ISSN: 1863-5598

ZKZ 64717
02–22

Bodo´s Power Systems®

Electronics in Motion and Conversion

February 2022

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**

Also suitable for 3-phase inductors

WIDE RANGE OF MODELS

7 models available with maximum test current from 100A to 10000A and maximum pulse energy from 1350J to 15000J

KEY BENEFITS

- Very **easy and fast** measurement
- **Lightweight, small and affordable price-point** despite of the high measuring current up to 10000A
- **High sample rate and very wide pulse width range** => suitable for all core materials

APPLICATIONS

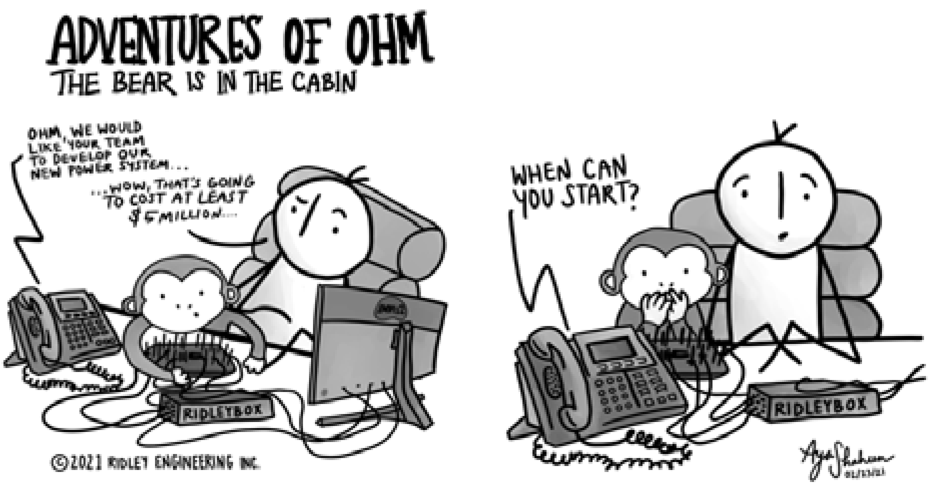
Suitable for all inductive components from **small SMD inductors** to **very large power reactors in the MVA range**

- **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


ADVENTURES OF OHM
THE BEAR IS IN THE CABIN
OHM, WE WOULD LIKE YOUR TEAM TO DEVELOP OUR NEW POWER SYSTEM...
...WOW, THAT'S GOING TO COST AT LEAST $5 MILLION...
WHEN CAN YOU START?
RIDLEYBOX
RIDLEYBOX
©2021 RIDLEY ENGINEERING INC.

Supporters & Friends

A Media
Katzbek 17a
D-24235 Laboe, Germany
Phone: +49 4343 42 17 90
Fax: +49 4343 42 17 89
info@bodospower.com
www.bodospower.com

Publisher
Bodo Arlt, Dipl.-Ing.
editor@bodospower.com

Editor
Holger Moscheik
Phone + 49 4343 428 5017
holger@bodospower.com

Editor China
Min Xu
Phone: +86 156 18860853
xumin@i2imedia.net

US Support
Rusty Dodge
Phone +1 360 920 7825
rusty@eetech.com

Creative Direction & Production
Bianka Gehlert
b.gehlert@t-online.de

Free Subscription to qualified readers
Bodo´s Power Systems
is available for the following
subscription charges:
Annual charge (12 issues)
is 150 € world wide
Single issue is 18 €
subscription@bodospower.com

Printing by:
Westdeutsche
Verlags- und Druckerei GmbH
Kurhessenstraße 4 - 6
64546 Mörfelden-Walldorf
Germany

The Joke of the Year?

Besides the announcements on power electronics and our local soccer team, I try to consume as much news as possible to stay informed of world events. Now, when I read that the European Union is about to label nuclear power as sustainable to justify or even increase investment in the technology, it seems like the joke of the year - even in January. The only thing sustainable about nuclear power is the sustainability of the radiation from the waste it produces and that future generations will have to deal with. How can they ignore all the risks associated with this technology? Chernobyl and Fukushima have taught us a lesson. To me, this is just a red herring to cover up the inability to accelerate the transition of renewables to meet the demand. And while nuclear power plants may produce less CO_2 emissions than the actual coal plants still in use, this surely can't be the way to go. Personally, I am glad to live in a state of Germany that recently turned off the last running nuclear plant and that our federal government is clearly saying no to this nonsense, even though it may not change anything. By the way, gas-fired power plants are environmentally friendly too they say. This is a slap in the face to everyone who works against climate change and global warming.

Back to business, I can't recall a single instance where people weren't excited or at least interested to learn more about our Chinese magazine when I mention it at business meetings. It's no secret that the Chinese market is very important for all kinds of companies involved in electronics and power electronics in particular. So, nothing new as far as that goes, but have you heard of WeChat, the Chinese version of the swiss army knife when it comes to social media, digital experience, and just about any other area of life you can think of? Believe me when I tell you that WeChat is a big thing and is certainly an amazing communication tool. And what if I told you that Bodo's Power Systems China is already there? My good friend Min Xu, the editor of Bodo's Power China, has designed a nice presentation introducing WeChat and their channel. Take a look here:
https://www.bodospower.com/pdf/bodos_wechat_china.pdf
and please feel free to contact him at xumin@i2imedia.net if you are interested.

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 our magazine with every single issue is available for free at our website bodospower.com.

My Green Power Tip for the Month:
Don't let them fool you, stay with as much renewable energy as possible. Saying nuclear power is eco-friendly is hilarious!

Kind regards

Events

Thermal Management Innovation 2022
Online March 14 – 18
www.ev-manufacturing.com/webinars-btm-innovation

CIPS 2022
Berlin, Germany March 15 – 17
www.cips.eu

APEC 2022
Houston, TX, USA March 20 – 24
www.apec-conf.org

SEMI THERM 2022
San Jose, CA, USA March 21 - 25
www.semi-therm.org

SEMICON China 2022
Shanghai, China March 23 – 25
www.semiconchina.org

EnerHarv 2022
Raleigh, NC, USA April 5 – 7
www.enerharv.com

DesignCon 2022
Santa Clara, CA, USA April 5 – 7
www.DesignCon.com

FORTRONIC 2022
Bologna, Italy April 12 – 13
www.fortronic.it

Smart Systems Integration 2022
Greneoble, France April 26 – 28
www.smartsystemsintegration.com

10 Years of Support

Vincotech has quite an anniversary to celebrate. This marks the tenth year the company has supported Plan International Germany's projects. Vincotech's social commitment runs deep; Plan International's humanitarian reach ranges wide. The two forged a partnership that has stood the test of time. Vincotech donates to advance the organization's philanthropic agenda every year. 2021 is no exception: in June the customer satisfaction survey was combined with a fundraising campaign, and in December instead of Christmas gifts the company donates €12,000 to support a project in Nepal.

Eckart Seitter, CEO, says, "Vincotech is all about reliable partnerships with customers and business partners. Society deserves nothing less from us. Giving back to the community and paying it forward to those less privileged is a reward unto itself. This is why we nurture our enduring partnership with Plan International, whose aid projects on behalf of children's welfare and rights are exemplary. We are proud to be contributing to initiatives as worthy as these."

2021's grant went to build schools in Nepal where mountainous terrain, harsh weather, sparse infrastructure and great distances make it difficult for many children to attend school. Plan International is building barrier-free classrooms in earthquake-proof buildings to afford educational opportunities to more kids. In winter, when the snow and cold make long journeys to school even harder, lessons are to be held over the radio and given by local teachers. Competitions and classroom book corners go to promote reading. Topics such as equality and hygiene are now on the syllabus. Separate sanitary facilities are to encourage girls to attend school.

PLAN INTERNATIONAL

Bringing hearts and minds together for children

www.vincotech.com

Collaboration to Advance and Simplify the Adoption of Electric Vehicles

Hitachi America and REE Automotive announced a strategic agreement to ease and accelerate the adoption of electric vehicles (EV) across the entire EV value chain, including enabling EV manufacturing at scale, delivering commercial vehicle charging infrastructure and energy management, and providing comprehensive digital fleet management and operations for full visibility across EV fleets as organizations transition over the next decade. Hitachi and REE will accelerate the development of advanced digital solutions for REE customers by co-creating a highly scalable Data-as-a-Service (DaaS) and Analytics-as-a-Service (AaaS) platform, which will enable next-generation connected commercial EVs. Leveraging Hitachi's Lumada data platform and REE's platform modularity and horizontal business strategy, the companies aim to bring to market a truly modular, smart EV solution to serve all segments, including delivery, logistics, and mobility-as-a-service. "We are excited to partner with REE to help accelerate the transition to EVs globally," said Hicham Abdessamad, Chairman and CEO, Hitachi America. "Hitachi is deeply committed to sustainability, and with our long history of innovation in energy, mobility, manufacturing and digital, together with REE's transformative, innovative approach to EV and autonomous vehicles (AV), we are well positioned to accelerate and ease the transition to zero-emission commercial vehicles at scale, a mission that we both share."

www.hitachi.us

GaN IC Design Center Dedicated to Electric Vehicles

Navitas Semiconductor announced the opening of an electric vehicle (EV) Design Center, further expanding into higher-power GaN markets. GaN-based on-board chargers (OBCs) are estimated to charge 3x faster with up to 70% energy savings compared to legacy silicon solutions. GaN OBCs, DC-DC converters and traction inverters are estimated to extend EV range or reduce battery costs by 5%, and to accelerate adoption of EVs worldwide by 3 years. An EV-upgrade to GaN is estimated to reduce road-sector CO2 emissions by 20%/year by 2050, the target of the Paris Accord. The Design Center, based in Shanghai, China, hosts a highly-experienced team of power system designers with comprehensive capabilities across electrical, thermal and mechanical design, software development, and complete simulation and prototyping capabilities. EV customers will be supported worldwide by the new team, from concept to prototype, through to full qualification and mass production.

Respected industry-expert, Mr. Hao SUN, the Sr. Director of the Shanghai Design Center, said "The design center will develop schematics, layouts, and firmware for full-function, productizable EV power systems. Navitas will work in partnership with OBC, DC-DC and traction system companies to create innovative, world-class solutions with the highest power density and highest efficiency to propel GaN into mainstream eMobility."

www.navitassemi.com

Honored for Substantial Contributions to Climate Change and Water Security Issues

The CDP (formerly known as the "Carbon Disclosure Project") released its Climate Change 2021 report, in which Delta was listed in the leadership level under "climate change" and "water security" issues among nearly 12,000 companies worldwide. The CDP assessment recognizes that Delta's business strategy is aligned with low carbon goals. Not only does Delta's Board of Directors actively participate in its sustainability strategy, but the management team also leads the ESG Committee in promoting various climate initiatives and implementing them in the core business and daily operations. The team received top ratings for "climate change governance," "business strategy and financial planning," and "emission reduction initiatives." In water security, Delta achieved a five-year water intensity reduction of 30% in 2020 and committed to a further 10% reduction in water intensity by 2025 compared to 2020. Delta has also assessed the water risk of its main plants and supply chains using the international water risk assessment tool and provided improved resources for high-risk areas or deployed production capacity to reduce its impact on water resources. The Company has been awarded the highest honor from CDP with an A-List leadership rating for its contributions to water security issues.

www.deltaww.com

Strategic Cooperation in Electric Mobility

Global automotive and industrial supplier Schaeffler signed an investment and strategic cooperation agreement with Leadrive on December 16th, 2021 in Shanghai to cooperate in electric mobility.

The purpose of the partnership is to conduct joint development in the electric mobility product areas including E-Axles by virtue of Leadrive's and Schaeffler's respective proprietary technology advantages in the field of electrical drive systems, motor control units and semiconductor power modules for electric vehicle applications, with the aim to start volume production for the first pilot project in 2023. In the meanwhile, Schaeffler will also invest in Leadrive by purchasing stakes in its latest B2 round of financing. "The electro-mechanical integration is a trend of electrical vehicle drive system. Leadrive and Schaeffler will strengthen their respective proprietary technology advantages in the field of 'electrical' and 'mechanical'," said Dr. SHEN Jie, Founder and General Manager of Leadrive. "Through this partnership, we will develop globally technical advanced electrical powertrain products together, including the 800V Silicon Carbide E-Axle."

The agreement was signed by Dr. SHEN Jie, Founder and General Manager of Leadrive Technology (Shanghai) Co., Ltd. and Dr. CHEN Xiangbin, President Automotive Technologies of Schaeffler Greater China, and was witnessed by Dr. Jochen SCHROEDER, President Business Division E-Mobility of Schaeffler Group from online connection.

www.leadrive.co

First World-Wide Carbon Neutral Circuit Board

AISLER announced at the World Ethical Electronics Forum (WEEF 2021) its plans to ship the first worldwide carbon-neutral circuit board by the end of 2022. That way, AISLER aims to be at forefront of decarbonating the development process of the electronics products of tomorrow. Starting next year, AISLER will use its service to reduce the impact on the environment. "By design, we have a much lower carbon footprint because we only manufacture locally. To make this affordable, we employ automation which allows us to achieve best-in-class production yields and lower costs. This alone however does not save us; everyone in our society needs to identify how we can jointly contribute to a carbon-neutral future," said Felix Plitzko, CEO and Co-Founder of AISLER. AISLER plans to ship its first carbon-neutral circuit boards at the end of 2022 with its Beautiful Boards product. Together with the German Fraunhofer IZM, AISLER will first sum up their carbon footprint, to then identify proper measures to reduce the product footprint down to 0. AISLER serves engineers as a convenient one-stop shop for circuit boards, parts, stencils and assembly to develop the products of tomorrow.

"The best way we can contribute is to help our customers with decarbonating their development process. With nearly 50,000 engineers as our customers, this is where we as a company have the best leverage and can contribute the most. The engineer should be in the driver seat of their supply chain and make their environmental contribution as easy as a snap," Plitzko further elaborated. AISLER also plans to go fully carbon-neutral by the end of 2023.

AISLER

www.aisler.net

HPMSIM Hitachi

Online Power Simulation Tool

HPMSIM, Hitachi's new online power simulation tool is designed to help assist you in choosing the right Hitachi IGBT, Hybrid SiC and SiC MOSFET, suited to your needs.

Our new platform allows you to analyse the performance of our products to fit your specific application.

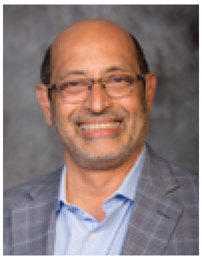
Product Portfolio for Chinese Market

SCHURTER's series of multi-functional power entry modules have received CQC or CCC approval for use in equipment for the Chinese market. Series 5707, DG12, and DG11, as well as Distribution Unit series 4752, add to SCHURTER's range of passive and electromechanical components designed for global application.
The compact and highly integrated power entry modules with or without EMC filters, include options such as line switch and/or 1- or 2-pole fuseholder. These series can also be specified with IP seal protection, important for many medical applications with exposure to drips and spills, or those that require cleaning. The PEMs are especially suited for use in any equipment where space is at a premium.

China Quality Certification [CQC] is mandatory for Power Entry Modules [PEM] with an EMC filter. PEMs without EMC filter require China Compulsory Certification [CCC]. The CQC Mark Certification is otherwise a voluntary product certification sanctioned by the China Certification & Inspection Group (CCIC) to manage the process for manufacturers interested in pursuing the China Compulsory Certification (CCC). It is a certification system in which merchants voluntarily participate. The voluntary product certification service (called CQC mark certification) carried out by CQC certification indicates that the product meets the relevant quality, safety, environmental protection, performance, and other standards by imposing the CQC mark.

www.schurter.com

Umesh Mishra Awarded IEEE Jun-ichi Nishizawa Medal



Transphorm announced that its co-founder and CTO Umesh Mishra, Ph.D. was awarded the IEEE Jun-ichi Nishizawa Medal. The honor is given to individuals who have demonstrated outstanding contributions to material and device science and technology, including practical application. Umesh was recognized for his contributions to the development of GaN-based electronics. This is the second IEEE award received by him, the first being the IEEE David Sarnoff Award for the development of GaN electronics. Umesh has a strong legacy in the field of GaN technology. In 1996, he co-founded Nitres Inc., the first start-up company to develop GaN LEDs and RF transistors. Nitres was acquired by Cree (now Wolfspeed) in 2000. He continued researching and developing GaN-based solutions, expanding focus to high voltage power conversion applications and, in 2007, co-founded Transphorm. Throughout his business career, Umesh has also served in the academic field as a Distinguished Professor in the ECE Department at the University of California, Santa Barbara (UCSB) where he has been a director of several GaN research centers.

www.transphormusa.com

Awarded the Highest Platinum Rating of Sustainability

ROHM has been awarded the highest rating of "Platinum" for its sustainability performance of 2021 by EcoVadis based in France for the first time. The «Platinum» rating is given to the top 1% of about 80,000 companies assessed across all industries. EcoVadis is the world's largest and most trusted provider of business sustainability ratings, founded in 2007 to promote the sustainability of supply chains around the world. About 80,000 companies in 160 countries across 200 industries are assessed in four areas of Environment, Labor and Human Rights, Ethics, and Sustainable Resource Procurement, and are rated in four levels: Platinum (top 1%), Gold (top 5%), Silver (top 25%), and Bronze (top 50%).

As ESG is becoming increasingly important, the assessment results of EcoVadis are recognized by many global companies as one of the most important factors in selecting suppliers.

ROHM received the highest performance score level of "Outstanding" in the environmental field, for their goal of reducing greenhouse gas emissions to zero by 2050 and for their longstanding efforts to promote greening in Japan and overseas. They also received high scores for Labor and Human Rights and Sustainable Resource Procurement fields and overall, putting it in the top 1% of the companies across all industries. Encouraged by the results of this assessment, ROHM will continue to promote CSR activities and work to solve social issues in order to realize a sustainable society, while aiming to be a company that meets the expectations of its stakeholders.

www.rohm.com

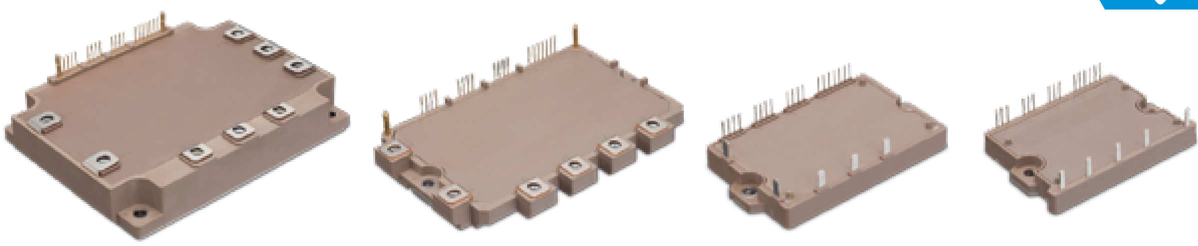
New Appointment for Industry Veteran Dhaval Dalal

Tagore Technology announced that power electronics industry veteran, Dhaval Dalal has joined the Tagore team. Dhaval Dalal has over 30 years of R&D experience at leading semiconductor and OEM companies including onsemi and Texas Instruments and as founder of power electronics consultancy, ACP Technologies LLC. In his new role, Dalal will focus on bringing Tagore's highly efficient, cost-effective power management solutions to market. Tagore Technology CEO, Amitava Das said: "For over 10 years Tagore has been at the forefront of disruptive semiconductor solutions and we are excited about the innovative GaN-on-Si power management products we offer. As we continue to expand our product portfolio, with Dhaval on board, we look forward to working even more closely with our customers to help solve their most challenging power management problems." Commenting on his new appointment, Dhaval Dalal said: "I am delighted to have the opportunity to help Tagore's customers bring their designs to market faster while increasing efficiency and reliability and reducing overall system cost." Dhaval Dalal is a Member of the Board of the Power Sources Manufacturers Association (PSMA) and Co-Chair of the PSMA Power Technology Roadmap Committee. Dalal holds a B.Tech in Electrical Engineering from the Indian Institute of Technology, Bombay, an M.S. in Electrical Engineering from Virginia Tech and an M.S. in Management Technology from National Technological University (now Walden University).

www.tagoretech.com

APEC 2★22

Visit Us in Houston, TX!
March 20-24
Booth #1308

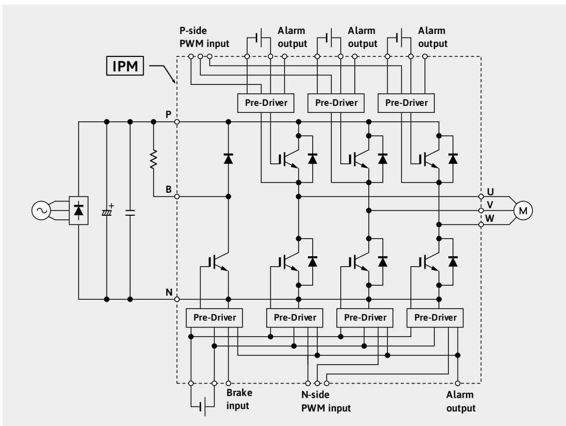


X series – Intelligent Power Modules (IPM)

ideal for Air Conditioners, Elevators and Servo Systems

FEATURES

- Reduction of losses and improvement of energy efficiency by optimizing 7th generation IGBT technology for IPM
- Embedded driver IC for optimum control and protection functions
- One wire provides three alarm signals: over-current, over-heating, under-voltage
- Temperature sensor analog output and warning function
- 6in1 and 7in topology (full inverter + brake)
- High temperature operating (T_j=175 °C)
- Reduced turn-on loss at high temperature operation by drive control
- Power range from 20 A to 450 A at 650 V and 10 A to 300 A at 1200 V



www.fujielectric-europe.com
www.americas.fujielectric.com/semiconductors

Fuji Electric
Innovating Energy Technology

Strengthening Aerospace and Defence Portfolio

TT Electronics announced it has acquired the Ferranti Power and Control business (Ferranti P&C) from Elbit Systems for £9 million. Ferranti P&C is a UK based manufacturer of power electronics and power systems for the aerospace and defence markets located in the greater Manchester area.

