, laser driver turn-on

continue to increase to accelerate C_{OSS} discharge. In this stage, discharging C_{GD} is added to the burden of the gate drive loop. As soon as V_{DS} begins to fall, laser current begins to rise. At this point, there is interaction between the gate drive and power loops. Inductance common to these loops, known as common source inductance (L_{CS}), carries the di/dt of the power loop resulting in a voltage drop that is subtracted from the gate drive potential, slowing the gate capacitance charging. It is critical to separate these loops as much as possible, as even common source inductance values of 100 pH can result in large increases in turn-on time

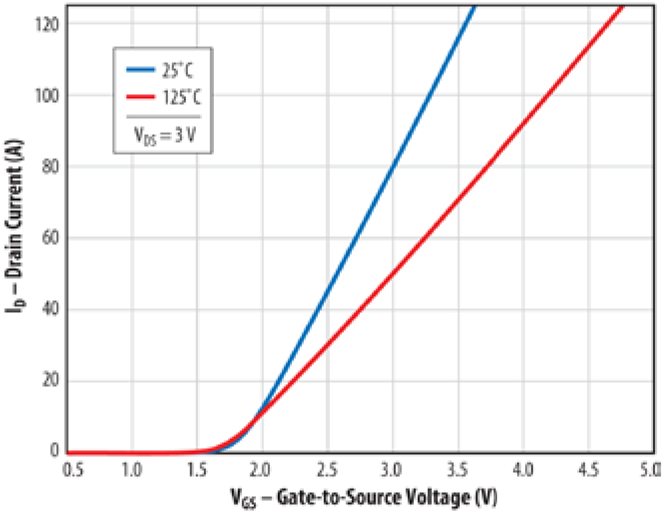

Figure 4: Transfer Characteristics of EPC2204

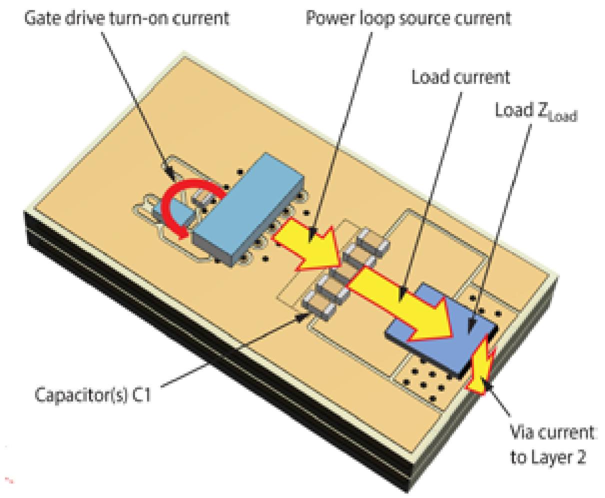

Figure 5: Top board layer layout

Stage 2 is completed when C_{OSS} is discharged and V_{DS} has collapsed completely. At this point, full laser drive voltage is applied across the power loop inductance resulting maximum di/dt. Minimizing L_{CS} is very important because with 25 pH at 100 A/ns gives a 2.5 V drop. For a 5 V gate drive, this leaves 2.5 V of gate drive potential, which will limit gate current and switching speed. Achieving a low L_{CS} requires a low inductance package and careful attention to layout where the two loops that contribute to common source inductance need to be separated right at the package, as shown in Figure 5. In addition wire bonds and clips in the source add inductance and thus not suitable packaging options.

Stage 3 requires the current in the laser to reach the required value and thus V_{GS} must continue to rise past the voltage necessary to achieve full current based on the transfer characteristics curve. Taking EPC2204 as an example, 80 A requires V_{GS} > 3 Vat 25 °C and > 3.7 at 125 °C, stressing that the voltage induced by the power di/dt over L_{CS} will be subtracted from V_{GS}. Stage 3 is completed when the laser achieves the full required current, typically at the peak of a resonant pulse in the case of a resonant laser drive topology where the laser drive capacitance and the power loop inductance form an LC tank. In this case, the LC determines the pulse width, and together with the laser drive voltage, controls the peak current and optical power [5]. In the case of an active turn-off topology, full current is reached when the laser voltage plus the laser driver voltage equals the laser drive source voltage. Figure 6a shows example waveforms of a resonant discharge laser driver with the yellow trace being laser current and dark blue trace representing optical power. Figure 6b shows example waveforms of an active turn-off laser driver with the blue trace representing optical power and the red trace being drain voltage.

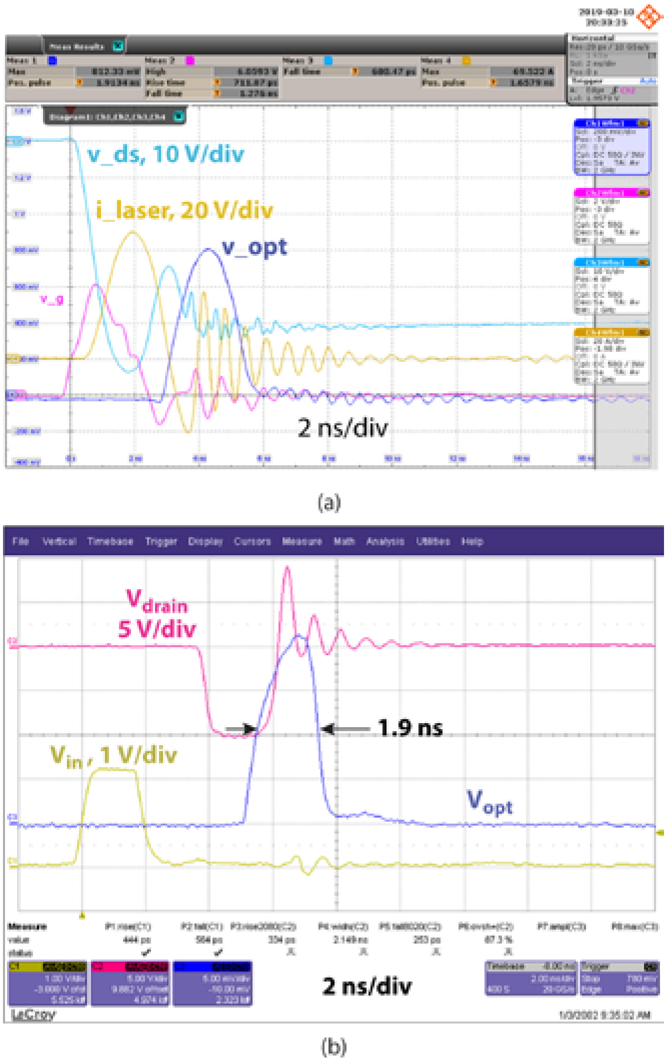

Figure 6: Laser driver waveforms of a. resonant discharge topology and b. active turn-off topology

For turn-off, in the resonant case, the laser driver is turned off close to or at zero current and must be low enough that the drain capacitance is mostly discharged but does not ring. Active turn-off manifests as a classic ZVS turn-off, with the laser driver disrupting the power loop, diverting current of the power loop into the C_{OSS}. Its rise in voltage across the power loop inductance drives the turn-off of current. A similar loop analysis to turn-on must be made for proper design.

Laser driver selection

Laser driver selection starts with determining the best semiconductor technology and packaging for extreme combination of speed and power. Packaging must have low inductance, but more critically, low common source inductance. Wafer level packaging provides the minimum inductance possible. Integrating the gate drive with the power FET, such as EPC's EPC21701 eToF™ laser driver, shown in Figure 7, reduces the number of package connections and board traces, reducing inductance and greatly reducing common source inductance. It also matches the gate driver to the power FET, which can enhance performance and reduce cost. It also reduces the size of the laser driver circuitry, which is especially important for multi-channel lidar systems.

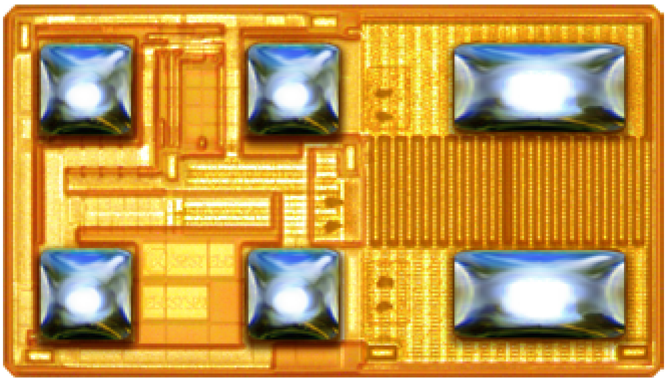

Figure 7: Bump side image of 1.7 mm x 1 mm EPC21701

The semiconductor technology chosen must have the lowest capacitance per peak current for the required voltage. eGaN® technology has Q_{GS} and Q_{GD} an order of magnitude lower than comparable silicon MOSFETs, and about half the Q_{OSS}, which together with the low resistance of the metal gate, ensures the fastest possible switching speed [6]. Once the technology is selected, peak current must be correctly sized. A device that is too small does not provide sufficient output power; a device too large results in a slower driver due to excess capacitance (and higher cost). The transfer characteristics curve, over the necessary temperature range, drives the selection.

Conclusions

Fundamentally, eGaN technology has vastly lower capacitance when compared with silicon MOSFET alternatives. Integration of the gate driver and chip-scale packaging greatly reduces inductance and allows one to take full advantages of their inherently high speed. Along with a low inductance layout, one can increase power and reduce pulse width of the optical pulse resulting in increased resolution, range, and field of view while reducing power consumption in ToF imaging systems, where the metric is the speed of light.

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SMPD™ : An Advanced Isolated Packaging to Fully Exploit the Advantages of SiC MOSFETs

In the standard discrete packages of power semiconductors, application specific topology needs are not taken into consideration. On the other hand, power modules, typically incorporating a full topology but feature complex package handling requirement. The advanced isolated packages from Littelfuse such as SMPD fill the gap between modules and discretes, offering the performance of power module with the flexibility of discrete devices.

By Aalok Bhatt, Francois Perraud, José Padilla, and Martin Schulz, Littelfuse

ISOPLUS - SMPD™ and its Advantages

SMPD stands for **S**urface **M**ount **P**ower **D**evice, the advanced top side cooled, isolated package pioneered by IXYS, now part of Littelfuse, back in 2012. As displayed in Figure 1, having the size of a two Euro coin, the SMPD offers several key advantages:

- Integrated Direct Copper Bonded (DCB) isolation provides best in class reliability under power and temperature cycling.
- IXYS proprietary DCB with 2.5 kV minimum isolation voltage.
- The optimized use of DCB space in component increases power density and simplifies thermal management.
- Allows fully automated pick & place and standard reflow soldering for the ease of manufacturing.

The SMPD is a revolutionary package which simplifies the way design engineers address their power semiconductor system integration and assembly. They are available in standard topologies such as buck, boost, phase-leg, or even customized combinations. They are available in a variety of technologies such as Si/SiC MOSFET, IGBT, Diode, Thyristor, Triac, or customized combinations with different voltage classes from 40V to 3000V.

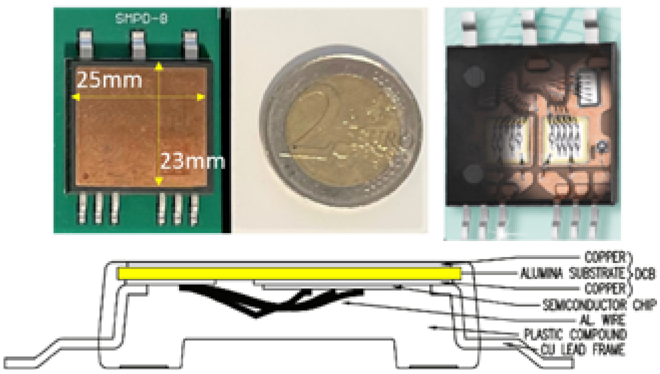


Figure 1: ISOPLUS SMPD™ internal construction and size

Performance advantages of SiC based SMPD compared to standard discrete

Dynamic measurements were carried out between the silicon carbide (SiC) MOSFET based SMPD and standard discrete packages to quantify the advantages Littelfuse SMPD can offer. The measurement principle is based on standard double pulse test setup as depicted in Figure 2 and the dynamic characterization platform from Littelfuse was used to conduct tests. The devices have been compared in terms of MOSFET switching parameters such as switching time T_{sw} and switching energy E_{sw} as well as the diode switching parameters such as reverse recovery time t_{rr}, maximum reverse current I_{rm}, and reverse recovery energy E_{rr}.

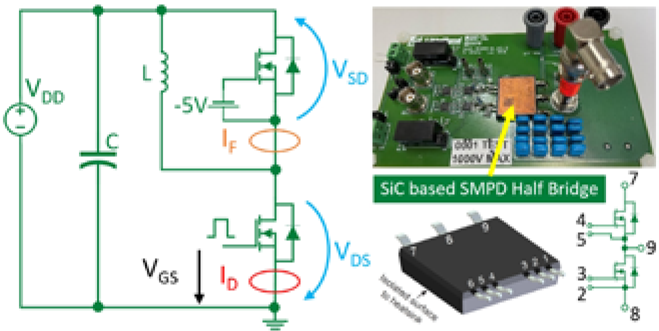


Figure 2: Double pulse test set up and dynamic characterization platform

As displayed in Figure 3, a 1200V SiC SMPD device was compared with standard discrete packaged devices having similar on-state resistance $R_{DS(ON)}$ and similar technology in terms of gate-to-source operating voltage (V_{GS}).

	SMPD™	TO-263-7L	TO-247-4L	TO-247-3L
Configuration	Phase leg	Single with kelvin source	Single with kelvin source	Single
SiC Dice	Die A	Die B	Die C	Die A
$V_{(BR)DSS}$ [V]	1200	1200	1200	1200
$R_{DS(ON)25}$ [mΩ]	80	80	80	80
I_{D25} [A]	25.5	30	36	39
$V_{GS,OP}$ [V]	-5 to +20	-5 to +20	-5 to +20	-5 to +20

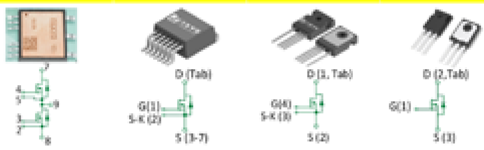


Figure 3: Devices compared featuring SiC MOSFETs

The measurement waveforms of gate voltage, drain current and body diode reverse recovery current are given in Figure 4. The gate voltage comparison reveals, that the SMPD with kelvin source not only speeds up charging of gate but also due to its low package inductance, it eliminates the gate oscillations at same operating conditions. The drain current comparison during turn-on reveals, that the TO-247-4L and TO-263-7L devices have about 25% higher peak current despite having similar channel resistance $R_{DS(ON)}$ and similar technology MOSFET dice. Consequently, these devices may experience more stress to the body diode due to higher values of maximum reverse recovery current I_{rm}. From the body diode's reverse current comparison, it can be observed, that despite having the same dice in SMPD and TO-247-3L packages, the SMPD offers shorter reverse recovery time with higher di/dt which in turn reduces the losses of body diode and increases overall system level efficiency.

The dynamic parameters are quantified and compared in terms of percentage comparison as can be seen in Figure 5. It is evident from measurements that by far, the SMPD offers significant reduction in all dynamic parameters as compared to standard discrete packages. It is observed that despite having the same dice in SMPD and TO-247-3L package, the SMPD offers significant performance improvements in the application. Assuming an application with 80 kHz switching frequency and 800 V drain-to-source voltage, the SMPD offers 21% switching loss reduction for medium load condition and 18% reduction for 80% load condition. The SMPD loss

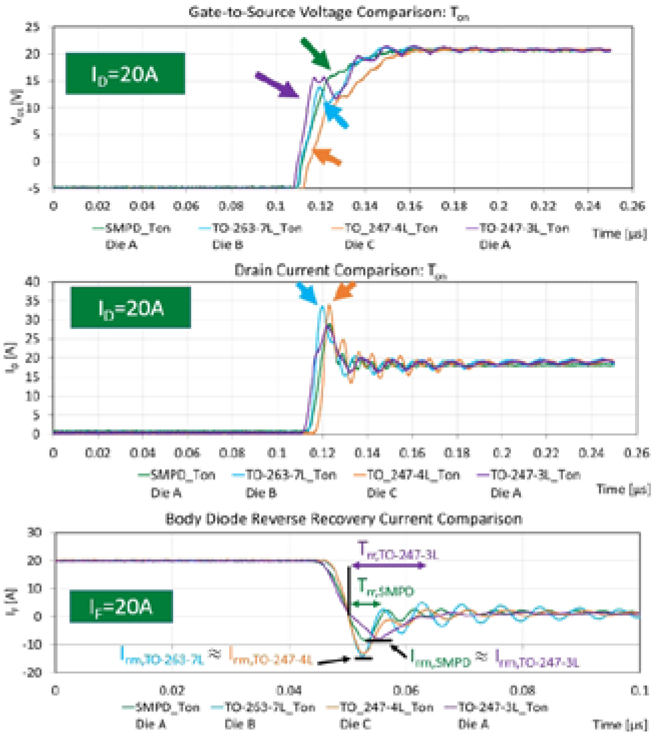


Figure 4: Waveform comparison between SMPD and standard TO-packages

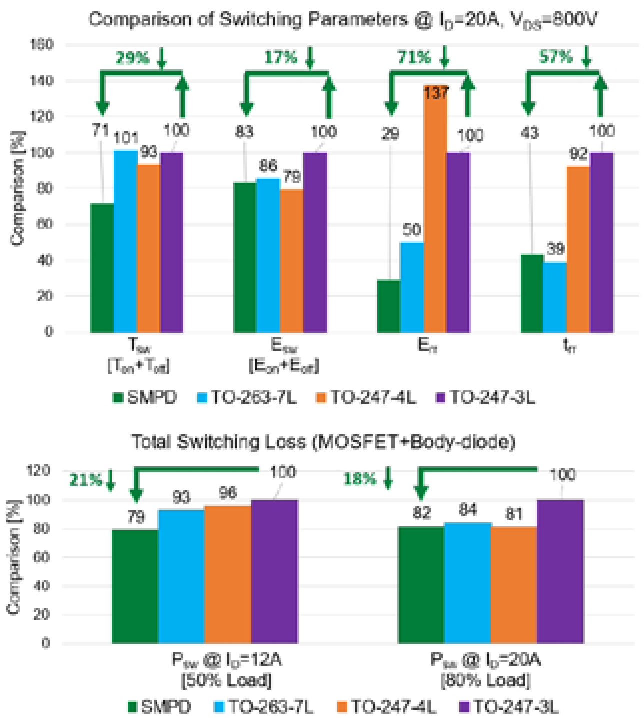


Figure 5: Comparison of relevant parameters between SMPD and standard discretes

reduction is more pronounced at medium load compared to all other discrete devices. The performance of TO-263-7L device is on par with SMPD for heavy load condition but the usage of this device usually needs an Insulated Metal Substrate (IMS) PCB which restricts the number of PCB layers, adds complexity in PCB design and includes nearly 50% higher cost compared to a standard PCB. The SMPD, offering kelvin source connections and minimized package-level stray-inductance, optimizes performance, efficiency, power density, and ease of manufacturing with standard PCB. Reflow soldering capability along with simplified thermal design add to the list of benefits.

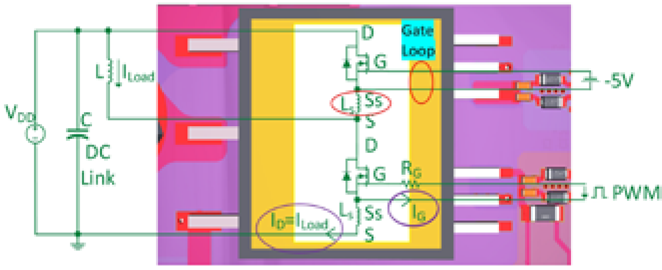


Figure 6: SMPD mounted on PCB with standard load circuit

Applicational advantage when using SiC MOSFETs in SMPD

The depiction of SMPD device mounted on PCB with standard load circuit is visualized in Figure 6.