The acquisition strengthens TT's UK aerospace and defence footprint and further enhances the capabilities of their power conversion and power management portfolio. With a recognised and reputable customer base, many of whom are supported by TT already, this acquisition will also bring opportunities for supply chain streamlining and consolidation for many key industry partners.

Ferranti P&C provides access to a range of recognised programs across both the military aerospace and commercial and business aerospace sectors with sole-sourced positions on major key platforms. TT is committed to investing in the business further to accelerate growth prospects and support continued expansion of differentiated engineering capability for the design and development of custom high-reliability power solutions. Richard Tyson, CEO, TT Electronics commented: "We are delighted to have completed the acquisition of the Ferranti Power and Control business. This represents a significant step and great addition for our power capability. The organisation is an ideal strategic fit within our existing UK footprint and adds further credibility and significant engineering expertise to our aerospace and defence offering. It's fantastic to be able to welcome the Ferranti Power and Control team into the TT group."

www.ttelectronics.com

Additions to European Sales Team

Indium Corporation is pleased to announce updates to its European sales leadership team headquartered in its Milton Keynes facility in the United Kingdom. Wolfgang Bloching and David McKee have both been promoted to the role of senior regional sales manager and Anders Lunden has taken a new role as regional sales manager. In his new role, Bloching is responsible for growing sales in Germany, Austria, and Switzerland for Indium Corporation's soldering products including solder paste, solder wire, engineered solder materials, and thermal management materials. He also manages the company's sales channel partners throughout his region. Bloching has more than 24 years of experience in electronics manufacturing. He joined Indium Corporation in 2009 and is a German State Certified Engineer in the field of electronics and process engineering. Joining Bloching as a senior regional sales manager is David McKee. McKee is also responsible for growing sales of the company's soldering and thermal management materials and managing sales channel partners throughout his region of eastern Europe. McKee has more than 35 years of industry experience. Since joining Indium Corporation in 2000, McKee has held and succeeded in multiple roles including process specialist, area sales manager, and key account manager. He holds a Higher National Certificate in Automotive and Mechanical Engineering from West Lothian College in Scotland. He is also an SMTA-certified process engineer and earned his Six Sigma Green Belt from the Thayer School of Engineering at Dartmouth College. Assuming a new role with Indium Corporation is Regional Sales Manager Anders Lunden, who has been with the company since 2019 and has more than 20 years of experience in the electronics industry. Lunden serves as Indium Corporation's lead sales contact and customer advocate for soldering products in Sweden, Denmark, Finland, Norway, the Baltic states, and Poland. He holds a bachelor's degree in electronic production from the KTH Royal Institute of Technology in Stockholm, Sweden.

www.indium.com

ECPE Events

Hybrid Event | ECPE Workshop 'Advanced Drivers for Si, SiC and GaN Power Semiconductor Devices'
15 - 16 February 2022, Berlin, Germany

ECPE Conference 'CIPS 2022 - 12th International Conference on Integrated Power Electronic Systems'
combined with ECPE Annual Event 2022
15 - 17 March 2022, Berlin, Germany

ECPE Tutorial 'Drivers and Control Circuitry for IGBTs and MOSFETs'
5 - 6 April 2022, Vienna, Austria (further information to be published soon)

ECPE Tutorial 'Testing and Electrical Characterization of Power Semiconductor Devices'
27 - 28 April 2022, Reutlingen, Germany

Hybrid Event | ECPE Tutorial 'EMC in Power Electronics'
28 - 29 April 2022, Hamburg, Germany (further information to be published soon)

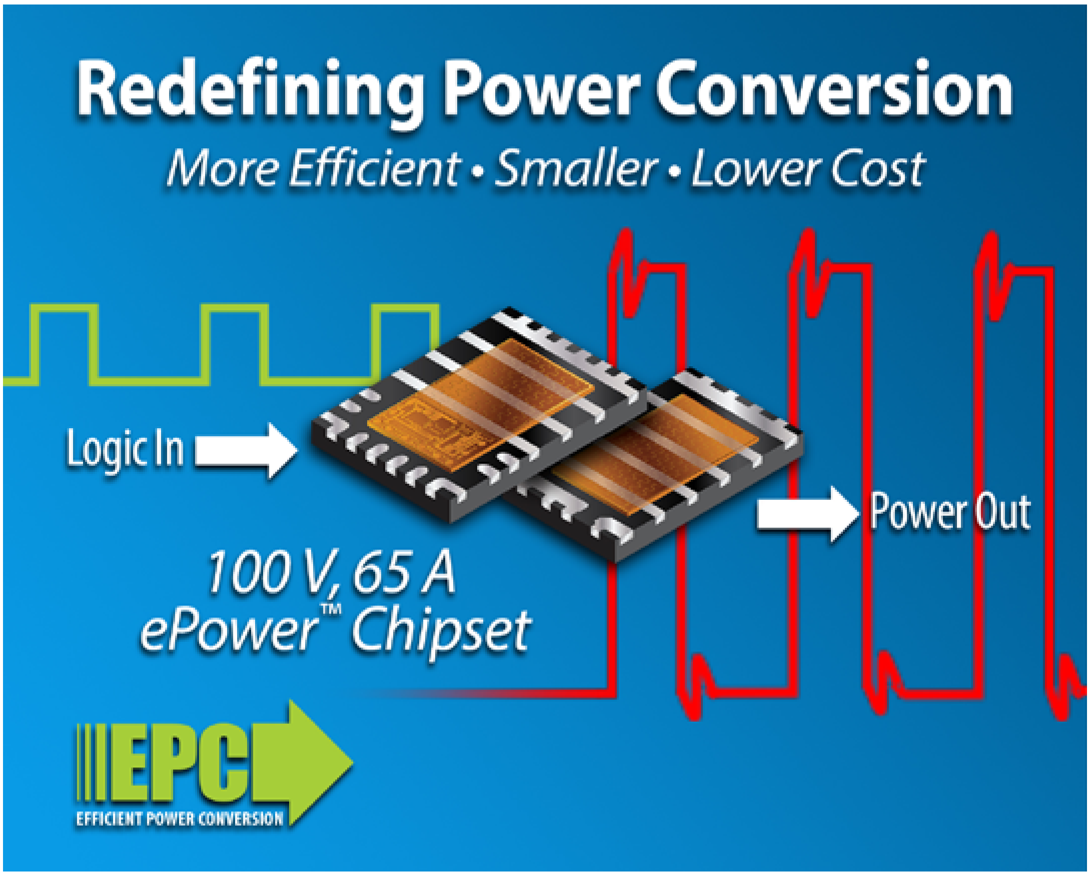
ECPE Online Tutorial 'Introduction to Power Electronics'
31 May - 1 June 2022, Digital Event (further information to be published soon)

ECPE Lab Course 'EMC Optimised Design (Parasitics in Power Electronics)'
23 - 24 June 2022, Berlin, Germany

ECPE Workshop 'High Power Electronics for a Successful Energy Transition towards 100 % Renewable Energy'
8 - 9 September 2022, Hannover, Germany
in conjunction with EPE '22 Conference

www.ecpe.org

ePower Chipset Family for High Power Density Applications



EPC has introduced a 100 V, 65 A integrated circuit chipset designed for 48 V DC-DC conversion used in high-density computing applications and in 48 V BLDC motor drives for e-mobility, robotics, and drones. The EPC23101 eGaN IC plus EPC2302 eGaN FET offers an ePower Chipset capable of a maximum withstand voltage of 100 V, delivering up to 65 A load current, while capable of switching speeds greater than 1 MHz.

- Key features of the EPC23101 integrated circuit using EPC's proprietary GaN IC technology include integrated 3.3 mOhm $R_{DS(on)}$ high side FET with gate driver, input logic interface, level shifting, bootstrap charging, gate drive buffer circuits and gate driver output to drive external low side eGaN FET
- The EPC2302 eGaN FET offers a super small $R_{DS(on)}$, of just 1.8 mOhm, together with very small Q_G, Q_{GD}, and Q_{OSS} parameters for low conduction and switching losses.
- Both devices feature a thermally enhanced QFN package with exposed top with optimized pinout between the two devices. The combined chipset footprint, is 7 mm x 5 mm, offering an extremely small solution size for the highest power density applications

When operated in a 48 V to 12 V buck converter, the EPC23101 + EPC2302 chipset delivers 96% efficiency at 1 MHz switching frequency and 97% efficiency at 500 kHz switching frequency and can deliver 65 A with less than 50 °C temperature rise.

The ePower family of products makes it easy for designers to take advantage of the significant performance improvements made possible with GaN technology. Integrated devices are easier to design, easier to layout, easier to assemble, save space on the PCB, and increase efficiency.

"Discrete power transistors are entering their final chapter. Integrated GaN-on-Silicon offers higher performance in a smaller footprint with significantly reduced design engineering required," said Alex Lidow, CEO and co-founder of EPC. "From the serenity or control environment of digital and analog controllers, the ePower Chipset translates the PWM command signals to high voltage and high current waveforms capable of driving real world loads. Designers can use the ePower Chipset to make lighter weight and more precise battery-operated BLDC motor drives for eMotion, robotic arms and drones, higher efficiency 48 V input DC/DC converters for data center, datacom, artificial intelligence, solar MPPT and other industrial and consumer applications."

Development Board

The EPC90142 development board is a 100 V maximum device voltage, 65 A maximum output current, half bridge featuring the EPC23101 Integrated ePower FET and EPC2302 eGaN FET. The purpose of this board is to simplify the evaluation process of the ePower Stage Chipset This 2" x 2" (50.8 mm x 50.8 mm) board is designed for optimal switching performance and contains all critical components for easy evaluation.

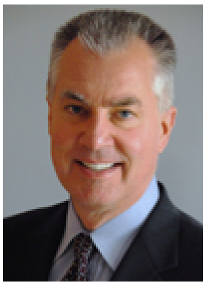
www.epc-co.com

Collaboration on SiC Power Stack Reference Design

E-mobility and renewable energy systems require power management solutions that drive performance and cost efficiencies in addition to speeding up development time. To keep pace with these requirements, Microchip Technology announced a collaboration with Mersen on their 150 kilovolt-ampere (kVA) three-phase silicon carbide Power Stack Reference Design. I had the chance to interview Perry Schugart, Technical Staff Engineer – Product Marketing at Microchip Technology, and Dr. Philippe Roussel, VP Strategic Marketing and Executive Expert at Mersen.

By Bodo Arlt, Publishing Editor, Bodo's Power Systems

Bodo: I have seen Microchip acquiring Microsemi and AgileSwitch to play in the power arena. Are there plans to include more than the power devices into the systems?



Perry Schugart

Perry: Microchip's great strength is in offering customers total systems solutions. As a leading global microcontroller provider, that means we can incorporate more of the power control circuit into systems based on products provided by Microchip. Microchip's company legacy provides important system solutions in that it addresses a critical piece of the power conversion system. Incorporating our controllers, we can support a customer's full inverter design.

Bodo: Mersen acquired Eldre and FTCAP on the way to provide systems. Are there plans to include the full drive, inverter and motor?

Philippe: It is true that Mersen is incrementally moving up in the value-chain, from stand-alone passive components to solutions. We aim at serving the power electronics market with sub- or full assemblies to facilitate our customer's development journey.

We want our customers to keep focusing exclusively on their core expertise being inverter topology and circuit design, whereas Mersen will take care of optimizing their systems in size, weight, efficiency, power density, kW/liter, $/kW and so on…

We have no intention to market our own Mersen-labelled inverters (to the exception of this Power Stack Reference Design), but we want to partner with our customers in a co-design spirit. In other words, to expand the cooperation overlap during the customer's design phase.

Dr. Philippe Roussel

Bodo: Are there plans beside bus bars, capacitors, fuses and cooling systems?

Philippe: Yes, there are! Our strategy is to expand our product portfolio towards additional key passive components. Naturally, magnetics, resistors or current sensors are on the short-list.

Mersen always grew by acquisitions and will continue to do so…

Bodo: The introduced Power Stack Reference Design should serve as a development tool for end customers, right?

Philippe: Yes, this is the exact purpose of this Power Stack Reference Design: to demonstrate that SiC technology can be deployed from end to end, from the semiconductor to the final system. We offer this development platform as well as customization and derating options (different geometry, voltage, current, switching frequency, cooling technique…) allowing our customers to experience SiC electronics and to fine-tune their own design.

Bodo: Are there any plans for design centers for example, to help engineers overcome the barriers using SiC?

Perry: We continue our collaboration with Mersen and are examining several potential options.

Philippe: Yes, there are several options on the table. It's been now a while that both teams are collaborating on various projects. Designing this Power Stack Reference Design was another great achievement. We now need to hear from the market before launching the next stage. More to come…

Bodo: What are the main target designs and markets of the Power Stack Reference Design?

Perry: It is Electric Vehicles (EVs), commercial transportation, renewable energy and storage systems. Microchip currently provides 700V, 1200V, and 1700V die, discrete, module, and SiC gate driver solutions. And we continue to develop SiC solutions beyond these voltage classes.

Philippe: Originally, we designed this inverter for a heavy-duty vehicle, based upon a real case-study. Since then, we have performed numerous adaptations to fit different applications such as DC-grid power management, Solid-State Transformer or EV charging station. In essence, we are agnostic regarding the application, and as we build on this Power Stack Reference Design with the support of Microchip, the possibilities are infinite!

Bodo: Thank you both for this informative update. I'll keep my eyes open for more to come!

www.microchip.com/SiC

www.mersen.com

Benefits of Using the 1700V and 3300V High Power Modules for Traction Applications

In this article we present the results of analysis of current requirements of traction converters powered by 750 V DC and 1500 V DC. Based on these application conditions we have also done a comparison of performance of modern 1700V and 3300 V Si IGBT, Hybrid Si IGBT / SiC SBD and Full - SiC MOSFET modules. These results are used for the evaluation of the benefits of different semiconductor technology when used in traction converters for different switching frequencies.

By Praneet Bhatnagar & Chris White, Hitachi Europe

The user requirements in case of propulsion inverters for light traction vehicles (such as trolleybuses, hybrid buses, tramways, metro / subway vehicles) gradually increase especially in the following areas:

1. high efficiency and power density
2. low volume and weight
3. high robustness
4. high reliability and lifetime

To meet these requirements, power semiconductor modules are the main drivers and their performance most significantly determines the performance of the main propulsion traction inverters. This performance benefits can be seen not just from an electrical performance perspective but also, we observe this on the mechanical aspects of the system design.

For light traction vehicles such as trolleybuses and trams, which are powered from 750 V DC networks, 1700 V Silicon (Si) IGBT power modules are used as standard, as was the case in metro vehicles. However, due to the increasing demands on the performance of metro vehicles, the 1500 V DC power supply is being implemented, especially for the newly built metro lines. For such converters it is imperative to use 3300 V Si IGBT modules in such applications. In the last two decades, IGBT modules have clearly dominated these applications. At present, however, the possibilities in the market for power modules of these voltage classes has changed.

In addition to Si IGBT modules with advanced chips, power modules with chips based on a new semiconductor material - Silicon Carbide (SiC) - have been developed. Due to its significantly better properties compared to silicon (lower leakage current, enhanced breakdown strength and higher thermal conductivity), it is possible to realize high power unipolar devices such as MOSFET and Schottky Barrier Diodes in voltage classes 1700 V and 3300 V [1]. Furthermore, there is an option of Hybrid modules featuring - a combination of Si IGBT chips for main switch and SiC SBD to provide free wheeling commutation, are also available [2]. Figure 1 below provides the schematic for those options discussed here.

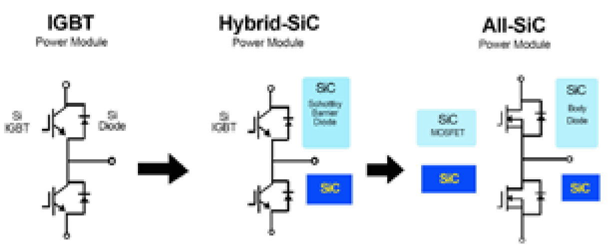


Figure 1: Concept of Hitachi Power Semiconductor Devices – Si IGBT, Hybrid Si IGBT / SiC SBD and Full – SiC MOSFET

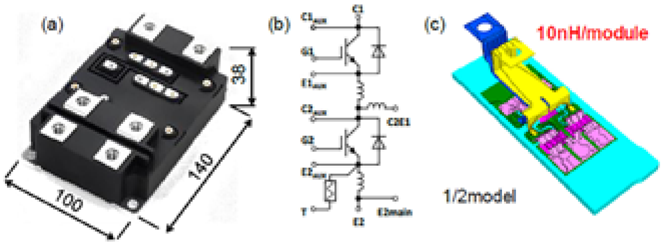


Figure 2: New Package for High Power Modules nHPD2 (new High-Power Density Dual) from Hitachi

Simultaneously with the introduction and development of the new semiconductor technology, significant efforts were made to develop the advanced package and interconnect technologies which resulted in a new concept of a new package form factor for high voltage devices. This advanced package began mass production manufacturing under various names by major suppliers of power modules after 2014 - nHPD2 at Hitachi [3] (shown in Figure 2), LinPAK at ABB, XHP 2 and 3 at Infineon, LV100 at Mitsubishi and others.

The result of these development trends leads to possibility where the world's leading suppliers of power modules currently offer in voltage classes 1700 V and 3300 V all three types of semiconductor modules - Si IGBT, Hybrid Si IGBT / SiC SBD and Full - SiC MOSFET modules, in the same advanced package (except 3300 V Hybrid module). For manufacturers of power converters for traction drives, this is an unusual situation where they can choose the optimal types of power modules that will fulfil the requirements for their specific traction applications.

Requirements and Analysis

In this section, three typical applications from the field of light traction vehicles were selected and operating conditions were specified for them. Furthermore, suitable types of Si IGBT, Hybrid Si IGBT / SiC SBD and Full - SiC power modules were selected for these applications with regard to the requirements of traction converters powered from 750 V DC and also 1500 V DC.

Application No. 1: The application considered here was the main propulsion inverters for trolleybuses and trams

Topology: 2 – Level 3 – Phase Inverter supplying 160 – 210 kW AC induction motor

V_{DC_Link} (V)	$V_{OUT(RMS)}$ (V)	$I_{OUT(RMS)}$ (A)	cos (Phi)	Fsw (kHz)	f_{OUT} (Hz)	T_A* (°C)	R_{thHS}** (K/kW)
450	420	350	0.83	≥ 2	50	40	20

* *maximum air ambient temperature*

** *thermal resistance of heatsink per 1 module*

Table 1 Application No 1 conditions applied for simulations

Erik Rehmann, GVA expert for Quality Management

gva-power.de

„WHERE INNOVATION GOES IN SERIES: GVA"

Our Development, Production and Quality departments are separated by one floor and two flights of stairs – nothing else. Because all GVA experts share the same systemic understanding and the latest know-how. That´s why we are able to mass-produce innovative developments in the shortest possible time. With guaranteed quality – and gladly also for you!

Your GVA expert:
Jürgen Kolasinski
+49 (0)621 / 78992-22
j.kolasinski@gva-power.de

in YouTube

GVA
POWER ELECTRONICS EXPERTS

Analysis and simulations will be performed for the following types of 1700 V modules:
MBM1000FS17G [4]
MBM1000FS17G2-C [4]
MSM900FS17ALT [4]

Application No. 2: The application considered here was the main propulsion inverters for 750 V DC metro vehicles
Topology: 2 – Level 3 – Phase Inverter supplying 2 AC induction motor (2 x 180 kW)

V_{DC_Link} (V)	$V_{OUT(RMS)}$ (V)	$I_{OUT(RMS)}$ (A)	cos (Phi)	Fsw (kHz)	f_{OUT} (Hz)	T_A* (° C)	R_{thHS}** (K/kW)
750	520 (motor) 672 (breaking)	465	0.86 -0.90	≥ 2.5	120	55	15

** water temperature*
*** thermal resistance of heatsink per 1 module*

Table 2 Application No 2 conditions applied for simulations

Analysis and simulations will be performed for the following types of 1700 V modules:
MBM1000FS17G [4]
MBM1000FS17G2-C [4]
MSM900FS17ALT [4]

Application No. 3: The application considered here are the main propulsion inverters for 1500 V DC metro vehicles
Topology: 2 – Level 3 – Phase Inverter supplying 4 AC induction motor (4 x 190 kW)

V_{DC_Link} (V)	$V_{OUT(RMS)}$ (V)	$I_{OUT(RMS)}$ (A)	cos (Phi)	Fsw (Hz)	f_{OUT} (Hz)	T_A* (° C)	R_{thHS} (K/kW)
1500	1060 (motor) 1340 (breaking)	490	0.85 -0.90	>500	100	40	60** 45 ***

** maximum air ambient temperature*
*** thermal resistance of heatsink per 1 module for MBM450FS33F*
**** thermal resistance of heatsink per 1 module for MBN1200F33F-C3*
Table 3 Application No 3 conditions applied for simulations

Analysis and simulations will be performed for the following types of 3300 V modules:
3 x par. MBM450FS33F [4]
2 x par. MBN1200F33F-C3 [4]
2 x par. MSM800FS33ALT [4]

Loss and temperature calculations will be performed for a range of switching frequencies in order to evaluate the benefits of using Hybrid Si IGBT / SiC SBD or Full - SiC MOSFET modules compared to previously dominant Si IGBT modules.

Simulation Results
In this section, calculations of power losses and junction temperature of selected 1700 V and 3300 V modules in typical applications (main propulsion inverters for trolleybuses, trams and metro cars) are performed by simulation using PLECS simulation tool. In particular, the influence of the required switching frequency of individual applications on the total power losses of the inverter is discussed.

Calculations are performed for operating conditions corresponding to today's typical traction drives, outlined in the previous section.

All types of power modules compared here have a maximum junction temperature of 150 °C, so we have chosen in the simulations 135 °C as the maximum junction temperature on transistor or diode chip with regard to sufficient lifetime under cyclic loading. The switching frequency was gradually increased until the value when the maximum junction temperature in the each of the module reached the selected limited value.

The simulation results are shown in the form of the dependence of the maximum junction temperature of the used power modules and the efficiency of the inverter on the switching frequency in Figures 3 to 5.

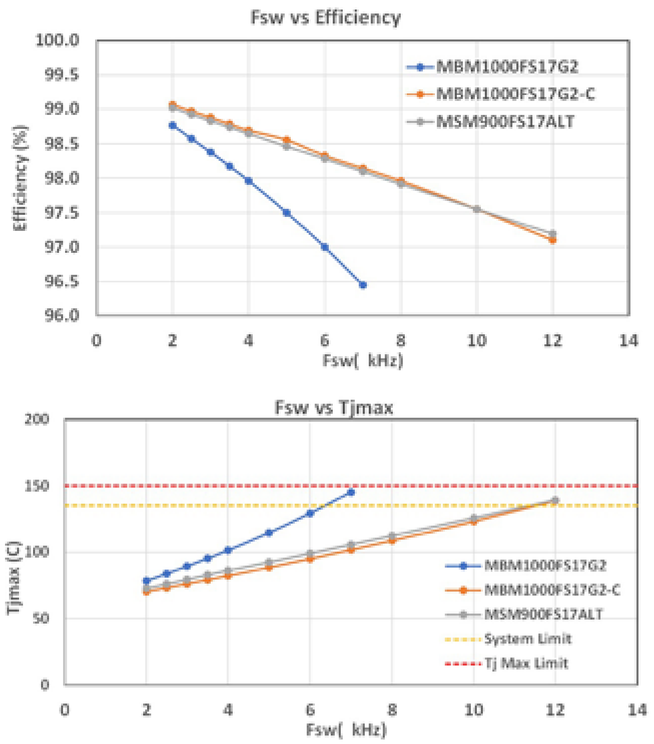


Figure 3: Dependence of maximum junction temperature and inverter efficiency on switching frequency for Application No 1

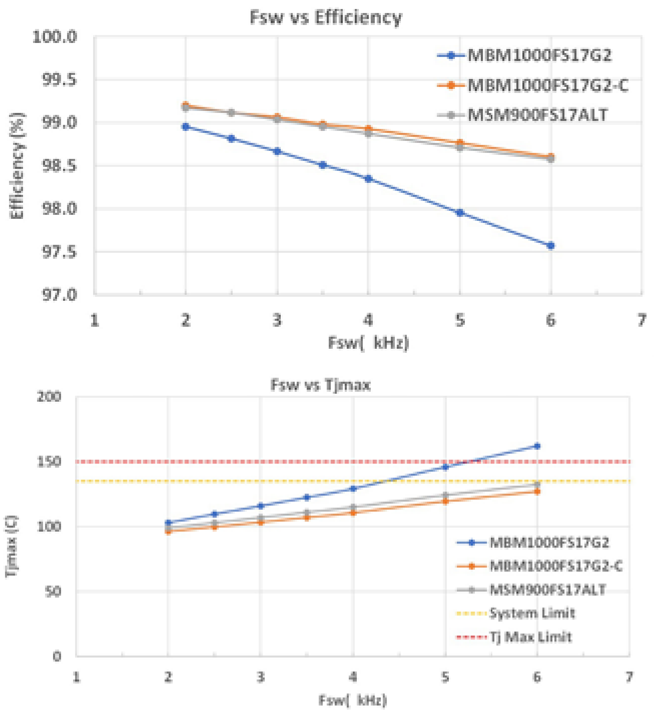


Figure 4: Dependence of maximum junction temperature and inverter efficiency on switching frequency for Application No 2

Evaluation of results and determination of recommendations
In this section, based on the results of simulations (total power losses, junction temperatures, and heatsink size), an evaluation of the benefits of using Hybrid Si IGBT / SiC SBD or Full - SiC MOSFET modules is performed compared to the previously dominantly used Si IGBT modules.

Evaluation of the comparison of 1700 V power modules

Results for the application No. 1 show that the maximum usable switching frequency for a Si IGBT module is only slightly higher than 6 kHz, while both the Hybrid Si IGBT / SiC SBD modules and the Full - SiC MOSFET modules can operate with a switching frequency of up to 10 kHz (i.e. with 1.5 x higher). At 7 kHz, the power losses of the whole inverter with Si IGBT modules are 7.8 kW, in the inverter with Hybrid Si IGBT/SiC SBD modules as well as with Full - SiC MOSFET modules the power losses are 4 or 4.1 kW, which is approximately 48 % less. The inverter with Hybrid Si IGBT/SiC SBD modules as well as with Full - SiC MOSFET modules have comparable power losses with the inverter with IGBT modules (at 4 kHz) up to a switching frequency higher than 10 kHz.

Results for the application No. 2 show that the maximum usable switching frequency for a Si IGBT module is only 4 kHz, while both the Hybrid Si IGBT/SiC SBD modules and the Full - SiC MOSFET modules can operate with a switching frequency of up to 6 kHz (i.e. with 1.5 x higher). At 4 kHz, the power losses of the whole inverter with Si IGBT modules are 6.1 kW, in the inverter with Hybrid Si IGBT/SiC SBD modules as well as with Full - SiC MOSFET modules the power losses are 3.9 or 4.1 kW, which is approximately 33 % less. The inverter with Hybrid Si IGBT/SiC SBD modules as well as with Full - SiC MOSFET modules have comparable power losses with the inverter with IGBT modules (at 3 kHz) up to a switching frequency higher than 6 kHz.

Since all the modules to be compared are in the same housings, a very compact inverter can be implemented.

In applications with current types of traction AC induction motors, the use of fast switching devices can bring some benefits (such as reduced additional motor losses caused by higher harmonics, lower torque pulsation and better control dynamics), but due to some negative effects (such as higher voltage stress on motor windings and bearing currents caused to higher values dv / dt) a significant increase in switching frequency does not make sense.

It is more propriate to use fast switching devices at switching frequencies comparable to today's IGBT modules, i.e. 2-3 kHz. Thanks to significantly lower power losses in the inverter, efficiency is increased and thus the energy consumption of the whole traction drive is reduced. Increasing the efficiency of the traction inverter is also very important for modern applications of so-called hybrid vehicles, which implement part of their driving cycle powered by traction batteries.

The situation in traction drives with a permanent magnet synchronous motor (PMSM) is somewhat different, which is a new trend in the last few years. For optimal design of traction PMSM, it is very suitable to have an inverter that can operate with a significantly higher switching frequency than the one with IGBT modules. The use of Hybrid Si IGBT/SiC SBD or Full - SiC MOSFET modules in these modern drives is therefore very suitable and advantageous, because in terms of system costs of the whole traction drive (inverter + PMSM), the higher costs of Full - SiC MOSFET modules are largely compensated.

In this particular application, the Hybrid Si IGBT/SiC SBD module achieves the same high performance as the Full - SiC MOSFET module, but its costs are significantly lower. It follows that the mentioned Hybrid module is from the point of view of technical - economic aspects the most suitable candidate for the realization of high efficiency and compact traction inverter for PMSM.

Evaluation of the comparison of 3300 V power modules

Results for the application No. 3 show that the maximum usable switching frequency for a Si IGBT module is only slightly higher than 1 kHz, while both the Hybrid Si IGBT / SiC SBD modules and the Full - SiC MOSFET modules can operate with a switching frequency of

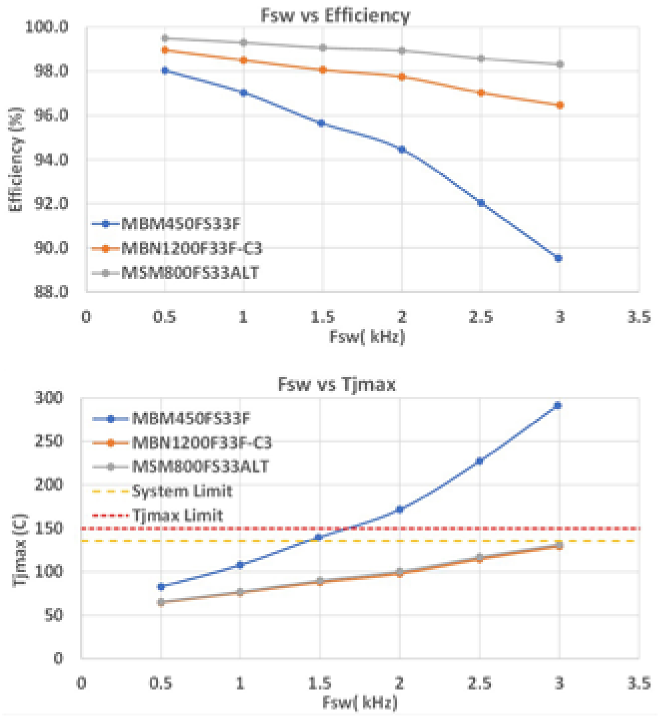


Figure 5: Dependence of maximum junction temperature and inverter efficiency on switching frequency for Application No 3

up to 3 kHz (i.e. with 3 x higher). At 1 kHz, the power losses of the whole inverter with Si IGBT modules are 23.4 kW, in the inverter with Hybrid Si IGBT/SiC SBD modules as well as with Full - SiC MOSFET modules the power losses are 11,6 or 5,4 kW, which is 50 to 77% less. The inverter with Hybrid Si IGBT/SiC SBD modules and has comparable power losses with the inverter with IGBT modules (at 1 kHz) up to a switching frequency 2,5 kHz as well as with Full - SiC MOSFET modules up to a switching frequency slightly higher than 3 kHz.

It should be noted here that the Hybrid module MBN1200F33F-C3 has a different topology (Single switch) and industry standard larger housing (IHM 140 mm x 130 mm) than the Si IGBT module and the Full - SiC MOSFET module (halfbridge in nHPD2 which is 100 mm x 140 mm). The inverter with these modules achieves similarly high performance as the one with Full - SiC MOSFET modules (usable switching frequency, junction and heatsink temperatures), but at the cost of twice the number of modules and 2.6 times larger and heavier heatsink. It is therefore not possible to build such a compact traction converter with these modules as with SiC MOSFET modules in an nHPD2 package. In addition, the advantage of the lower cost of hybrid modules over Full - SiC MOSFET modules is negated in this case by the total number of modules.

For applications with current types of traction AC induction motors and traction permanent magnet synchronous motor (PMSM) the conclusions similar to those made in section 4.1 for 1700 V power modules apply. This is especially true for applications with PMSM, because a higher switching frequency is really necessary to design an optimal high voltage motor of this type in this power range.

Impact of SiC on System Cost

During the last few years a significant price decrease of SiC semiconductors has been observed. The break even for inverter systems in the range of several 100kW with SiC inside and reduced passive components compared to standard Silicon solutions with dedicated passive components is more and more feasible. With the advancement of front-end processing technology and improved raw material sources shows promising future for power modules using SiC technology. An example of improved processing technology is the dedicated screening in the Front End Factory from

Hitachi there is no need to apply an additional Schottky Barrier Diode with the SiC MOSFET. The screening will detect 100 % of possible stacking failures in the raw material. This increases the available area for the SiC chips on the substrate and reduces the cost. This will result in further reduced system costs beside the well-established technical performance. Horowitz et al. [5] demonstrated, through a bottoms-up model that the savings from space and cooling in a SiC-based 1-MW variable-frequency drive resulted in an overall drive cost similar to the current industry standards. We believe the traction applications presented here will have similar overall system cost with SiC power modules.

Conclusions

It is very well known within the industry now that biggest advantages of IGBT modules for the assessed traction conditions are the wide availability of suitable types with sufficient current capacity, low conductivity losses, sufficient short-circuit resistance and reasonable prices. However, with this comes the biggest disadvantage of having a strongly temperature dependent switching losses, which limit the use of higher switching frequencies for these applications. This has been suitably demonstrated with the three application case studies presented here.

From the results presented in this study we can observe that the implementation of Full - SiC MOSFET modules result in significantly lower power losses at similar operating switching frequency of Si IGBT modules. The other perspective would be to have power losses similar to Si IGBT modules but then the operating switching frequency would be significantly higher. The disadvantages are low short circuit withstand capability and at present significantly higher prices compared to similar Si IGBT modules. With applications which have higher DC voltage requirements of 1500 V the implementation of the SiC MOSFET modules is critical to achieve higher switching frequencies and compact inverter sizes.

The use of Hybrid Si IGBT / SiC SBD modules offers a certain compromise between Si IGBT and Full - SiC MOSFET modules in terms of the achieved technical parameters and costs. Their advantage over Si IGBT modules are identically low conductivity losses, but lower switching losses, which will allow either an increase in switching frequency or a reduction in cooling requirements. Compared to Full - SiC MOSFET modules, they have higher short circuit withstand capability and especially lower costs. Overall, with these application case studies we have been able to demonstrate that the use of Si IGBT hybrid power module has suitability in applications for DC link voltage range of 750 V. These power modules need to be assembled in a low inductance package to have the benefit of higher switching frequency.

References

[1] K. Saito, P. Bhatnagar: Value Enhancement of Full SiC 3.3 kV Power Module in nHPD2 Package, Bodo's Power Systems; March 2020, 26-30

[2] Y. Sekino, A. Iso, Y. Harada, T. Moriya, et al.: 3.3 kV SiC Hybrid module with High Power next Core (HPnC), Proc. PCIM Europe 2018

[3] D. Kawase, K. Nagashima, T. Hirayama, K. Azuma, et al: nHPD2 (next High-Power Density Dual) with next generation chip suitable for low internal inductance package, Proc. PCIM Europe 2016

[4] https://www.hitachi-power-semiconductor-device.co.jp/en/products/igbt/index.html

[5] K. Horowitz, T. Remo, and S. Reese:A Manufacturing Cost and Supply Chain Analysis of SiC Power Electronics Applicable to Medium-Voltage Motor Drives, No. NREL/TP--6A20-67694. National Renewable Energy Lab.(NREL),Golden, CO (United States), 2017

We would also like to acknowledge the contribution of Dr Miroslav Hruska from Siemens Advanta Development, Czech Republic towards this article.

About the Authors

Dr Praneet Bhatnagar is a Principal Application Engineer at Power Device Division, Hitachi Europe working in the area of high-power semiconductors with European customers in the field of traction applications. He has a Phd in SiC Devices from Newcastle University and has worked in the semiconductor industry for the past 15 years in research and development of IGBT and MOSFET technologies. Contact email – Praneet.Bhatnagar@hitachi-eu.com

Mr Chris White graduated with a master's degree in Electrical and Electronic Engineering from the University of Cambridge. As Engineering Manager in the Power Device Division of Hitachi Europe he is responsible for the provision of technical, application and design in support for customers using IGBT and SiC MOSFET modules across a range of industries including EV/HEV applications. Contact email - Chris.White@Hitachi-eu.com

https://pdd.hitachi.eu

Snubber Network Choices, Design and Evaluation

Power conversion circuits use snubber networks extensively to control voltage overshoots, improve efficiency and minimize EMI. This article discusses some circuit options and the design basics. Measurement of snubber performance is also discussed, with examples of pitfalls and best techniques for accurate results.

By Paul Lee BSc CEng MIET, independent author, power conversion electronics and Dr. Markus Herdin, Market Segment Manager Industry, Components, Research & Universities at Rohde & Schwarz, responsible for the Segment Power Electronics T&M

Power electronics has a variety of antiquated terms, some dating back centuries and perhaps 'snubber' is one, derived from Middle English which was spoken until the 15th century. The meaning of the word was originally to 'scold' or 'curse' but is now taken to indicate 'cutting short' or 'damping' in the electronics context. Specifically, a snubber is usually a network of components used to control and limit voltage or current excursions and is seen protecting the coils of relays and across semiconductor switches and rectifier diodes. Snubbers can also limit voltage and current edge rates, reduce EMI, limit power dissipation stress in semiconductors and reduce total switching losses, all dependent on the power conversion topology chosen and complexity of snubber. A typical RCD snubber network is shown in Figure 1, here used in an off-line flyback converter.

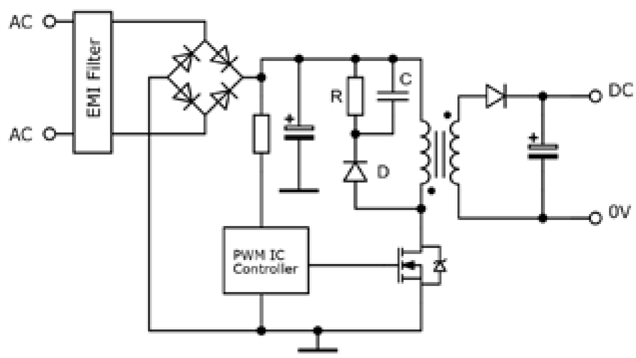


Figure 1: A common RCD snubber network in an off-line flyback converter

Snubber effects

The common use for a snubber is to limit voltage transients due to circuit parasitic effects. Switching power converters operate with pulsed current (i) by their nature and when this passes through transformer leakage or connection inductance (L), a voltage (V) is generated from the familiar relationship V = -L.di/dt. This impulse voltage causes ringing between the inductance and circuit capacitances, typically at a frequency of tens of MHz, with a peak value that can add hundreds of volts to the normal expected circuit value. The ring is typically non-sinusoidal due to the non-linear characteristic of switch capacitances with voltage. Modern wide band-gap semiconductor switches can operate with a di/dt of 2kA/µs or more, producing 2V for every nanohenry of inductance, and a transformer can easily have microhenries of leakage. Even a TO-247 transistor package has around 10-20nH inductance internally. In practice, such high current edge-rates are often deliberately slowed by other means such as gate resistors or inserted drain-gate capacitance, to make circuits practical and to prevent excessive EMI, but at the expense of some conversion efficiency. A snubber damps, and in this case also clamps the ringing voltage, which is reduced in amplitude and duration. Figure 2 shows the ringing that might occur in the circuit of Figure 1, without and with a snubber.

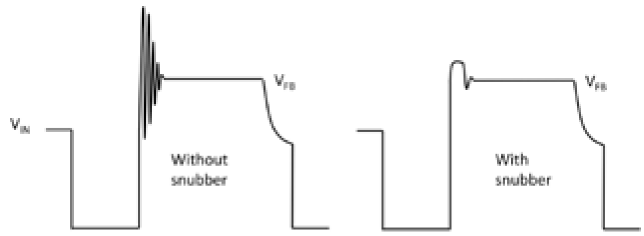


Figure 2: Typical switching waveforms of Figure 1 without and with a snubber

The damping and voltage clamping effect of a snubber is achieved by diverting energy into the capacitor in the network and slowing the voltage edge-rate. This can also serve to reduce switch dynamic losses by separating the overlap of current and voltage in a 'hard' switched converter, reducing the transient, high dissipation that occurs.

Snubber choices

Before a snubber is chosen and dimensioned, it is normally beneficial to investigate why the level of overshoot and ringing is present. Good transformer design can minimize leakage inductance and interleaving of windings can reduce it substantially; simply 'sandwiching' a transformer secondary between two primary windings can reduce leakage by a factor of around four compared with a single primary. Circuit track and connection inductances can also be minimized by good, compact layout. As a general rule, if the frequency of ringing is less than 100x the converter switching frequency, the cause should be examined first, as an effective snubber is likely to dissipate excessive power. It is also the case that there is no 'correct' snubber type and values – practical designs are always a compromise between acceptable component stress, EMI, snubber dissipation, cost and complexity.

A simple RC snubber (Figure 3A), is often used directly across a switch or diode to damp oscillations which occur at a frequency set by the device capacitance and circuit inductance. In the case of the MOSFET in the figure, this is output capacitance Coss and LLK, the transformer leakage inductance. LLK can be measured relatively easily, by shorting all transformer windings except the primary and measuring the resulting primary inductance. This is likely to be more dominant than connection inductance in practical circuits. Frequency of the ringing fR can be observed and from that, the characteristic impedance (Z) of the resonant circuit can be established:

$$Z = 2 \cdot \pi \cdot f_R \cdot L_{LK} \qquad \text{Equation 1}$$

This is the starting point for the resistor value in the snubber network which forms the damping action. The capacitor blocks current from the DC rail and is a value that allows the resistor to be effective, while minimizing dissipation at the switching frequency. A value C, that gives the same impedance as the resistor at the ring frequency is a starting point.

$$C = 1/(2\cdot\pi\cdot f_R\cdot Z) \qquad \text{Equation 2}$$

The power dissipated P in the resistor, is determined from the energy expended charging and discharging the capacitor each switching cycle from zero to V, the sum of input and flyback voltage VFB. Dissipation is given by:

$$P = C\cdot V^2\cdot f_S \qquad \text{Equation 3}$$

Note that the dissipation does not depend on resistor value. If P is too high, a smaller capacitor will be necessary with a higher consequent ring voltage. Some simple flyback circuits operate in variable frequency 'boundary' conduction mode, where the PWM frequency can go very high at light load. This can cause excessive snubber dissipation and make light load efficiency very poor.

A 'rule of thumb' sometimes used to get starting component values, is to add a capacitor on its own that is observed to half the ring frequency, then a resistor is added to show acceptable damping of the ring waveform.