The SMPD offers multiple advantages in application:

- The Gate drive path is separated from load circuit thanks to kelvin source. No negative feedback of load current into gate loop which improves EMI and reduces the risk of parasitic turn-on.
- Most of the stray inductance L_S is excluded from gate loop, enabling faster switching, reduced losses, improved efficiency and reduced gate oscillations.
- Minimized mutual parasitic inductance and coupling capacitance of the package.
- Minimized losses which improves efficiency. It also keeps the junction temperature T_{vj} low which simplifies thermal design.
- DCB based, fully isolated package with reduced mounting and cooling efforts [1]

By using SMPD in the application, designers can achieve shorter power loops along with reducing the number of necessary components. The shorter power loop minimizes stray inductance which helps to mitigate gate ringing and drain voltage overshoot. The power loop optimization by using SMPD compared to standard TO-packages is depicted in Figure 7.

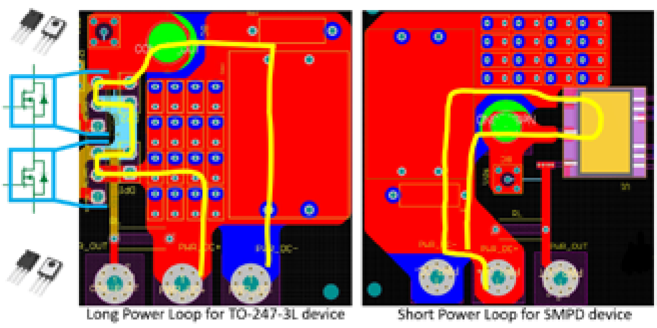
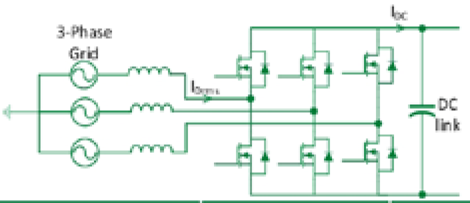


Figure 7: Shorter power loop with SMPD compared to standard discrete devices



	SiC SMPD 25mΩ		SiC TO-247-3L SiC TO-247-4L 25mΩ	
Total number of device	3	+	12	✗
No. of isolation pad	No need	+	12	✗
Mounting efforts	Simplified	+	12 screws 12 washers	✗
R_{thJH} per device [K/W]	0.85	+	1.33	✗
P_{DJH} per device [W]	176 ↑36%	+	113	✗
Total Semiconductor Area on PCB [mm²]	2453 ↓57%	+	5651	✗

For 3L/4L device: Assumed Silpad R_{thch} = 1K/W acc. to Sil-Pad® 2000 datasheet

Figure 8: The 22kW AFE design example using SMPD

Power stage building block using SMPD in SiC MOSFET based application

The Littelfuse SMPDs are available in standard power electronic building blocks. The 22kW active front end (AFE) converter can be visualized in Figure 8 using SMPD assuming 380V AC input, 750V DC output, 55 kHz switching frequency and 65°C heat-sink temperature. By using SMPD in AFE converter, the designers can achieve 36% higher power capability with less components. The SMPD based design occupies 57% less PCB area compared to TO-247-3L/TO-247-4L based design having the same dice.

Summary

By comparing the Littelfuse SMPD performance to the standard discrete packages, advantages of SMPD are evident. The usage of SMPD in application reduces mounting efforts, enables space saving, provides DCB based isolation, increases power density and efficiency along with simplified thermal design compared to the standard discrete packages. The SMPD package furthermore allows integration of sensing elements like for example NTC thermistors to enable temperature monitoring of semiconductor or a shunt resistor to measure device current. The Littelfuse SMPD product portfolio can be checked at Littelfuse web page [2].

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[2] Littelfuse SMPD product offering; https://www.littelfuse.com/products/power-semiconductors.aspx

www.littelfuse.com

500 kW DC-DC Conversion using 1200A / 1200V SiC Power Modules

Power-electronic-converter developers continuously strive for higher converter power densities at highest efficiency. This has become even more important considering the common goals for reduction of CO2 emissions and the responsible use of electric energy and materials. To achieve further improvements especially in the DC-DC converter design, SiC power modules are considered as key-enabling technology.

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Introduction of DC-DC Converters and Applications

To increase power density, it is common practice to design power converters for higher switching frequencies. In many applications, higher switching frequencies lead to smaller filters with reduced inductance and capacitance values. Particularly for applications with 16.7 Hz, 50 Hz or 60 Hz transformers the optimization potential is huge, since size and weight of transformers strongly depends on their fundamental operation frequency. This explains the motivation of engineers to transforms AC voltages indirectly through high-power DC-DC converters, which provide galvanic insulation via medium-frequency transformer. Such Solid-State Transformers (SST) are discussed today for grid and railway applications [1] [2].

Also by itself, high-power DC-DC converters, are essential in various applications like charging parks for electric vehicles [3], battery energy storage systems and photovoltaic [4], DC energy distribution systems [5] or railway auxiliary converters [6].

For galvanic insulation, DC-DC converters usually use transformers that operate at relatively high frequencies. The fundamental frequency of transformer voltage and currents is often same or similar to the switching frequency of the power semiconductors used. Higher switching frequency of the power semiconductors potentially allows shrinkage of the transformer since less magnetic materials are required. Furthermore, with increasing frequency, eventually the magnetic material for the transformer core can be changed for a more efficient or cheaper one.

To maximize switching frequency for high-power DC-DC converters, without scarifying converter efficiency, SiC power modules are the preferable solutions, since they provide lower switching losses compared to conventional IGBT technology. The following article demonstrates a DC-DC converter design with a nominal power rating of 500 kW utilizing 1200 V / 1200 A Mitsubishi Electric SiC power modules.

500 kW DC-DC Converter Prototype

For the high-power DC-DC converter, a Dual Active Bridge (DAB) topology is chosen. It offers galvanic isolation, bidirectional power flow and soft-switching capability. The basic equivalent circuit diagram is shown in Figure 1. It consists of four half bridges (HB) interconnected by a medium frequency transformer (MFT). Depending on the setup, an auxiliary inductor in series to the transformer might be necessary, or the transformer itself with its natural leakage inductance is sufficient to provide the inductance L_σ. The power flow of the DAB is controlled by changing the phase shifts of these four half bridges. The resulting control parameters are the phase shift angles δ_1, δ_2 and φ as shown in Figure 1. This general modulation is called Triple Phase Shift (TPS). The most commonly used TPS modulations are the triangular and trapezoidal modulation [7].

However, in this paper only Single Phase Shift (SPS) as the simplest modulation scheme is used. For SPS the phase shifts within the full bridges (HB1 to HB2 and HB3 to HB4) are equal to zero ($\delta_1 = \delta_2 = 0$) and the power flow is only controlled by the phase shift φ between DC1 and DC2 side. The transferred power can be calculated according to (1) and (2) [8].

$$P_{\mathrm{out}} = \frac{1}{T_{\mathrm{P}}} \int_0^{T_{\mathrm{P}}} v_1(t) i_{\mathrm{L}\sigma}(t) dt \quad (1)$$

$$P_{\mathrm{out}} = \frac{n V_{\mathrm{DC1}} V_{\mathrm{DC2}}}{2\pi f_{\mathrm{sw}} L_\sigma} \varphi \cdot \left(1 - \frac{|\varphi|}{\pi}\right) \quad (2)$$

The maximum transmissible power for the DAB in SPS operation can be calculated from (2) and is achieved for $\varphi = \pm \pi/2$.

$$P_{\mathrm{out,max}} = \pm \frac{n V_{\mathrm{DC1}} V_{\mathrm{DC2}}}{8 f_{\mathrm{sw}} L_\sigma} \quad (3)$$

It can be observed, that the stray inductance of the AC circuit is a critical design parameter to achieve high power of the DAB. With a fixed switching frequency, it limits the maximum power throughput.

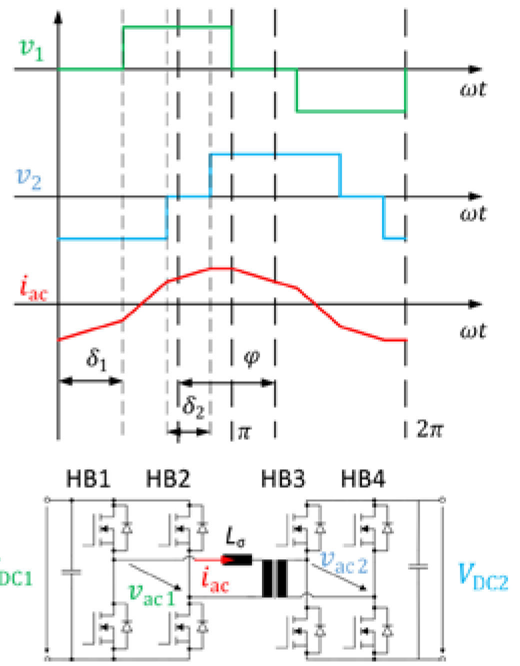

Figure 1: Current and voltage waveform for DAB with TPS and equivalent circuit diagram

Hardware Setup of the DAB

In order to characterize the DAB at high power, the test setup in Figure 3 has been built. The core of the power electronics is the 1200 V / 1200 A FMF1200DX1-24A SiC MOSFET half-bridge module. It has an integrated short circuit detection and protection [9].

As a core material for medium-frequency transformers, nano-crystalline material is often used since it provides high saturation flux density and low losses. However, the transformer in the presented DC-DC converter has a core made of ferrite which offers a cost-effective solution even compared with low frequency transformer. That ferrite core material can be used in such 500 kW converter is enabled by the low switching losses of the SiC power modules and the resulting high switching frequencies. Furthermore, the transformer uses a strip winding for low leakage inductance and forced air cooling. The medium-frequency transformer and its dimensions are shown in Figure 2. The resulting leakage inductance and magnetizing inductance as well as the DAB parameters are shown in Table 1. The leakage inductance is a crucial parameter. Its limits the rate of current rise in case of $V_{DC1} \neq V_{DC2}$. Furthermore, according to (3), it must be lower than 3.5 µH to avoid power derating at given DC-DC converter parameters.

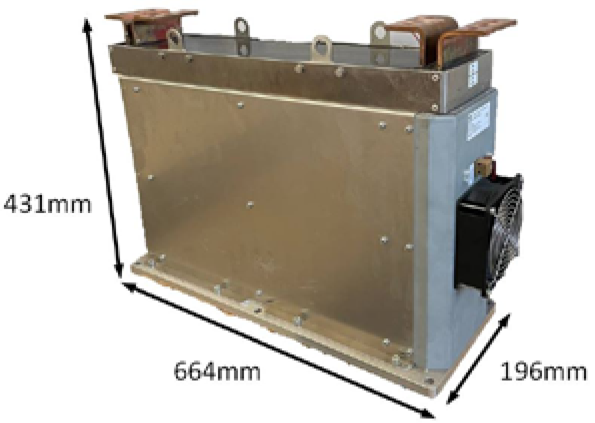

Figure 2: Medium Frequency Transformer

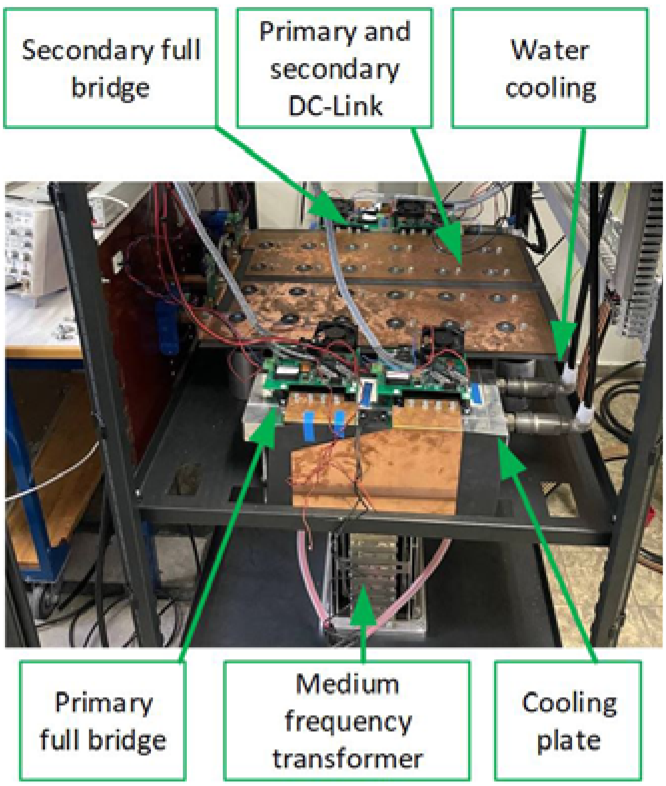

Figure 3: Dual Active Bridge test setup

DAB parameter		
L_{AC1}	AC1 inductance	300 nH
L_{AC2}	AC2 inductance	100 nH
$V_{DC1/2}$	In- Output voltage range	500-850 V
f_{sw}	Switching frequency	20 kHz
P_{out}	Nominal output power	500 kW
C_{DC}	DC-Link capacitance	4.6 mF
t_{dt}	Inverter deadtime	250 ns
Transformer parameter		
n	Transfer ratio	1:1
$L_{\sigma,T}$	Leakage inductance	200 nH
$L_{h,T}$	Magnetizing inductance	250 µH
	Transformer volume	56.l l
	Transformer weight	Ca. 110 kg
P_{max}	Maximum power rating	640 kW

Table 1: Dual-Active Bridge and Transformer Parameters

In order to measure the semiconductor losses a calorimetric measurement system for the DC1 and DC2 side full bridge is implemented. The inlet temperature T_{in} and outlet temperature T_{out} as well as the water flow rate Q in each full-bridge cooling plate is measured separately. With the heat capacity C_p and the density of water ρ, the losses for all full-bridge switches can be calculated according to (5) [10]. The overall measurement setup is shown in Figure 6. DC-DC converter input and output are connected and supplied by one power supply. The power drawn by the power supply corresponds to the losses of the DC-DC converter. Hence, accurate power loss measurement of the DC-DC converter is possible. The calorimetric measurement enables further break down between DC1- and DC2-side power module losses and transformer losses.

$$P_{v,calorimetric} = (T_{out} - T_{in})\ Q \cdot c_p \cdot \rho \quad (5)$$

Experimental Results

The experimental results are obtained on the hardware setup previously described and as depicted in Figure 6. For these measurements only transfer ratio of one ($V_{DC1} = V_{DC2}$) is investigated. The specifications of the prototype are given in Table 1. Measurements were done up to $P_{out} = 504\ kW$ and up to $V_{DC} = 800V$ to evaluate the performance. A full analysis of the DAB is done in [11].

In Figure 4, the efficiency of the DAB over the transferred power is illustrated. The maximum efficiency is reached for $P_{out} = 110$ kW and $V_{DC} = 500$ V of $\eta = 98.24$ %. For operation points with low output power Zero Voltage Switching (ZVS) is not achieved and efficiency

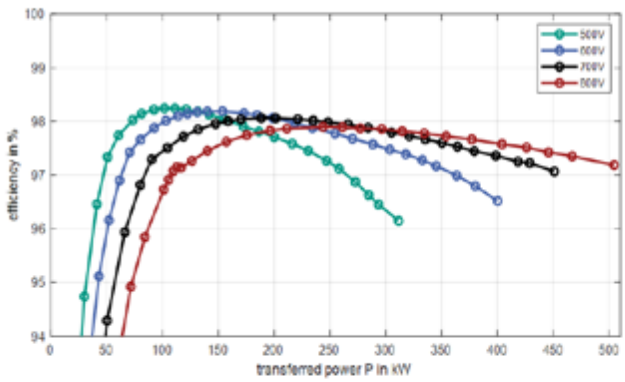

Figure 4: Efficiency of the DAB for different DC-Link voltages V_{DC} and conversion ratio of 1:1

drops accordingly. The calorimetric measurement allows the further break down of different loss components. Hence, Figure 5 shows the losses of the DC2-side power module. The power rating, where ZVS is achieved is clearly visible as power module losses become minimal [11], [12].

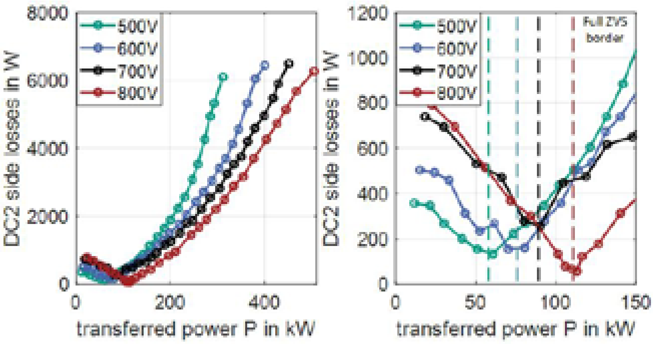

Figure 5: Calorimetric measured losses in DC2 side semiconductor

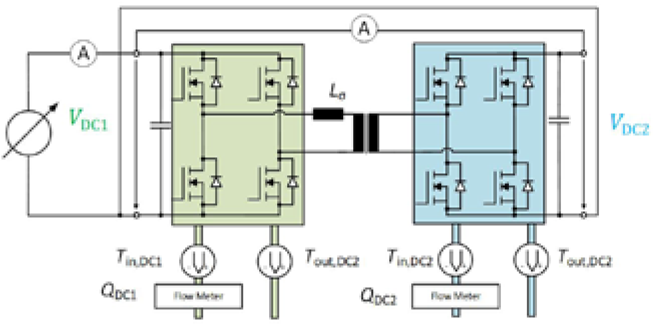

Figure 6: Measurement setup for 1:1 operation with calorimetric measurement

Mitsubishi Electric's High-Power SiC Power Modules

As shown in the previous chapter, SiC power modules have enabled a 500 kW DC-DC converter operated at a switching frequency of 20 kHz. For the regarded converter design and its medium-frequency transformer, it was possible to use ferrite core material which has lower core losses compared to a conventional silicon steel and is more cost effective compared to nano-crystalline core material. This game changer was enabled by the 1200 V / 1200 A SiC industrial power module from Mitsubishi's 1st Generation which has been used in this project.

Today, Mitsubishi Electric offers its 2nd Generation industrial SiC Power Modules [13] [14]. The entire SiC line-up is shown in Table 2. The availability of SiC devices for different voltage and current ratings allows competitive DC-DC converter designs for a wide range of applications.

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www.mitsubishielectric.com

Application	Discretes	Home Appliances	Traction			Industrial						
Package		DIPIPM									IPM	
SiC	Full-SiC	Full-SiC	Full-SiC	Hybrid	Hybrid	Full-SiC		Full-SiC	Full-SiC		Full-SiC	Hybrid
Connection	1in1	6in1	2in1	2in1	2in1	4in1	2in1	2in1	4in1	2in1	6in1	2in1
600V		15A, 25A										
1200V	80mΩ*, 40mΩ*, 22mΩ*					400A	800A	400A	300A, 400A	600A, 800A, 1200A	75A*	100A, 150A 200A, 300A 400A, 600A
1700V				1200A	1200A					300A		
3300V			185A, 375A 750A	600A								

* Under development

Table 2: SiC Lineup

The Latest 3.3 kV IGBT4 Opens New Horizons in Power Density

For many years, Infineon Technologies has consistently improved the performance of 3.3 kV IGBT semiconductors in industrial high-voltage (IHV) housings. The latest 3.3 kV IGBT4 and EC4 technology with high electrical robustness has enabled modules with rated currents up to 2400 A in IHV housings – B series (IHV B).

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The features of these new modules are especially attractive for applications such as traction, medium-voltage drives (MVD) and high-voltage DC transmission (HVDC), where the focus is on high power density without compromising service life.

One of the most common trends in power electronics is the permanent increase in power density. This trend is observed in demanding applications like traction, medium-voltage drives (MVD) and high-voltage DC transmission (HVDC), which also have strict requirements in regards to electrical robustness and reliability. To meet the latest application requirements, Infineon has developed the 3.3 kV IGBT4 and EC4 technology with increased current density, high electrical robustness, and twice the power-cycling capability of the 3.3 kV IGBT3 generation.