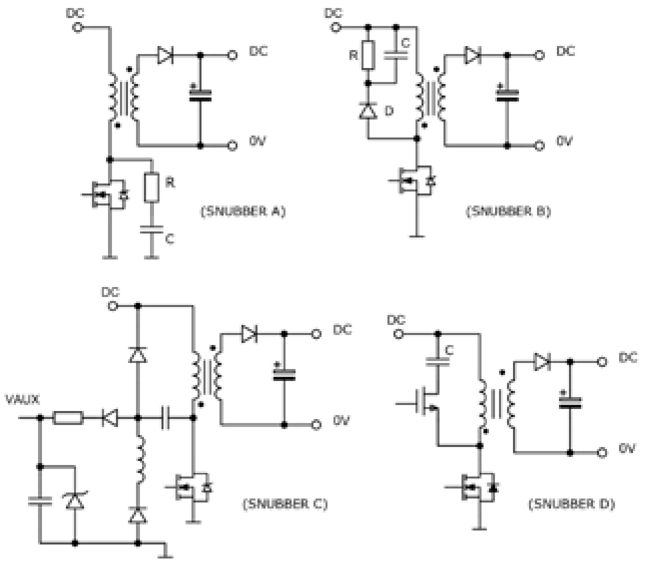


Figure 3: A selection of snubber circuits – simple RC (A), RCD (B), lossless passive (C), active clamp (D)

The RCD snubber network (Figure 3B), provides a more secure clamping action of drain voltage and is preferred when the peak voltage expected at high line is close to the maximum for the switch. This is common in off-line converters where 650V rated devices are used for their availability and economy. In this circuit, operating in discontinuous conduction mode (DCM), when the MOSFET turns off and the drain voltage flies higher than the DC input rail, the diode conducts and charges the capacitor to the flyback voltage VFB. If the capacitor is large enough, it will remain at this nominal voltage over each switching cycle, absorbing ripple current from the ringing waveform. As a starting point for the design, note that the voltage VLK across LLK after the switch turns off and the diode conducts is the capacitor voltage, less the flyback voltage on the transformer primary:

$$V_{LK} = V_{CAP}-V_{FB}$$

The current through LLK is a downward ramp, with slope:

$$i/t = -V_{LK}/L_{LK} = -(V_{CAP}-V_{FB})/L_{LK}$$

Current (i) starts at the peak value of the transformer magnetizing current i_{PK} and the linear ramp has a duration t_{SN} , so substituting and rearranging:

$$i/t = t_{SN} = i_{PK}\cdot L_{LK}/(V_{CAP}-V_{FB})$$

The average current during the linear ramp is $i_{PK}/2$ and over a switching cycle it is $(i_{PK}/2)$ multiplied by (t_{SN}/t_C), where $t_C = 1/f_S$. We can now say that the power to be dissipated P_{SN} in the snubber in a switching cycle is:

$$P_{SN} = (i_{PK}/2)\cdot(t_{SN}/t_C)\cdot V_{CAP} = (i_{PK}/2)\cdot(t_{SN}\cdot f_S)\cdot V_{CAP}$$

Substituting t_{SN}:

$$P_{SN} = L_{LK}\cdot i_{PK}{}^2\cdot V_{CAP}\cdot f_S/(2\cdot(V_{CAP}-V_{FB}))$$

VCAP is chosen so that VCAP + VFB + VIN(max) does not exceed the switch breakdown rating with a good margin and all the other parameters are set by the circuit, while LLK can be measured. The resistor value R, to give this dissipation is given by:

$$R = V_{CAP}{}^2/P_{SN}$$

The capacitor value is not critical and is chosen for a ripple voltage, producing a maximum permissible ripple current through the component's ESR and consequent heating. The component will typically be a polypropylene type for low loss. The ripple ΔV_{CAP} is given by:

$$\Delta V_{CAP} = V_{CAP}/C.R.f_S$$

The diode should be a fast recovery type to avoid significant discharge of the capacitor as the diode becomes reverse biased. Forward recovery should also be low, as it adds a few volts to the clamped value.

For circuits operating in continuous conduction mode (CCM), and for forward or 'buck' derived circuits, the selection of components for an RCD clamp is similar and design equations can be found in the literature.

There are many more versions of snubbers that can be applied to switches including the circuit shown in Figure 3C. This is a 'lossless' snubber that 'recycles' the clamped energy. It can also be arranged for the energy to contribute to the power supply low voltage auxiliary rail for further power savings.

Other snubbers take the form of 'active clamps' which typically use MOSFETs to clamp the over-voltage (Figure 3D). The MOSFET usually requires a 'high-side' drive, offset from ground, but control ICs are available with this built-in. The circuit is similar to the active clamp used in forward converters to provide efficient transformer reset.

Example and evaluation of an RC snubber performance

The designs described assume that the leakage inductance can be measured, ideally at the switching frequency. This can be done in many circuits with an impedance analyzer or precision LCR bridge. However, the leakage inductance can sometimes be a low figure, which can be difficult to measure, especially in non-isolated power converters, where track and connection inductances dominate. Or sometimes, there is no LCR bridge or impedance analyzer available in the lab. In this case, inductance can be inferred by observing the ring waveform and adding an extra known capacitance C2 to the existing switching node capacitance C1 and observing the change in ring frequency.

As an example, a rectifier diode in a converter operating at about 38.5KHz without snubbing was observed to ring under reverse bias at a frequency f1 of 25.584MHz as shown in Figure 4. An additional capacitor of actual measured value 178pF was added and the frequency of the ring shifted to f2 or 21.9Mhz (Figure 5). At the two resonant conditions, the leakage inductance is constant so it can be stated:

$$L_{LK} = 1/(4.\pi^2.f1^2.C1) = 1/(4.\pi^2.f2^2.(C1+C2))$$

Solving for C1 gives 488pF

Solving for L_{LK} gives 108nH

Figure 4: A measured switching diode waveform with no snubber

Figure 5: As Figure 4 but with known 178pF capacitor added

From Equation 1, if we assume the ring frequency will remain around 23MHz, the snubber resistor R_{snub} starting value for critical damping would be around 16 ohms. However, a value of 35 ohms is chosen for slight underdamping while still limiting the peak voltage to a safe value of around 27V. From Equation 2, with Z = 35 ohms, C_{snub} = 197pF and a standard value of 180 pF is chosen. From Equation 3, dissipation in R_{snub} is just 5mW. At high voltages, the power can be significantly higher although some proportion is dissipated in the switch as it transitions through its linear region. The result is the waveform shown in Figure 6 showing voltage limited to a safe value and faster damping of the ring.

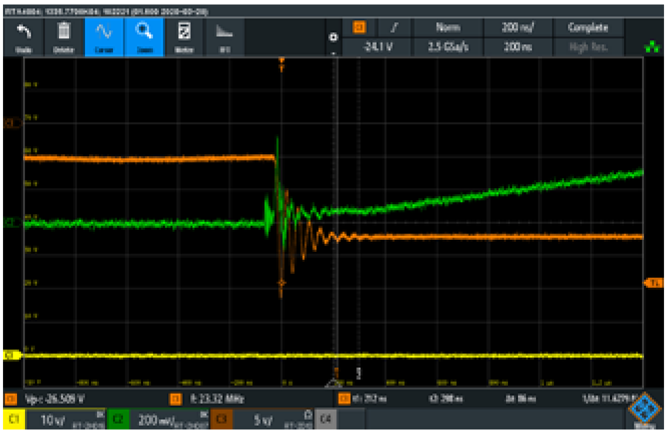


Figure 6: Waveform with calculated snubber values

Tips on selecting measurement equipment

Frequency is most easily measured with an oscilloscope, and a low capacitance, high bandwidth probe should be used to avoid affecting the measurement. For work on standard converter types, the R&S RTM3000 or R&S RTA4000 oscilloscopes are a good choice. They provide a measurement bandwidth of up to 1GHz, a power analysis option to automate standard measurements and powerful FFT functionality, which is helpful for general analysis as well as EMI-related debugging.

For more complex converter types like the active clamp flyback converter, a digital trigger system, as available on the R&S RTO6 oscilloscope, is a valuable function. It provides a much higher trigger sensitivity than analog trigger systems found on standard oscilloscopes, in particular if combined with the so-called HD-mode, and allows for complex trigger setups. The HD-mode enhances the vertical measurement resolution and precision by filtering, to give sharper waveforms with details that might otherwise be masked by noise. Advanced triggering is also useful for snubber waveforms that are fast compared with the PWM frequency and may also have intentional jitter, introduced by the PWM controller for EMI mitigation reasons.

Probes are available with a range extending to several GHz bandwidth for transmission-line types, used with a 50-ohm oscilloscope input impedance. When measuring just frequency, the ring waveform can often be observed by simply bringing the tip of a probe close to the circuit without touching, to guarantee no loading.

When amplitude measurements are required to ensure that a semiconductor switch is not stressed, high accuracy is necessary, as safety margins are often small. In many circuits, the voltages are high, approaching the voltage ratings of typical oscilloscope probes, so a good solution is to use a high-voltage differential probe like the R&S RT-ZHD models. For best measurement results,

Figure 7: R&S RTO6 oscilloscope with R&S RT-ZHD high-voltage probe and R&S RT-ZC current probe

it is important to use them with the short leads delivered, as the probe is specifically compensated for them. The long measurement leads also supplied as a standard accessory can be used if a reduced measurement bandwidth is acceptable, for example when the expected rise times allow limitation of the bandwidth to 5MHz with the integrated lowpass filter in the probe.

As an alternative to high-voltage differential probes, oscilloscopes are available with isolated inputs with typically 500MHz bandwidth and 1000Vrms input rating.

Further parameters to consider when selecting a high-voltage differential probe are low noise, high linearity, the ability to compensate for a high DC offset and low drift.

Conclusion

Snubber networks are useful tools that that can reduce stress on semiconductors, improve system efficiency and reduce EMI. However, snubber waveforms can be difficult to measure accurately with their high frequency ring often offset from ground by high voltages. Additionally, the trend to faster, wide band-gap semiconductors in silicon carbide and gallium nitride with low device capacitances provides a further measurement challenge with higher frequency ringing. Accurate results can however be achieved by use of suitable probes and probing techniques along with knowledge of potential error sources.

Further resources:

(1) Rohde & Schwarz application note 1SL363:
Verification methods of snubber circuits in flyback converters
https://www.rohde-schwarz.com/appnote/1SL363

www.rohde-schwarz.com

Right Technology for Lighting Dimmers

Aiming to get the right technology for lighting dimmers applications, here we investigate the impact of the main parameters (and so to the MOSFET technology generation) on the electrical and thermal performance, and the EMC emission for a commercial 300W lighting dimmer.

By G.Belverde, G.Sorrentino, A.Scuto, D.Nardo
Application Engineers, STMicroelectronics PDG PTD Catania

Introduction

The lighting dimmers are top selling product on the north America market, they are widely used to trim the lamp brightness in every home. Thanks to the use of dimmers, money on energy expenses and maintenance costs could be saved.
In this kind of applications, the MOSFET is used like a controlled switch aiming to partialize the sinusoidal voltage to supply the load (led or halogen lamp), with a corresponding variation in brightness.
Recent changes to the lighting industry are pushing LED on the market thanks to the improvements to this technology to push the efficiency and durability to new standards.
With LED replacement of older halogen lamps some problems could rise on the dimming system.
Trying to solve flickering, strobing and early burnout of LEDs systems, new control strategies have been developed on the modern lighting dimmers.
The classical TRIAC control strategy “forward phase” has been flanked and, in some cases, replaced by the modern dimmers working on “reverse phase” technique.
In both case the switching frequency of the MOSFETs inside the dimmers is very low because of the sync. with network frequency (50-60Hz) so the switching performance of the switches is not so important with respect to other parameter like the statical Ron resistance or the EMC behavior.

Dimmer’s fundamentals and control strategies

The lighting dimmers are devices connected between the home network and the light fixture and they are used to regulate the brightness of lights inside the home.
They partialize the voltage waveform applied to the lamp to lower the intensity of the light output.
There market spread a wide variety of models specifically developed to drive incandescent, halogen, fluorescent lights (CFL) and light-emitting diodes (LED).
There are several types of electronic dimmers working with different devices (TRIACs or MOSFETs) and different strategies since each type of lighting source has individual characteristics, but in any case, there are mainly two strategy of lamp load adjustment based on the following types:

Leading Edge or forward Phase Dimming

Here the dimmer partializes the initial part of the half wave, so the electric current is deactivated in the front part of the AC input waveform immediately after zero crossing.
The forward Phase Dimming was the control strategy used by the TRIACs and initially used for all dimmers, they work best with traditional incandescent and halogen lights.
A smooth turn on of the MOSFET is preferable to minimize EMC emissions.

This is a classical method, and it is generally suitable for the regulation of:

- Magnetic Low voltage (MLV) assimilable to an inductive load since they use a magnetic transformer for LV, CFL and 230 V LED lamps.
- Incandescent or Halogen lamp (120V, no transformer) assimilable to a resistive load.

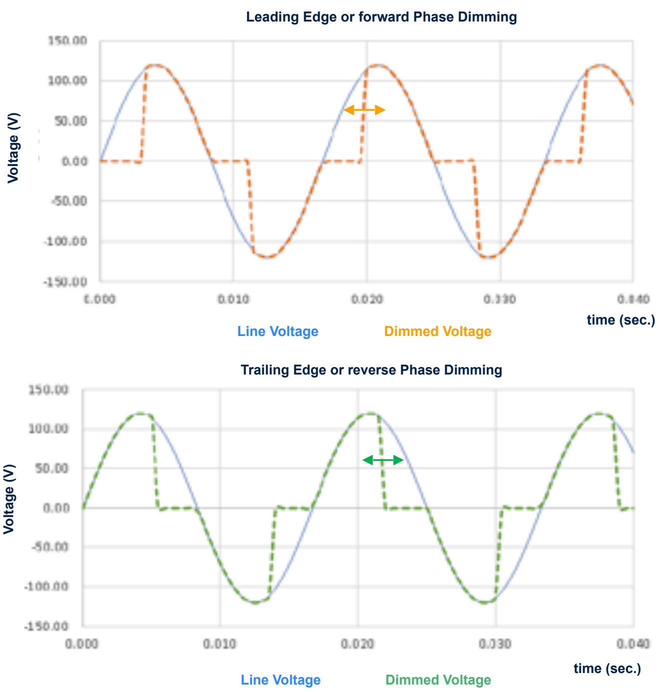


Figure 1: Leading Edge or forward Phase Dimming and Trailing Edge or reverse Phase Dimming

Trailing Edge or reverse Phase Dimming

Here the dimmer partializes the final part of the half wave, so that the electric current is turned off at the end of the AC input waveform just before passing through the zero crossing. This method is generally more suitable for the regulation of electronic transformers for low voltage / incandescent / halogen lamps (halogen or LED). Electronic Low-voltage (ELV) are assimilable to a capacitive load.

The reverse mode strategy was developed to avoid or minimize the flickering on the LED lamps in some specific cases, for this reason Trailing edge dimmers work best with LED lights.

In this kind of dimmers, a smooth MOSFET turn off is preferred to minimize the EMC emissions.

Experimental test
A commercial Dimmer Trailing Edge, reverse Phase-Dimming topology 300 W, 120VAC, 60Hz for the USA market has been used like a test vehicle and a dimmable LED load lamp ≈300W 120VAC has been coupled to the dimmer for these tests.

In order to perform the test and be able to measure temperatures, voltages and currents on the boards they have been disassembled and the power devices have been reworked and mounted in the right way.
In any case no changes have been made on the original driver stage circuit.
All the MOSFETs are assembled in TO220-FP.

Bench test setup
The system efficiency, switching energy (at turn-off) and the case temperatures of the switches has been measured in the whole power range from 30W to ≈300W.
The EMC emission has been measured at 150W of Power output since this is the point with maximum Id current in the Power MOSFET at turn-off. The Id commutation current level could impact to the EMC performance.
The temperatures have been measured with a thermal camera in steady state.
The table show the main parameters for the MOSFETs under comparison.

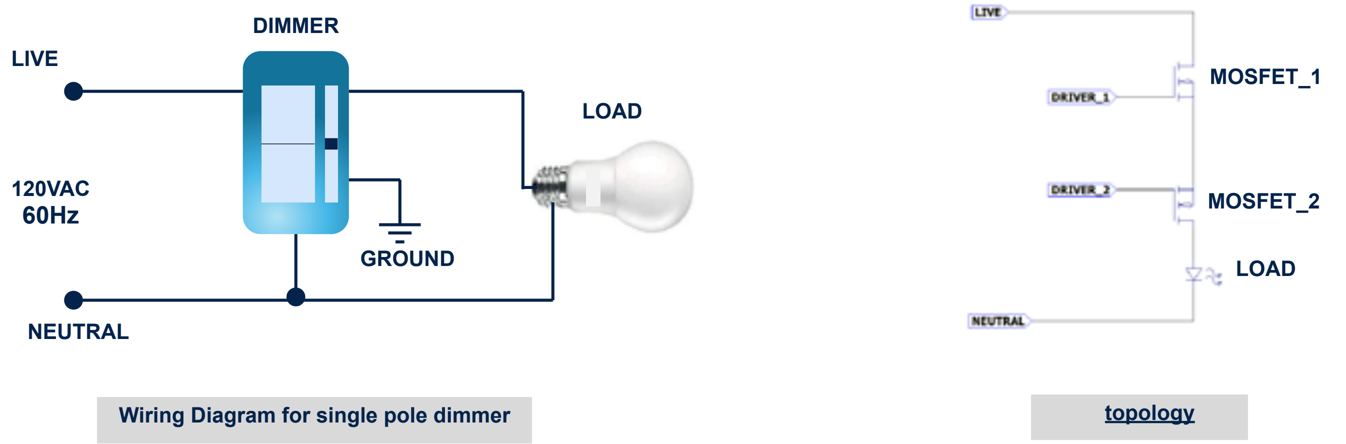


Figure 2: Wiring Diagram for a commercial dimmer and power stage inside the dimmer

Wiring Diagram:
The dimmer is a very simple black block with three terminals (plus ground) connected like the below schematic. It has a mechanical switch to turn on/off the source and a slider used to dim the light to the preferred level.

Power stage:
Two MOSFETs are used inside the dimmer for each channel, they are connected in back-to-back topology since the dimmer must be able to work bidirectionally following the network voltage.
A driver stage is used to drive properly each gate with the correct timing according with the light level set by the user.

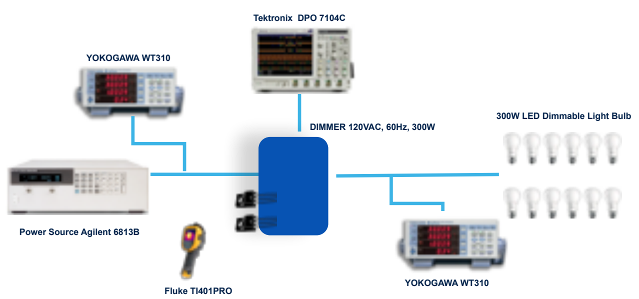


Figure 3: Bench test

	STF75NF25 Planar STripFET II	Competitor
RDSon (mΩ) measured @ Id=15A, Vgate=10V	43	45
Gate charge total (nC)	88	22
VGSth (V)	4	3
Ciss (pF)	3084	1800
Coss (pF)	263	110
Crss (pF)	44	5

Table 1: Main MOSFET's parameters

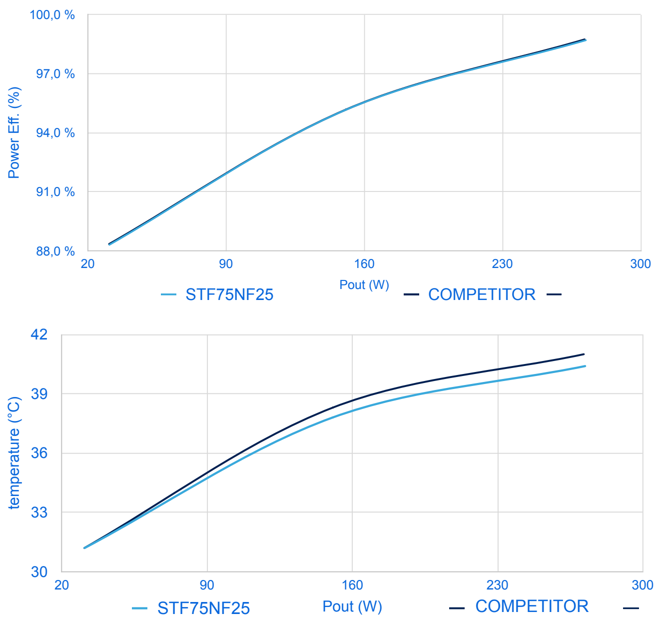


Figure 4: System efficiency and case temperature of a single MOSFET

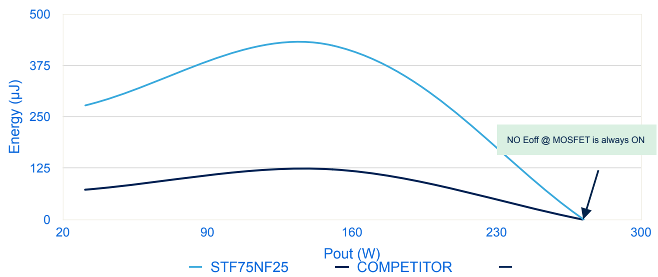


Figure 5: Turn-off loss (single MOSFET)

Experimental results
System efficiency is quite the same for the two MOSFETs in the whole range of power output.

Measuring the case temperatures of the MOSFET (without heatsink), the differences between the two devices are less than 1 Celsius degree in the whole range.

For the switching energy at turn-off, of course the fast MOSFET is able to perform fast switching with respect to the slower MOSFET.

Test condition

- Input AC voltage: 120 VAC, 60Hz
- Output power : 150W (maximum peak current)
- LOAD = 300W LED lamp
- Rg=100Ω
- Quasi peak EMC
- Frequency : 150 KHz – 30 MHz
- R&S ESRP3 receiver
- LISN EMCO 9 KHz – 30 MHz
- Measures performed in anechoic chamber

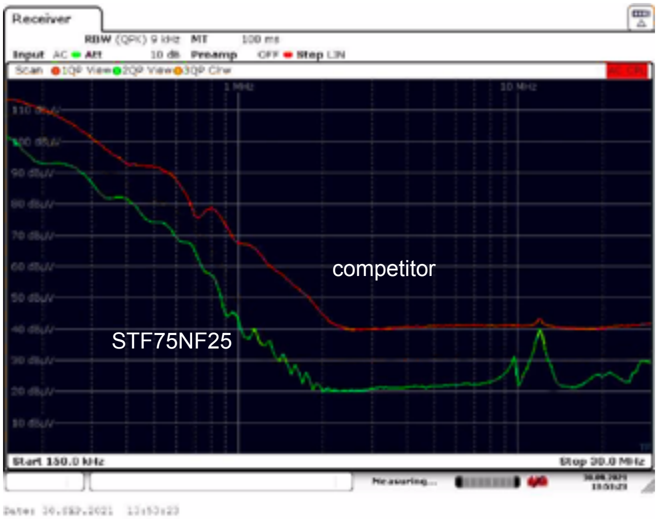


Figure 6: Quasi Peak EMC emissions

Since the switching frequency is 120 Hz these energy losses are negligible with respect to the static conduction loss (Rds_on) and do not impact the system efficiency.