3.3 kV IGBT4 and EC4 technology with high electrical robustness

The new 3.3 kV IGBT4 and EC4 chip set has been developed for up to 60 percent higher current density per IHV B as compared to IGBT3 modules with the same housing footprint – 190 x 140 mm (Figure 1) and maximum feasible current density. As a result, the nominal current rating is increased from 1500 A for the IGBT3 generation to 2400 A for the IGBT4 generation. A further module in the 3.3 kV IGBT4 portfolio has a nominal current rating of 1600 A in a smaller housing with a footprint of 130 x 140 mm. Thus, the current density of this module is 56 percent higher than the current density of the 1500 A module from the previous generation. A doubling of the power density is achievable when you compare the 1200 A IGBT3 module and 2400 A IGBT4 module in the same housings.

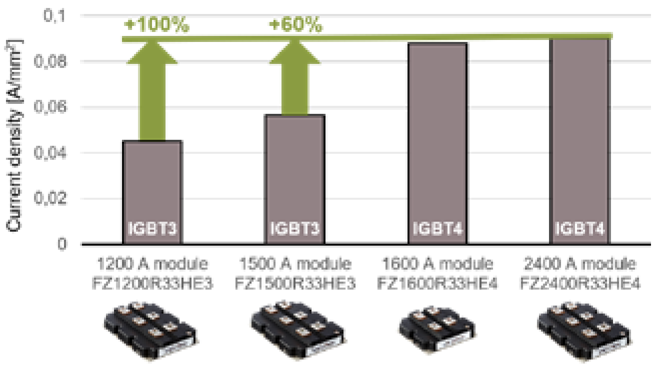

Figure 1: Current density increase in the latest 3.3 kV IGBT4 modules

Such a drastic current density increase has been achieved by the redesign of the substrate layout and the internal interconnection layout, which provides more space for the die attach, thus enabling an increase in active area. Together with an optimized emitter concept for the IGBT4, this results in significantly reduced static losses. The EC4 features a different emitter concept combined with a reduced thickness to ensure low static diode losses [1].

Increasing the current density also requires high electrical robustness of the new chip set under switching conditions. Therefore, the 3.3 kV IGBT4 technology has been developed to ensure a 4800 A turn-off current for the 2400 A module. A detailed analysis of the inherent destruction limit, combined with an adjusted turn-off speed for the 1600 A and 2400 A modules, has enabled the modules to achieve outstanding electrical reverse bias safe operating area (RBSOA) robustness. The switching diagram with 2 x I_{nom} commutated current shown in Figure 2 demonstrates the high RBSOA robustness of the 2400 A module.

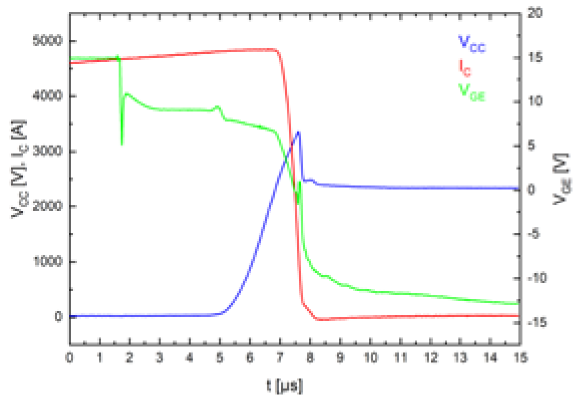

Figure 2: FZ2400R33HE4 turn-off diagram at I_C = 4800 A, V_{CE} = 2400 V

High-rated current usually results in increased power dissipation of the diode. Therefore, the 2400 A IGBT4 module offers a 125 percent increase in the safe operating area (SOA) limit of the diode compared to the 1500 A IGBT3 module [2,3]. Figure 3 shows recovery diagrams with high di/dt at V_{CE} = 2400 V and I_C = 4800 A. This demonstrates a reverse-recovery power peak up to P_{RQM} = 5.4 MW within the SOA limits.

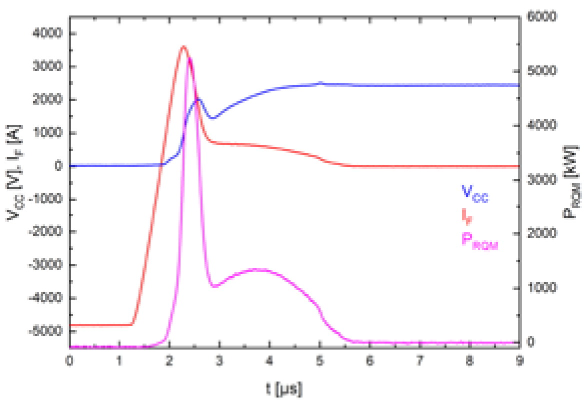

Figure 3: FZ2400R33HE4 diode turn-off diagram at I_R = 4800 A, V_{CE} = 2400 V

3.3 kV IGBT4 modules in traction applications

Traction is one of the most demanding applications for power semiconductors. The high demand for acceleration and deceleration leads to challenging performance requirements in terms of current per module. In addition, the high frequency of starts and

stops results in aging effects within the IGBT module, which should function reliably in the field during its typical lifetime of 30 years [4]. Doubling the power-cycling capability of the modules with the latest IGBT4 and EC4 diode technology is an important feature for traction applications. It enables an increase of the junction temperature cycle and, as a result, peak junction temperatures for IGBT4 modules in the applications that are limited by power-cycling capability.

In Figure 4 there are two power-cycling diagrams vs. the junction temperature cycle ΔT_{vj} for 3.3 kV IGBT3 and IGBT4 IHV B modules, respectively. For the application example shown in Figure 4, ΔT_{vj} is defined at 50 K for the IGBT3 module, and at 58 K for the IGBT4 module. Assuming that the junction temperature drops to the ambient temperature T_{AMB} = 50°C at every load cycle, the peak junction temperature of IGBT3 modules would be limited to 100°C, and 108°C for IGBT4 modules. The delta of 8°C indicates twice the power-cycling capability of the IGBT4 modules.

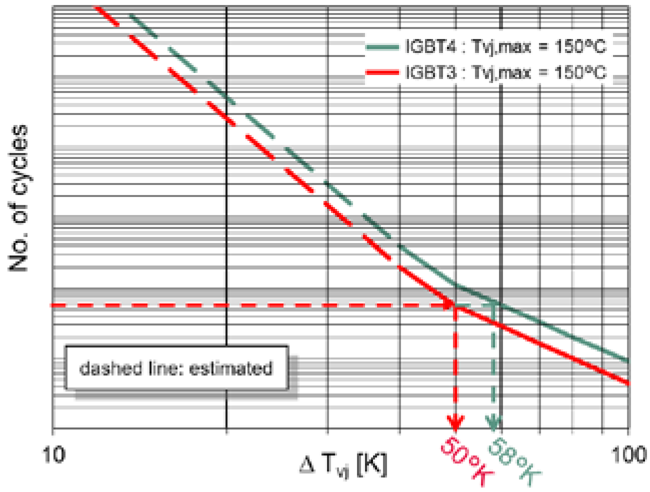

Figure 4: Power-cycling diagrams for 3.3 kV IGBT3 and IGBT4 IHV B modules

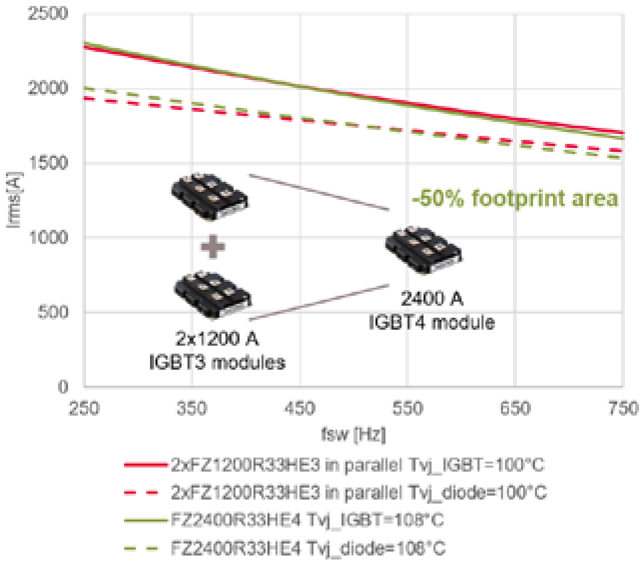

Figure 5: Electrical performance benchmark of two FZ1200R33HE3 modules vs. one FZ2400R33HE4 under the following conditions: V_{CC} = 1800 V, T_{AMB} = 50°C, f_{out} = 50 Hz, m = 0.9, cos φ = 1 (IGBT benchmark), cos φ = -1 (diode benchmark)

Based on these application conditions, electrical performance simulations for a two-level topology are performed in IPOSIM with highly efficient, liquid-cooled heat sinks (R_{thHA} = 5 K/KW for IHV B 190 x 140 mm and R_{thHA} = 7 K/kW for IHV B 130 x 140 mm). The application example (see Fig. 5) provides an electrical performance comparison of two parallel 1200 A IGBT3 modules FZ1200R33HE3 with a 2400 A IGBT4 module FZ2400R33HE4. It can be seen that the output RMS current capability of one 2400 A IGBT4 module is the same as two 1200 A IGBT3 modules in parallel.

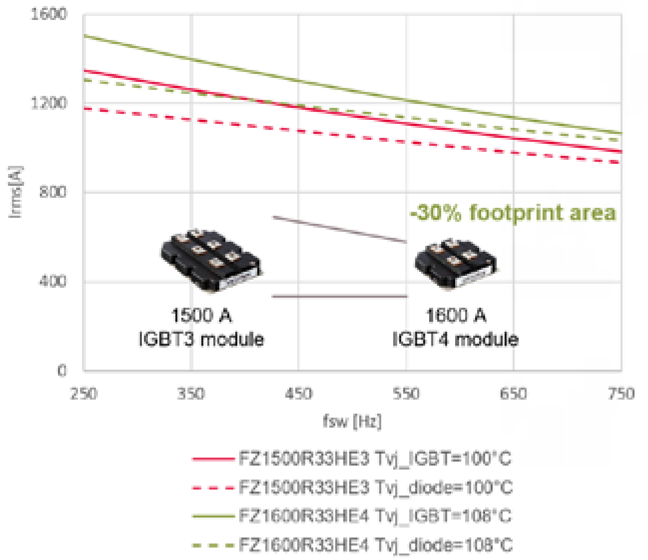

Figure 6: Electrical performance benchmark of FZ1500R33HE3 vs. FZ1600R33HE4 under the following conditions: V_{CC} = 1800 V, T_{AMB} = 50 °C, f_{out} = 50 Hz, m = 0.9, cos φ = 1 (IGBT benchmark), cos φ = -1 (diode benchmark)

The second example (see Figure 6) shows the feasibility of replacing a 1500 A IGBT3 module FZ1500R33HE3 (190 x 140 mm footprint) with a 1600 A IGBT4 module FZ1600R33HE4 in a smaller housing with 130 x 140 mm footprint. Output RMS current capability of the 1600 A IGBT4 module is 4 to 10 percent higher than the 1500 A IGBT3 module that has a bigger housing, proving that a reduction in the heat sink area of up to 30 percent is feasible.