Quasi Peak EMC comparison
For optimal results the test has been performed inside an anechoic chamber in order to minimize the environmental noise.

Clearly arise that the faster MOSFET gets higher levels of emissions on the whole range of frequencies (150KHz-30MHz).

Conclusion
A standard NF family MOSFET by STMicroelectronics has been compared to a fast MOSFET in a standard lighting dimmer for USA market.

Despite the competitor MOSFET has faster turn-off both system efficiency and case temperatures of the MOSFETs are quite the same.

Since the switching frequency of the system is about 120Hz, the switching performance of the MOSFET doesn't impact the performance in this kind of application.

A fast-switching transitions associated to the latest technology available on the market, generates higher EMC emissions that can easily exceed the mask CISPR15 used for this kind of lighting dimmer applications.

The well-established technology like NF can be easily sustain this kind of application since it is able to give the same performances of a fast technology but with less noise and EMC emissions, it represents the appropriate solution for light dimmer. In addition, a fast and highly optimized technology for Rds_on per area could be less robust during line transient due to the smaller silicon area and consequent lower thermal capability.

www.st.com

How to Hack your AC/DC Converter – Part 2

How can you 'hack' something as basic as an AC/DC converter module? This article will use the example of a board-mounted power supply to demonstrate five possible AC/DC converter 'hacks' that could also be used for various other applications.

By Steve Roberts, Innovation Manager, RECOM

Let's assume you have a power monitoring application in an electric vehicle (EV) charging application in which the auxiliary power supply needs to have multiple input options: three phase or single phase AC or high voltage DC or low voltage DC. Additionally, the charging application needs to be able to generate bipolar (±10V) output rail voltages to power the calibrated current and voltage sensors and amplifiers (Figure 1).

You check the manufacturer's datasheets and find that a power supply with all of these particular input and output voltage combinations does not exist as a standard product. What can you do? You need to start hacking your AC/DC!

Hack #1: Use dropper diodes.
Low power AC/DC converters do not normally offer adjustable output voltages. The reason is simple: Unlike, say, an isolated 24-to-5V DC/DC converter, which might have a transformer with a 5:1 turns ratio, an equivalent AC/DC converter with 230VAC RMS input to 5V output will need a transformer with a 65:1 turns ratio. This is because the rectified AC voltage is significantly higher than the output voltage. The control loop in

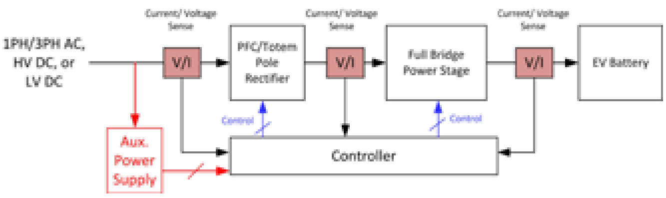


Figure 1: EV charging system with universal AC or DC supply.

an AC/DC converter is optimised to compensate for a wide range of input voltages (typically 85-264VAC) and a fixed output voltage. If the output voltage was also made adjustable, the worst case input/output voltage combination combined with the high turns ratio could easily facilitate the converter operation to become unstable.

Evidently, it is possible to place positive and negative voltage LDO linear regulators on an AC/DC with ±12V outputs to regulate the voltages down to ±10V, but is there a cheaper and simpler hack?

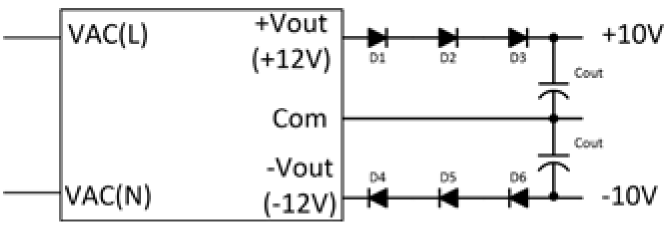


Figure 2: Diode dropper

Silicon diodes have a typical 0.6V-0.7V forward voltage drop across them. Hence, three in series will drop 2.1V (Figure 2):

The heat dissipation in the diodes needs to be properly managed; for a 500mA output current, the power dissipation will be 350mW, so this requires suitably-rated diodes.

A similar solution can be applied on a single output AC/DC module to drop, say, a 15V output down to around 13.6-13.8V to trickle charge a 12V battery by inserting two diodes in series with the +Vout (Figure 3). Such trickle chargers are useful in applications, such as emergency lighting or fire alarms, which need to be normally mains powered but also need to operate independently without the AC supply.

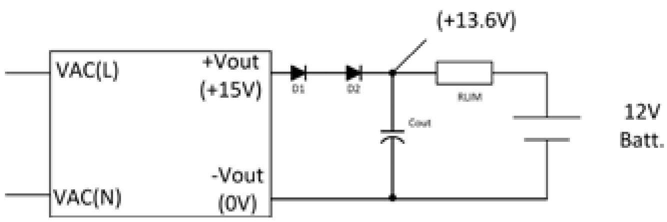


Figure 3: Diode dropper battery trickle charger

Hack #2: Adjustable positive and negative output voltage rails
Negative voltage regulators are not cheap, and they require a bipolar output power supply. Is it possible to make a dual rail power supply with a single output AC/DC? This next hack will demonstrate how. Non-isolated switching regulators have the same basic function as linear regulators, and it has a several pin-compatible modules available (e.g. RECOM's R-78 series). However, internally, they are very different. If the output of a switching regulator is tied to ground, the switching regulator GND pin is forced to go negative. The result is a positive-to-negative regulator (Figure 4).

Figure 3 shows a multiple output power supply (+12V, adjustable +1 to +10V and adjustable -1 to +-10V), which only uses three low-cost main components. The RAC05-12SK is a universal AC input (85VAC to 264VAC) 5W board-mount power supply, which despite having an only 1"x1" footprint, needs no external components. This is because the fuse and Class B EMI filter are all built in.

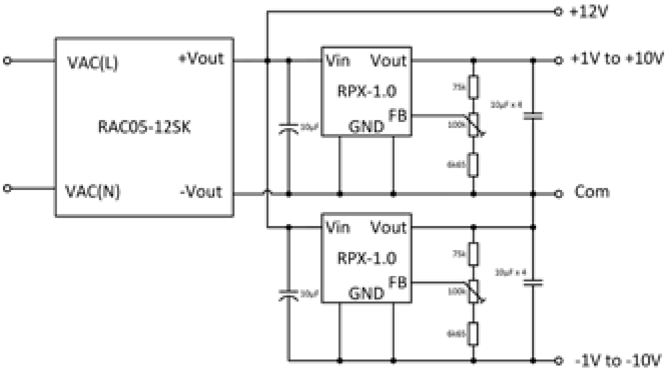


Figure 4: Adjustable bipolar (±) output rails from a single output AC/DC converter

Two RPX-1.0 non-isolated SMD switching regulator modules are used to generate the adjustable output rails, one of which is used in the positive-to-negative configuration. The RPX-1.0 is a complete DC/DC power supply with integrated inductor. Although it can deliver an impressive 1A output current, the case size is only 5mm x 3mm with a low profile 1.6mm height. Therefore, the entire multi-output rail power supply could be built into a 1" x 1" board space by mounting the SMD components on the underside of the PCB next to the output pins (Figure 5).

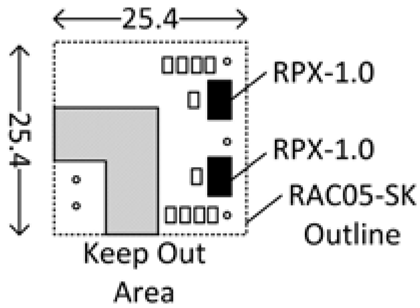


Figure 5: Triple output AC/DC layout possibility with SMD components mounted on the underside of the PCB to keep within a 25.4 x 25.4mm (1" x 1") overall footprint.

Another advantage of using output side post-regulators is that the output voltages remain fixed even if the loads are highly asymmetric. A bipolar output AC/DC has two output voltages, but how do you regulate two opposing output voltages with only one feedback loop? There are two choices: Either you regulate the overall difference between the positive and negative output voltages and let the common pin (centre tap) of the output transformer float (Figure 6), or you only regulate the negative output and let the positive output float, or you regulate the positive output only and

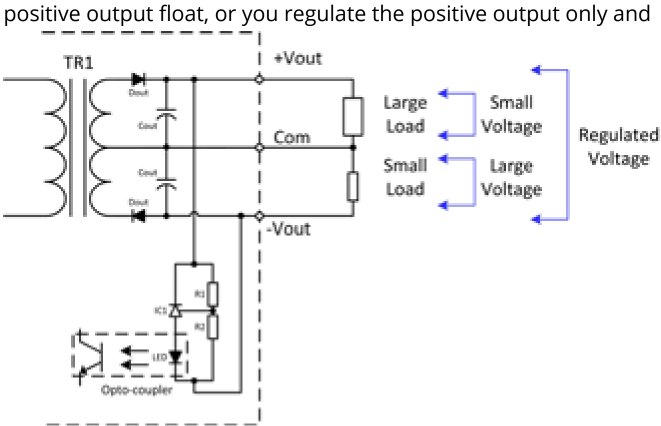


Figure 6: Asymmetric outputs with asymmetric loads (regulation across +ve and –ve outputs)

let the negative output float. However, if the output loading is very asymmetric, say, full load on one output rail and only 10% load on the other, then the output voltages will also be asymmetric (Table 1).

Regulation Method	Positive Load	Negative Load	Positive Voltage	Negative Voltage	Overall Voltage
Positive to Negative	100%	100%	+12V	-12V	24V
	100%	10%	+11V	-13V	24V
	10%	100%	+13V	-11V	24V
Negative only	100%	100%	+12V	-12V	24V
	100%	10%	+11V	-12V	23V
	10%	100%	+13V	-12V	25V
Positive only	100%	100%	+12V	-12V	24V
	100%	10%	+12V	-11V	23V
	10%	100%	+12V	-13V	25V

Table 1: Comparison of bipolar regulation methods (typical values for ±12V nominal output). Regulated output shown in blue

All of these regulation methods offer the same output voltages with balanced loads. However, there are differences among them if unbalanced loads are used. The advantage of regulating the combined output voltage is that the sum of the negative and positive rails remains fixed, but only regulating the positive or just the negative output offers less variation on that particular rail. There is no universal solution.

However, if switching regulators are used to post-regulate the outputs as shown in Figure 4, both the output voltages remain stable over all load combinations, even down to no load/full load conditions.

There is an additional advantage to using switching regulators on the outputs: They also deliver constant power. Lower the output voltage, the higher the output current. If, in the example of Figure 4, the regulated outputs were adjusted to ±3.3V, then, as long as the overall load was less than 5W, the maximum output current per rail that could be drawn would be up to 1.5A. This is much higher than the AC/DC's nominal 416mA output current. It is useful because the majority of multi-rail applications need significantly more power on the one rail than on the others (main load + auxiliary loads), but this is not a problem when switching regulators are used. For example, in Figure 4, +12V @ 0.1A, +3.3V @ 1A and -3.3V @ -0.15A would be possible with all of the output voltages tightly regulated.

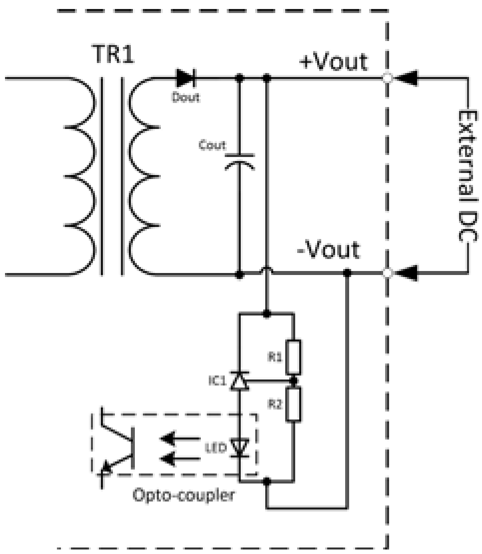


Figure 7: Typical output stage of an AC/DC converter

So far, we have only considered hacking the output of an AC/DC module, but what if we wanted to use alternative power sources? This is about Hack #3.

Hack #3: External DC supply on the AC/DC output
In a few specific field applications, it is necessary to be able to use either an AC or a DC battery supply, whichever is available. As it can be seen in Figure 7, if an external DC supply was connected to the output of a switched-off AC/DC converter, the output diode, D_{out}, would stop the external current flowing back through the output winding of the transformer.

However, the shunt regulator, IC1, would still be in-circuit. If the external voltage exceeded the set point of the shunt regulator, it would conduct and begin feeding the current through the optocoupler LED. As the AC/DC converter is inactive, there is no mechanism that would control this optocoupler current. Owing to this, the opto-LED could easily burn out. Therefore, placing an external voltage directly across the output of an AC/DC converter is not advisable.

Using two OR-ing diodes could be considered to steer whichever supply voltage is higher through to the application without letting the two supplies interacting with each other (Figure 8).

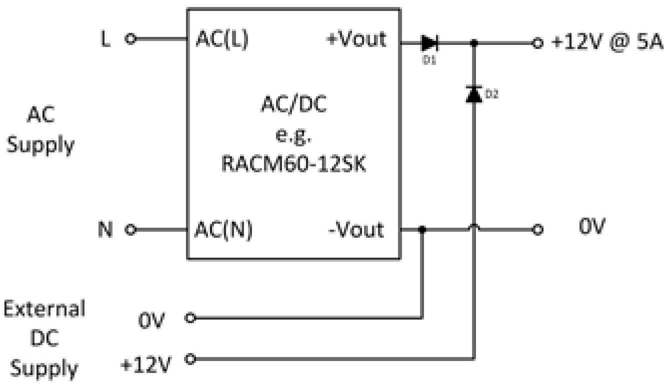


Figure 8: OR-ing diodes for an AC or an external DC supply

However, this hack, although simple, suffers from two big disadvantages. Firstly, the output voltage is always one diode drop lower than the supply voltage. Secondly, with higher current loads, the power dissipation in the diodes becomes significant (in the example shown in Figure 8, 3.5W). This means that large, expensive power diodes would be required with possibly additional heatsinking. Furthermore, the power wasted in diode D2 would harm the battery lifetime.

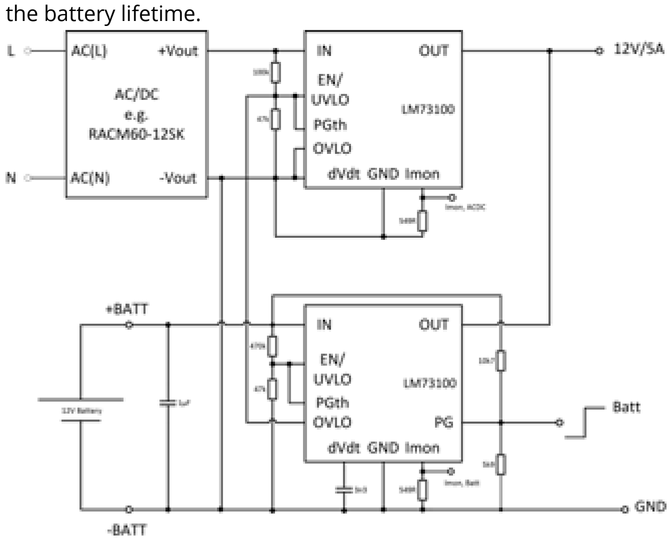
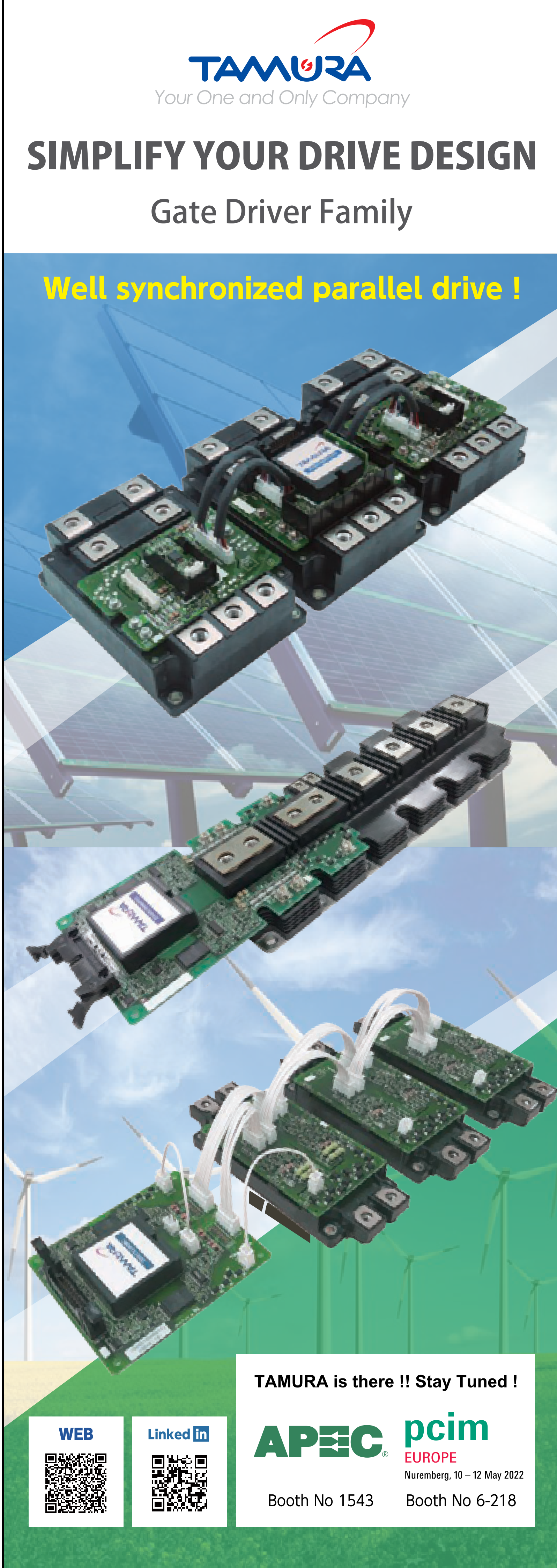


Figure 8: OR-ing diodes for an AC or an external DC supply



A better hack would be to use an ideal-diode IC, for example, the LM71300 from Texas Instruments that has integrated FETs for a very compact solution (Figure 9). This solution has the added advantage: the battery is protected from a damaging deep discharge by the under voltage lockout (UVLO) feature and the application is protected from the high-surge current capability of the battery by the dVdt control. Additionally, the load current from both sources can be monitored using the I_{mon} outputs.

Hack #4: AC Phase Redundancy

Up until now, the hacks have all been concerned with the output side. This is reasonable, considering that the AC mains is a hazardous voltage and should be treated with the greatest respect. However, returning to our EV charger specification mentioned in the introduction, it can, presumably, function with single phase, multi-phase or high voltage DC supplies. The following hack, consequently, concerns the input side.

The half-wave rectified three phase input circuit shown in Figure 10 will have a rectified DC voltage of approximately 1.17 x V_{phase}, or about 270V for a nominal 230V single phase voltage. This is extremely high for a standard 230V±10% input AC/DC converter, but acceptable for an AC/DC converter designed to operate with up to 277VAC (the phase-to-phase voltage for 115VAC supplies). The circuit shown in Figure 10 uses input fuses to protect the three phase supply if any of the diodes fail, and the metal oxide varistor (MOV) to absorb excessive voltage surges that could damage the converter. The MOV is optional, as the converter itself is internally fused, but it may be required under local wiring regulations. The input diodes must have a suitable reverse voltage rating.

If any of the three phases drops out, the converter will still function. So, this hack is especially useful for powering three phase monitoring applications and sounding an alert in the case of any individual phase failure.

The RECOM /277 series have an AC input voltage range of 85-305VAC. Thus, any /277 type converters can be used in this configuration as long as a neutral connection is available.

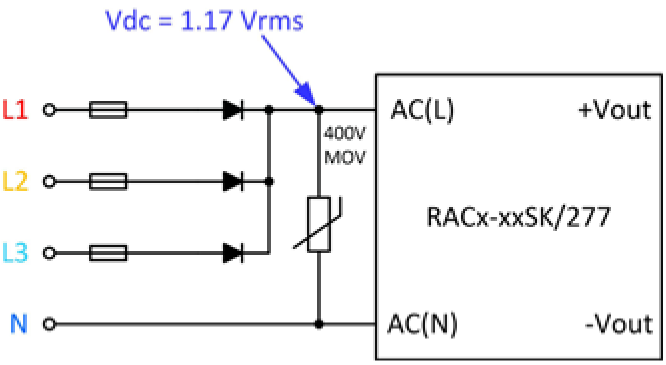


Figure 10: Phase Redundancy using a half wave three-phase rectifier

If a neutral line is not available, the voltage between two phases (√3 x V_{rms} or around 400V for a 230V single phase voltage) is too high for many AC/DC converters unless they have been specially designed for such purposes, such as the /480 series, which have an AC input voltage range of 85-528VAC or a DC input voltage range of 120V-745VDC.