Summary

The latest 3.3 kV IHV B modules, based on the IGBT4 and EC4 diode technology with high electrical robustness, demonstrate outstanding performance in demanding applications that are limited by power-cycling capability. The 1600 A IGBT4 module can replace the 1500 A IGBT3 module, and thereby reduce the size of the housing. One 2400 A IGBT4 module can eliminate the parallel connection of two IGBT3 modules with current rating 1200 A.

References

[1] Jadhav V., Mansueto S., Buerger M., Schwarzer U., Car D., Felsl H., Soellradl T., Kurzmann T.: Latest IGBT4 chip technology enables the first 2000 A 3300 V module in IHV package, PCIM Europe digital days 2020
[2] Datasheet FZ2400R33HE4, www.infineon.com
[3] Datasheet FZ1500R33HE3, www.infineon.com
[4] Infineon Technologies AG, AN2019-5 “PC and TC diagrams,” Application Note 2019

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HIGH RELIABLE WEB SOLUTIONS FOR DESIGN OPTIMIZATION

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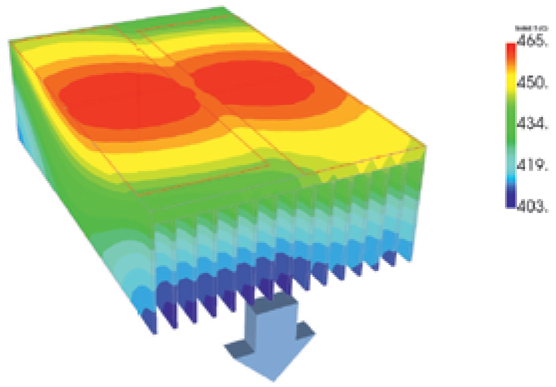
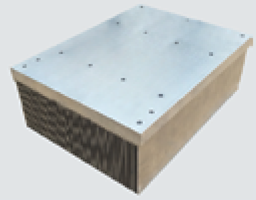


AIR FLOW



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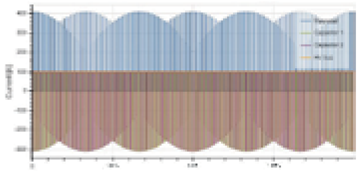
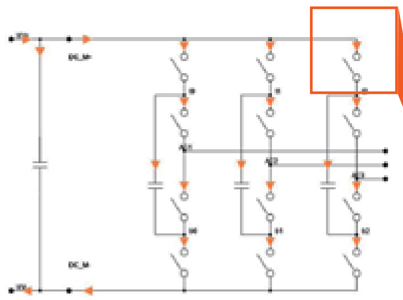
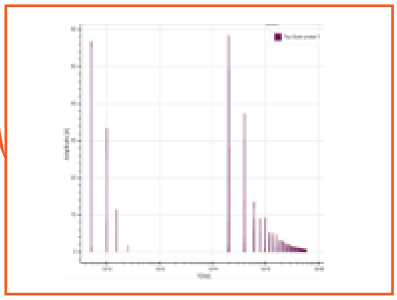
LAMINATED BUS BAR SIZING TOOL

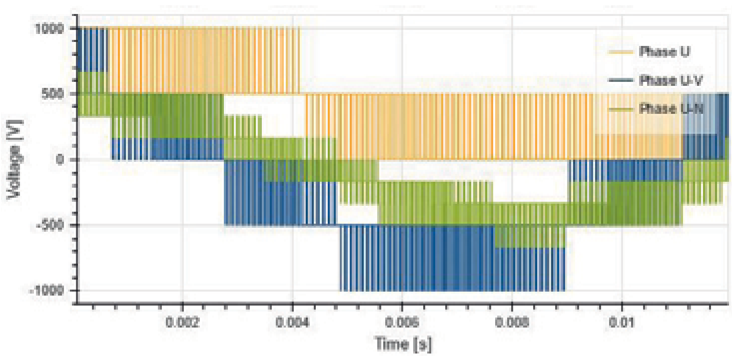




3-level NPC converter electrical diagram



Fourier series of AC current through top outer switch



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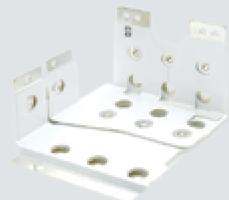

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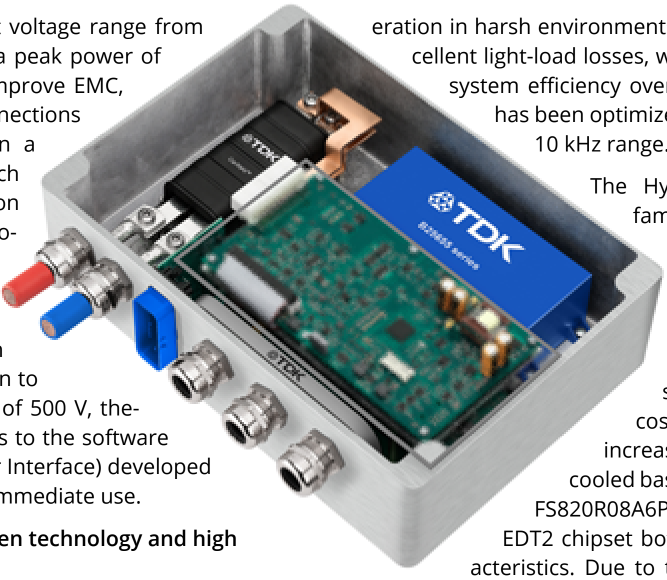
Expertise, our source of energy

Compact, Modular Inverter Manufactured Using Standard Components

Mankel-Engineering has worked together with TDK and Infineon Technologies to develop an extremely compact motor inverter. It has a modular design and is based on standard components, resulting in a cost-effective solution for a wide range of drive tasks for e-mobility and industrial electronics.

By Dipl. Ing. Wolfgang Rambow, TDK Electronics, Munich; Fabian Beck, TDK Electronics, Heidenheim Elvis Keli, Infineon Technologies, Warstein; Katharina Mankel, Mankel-Engineering, Biedenkopf

The inverter features a wide input voltage range from 240 V DC to 475 V DC and offers a peak power of 120 kW at 400 VDC. In order to improve EMC, all of the inverter's electronics, connections and feedthroughs are installed in a shielded aluminum housing, which also integrates the liquid cooler on the underside. This is used for cooling the IGBT module as well as the passive components. The maximum coolant supply temperature is 65 °C, which is common in the automotive industry. In addition to the version with a DC link voltage of 500 V, there is also an 850 V version. Thanks to the software package with a GUI (Graphical User Interface) developed in-house, the inverter is ready for immediate use.



Standard IGBT modules with proven technology and high performance

At the heart of the inverter is the Infineon HybridPACK™ Drive Module FS 820R08 PinFin (Figure 1) with a maximum voltage of 750 V, which is used in the described converter with a DC link voltage of 470 V max.

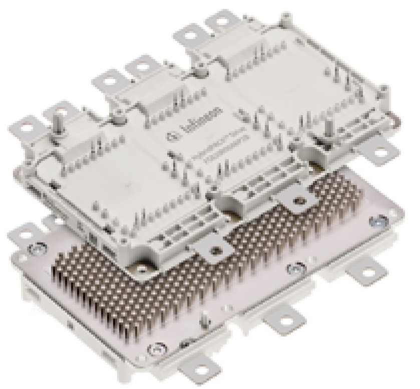


Figure 1: The HybridPACK™ series is extremely robust and reliable.

The HybridPACK™ Drive is a very compact power module that is ideal for main inverter applications in hybrid and electric vehicles (xEV). The FS820R08 (820 A/750 V) power type is a six-pack module optimized for inverters with a maximum of 150 kW. The power module implements the EDT2 IGBT chip generation, a micro-pattern trench-field-stop cell design for the automotive industry. The chipset features high current density combined with short-circuit robustness and increased reverse voltage for reliable inverter operation in harsh environments. The EDT2 IGBTs also deliver excellent light-load losses, which help to significantly improve system efficiency over a real driving cycle. The chipset has been optimized for switching frequencies in the 10 kHz range.

The HybridPACK™Drive power module family is equipped with mechanical guide elements, allowing for simple customer assembly. In addition, the press-fit pins for the signal connections avoid additional time-consuming selective soldering processes, resulting in cost savings at the system level and increasing system reliability. The direct-cooled baseplate with PinFin structure in the FS820R08A6P2B module and the implemented EDT2 chipset both feature superior thermal characteristics. Due to the high clearance and creepage distances, the module family is also suitable for increased system operating voltages and supports modular inverter applications in terms of power and voltage, providing scalability.