As mentioned in the introduction, this hack should be used with care, as hazardous voltages are involved. Additionally, safety regulations may require additional safeguards, such as wider creepage or clearance distances or enhanced insulation withstand voltage, which would make such a hack unacceptable. For example, any circuit that is hard-wired to the mains supply is required to meet the safety requirements for over-voltage category III or IV.

This leads us to the final hack: grounding the output of an AC/DC for safety.

Hack #5: Output grounding

As AC/DC converters are isolated, the low voltage DC output is floating (galvanically isolated) from the mains supply and can be used as either a positive or negative supply. For example, a common communications supply bus voltage is -48VDC and this can be supplied by any AC/DC with 48V or ±24V output by tying the +Vout pin to 0V and using the –Vout pin for the supply rail.

For some applications, it is either advantageous or unavoidable to ground one of the output pins. At first glance, this would seem a simple enough thing to do, much like the comms power supply application that was mentioned. However, the regulations intended for AC/DC power supplies are not just about safety; there are EMC considerations that also have to be taken into account. Any circulating or induced currents that flow through the insulation capacitance can cause interference, which can make the final application fail the EMC testing. Also, grounding the output is almost guaranteed to cause such an unintended current loop. For instance, for a Class B device, even a loop current of a few tens of micro-amps can push the test results outside of the limits.

The required hack to meet EMC limits with a grounded output is to fit an external line filter with a common mode choke (Figure 11).

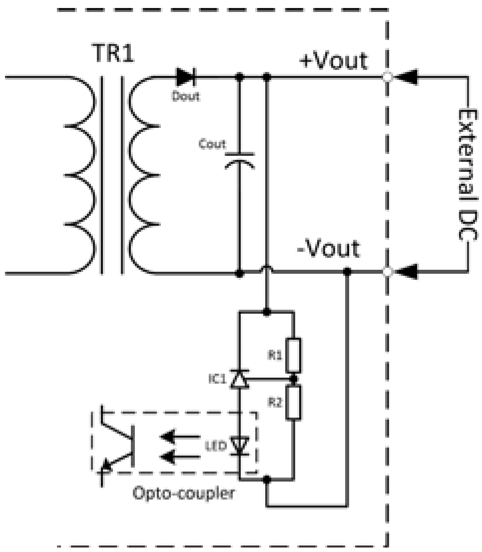


Figure11: Recommended input line filter when the output is grounded.

The two Y-caps create a low impedance path for any circulating interference currents back to ground while the common mode choke (CMC) impedes common mode interference that occurs on both the VAC(L) and VAC(N) pins simultaneously. Consequently, these are not seen by the input filter of the AC/DC module. Finally, the X-cap across the input helps attenuate differential mode noise in combination with the leakage inductance of the CMC. The high ohmic resistor across Cx is optional and used to discharge the capacitor when the power is turned off (required by some safety standards). Pre-built AC line filters are available from many suppliers, including RECOM.

This article is the second part of a two-part series, the first being “How to hack your DC/DC converter” - Bodo’s Power systems 01/2022

www.recom-power.com

Generating Power: Charging Speeds and the Role of the Battery Management System

Jake Schmalz discusses the importance of a battery management system (BMS) in protecting lithium-ion batteries throughout the charging process to expedite the charging speed and avoid over-heating.

By Jake Schmalz, Director of Engineering, Briggs & Stratton

Ensuring that battery charging is efficient and safe is crucial for all battery powered solutions. If the charge time takes too long users will be put off. However, rushing the charge and forgoing safety could damage the battery. Finding a suitable charge time without compromising on safety is a must to ensure consumer demand and facilitate businesses' desire to move towards battery powered solutions.

For many businesses wanting to move into the battery world, charging is often an afterthought. Vast amounts of time are spent understanding the power output needs without considering how long or how best to charge the battery to deliver the desired power. Forgoing this crucial step can greatly impact the effectiveness of the power solution for the end user. When it comes to developing a high-quality and well-designed battery solution, there are a range of factors to consider including: the type of cells, the Battery Management System (BMS) and whether the batteries are interchangeable or fixed.

Figure 1: Briggs & Stratton's Vanguard® Battery Line-Up

Types of Charging Cells

Batteries are made up of a series of charging cells that work together to convert chemical energy to electrical energy due to the build-up of ions in the battery electrolyte. During the charging process the flow of electrons is from the cathode to the anode, via a power source. This enables the conversion of electrical energy back to chemical energy.

The speed at which this process can take place safely depends on the type of cells that the battery consists of. For instance, "Power Cells" are built to handle high charging rates (C-rates) without much degradation to their lifespan. Due to the high demands, there is often trade-off for using these batteries as the increased energy conversion often results in a shortened lifespan from the outset of the battery.

At the other end of the spectrum there are "Life Cells." Life Cells sacrifice high power output and fast C-rates for longer useful life. This results in a slower charging process; however, the longevity of the battery is greatly increased. Life Cells suffer greatly from charging faster than their recommended limits, so it is important to understand the end users' requirements before selecting these.

In between these two types are "Mid-Range Cells" which strike a balance between power output and lifespan. For many looking to capitalise on the movement to electrified power, Mid-Range Cells offer an effective solution. The tendency is to navigate towards increased power output; however, "Power Cells" often have high costs upfront and – in the long-term – the accelerated charging rates may shorten the useful life of the battery. This results in needing to replace the battery sooner, further bolstering the cost to the end user.

Overall, understanding the exact needs from power output to charging speed can help with the structural composition of the battery and the type of cells that it consists of to generate the power required.

Figure 2: Vanguard® 5kWh Commercial Lithium-Ion Battery Pack

The role of the BMS

Battery Management Systems (BMS) are ideal for use on lithium-ion batteries as they work to safeguard the longevity of the battery. As current enters the battery pack the BMS intuitively determines where the input is directed throughout the cells. This is carefully done to prevent over-heating and damage to the internal components of each cell. If this were to be left un-monitored by the BMS then there is a risk of too much voltage going to the individual cells, causing damage to the cathode. This can result in the decomposition of the metal structures at the cathode and the production of too many lithium-ions, resulting in an unstable cell structure.

Operating with an effective "Power Map" (such as with Vanguard's 10kWh Commercial Lithium-Ion Battery Pack), constant information can be gauged from the health of the battery. From constantly communicating with the charger and monitoring current flow to cell and pack temperature, the BMS can optimise the C-rate helping to speed up charge times without causing battery degradation. This allows for maximum charging power within a safe range, while preserving the life requirements of the pack. The result is the shortest charge time that will maintain both the safety and long-life expectations for the battery.

Protecting the internal chemistry

During the charging process the BMS controls the transfer rate of lithium-ions within the battery to minimize dendrite growth (a form of lithium plating) on the negative electrode. Current moves from the anode to the cathode during the charging process and uncontrolled build-up can greatly impact the effectiveness of the cathode. This is incredibly important for power output which moves from the cathode to the anode. Without a BMS – or with an inadequate Power Map – dendrite growth will more quickly limit the useful energy (capacity) of the battery, which may eventually lead to a dangerous shorting out of the battery.

Figure 3: Vanguard® Battery Charger

Best practices for boosting battery longevity

To boost battery longevity, it is key to keep the battery away from extremes. Charging in very low temperatures or from very low states of charge will shorten the life of the battery. This is because the battery is not in the optimum condition for the chemical re-actions to take place internally and can result in damage to the anode or the cathode. Another issue can be keeping the battery at full charge for long periods of time.

The BMS plays a vital role in supporting users during non-ideal conditions as it monitors and controls the input and output of the battery to ensure safe operation, reliable performance, and long life. For example, an effective BMS will not allow a battery to be-gin charging if the temperature is too low.

Figure 4: Vanguard® 3.8kWh Commercial Lithium-Ion Battery Pack

Interchangeable or fixed?

Depending on the power requirements, the use of interchange-able or fixed battery solutions varies. As the list of applications and use-cases for lithium-ion batteries continues to grow, at Briggs & Stratton we work closely with manufacturers and design-ers to understand their power needs to create an ideal solution bespoke to them. A core understanding of the customer and end user shapes the development of the battery.

Sometimes, large, fixed packs are ideal due to the amount of energy required which makes it unfeasible to easily change the batteries. For others, smaller, interchangeable packs are the best route. Interchangeable packs certainly offer greater flexibility and essentially infinite run-times (i.e., one charges while one is being discharged); this can be especially valuable to commercial users of compact equipment. However, this is not a solution that can be applied to every power need.

In summary

Understanding the needs of the end user is crucial to the develop-ment of an efficient and safe battery that generates the specific power output needed without compromising on the safest charg-ing process. From the use of Power Cells to Life Cells, the use of the BMS is fundamental to protecting overall battery health and ensuring the longevity of the battery.

www.briggsandstratton.com

www.vanguardpower.com

Technology Predictions: 2022 Will See Innovation Adapt to Support Electrification and Drive Growth

Vicor Corporation released its industry predictions for 2022, covering 3 areas: Automotive, Hyperscale Computing and Aerospace & Defense.

Another year into the COVID-19 crisis has shown that the drive for innovative power solutions has waned little, however progress does not come without its challenges. The three examples below reflect on how each sector can benefit from the drive for electrification and increased need for modular solutions, amongst other challenges and trends being seen in the industry as we approach the third year of a global pandemic.

Predictions for Automotive – Electric vehicles will be shedding up to 25 pounds while manufacturers are looking for innovative ways to give batteries a second life (by Nicolas Richard, Vicor's Director of EMEA Automotive Business Development)

Today's electric vehicles have as many as three separate batteries – one at 400V or 800V (traction battery), and a distribution system that operates from secondary 12V and 48V batteries.

Manufacturers are looking to reduce vehicle weight and can eliminate up to 25 pounds in BEVs (battery electric vehicles) and reduce power system complexity by architecting the traction battery to power the 12V battery loads. This makes the 12V battery redundant and expendable. As we move through 2022, we expect to see this modular approach to power delivery being adopted by OEMs seeking to electrify and differentiate their fleets, offering extended range and better overall performance.

We also expect to see the momentum pick up behind EV battery re-use, ensuring that they can be re-purposed for power forklifts or to serve as reserve power for homes. In larger high power commercial vehicles, there is growing interest in using hydrogen fuel cells for power, which will generate a greater demand for high efficiency DC-DC conversion.

Lastly, within the vehicle itself, ride comfort will also become increasingly important for driver and passengers. We believe there will be a greater demand for electrically powered active suspension, again highlighting the need for high efficiency power management solutions.

Predictions for High-Performance Computing – Data Centre growth will continue to accelerate with the catalyst of the pandemic (by Lev Slutskiy, Vicor's Regional Manager)

In 2022, the global hyperscale computing market will continue to grow, from about $147 billion last year with a projected revenue CAGR of 27.4% through 2028 [1]. Key growth drivers will include increasing cloud workloads, data centre optimisation, social media platforms, and the emergence of data-as-a-service.

We believe the debate between adopting AC or DC power will continue between data centre operators. Benefits of DC distribution include elimination of large AC-DC UPS systems, and no concerns about compute load distribution. Modern data centres use the most common approach of bringing 3 phase AC to the building and then split them into three single phase AC lines backed up by their own UPS systems.

The trend towards the increased share of the renewable "green" energy continues and the high voltage DC will be provided by primary energy source in more and more cases especially at the edge.

COVID-19 has accelerated data growth, and this trend will continue after the pandemic. As 5G takes hold, network infrastructure will grow more complicated, with more computing nodes nearer to the user to reduce latency and allow the greater use of IoT applications.

As IoT develops, more computing power will be needed to improve security increasing overall computing power demanded in the edge, fog and in the central applications. Vicor has started early to meet this trend by building the smallest, densest power converters to support this trend. Data centres clearly need to reduce energy consumption by adopting power dense modules, which will in turn minimise the air-cooling load.

The supply chain continues to be disrupted and we anticipate difficulties until at least the end of 2023.

Predictions for Military and Aerospace – Innovation and demand for higher efficiency will continue despite the pandemic and the growing skills shortage (by Teo DeLellis, Vicor's Business Development for Aerospace.)

Innovation and demand for higher efficiency will continue to cause growing interest in electrification to replace mechanical systems and chemical fuels. For example, advanced submersibles are replacing hydraulics with electric power, while electric aircraft are setting new range and speed records.

Power management for electrically driven drones will continue to be a critical factor, while the growing interest in directed energy weapons such as lasers for both shipboard and vehicle use, will require solutions to manage new power sources such as solid-state batteries.

There is also an increasing demand for power electronics technologies to conform to the requirements of standards such as the Sensor Open System Architecture (SOSA).

The bounce back from the pandemic continues to see a surge in demand for electronics in military and aerospace markets, causing Vicor and others to quote increased extended lead times for some products. This is expected to extend well into 2022 – Vicor is mitigating this by expanding its production facilities.

Further fall out from the pandemic is being seen in civil avionics where air travel is still not back to its pre-COVID level. We expect it will be 2023 before both civil avionics and the aftermarket are back to their pre-COVID levels.

As with other engineering sectors, we continue to see a growing skills shortage. It is estimated that by the year 2030, there will be a global skilled labour shortage of up to 85 million jobs, which equates to $8.5 trillion, according to a recent Korn Ferry report. Recruiting young engineers could be essential in preventing a prolonged shortfall. This could be achieved in this sector by adopting innovative electric power technologies that show how the industry is responding to environmental concerns and is committed to renewable energies.

The growing European space sector will also see increasing use of electric ion propulsion for spacecraft, primarily for station keeping for the new constellations of space borne broadband satellites.

www.vicorpower.com

Optimized Sigma-Delta Modulated Current Measurement for Motor Control – Part 2

In Part 2 of the series, a sinc filter structure optimized for synchronization is proposed. The filter improves measurement performance in applications that require tight timing control of the feedback chain. Part 2 then moves on to discuss the implementation of sinc filters using HDL code and how to optimize the filters for FPGA implementation. Finally, measurement performed on an FPGA-based 3-phase servo drive are presented.

By Jens Sorensen, Shane O'Meara, and Dara O'Sullivan, Analog Devices

Sinc Filters Optimized for Synchronization

As discussed in Part 1, an alias-free sigma-delta measurement is possible through the correct alignment of the sinc filter impulse response to PWM. While the method is straightforward, it is difficult—and in many cases impossible—to find a system configuration that gives the desired result. To illustrate this, assume the sinc filter and the PWM block shares a common system clock source that runs at fsys. The modulator clock, fmclk, is then determined by Equation 1.1

$$f_{mclk} = \frac{f_{sys}}{D_{mclk}} \quad (1)$$

Where Dmclk is the clock divider for the modulator clock. Similarly,

$$f_{pwm} = \frac{f_{sys}}{D_{pwm}} \quad (2)$$

Where DPWM is the clock divider determining the PWM frequency. Finally, the decimation rate (data rate) from the sinc filter is given

$$f_{dec} = \frac{f_{mclk}}{D_{dec}} = \frac{f_{sys}}{D_{mclk} \times D_{dec}} \quad (3)$$

Where Ddec is the clock divider for the decimated clock. To avoid drift between the impulse response and the PWM cycle, there must

$$\frac{f_{dec}}{f_{pwn}} = N \quad (4)$$

Where N is an integer. By combining Equation 2, Equation 3, and

$$\frac{D_{pwm}}{D_{mclk} \times D_{dec}} = N \quad (5)$$

Clearly, only a limited selection of clock scalers, Dx, satisfy Equation 5. Furthermore, most often there are tight restrictions on how the clock scalers can be selected. For example, a system may be required to run at a certain PWM frequency (for example, 10 kHz) or use a certain modulator clock (for example, 20 MHz). Another complication is the limited number of options when it comes to selecting the modulator clock. For example, if fsys is 100 MHz, the only reasonable choices for Dmclk falls in a limited range of integers of 5 to 10 (20 MHz down to 10 MHz).

Given all these restrictions, it is very difficult—if not impossible—to find clock scales that give the desired alignment between impulse response and PWM. What typically happens is the user is forced to select clock scalers that satisfy Equation 5 rather than selecting clock scales that result in the desired PWM frequency, modulator clock, and signal-to-noise ratio (SNR). Also, if one of the frequencies changes over time, it becomes impossible to find a valid configuration. This is quite common in multiaxis systems where a single motion controller synchronizes multiple motor controllers in a network.

While the alignment scheme gives excellent measurement performance, it can prove to be impractical. In the following section, a new type of sinc filter is presented. The filter offers optimum measurement performance and at the same time allows the user to select all clock dividers independently.

Flushing Sinc Filter

A traditional third-order sinc filter is shown in Figure 1. The filter generates the modulator clock to the ADC by scaling the system clock and, in return, the ADC generates a 1-bit data stream to the filter. The filter function itself consists of three cascaded integrators, 1/(1 – z–1), clocked at the same rate as the modulator and three cascaded differentiators, 1 – z–1, clocked at the decimated clock.

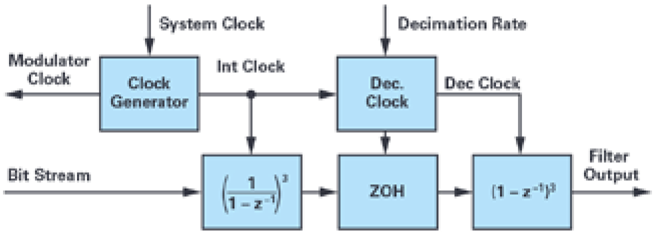


Figure 1: Traditional third-order sinc filter.

The sinc filter and ADC are operated by continuously applying a clock to both. As a result, the filter outputs data continuously at a fixed rate determined by the decimated clock. The data rate from the filter is typically higher than the update rate of the motor control algorithm, so a number of the filter outputs are rejected. Only when the impulse response is centered around the ideal measurement is the output captured and used as feedback.

With space vector modulation, the phase current only assumes its average value two times per PWM period. Following this, there are only two possible alias free sinc data output per PWM cycle, so there is no need to let the filter run continuously. It is actually sufficient to only enable the measurement when the feedback is needed and then disable the measurement at all other times. In other words, the measurement operates in an on-off mode, not unlike a conventional ADC.

A problem with the on-off mode of operation is that the modulator and filter clocks are derived from the same system clock. That means both the filter and the ADC operate in an on-off mode, which is not recommended because it will result in reduced performance. The reason is that the modulator in the ADC is a higher order system with a certain settling time and damping. So, when first applying a clock to the ADC, the modulator needs to settle before the output bit-stream can be trusted. To solve these problems, a new filter structure is proposed (see Figure 2).

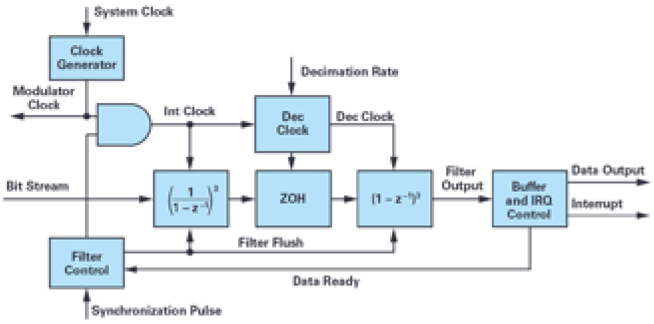


Figure 2: Sinc filter designed for on-off operation and flush of all states.

As the standard sinc filter, the core consists of three cascaded integrators and three cascaded differentiators. However, the filter has several features that allow for new operating modes. Firstly, the filter has a new clock generator function that separates the modulator clock from the integrator clock. That makes it possible to continuously clock the ADC, but only enables the integrator clock when obtaining a measurement. Secondly, the filter has a new filter control function. With reference to a synchronization pulse, the control block handles all timing and triggering needed to operate the filter. The primary function of the filter controller is flushing the filter, which involves initializing all filter states, and timers filter ahead of starting a new measurement, as well as enable/disable the integrator clock at the right instances. Finally, the filter has a new buffer and interrupt control unit, which sorts through the output data and captures the correct measurement. The buffer and interrupt unit also notifies the motor control application by interrupting when a new measurement is ready to be consumed. The timing diagram in Figure 3 shows how the filter operates.

HDL Implementation of Sinc Filters

The authors have found that several of the publicly available sinc filter HDL examples have shortcomings that negatively affects filter performance or leads to unexpected behavior. This section will discuss some of the implementation issues and how to design HDL code for optimum performance on an FPGA.

Integrators

In its purest form a sinc3 filter consists of three cascaded integrators and three cascaded differentiators, see Figure 1. First, consider a pure integrator in the z-domain2:

$$\frac{y(z)}{u(z)} = \frac{1}{1-z^{-1}} \tag{6}$$

Where u is the input and y is the output. The integrator has the difference equation:

$$y[n] = u[n] + y[n-1] \tag{7}$$

This first order equation is equivalent to an accumulator, which lends itself very well to implementation in clocked logic such as an FPGA. A common implementation approach is a D-type flip-flop accumulator as shown in Figure 4.

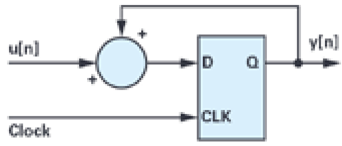


Figure 4: Implementation of an accumulator with a D-type flip-flop.

This circuit can be implemented on an FPGA with only few logic gates. Now, when cascading three pure integrators, the transfer function in the z-domain is defined by Equation 8.