Compact DC link solutions from TDK

The specially adapted high-performance DC link capacitor from TDK's PCC (Power Capacitor Chip) program offers a capacitance of 650 µF at a voltage of 500 V DC (Figure 2). This robust capacitor with automotive approval according to AEC-Q200 is manufactured on a fully automated production line and stands out thanks to its high continuous and peak current values of up to 180 A. Many Tier1/OEMs already use customized solutions of this capacitor in their series converters. This capacitor has also set a quasi-standard. Its low ESL values of minimum 10 nH support the EMC filter whilst also protecting the semiconductor module from switching overvoltages – known as overshoot. Furthermore, it has been designed for a continuous voltage of 500 V to also compensate for the overvoltages that occur during charging. Its welded contact points, instead of the soldered connections used by many competitors, have also set the standard for maximum current load capacity for years – especially when under maximum strain due to temperature – and ensure an outstanding level of reliability in automotive technology. The integrated busbars balance the installed capacitor stack and thus allow the greatest possible use of their capacity for all semiconductor switches. The overlapping design of the busbars up to the semiconductor module simultaneously reduces the apparent inductance ESL so special snubber capacitors are generally not required. By producing its own films, TDK can even be used here at temperatures of up to 110 °C for a limited time.

TOWERING EFFICIENCY

Seven new D2PAK-7L 750V SiC FETs, ranging from **11mΩ to 60mΩ, deliver design flexibility with multiple options** optimized for high-power applications requiring maximum efficiency and excellent cost-effectiveness in a thermally enhanced SMT package.

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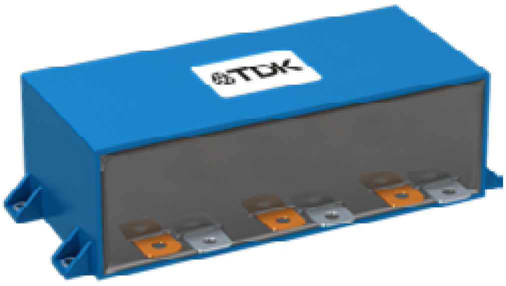

Figure 2: The geometry and connections of PCC capacitors from TDK are precisely matched to the IGBT modules. This results in very low inductance values.

EMC under control with new TDK CarXield™ series high-current filters

CarXield™ (Figure 3) is a new, modular EMC filter series connected between the high-voltage battery and the DC link input of the inverter. On these filters, the HV-DC power connections are connected directly to the filter. For this purpose, the filter has unique L-shaped connections – specially designed for increased current load capacity and improved creepage distances to accommodate the tubular cable lugs. The filter combination used very significantly reduces the high-frequency interference that always occurs when the power module is switched. However, signals within the acoustically perceptible range are also significantly reduced. The filters are currently available for voltages of 500 V DC or 900 V DC at currents of up to 400 A at 85 °C.

Figure 3: EMC filters from the new CarXield series. They are suitable for currents of up to 400 A.

The CarXield EMC filters cover the different power and voltage classes. This has already been taken into account, even for the next IGBT generations with 1200 V as well as wide-band-gap modules such as 1200 V SiC and thus a maximum of 850 V DC link voltage. Different versions of the busbars are available for maximum flexibility. There is also a version without an integrated busbar.

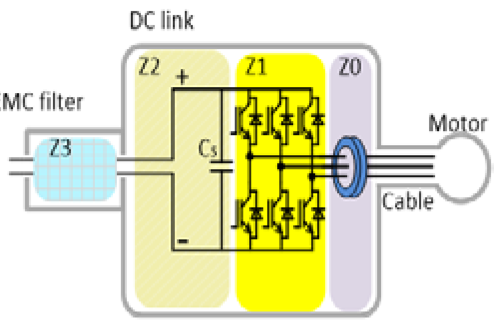

Figure 4: EMC zone diagram. In zone Z0, the AC connections for the motor and specially shaped TDK ferrite cores can attenuate high-frequency interference.

Figure 4 shows the typical systematic structure and arrangement of the EMC filter components in the form of a zone regime within a typical inverter, where zone Z3 stands for the CarXield™ and Z0 for an additional common mode attenuating core above the AC connections. Further measures include the clean arrangement, separation, and shielding of the respective components to achieve the best possible EMC results.

Measurements carried out in the Mankel-Engineering laboratory show the excellent EMC performance of the CarXield filter as well as that of the inverter when subjected to a load versus the limit requirement of CISPR 25, Class HV5 (Figure 5).

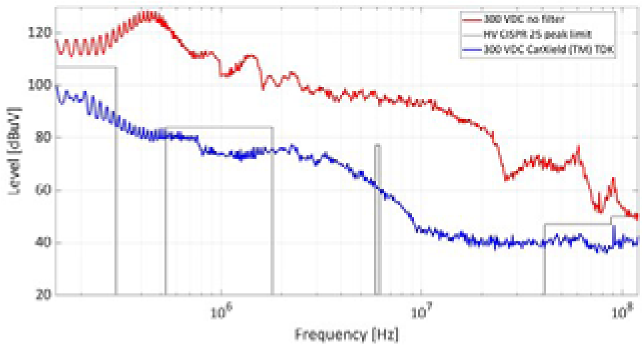

Figure 5: Thanks to the use of CarXield (blue curve), high-frequency interference was reduced below that of CISPR 25, Class HV5.

TDK components for the controller and interface module

In addition to the high-voltage power unit, the inverter requires a controller as well as interfaces, such as for speed and direction detection, which are supplied with 12V. TDK also supplies a broad portfolio of components for this purpose. Gate drive transformers, for example, are an integral part of the controller unit. For example, the EPCOS E13EMHV series of compact SMT transformers (B78308*A003) with high dielectric strength is suitable for a wide variety of DC-DC converter topologies (Fig. 6). Insulation clearances comply with IEC 60664-1, 61558-2-16, achieving a high working voltage of 1000 V DC. Transient overvoltages of up to 2500 Vpeak are permitted. The high dielectric strength between the primary and secondary sides is 3000 V AC (50 Hz, 60 seconds). The types of the new series are available with different transformation ratios.

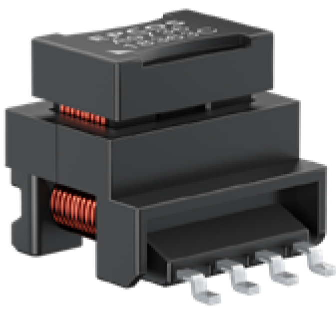

Figure 6: E13EMHV series gate drive transformers are suitable for flyback, push-pull and half-bridge DC/DC converters.

TDK offers special CAN bus chokes of the ACT1210 and ACT45B series for the digital communication interfaces. They prevent ringing when the level of the CAN bus signals changes, enabling interference-free communication.

In addition to the components described above, TDK offers a wide range of reliable and durable passive components and sensors tailored to the stringent requirements of the automotive and industrial sectors.

www.tdk-electronics.tdk.com

Flux-Cored Wire for Robotic and Manual Soldering

Indium Corporation® announces that it is now offering CW-818, a no-clean, high-reliability flux-cored wire designed to minimize cycle times in manual and robotic soldering processes while delivering top tier soldering speed and spread. Designed to meet the requirements of manual and robotic soldering processes, Indium Corporation's halide-free CW-818 combines superior soldering speed and spread with improved overall cleanliness (with clear/light-colored residue, charring resistance, and spatter control technology) to deliver a flux-cored wire with enhanced cleanliness, even at higher soldering iron tip temperatures. CW-818 excels in manual and robotic soldering applications where the J-STD-004C high-reliability category is desired or required; or applications where extra wetting power is needed to achieve a higher throughput.

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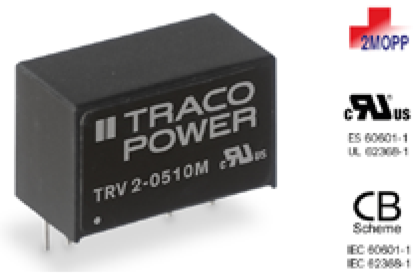
2 Watt High Isolation DC/DC Converter

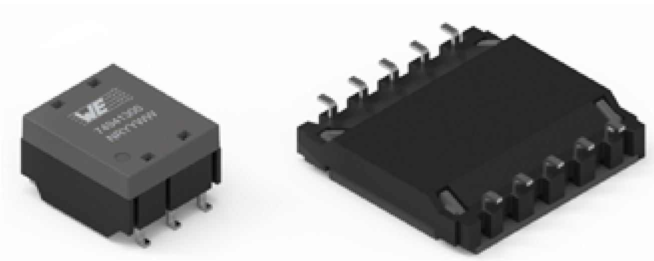
The TRV 2M is a series of 2 Watt DC/DC converters in a compact SIP-9 package with reinforced isolation of 5000 VAC for medical and industrial applications. The series offers a 1.5:1 input voltage range with a nominal input ranging between 5 and 24 VDC. With a continuous short circuit protection and a low leakage current of less than 2µA, this converter series is especially suited to protect any connected interfaces or applied parts to patients.



Featuring almost fully regulated outputs this series provides a great level of regulation without affecting the cost efficiency. It is an ideal solution for applications where an unregulated DC/DC converter would not meet you regulation requirements but cost still is a critical factor. Together with an operating temperature range from -40 to +80C° without derating and certifications according to IEC/EN/ES 60601-1 3rd ed. for 2xMOPP and IEC/EN/UL 62368-1 this series is suitable for many different applications where a medical isolation system and short circuit protection is needed.

www.tracopower.com

Reliable Battery Management



With WE-BMS, Würth Elektronik presents signal transformers for battery management systems which, thanks to their galvanic isolation of 4300 VDC/1 min and high operating voltage of up to 1000 VDC, are ideal for use in energy storage systems, E-bikes or E-scooters. Besides the transformers, the WE-BMS series components also include at least one common-mode choke to filter common-mode interference. Würth Elektronik's design offers far longer physical creepage than comparable products on the market yet is very compact. Low-profile component variants of 3.45 mm height are also available.

As the product code WE-BMS spells out, the transformers are absolutely optimized for battery management systems. They are primarily used to ensure reliable operation and provide information about the charging status. The individual cells of a battery pack are connected in series, as are the downstream BMS controllers. Voltage differences and electromagnetic interference may occur between series-connected components or boards. The WE-BMS transformer serves to isolate components from each other and suppress EMI. Applications include storage systems for solar installations or uninterrupted power supplies (UPS). As the WE-BMS series is AEC-Q200 qualified, it is also very well suited for E-mobility applications. WE-BMS supports serial daisy chain, isoSPI and SPI.

www.we-online.com

Combiners Make 5G, Fiber Broadband, and Security More Accessible

Since the line's introduction, ABB Power Conversion's Power Express combiners have helped provide safe and effective remote powering for indoor loads that exceed the capabilities of a single Class 2 circuit. Initially introduced with eight circuits to power up to 600W, ABB has announced the addition of two- and four-circuit combiners to its Power Express product family, offering flexible options to meet users' unique needs while complying with NEC requirements.