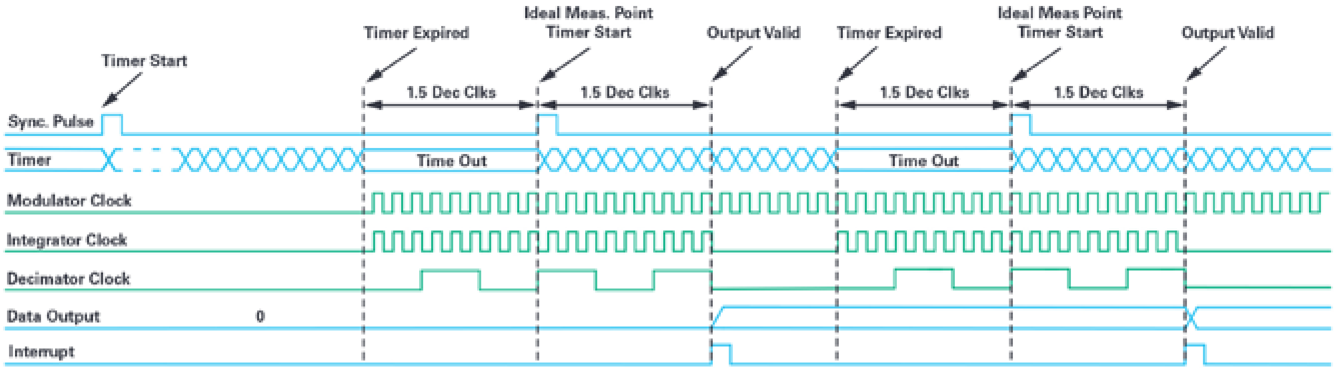


Figure 3: Timing diagram of sinc filter operating in an on-off mode.

To start a measurement a synchronization pulse (sync pulse) is applied to the filter controller. Typically, this pulse indicates the start of a new PWM cycle. The sync pulse starts a timer, which is configured to expire exactly 1.5 decimation cycles before the desired measurement point. At this point, the integrator clock and decimated clock are enabled and the filtering process begins. After 3 decimation cycles (the settling time of a third-order sinc filter), the buffer and interrupt controller captures the data output and asserts the interrupt. In Figure 3, notice how the measurement is centered around the sync pulse. The sequence repeats itself at the next sync pulse, but the modulator clock remains on once the filter has been started.

The proposed sinc filter solves the problem of synchronization of a conventional sinc filter. The filter and its operating mode do not make any assumptions about the PWM frequency, the modulator clock, or the decimation rate. It works equally well with all system configurations and even if the PWM frequency varies over time. Since the filter is effectively reset for every measurement, it is also insensitive to drift between the clocks.

$$\frac{y(z)}{u(z)} = \left(\frac{1}{1-z^{-1}}\right)^3 = \frac{1}{1-3z^{-1}+3z^{-2}-z^{-3}} \tag{8}$$

The difference equation for the three cascaded integrators is shown in Equation 9:

$$y[n] = u[n] + 3y[n-1] - 3y[n-2] + y[n-3] \tag{9}$$

Notice how the input at sample n affects the output at sample n.

If the three integrators are implemented with the D-type flip-flip accumulator in Figure 4, the result is as shown in Figure 5.

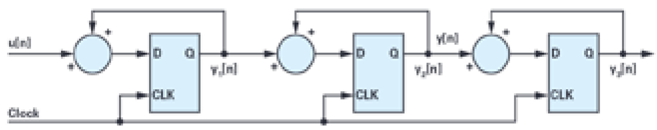


Figure 5: Three cascaded accumulators implemented with D-type flip-flops.

Since this is a clocked circuit, it will take several clocks for a change of the input to affect the output. This becomes even clearer when examining the difference equations for the cascade accumulators (see Equation 10).

$$
\begin{aligned}
y_1[n] &= u[n] + y_1[n-1] \\
y_2[n] &= y_1[n-1] + y_2[n-1] = u[n-1] + y_1[n-2] + y_2[n-1] \\
y_3[n] &= y_2[n-1] + y_3[n-1] = u[n-2] + y_1[n-3] + y_2[n-2] + \\
&\quad y_3[n-1]
\end{aligned}
\tag{10}
$$

This difference equation is quite unlike the one for the pure integrators (see Equation 9). With the accumulators, it takes two clocks before an input affects the output, whereas with pure integrators, the input affects the out immediately. To illustrate this, Figure 6 shows the step response of Equation 9 and Equation 10, respectively, when a unit step is applied at sample number 5. As suspected, the accumulators are delayed by two samples compared to the integrators.

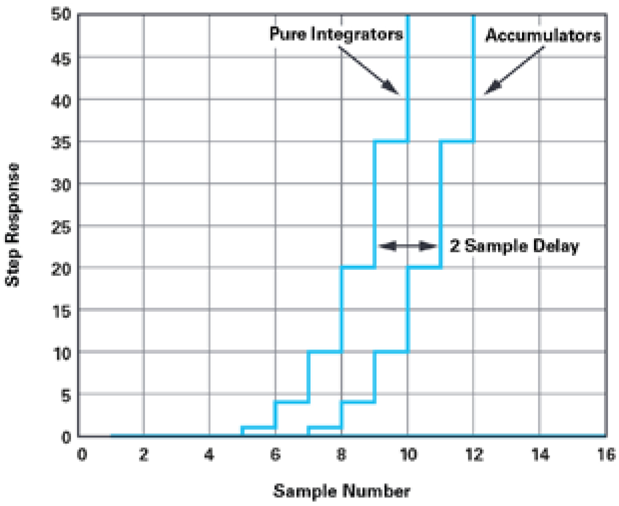


Figure 6: Step response of three cascaded integrators and three cascaded accumulators.

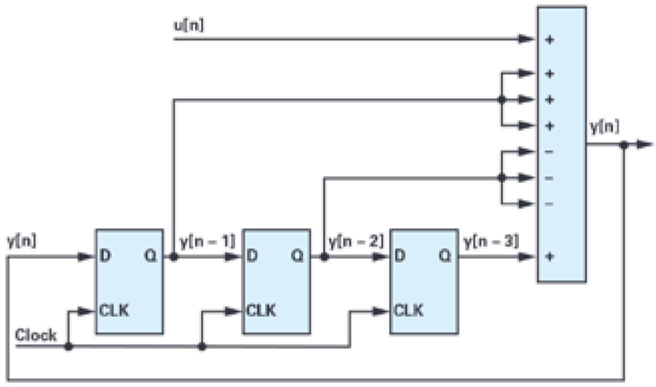


Figure 7: Implementation of three cascaded integrators.

In most publicly available sinc filter examples, it is recommended to implement the integrators with D-type flip-flop accumulators. The main argument for this is low gate count, but the lightweight implementation comes at a cost. Compared to the filter's group delay, an additional delay of two modulator clocks may seem insignificant, but the delay impacts the filter's ability to attenuate higher frequencies, and as a result, the accumulator implementation gives fewer effective numbers of bits than a pure integrator would. Furthermore, the proposed flushing sinc filter requires an ideal transfer function in order to work correctly. For those reasons, no sinc filter implementation should rely on accumulators to implement the integrator stage.

To get the ideal sinc3 response, a direct implementation of the difference from Equation 9 is proposed. The result is shown in Figure 7. Note how the block diagram consists of two parts: a clocked logic part (the flip-flops) and a combinatorial part (the summations). This realization requires more gates, but it has the desired filter performance and delay.

Differentiators

Similar to the integrators, many of the publicly available sinc filter examples implement the differentiator stage incorrectly, which results in reduced filter performances and unexpected delay. This section discusses the differentiator stage and makes recommendations on how to implement an FPGA for optimum performance. First, consider a pure differentiator in the z-domain in Equation 11 and the corresponding difference in Equation 12.2

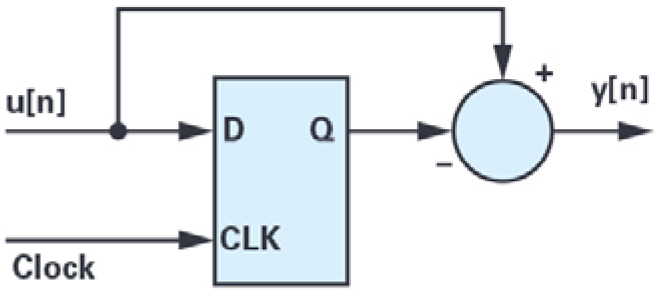


Figure 8: Differentiator implemented with D-type flip-flop.

```
always @(posedge clock)
begin
      y1[n] <= u[n] – u[n-1];
      y2[n] <= y1[n] – y1[n-1];
      y3[n] <= y2[n] – y2[n-1];
      u[n-1]  <= u[n];
      y1[n-1] <= y1[n];
      y2[n-1] <= y2[n];
end
```

Figure 9: Three differentiators implemented as clocked logic.

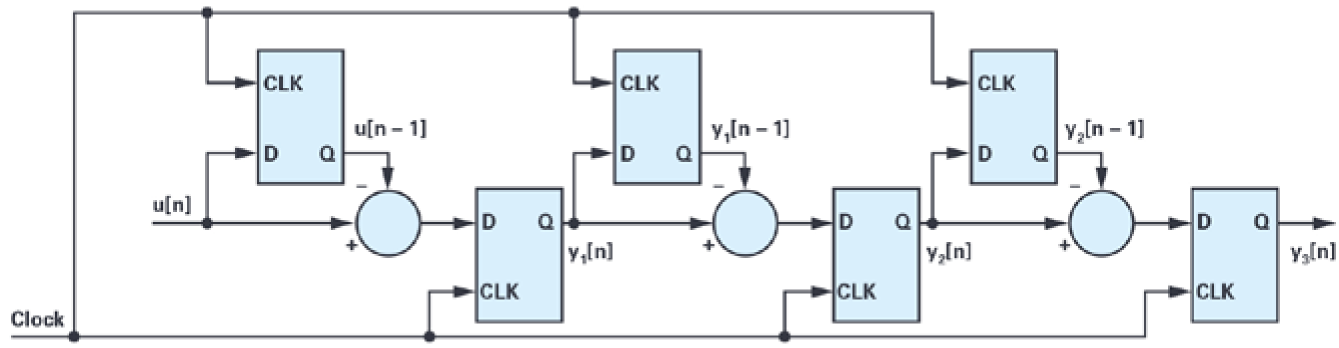


Figure 10: Differentiators implemented with clocked assignements.

$$\frac{y(z)}{u(z)} = 1 - z^{-1} \tag{11}$$

$$y[n] = u[n] - u[n-1] \tag{12}$$

To realize a differentiator on an FPGA a D-type flip-flop is most commonly used, see Figure 8.

```
always @ (posedge clock)
 begin
    u[n-1] <= u[n];
    y1[n-1] <= y1[n];
    y2[n-1] <= y2[n];
end
assign y1[n] = u[n] – u[n-1];
assign y2[n]= y1[n] – y1[n-1];
assign y3[n] = y2[n] – y2[n-1];
```

Figure 11: Three differentiators implemented as a mix of clocked logic and combinatorial logic.

A common way to implement the three D-type flip-flop differentiators is illustrated with the following HDL code snippet. Here, pseudo-Verilog is used, but the principles applies to other languages, too.

As with any clocked assignment, all the right-hand side statements are evaluated first and assigned to the left-hand side.3 Everything is clocked and all assignments are updated in parallel. This is a problem because the output terms (yx[n]) relies on the delayed terms (u[n-1] and yx[n-1]) being updated first. As a result, the previous Verilog snippet implements to logic, as shown in Figure 10.

Due to the clocked assignments, the delay of the differentiators is six clocks rather than the expected three clocks. Since the differentiators are clocked with the decimated clock, this effectively doubles the filter's group delay and settling time. However, it also affects the filter's attenuation and the frequency response is not that of an ideal third-order sinc. The implementation in Figure 10 is often seen in published sinc filter examples, but it is highly recommended to choose an approach that mimics an ideal differentiator stage.

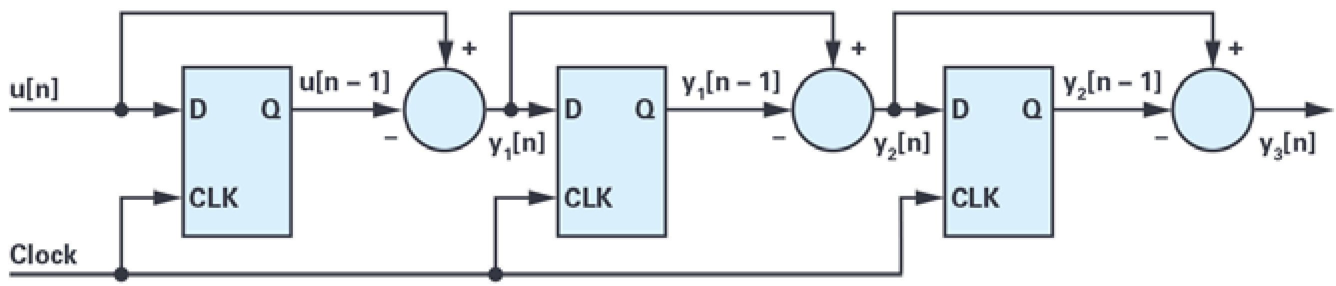


Figure 12: Implementaion of three cascaded differentiators using a mix of clocked logic and combinatorial logic.

The previous Verilog code snippet can be separated into two parts: a combinatorial part that calculates the current outputs and a clocked logic part that updates delayed states. This separation makes it possible to move the combinatorial part outside the always clocked block as shown in the code snippet shown in Figure 11.

With the combinatorial assignments, there is no additional delay associated with the calculation of yx and the total delay is brought down from 6 clocks to the ideal 3 clocks. The block diagram for the recommended implementation of the differentiators is shown in Figure 12.

By combining the proposed implementation of the cascaded integrators and differentiators, the sinc filter gets ideal characteristics in terms of attenuation and delay. All sigma-delta-based measurements will benefit from the optimized filter implementation, but especially the flushing sinc that relies on knowing the exact filter delay.

Measurements

The proposed sigma-delta measurement system has been implemented and tested together with a servo motor controller based on a Xilinx® Zynq®-7020 SoC.4 The system consists of a 60 V, 3-phase permanent magnet servo motor (Kinco SMH40S 5) and a 3-phase switching voltage source inverter. The SoC runs a field-oriented motor control algorithm, as well as software for capturing measurement data in real time.

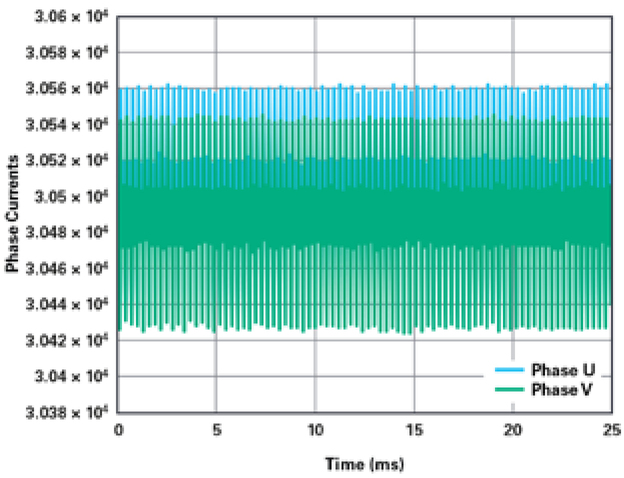
For phase current measurement, the system has two isolated sigma-delta ADCs (ADuM7701) followed by two third-order sinc filters. The sinc filters are implemented using the design recommendation discussed in this article, including the flushing sinc mode of operation. For comparison, measurement results for both the traditional, continuously operating filter and the flushing filter will be presented.

While the control system has closed loop field-oriented control, all measurements are performed with the open-loop control. A closed current loop is sensitive to measurement noise and the noise will couple through the current loop. By operating in open-loop, any effects from the current controllers are eliminated, which makes it possible to compare results directly.

Except for mode configuration and alignment to PWM, the measurements were done with the identical configurations including the decimation rate, which was set to 125. Any difference in the measurement results can therefore be contributed to the effect of aligning the sinc3 impulse response correctly to PWM or not. The control algorithm is executed at 10 kHz and the modulator clock is 12.5 MHz.

Unaligned Impulse Response with Continuous Sinc Filter Operation

In the first example (see Figure 13a), the impulse response is uncorrelated to the PWM waveform. Figure 13b shows two phase current measurements when the motor is stopped but the power inverter is switching with a duty cycle of 50% on all phases. In this operating mode, the measurement shows the noise level of the measurement. Figure 13b shows the phase currents when the motor is running open-loop at 600 rpm. The motor has four pole pairs, so the electrical period is 25 ms. Both plots show significant noise that would severely affect the performance of any closed-loop current controller. The noise level is unrelated to the magnitude of the fundamental phase current, so the noise is relatively worse at light load. The noise in this example is due to an unaligned sinc



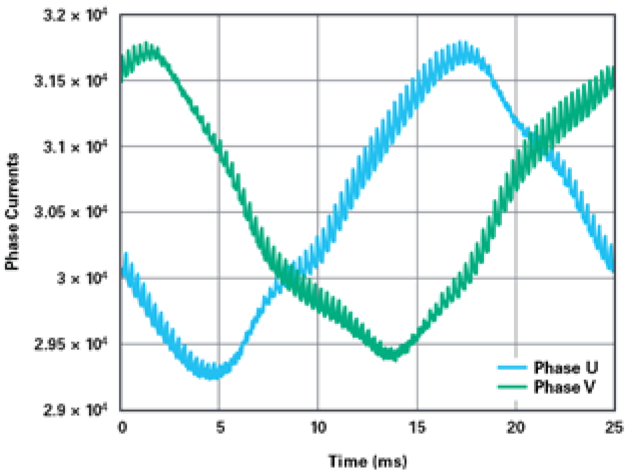
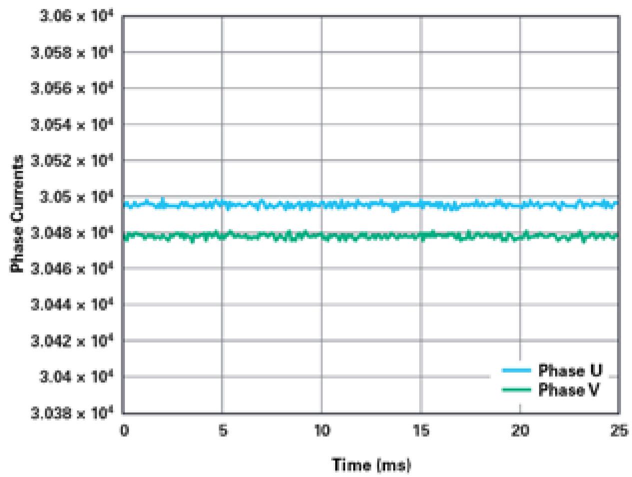


Figure 13: Continuous operating mode with the sinc filter impulse response unaligned to PWM.



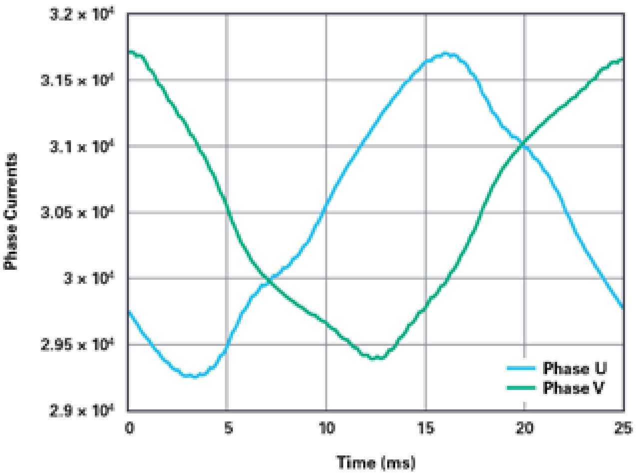


Figure 14: Continuous operating mode with sinc filter impulse response aligned to PWM.

filter impulse response and it would have little or no increase to the decimation rate (attenuation) of the sinc filter.

Aligned Impulse Response with Continuous Sinc Filter Operation
Figure 14 shows measurement results when there is an integer number of decimation cycles per PWM period and the impulse response is aligned with the ideal measurement point. The results in Figure 14 are directly comparable with the results in Figure 13.

When comparing Figure 13 and Figure 14, the filters are using the same decimation rate, but the noise level has been reduced significantly. The examples illustrate how important system configuration and synchronization are to fully utilize the performance of a sigma-delta-based signal chain.

Flushing Sinc Filter
While the results for the continuously operating sinc filter in Figure 14 were satisfactory, the filter still has difficulty in finding a configuration that enables synchronization. While it is possible to synchronize a continuously operating sinc filter to PWM, it is often not practical. That problem is solved with the flushing sinc filter.

Figure 15 shows measurement results for a flushing sinc filter. The filter is configured to only run for 3 decimation cycles around the ideal measurement point. Performance is, as expected, similar to the continuously operating filter in Figure 14.

For comparison, the flushing filter uses the exact same configuration as the continuously operating filter. The difference is that the continuously operating filter must use this configuration or performance will deteriorate, as illustrated by the results in Figure 13. The flushing filter, on the other hand, will maintain its optimal performance with any possible system configuration.

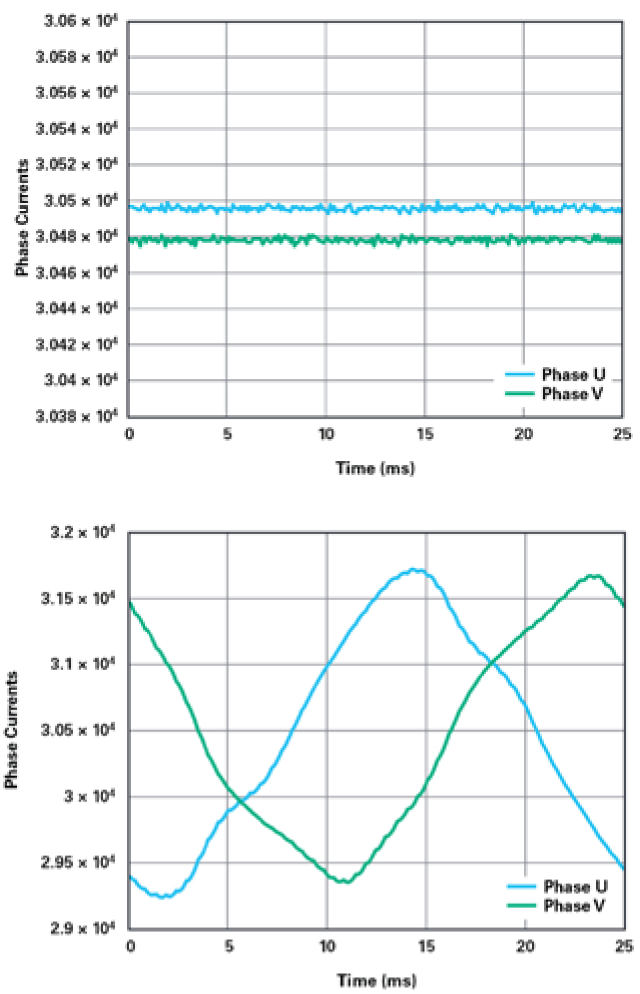


Figure 15: Flushing sinc filter with sinc filter impulse response aligned to PWM.