In addition, ABB has developed a 1-rack-unit (RU)-high SPS Power Express shelf to address systems that use a commercial AC power input but do not have the space or desire for a separate DC power shelf. These latest additions to the Power Express family enable ABB to provide a comprehensive set of solutions to meet the Class 2 power needs of customers' unique applications. "These more compact, flexible combiners will help companies with lower budgets or smaller spaces reap the safety and compliance benefits of combined Class 2 circuitry when creating infrastructure to support 5G and Wi-Fi hotspots, fiber applications, distributed antenna systems (DAS), and security cameras," said Raj Radjassamy, 5G and wireless segment leader for ABB Power Conversion.

www.abbpowerconversion.com

Buck Switcher IC for Low-Part-Count Automotive PSUs

Power Integrations announced a high-current member of its LinkSwitch™-TN2Q automotive switcher IC family which provides up to 850 mA of output current without the need for metal heatsinking. The integrated ICs support a wide input voltage of 30 to 550 VDC, enabling the devices to start up and operate below the required Safety Extra Low Voltage (SELV) threshold in functional safety EV applications.

Edward Ong, senior product marketing manager at Power Integrations, said: "As electronics in electric vehicles grow more sophisticated, automotive customers need higher supply currents to drive them. The 850-mA rating for this new IC represents an increase of 230 percent in available output current compared with other members of the LinkSwitch-TN2Q family. LinkSwitch-TN2Q ICs reduce part-count by including control, driver, protection circuitry and a 750 V power MOSFET in an SMD package.”

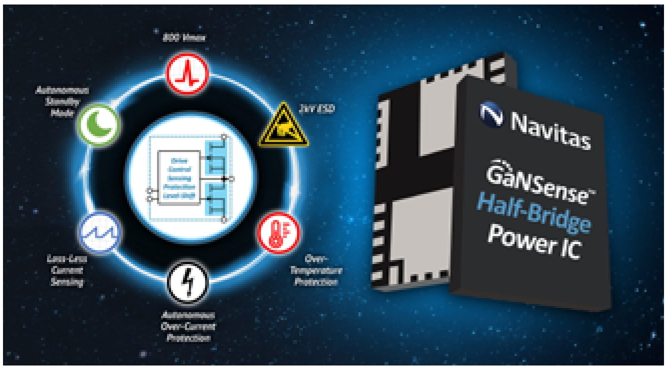
LinkSwitch-TN2Q ICs are AEC-Q100 qualified and support buck, buck-boost and non-isolated flyback converter topologies. Each device incorporates a 750 V power MOSFET, oscillator, on/off control, a high-voltage switched current source for self-biasing, frequency jittering, fast (cycle-by-cycle) current sensing and current limit, hysteretic thermal shutdown, and output over-voltage protection circuitry in a monolithic IC. LinkSwitch-TN2Q ICs consume very little current in standby, resulting in power supply designs that easily meet less than 50 mW no-load at 400 VDC input. Comprehensive protection features enable safe and reliable power supplies, including protection against input and output overvoltage, device overtemperature, lost regulation, and power supply output overload or short-circuit faults.

www.power.com

Gallium Nitride Half-Bridge Power ICs

Navitas Semiconductor announced GaNSense™ half-bridge power ICs. These half-bridge ICs enable a new level of MHz switching frequencies while reducing the system cost and complexity compared to existing discrete solutions.

GaNSense half-bridge power ICs integrate two GaN FETs with drive, control, sensing, autonomous protection, and level-shift isolation, to create a fundamental power-stage building block for power electronics. This single-package solution reduces component count and footprint by over 60% compared to existing discretes, which cuts system cost, size, weight, and complexity. The integrated GaNSense technology enables autonomous protection for increased reliability and robustness, combined with loss-less current sensing for higher levels of efficiency and energy savings. The high integration levels also eliminate circuit parasitics and delays, making MHz-frequency operation a reality for a broad range of AC-DC-power topologies including LLC resonant, asymmetric half-bridge (AHB), and active-clamp flyback (ACF). The GaNSense half-bridge ICs are also a perfect fit for totem-pole PFC, as well as motor-drive applications.



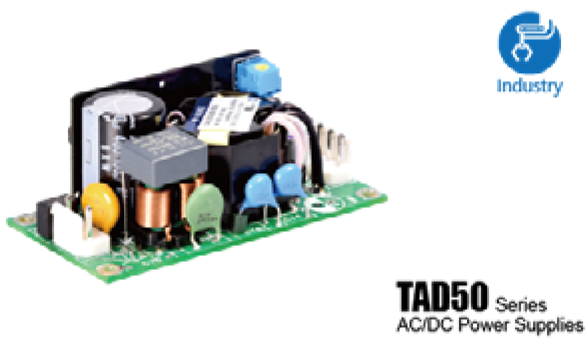
GaNSense half-bridge ICs are anticipated to have a significant impact in all Navitas target markets including mobile fast chargers, consumer power adapters, data center power supplies, solar inverters, energy storage, and EV applications.

www.navitassemi.com

Compact Industrial AC/DC Power Supplies

P-DUKE has added the TAD50 series to its open frame power supplies portfolio from 15W to 450W. It has a compact 3"x1.5" footprint and delivers 50W continuous output power. In addition, a peak power function is available that enables the power supply to deliver up to 140% of rated output power for 5 seconds. This series is designed with a high conversion efficiency of 90.5% to 92.5%, enabling full-power operation from -40°C to +55°C ambient temperature without derating or forced air cooling. With forced air cooling or with output power derating the TAD50 series can perform up to +85□. The universal input voltage range is 85-264Vac (120-370Vdc) and outputs are available from 5, 7.5, 9, 12, 15, 18, 24, 36, 48 and 53Vdc with output adjustability of -10% to +10% or -20% to +10%, depending on output voltage.

The TAD50 series features full protection against output short-circuit (continuous, automatic recovery), over-load (hiccup mode, automatic recovery) and output over-voltage (latch mode). The TAD50 series allows operating altitudes of up to 5000m and has a 3kVac/1 minute reinforced I/O-insulation and over voltage category OVC III. The integrated EMC filter complies with EN 55032, class B for conducted and radiated emission.



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High-Voltage Power Film Capacitor for DC Filtering Applications

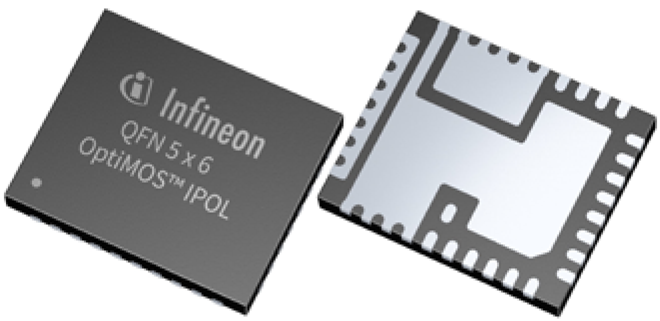
KYOCERA AVX releases its 1,000th TRAFIM Series high-voltage power film capacitor for DC filtering applications up to 6,000VDC. TRAFIM Series capacitors are widely renowned for their high energy density and controlled self-healing technology, which ensures proven-safe, high-reliability performance over 100,000-hour lifetimes at rated voltage and 80°C hot spot temperature - and up to 240,000 hours with appropriate derating - in a wide range of high-voltage industrial, military, research, traction, power transmission, and renewable energy applications.

TRAFIM Series capacitors feature large, rectangular, hermetically sealed, unpainted, and nonmagnetic stainless steel cases with volumes up to 46L and are currently available as 1,000 unique part numbers - including the TRAFIMA00, released in September 2021 - with 12 standard voltage ratings spanning 1,950VDC to 6,000VDC, capacitance values extending from 110µF to 10,600µF ±10% tolerance (standard), or ±5% or ±2% on request), and operating temperatures spanning -55°C to +95°C. The series also delivers high specific energy, up to 495J/L, and long-lifetime performance extending up to 100,000 hours at rated voltage and 80°C hot spot temperature with a 2% end-of-life capacitance reduction (ΔC/C) and up to 240,000 hours with appropriate derating. Its two standard case sizes measure 340mm x 117mm and 340mm x 165mm (L x W), are available with heights spanning 215mm to 815mm, and feature an integrated grounding nut. They are also available with two or four M8 or M17 female or M12 or M30 male terminals and with optional mounting brackets.

www.kyocera-avx.com

DC-DC Regulators with Fast COT Engine

Infineon Technologies introduced a family of OptiMOS™ 5 IPOL buck regulators with VR14-compliant SVID standard and I²C/PMBus digital interfaces for Intel/AMD server CPUs and network ASICs/FPGAs. Housed in a 5 x 6 mm² PQFN package, these devices are a fully integrated, and efficient solution for next-generation server, storage, telecom, and datacom applications, as well as distributed power systems.



The OptiMOS IPOL single-voltage synchronous buck regulator TDA38640 supports up to 40 A output current. The device comes with Intel SVID and I²C/PMBus digital interfaces and can be used for Intel VR12, VR12.5, VR13, VR14, IMPVP8 designs, and DDR memory without significant changes to the bill of materials (BOM). Infineon's TDA38740 and TDA38725 digital IPOL buck regulators support up to 40 A and 25 A output current, respectively and come with a PMBus interface. All three new devices use Infineon's proprietary fast constant on time (COT) PWM engine to deliver industry-leading transient performance while simplifying the design development.

The onboard PWM controller and OptiMOS FETs with integrated bootstrap diode make these new devices a small footprint solution with highly-efficient power delivery. In addition, they provide the required versatility by operating in a broad input and output voltage range while offering programmable switching frequencies from 400 kHz to 2 MHz. A multiple time programming (MTP) memory allows customization during design and high-volume manufacturing, significantly reducing design cycles and time-to-market. They also offer a digitally programmable load line that can be set via configuration registers without external components, resulting in a simplified BOM. The device configuration can be easily defined using Infineon's XDP™ Designer GUI and is stored in the on-chip memory.

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