The magnitude of the noise with the unaligned, continuously operating sinc filter (Figure 13a) is approximately 120 counts out of a 16-bit signal. That corresponds to a loss of approximately the lower 7 bits due to noise. The noise level of the flushing sinc filter (Figure 15a) is approximately 5 counts out of a 16-bit signal, corresponding to losing less than 3 bits due to noise.

Summary
Sigma-delta-based phase current measurement is widely used in motor drives, but getting optimum performance requires correct configuration of the whole system. This article discussed the sources that can lead to poor performance and how to correctly set up a system.

Configuring a system for optimum current feedback performance can be challenging and, in some cases, impossible. To solve this, a new type of sinc filter was proposed. The filter operates in an on-off mode and guarantees optimum performance with any system configuration.

Implementing a sinc filter on an FPGA requires development of HDL code. The article discussed several implementation techniques that lowers delay in the filter and increases attenuation.

References

1 Dara O'Sullivan, Jens Sorensen, and Aengus Murray. "AN-1265: Isolated Motor Control Feedback Using the ADSP-CM402F/ADSP-CM403F/ ADSP-CM407F/ADSP-CM408F Sinc Filters and the AD7403". Analog Devices, Inc., April 2015.
2 Alan Oppernheim and Ronald Schafer. "Discrete-Time Signal Processing". Third edition. Prentice Hall Inc., 2010.
3 Rajeev Madhavan. "Quick Reference for Verilog HDL." Automata Publishing Company, 1995.
4 "Zynq-7000 SoC Data Sheet: Overview." Xilinx, Inc., July 2018.
5 "KNC-SRV-SMH40S Servo." Anaheim Automation, Inc., April 2019.

About the Authors

Jens Sorensen is a system applications engineer at Analog Devices, where he works with motor control solutions for industrial applications. He received his M.Eng.Sc. from Aalborg University, Denmark. His main interests are control algorithms, power electronics, and control processors.

Dara O'Sullivan is a system applications manager with the connected motion and robotics team within the Automation and Energy Business Unit at Analog Devices. His area of expertise is power conversion, control, and monitoring in industrial motion control applications. He received his B.E, M.Eng.Sc., and Ph.D. from University College Cork, Ireland, and he has worked in industrial and renewable energy applications in a range of research, consultancy, and industry positions since 2001.

Shane O'Meara is a system applications engineer with the Connected Motion and Robotics Team at Analog Devices. His area of expertise is precision conversion and signal chains for control and monitoring in industrial motion control applications. He received his B.Eng. from the University of Limerick and joined Analog Devices in 2011.

www.analog.com

AC/DC Converter ICs Equipped with Integrated High Voltage SJ MOSFET

ROHM developed the AC/DC fly-back converter ICs with an integrated 730V breakdown MOSFET the BM2P06xMF-Z series (BM2P060MF-Z, BM2P061MF-Z, and BM2P063MF-Z). These devices are ideal for auxiliary power supply and Switch Mode Power Supply (SMPS) solutions for industrial drives as well as home appliances – including air conditioners, white goods, and factory automation equipment. These fly-back ICs require no additional heatsinks and

no discharge resistors and capacitors. It helps designers to shorten design time, simplify the circuitry, reduce cost and increase reliability by offering integrated solutions. They are equipped with an original low-loss SJ (Super Junction) MOSFET together with optimized PWM control circuitry – facilitating the development of 85V to 264V AC/DC converters. Adopting a surface mount package supports automatic board mounting (which was previously difficult to do in the past). Meanwhile, the implemented functions ensure compliance with the IEC62368 safety standard, even when the discharge resistor (a source of loss during standby) is removed. Additionally, original low standby power control technology is applied – resulting in extremely low standby power consumption. Supply voltages up to 60V (VCC) are also supported – eliminating the need for an external step-down power supply circuit.

Compared to general products with equivalent performance, automatic mounting contributes to lower factory mounting costs. Moreover, ROHM is able to reduce standby power by over 90% along with the number of power supply circuit components by four, contributing to greater power savings and higher reliability in applications.

www.rohm.com

X-Band GaN on SiC Solutions

Richardson RFPD announced the availability and full design support capabilities for a lineup of X-band GaN on SiC devices from Wolfspeed. Wolfspeed's portfolio of high-performance X-band solutions features a variety of power levels to optimize system performance, as well as backend support tools to assist in system design and integration. The product offering includes discrete transistors, impedance-matched FETs and multistage MMIC amplifiers. The devices are well suited for pulsed and continuous wave X-band applications, including airborne and marine radar, weather radar, air traffic control, and test instrumentation.

www.richardsonrfpd.com

Silicone Technologies for Advanced Semiconductor Packaging

Dow introduced its latest silicone technologies for advanced semiconductor packaging at SEMICON® Taiwan 2021. These silicone-organic hybrid adhesives, silicone hotmelt solutions and silicone die-attach films (DAF) deliver improved performance, durability, uniformity and processability vs. traditional organics. Dow's technologies are engineered to address top trends in advanced semiconductor packaging, including ever-thinner, smaller and more-complex designs, by mitigating stress from mismatched coefficients of thermal expansion (CTEs) that can cause warpage. They also provide greater durability and reliability for applications exposed to harsh environmental conditions in industries such as aerospace and automotive electronics.

"While advanced packaging designs are essential to meet increasing demand for higher performance and expanded functionality in electronics, they can also place greater thermal, electrical and mechanical stresses on the chip," said Jayden Cho, Dow's global segment leader for Displays & Microelectronics. "To address this situation and help customers improve quality, consistency and pro-

cessability, Dow has developed an array of novel silicone technologies specifically designed for side-by-side and stacked chip configurations and MEMS devices. Our silicone products surpass organics by optimizing thermal stability, stress relaxation and durability in many different types of packaging."

www.dow.com

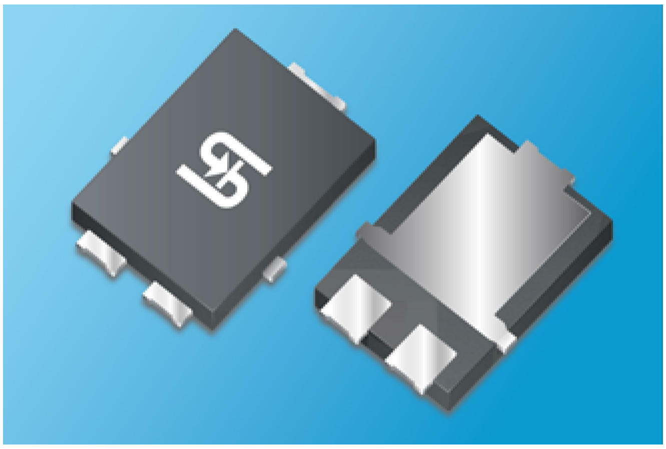
Great Breadth of Supercapacitors

Transfer Multisort Elektronik (TME) has further strengthened its portfolio of supercapacitors with the addition of 15 SPSCAP products. Market demand for supercapacitors has grown dramatically in recent years, providing a way of storing energy and maintaining voltage under operating conditions and in locations where conventional batteries simply would not be applicable. Among the sectors in which they are currently seeing most traction are automotive, where they are being incorporated into electric vehicle (EV) powertrains, and Internet of Things (IoT) networks, where they can support energy harvesting activities. They are also becoming commonplace in consumer electronic devices, being featured in the camera flash subsystems of smartphones, as well as in backup power supplies, etc. Given the increasing supercapacitor uptake now being experienced, access to robust and dependable supply chain channels is going to be vital. The SPSCAP components now stocked by TME can be supplied to customers in a wide array of capacitance values, spanning from 1F through to 3000F. These cylindrical format components utilize an acetonitrile electrolyte and have voltage ratings of 2.7VDC, 2.85VDC and 3VDC. They come with either radial or axial leads attached. Modules that are designed for higher voltage usage are also offered. These are rated at 16V. All of these products support a working temperature range of -40°C to 65°C. Depending on the particular model, they have duty cycle figures of between 500,000 and 1 million.

www.tme.com

Fast Recovery Epitaxial Diode Series

Taiwan Semiconductor announces the extension of its recently launched line of fast recovery epitaxial diodes. The PUUPxxH family extends the benefits of FRED technology to applications requiring up to 6A of operating current. These AEC-Q101 qualified devices deliver optimized switching speed vs. reverse recovery time. Their soft reverse recovery results in lower noise switching while achieving low losses and increased efficiency. The TO-227 package heat spreader contacts provide excellent heat transfer. In addition to the 100V and 200V rated 3A, 4A and 6A models in the PUUP series, 3A and 4A versions are available in SOD-128 and DO-214 packages.



"The PUUP series' FRED technology delivers increasing efficiency and power density in switching power applications in newer more thermally advantageous packaging," said Vice President, TSC Products, Sam Wang. "And for instant upgrade to the benefits of this technology, 3A and 4A versions are also offered in historical packaging." Applications include switching power conversion in automotive, lighting, industrial and communications. Specific applications benefiting from AEC-Q qualification include fuel injection systems, electrification of transportation and automated navigation.

Design resources include comprehensive datasheets and spice models for each component in the series.

www.taiwansemi.com

3-Level 800V GaN Inverter

hofer powertrain and VisIC Technologies announce a partnership to work jointly on a GaN-based inverter for 800V automotive applications. "Our partnership with hofer powertrain for the development of gallium nitride-based power inverters in electric vehicles is the breakthrough of gallium nitride technology for 800V battery systems in the automotive industry", said Tamara Baksht, CEO of VisIC. "VisIC's D3GaN technology was developed for the high-reliability standards of the automotive industry and offers the lowest losses per RDS (on). It also simplifies the system solution and enables highly efficient and affordable powertrain platforms solutions. The ability to support cars with 800V battery, along the 400V battery, is the significant step forward in GaN worldwide adoption by automotive electrical driveline".

hofer powertrain has been working for more than 5 years on the development of 3-Level inverters for automotive powertrain applications, revealing vast benefits that the 3-Level topology brings compared to today's state-of-the-art 2-Level inverters using IGBTs or SiC chips. The special properties of the 3-L topology of an inverter lead to improved overall system energy consumption at the relevant reference driving cycles, such as WLTP, due to reduced harmonic losses in the motor. Moreover, the Noise Vibration Harshness (NVH) behavior of the complete Electric Drive Unit can be improved due to the better Total Harmonic Distortion of the output current affecting noise reduction.

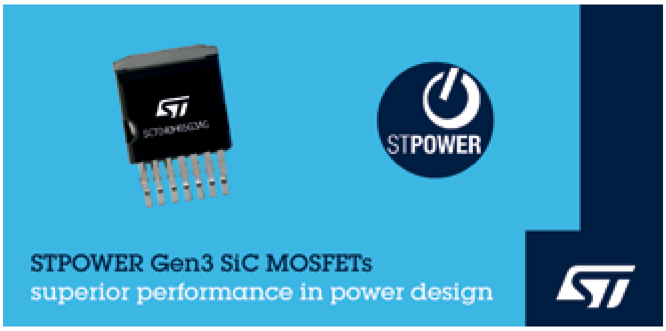
Finally, costs are reduced regarding Electro Magnetic Compatibility measures to meet the increasingly strict requirements (like Comité International Spécial des Perturbations Radioélectriques 25 class 5), due to the better common-mode behavior of the hofer powertrain 3-Level inverter.

www.visic-tech.com

Silicon-Carbide Power Devices for E-Mobility and Energy-Efficient Industry

STMicroelectronics is introducing its third generation of STPOWER silicon-carbide (SiC) MOSFETs, advancing the state-of-the-art in power devices for electric-vehicle (EV) powertrains and other applications where power density, energy efficiency, and reliability are important target criteria.

ST has incorporated design know-how to open up even more of SiC's energy-saving potential. The effort continues to drive the transformation of the EV and industrial markets. With the acceleration of the EV market many car makers and automotive suppliers are now embracing 800V drive systems to achieve much faster charging and help reduce EV weight. These systems allow the car makers to produce vehicles with longer driving ranges. ST's SiC devices are specifically optimized for these high-end automotive applications including EV traction inverters, on-board chargers, and DC/DC converters, as well as e-climate compressors. The new generation also suits industrial applications by boosting the efficiency of motor drives, renewable-energy converters and storage systems, as well as telecom and data-center power supplies. ST will offer the third-generation devices in various forms, including bare dice, discrete power packages such as STPAK, H2PAK-7L, HiP247-4L, and HU3PAK and power modules of the ACEPACK family. The packages offer innovative design features such as specially placed cooling tabs that simplify connection to base-plates and heat spreaders in EV applications. The options give designers choices that are optimized for applications such as EV main traction inverters, on-board chargers (OBCs), DC/DC converters, e-climate compressors, and industrial applications such as solar inverters, energy storage systems, motor drives and power supplies.

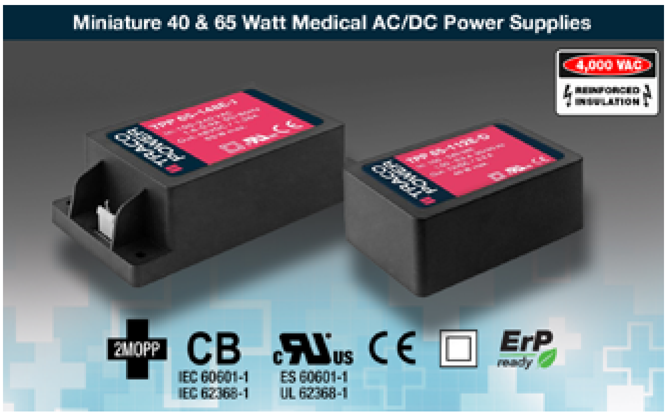


www.st.com

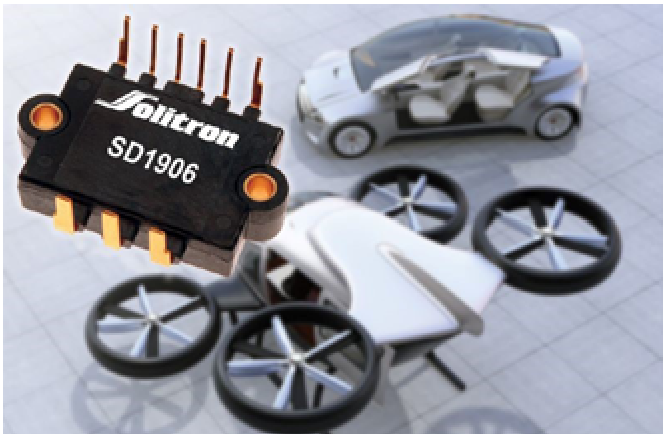
Encapsulated AC/DC Power Supplies

TRACO POWER announces their TPP 40E & TPP 65E families of miniature encapsulated AC/DC power supplies with safety approvals for both Medical and Industrial applications. Consisting of 6 models within each wattage family offering single outputs of 5 / 12 / 15 / 24 / 36 / 48 V with up to 94% efficiency. The small footprint with PCB or chassis mount versions make these products an attractive solution for a wide range of requirements. The TPP 40E / TPP 65E families are 2xMOPP compliant and rated for BF (body floating) for applied parts applications, insuring both patient and operator protection. Using high quality components and high efficiency topologies enables wide operating temperatures and high reliability exceeding 1.4 million hours MTBF (MIL-HDBK-217F, ground benign) and supported with a 5 year product warranty.

www.tracopower.com



1200V, 100A Power Modules

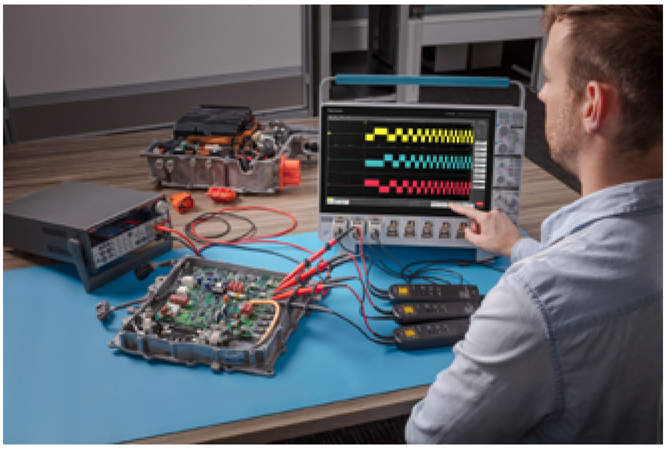


Solitron Devices is pleased to announce the introduction of the SD11906, SD11907, SD11956 and SD11957 1200V Silicon Carbide (SiC) Half Bridge Power Modules. Solitron has developed this power module series to maximize the benefits of SiC, with a unique robust, simple, and cost-effective module format. The 37mm x 25mm x 9mm outline is a fraction of the size and weight of competitive modules. The integrated format maximizes power density while minimizing loop inductance with a pin configuration to allow simple power bussing. The SD11906/07/56/57 are half bridge configurations with two 1200V, Low RDS(on) 13mΩ SiC MOSFETs. The SD11906 and SD11956 feature freewheeling 1200V SiC Schottky diodes in parallel with the MOSFETs inside the module. The pinout configuration separates the power bus from the gate and source controls to ease and simplify board layout. All four devices feature continuous drain current of 105A. This series is designed for demanding applications such as avionics based electromechanical actuators and power converters. With operating temperatures of -55°C to 175°C, construction includes copper baseplates and Alumina Nitride insulators ensuring TCE matching and high thermal transfer. Isolated, integrated temperature sensing enables high level temperature protection on the SD11906 and SD11907.

www.solitrondevices.com

Mixed Signal Oscilloscope for Power Integrity Testing

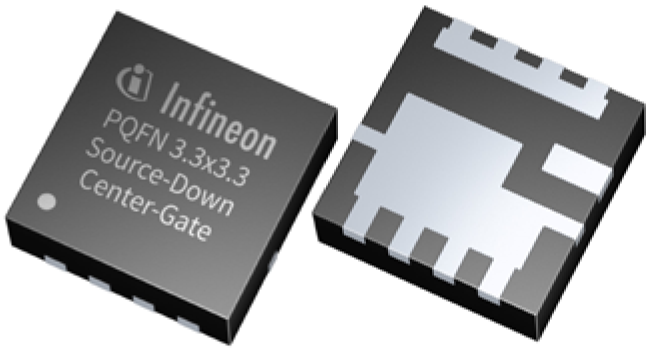
Tektronix announced the launch of its latest version of the 5 Series mixed signal oscilloscope (MSO). With numerous enhancements, the 5 Series B MSO delivers even more versatility while continuing to provide high-fidelity waveforms, unique spectrum analysis capabilities, and flexible signal access appreciated by engineers



around the world. Built on the performance and integrity that engineers rely on with the original 5 Series MSO, the B version includes customer-centric updates led by a new auxiliary trigger input that lets users synchronize the oscilloscope to an external signal without consuming any of the 4, 6, or 8 full-capability input channels. For the optional, built-in arbitrary/function generator, the maximum frequency output increases from 50 MHz to a best-in-class 100 MHz; enabling higher frequency stimulus for measurements such as Bode plots and impedance measurements. These capabilities are invaluable for making fast, thorough checks of power integrity on power distribution networks. To serve the needs of engineers working and collaborating outside the lab, the 5 Series B MSO works with new tools for offline analysis and cloud data storage. TekScope™ PC software enables analysis of oscilloscope waveform data anywhere, without tying up the oscilloscope. Controls are built into the scope to enable saving to TekDrive cloud storage with a single press of a button so users can easily save waveform data to the cloud, allowing teams to work and collaborate across the world.

www.tektronix.com

Power MOSFET Package Enables Innovative Source-Down Technology



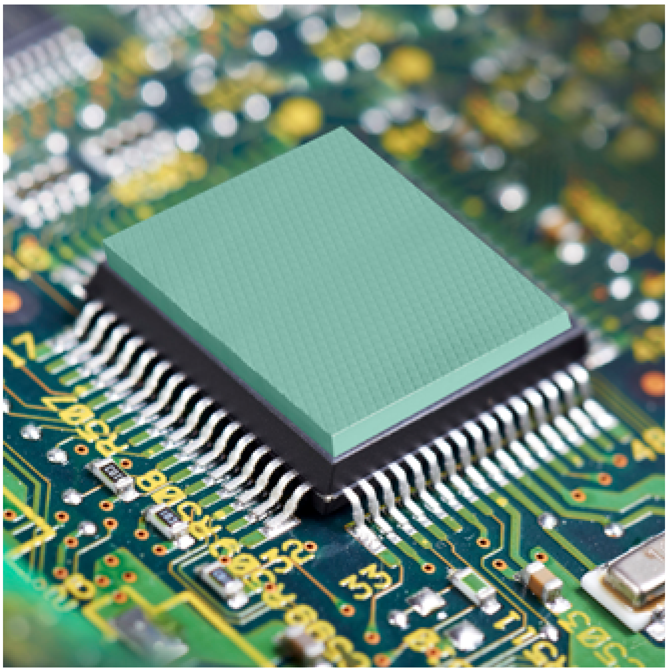
High power density, optimized performance, and ease of use are key requirements when designing modern power systems. To offer practical solutions for design challenges in end applications, Infineon Technologies launches OptiMOS™ Source-Down (SD) power MOSFETs. They come in a PQFN 3.3 x 3.3 mm 2 package and a wide voltage class ranging from 25 V up to 100 V. This package sets a new standard in power MOSFET performance, offering higher efficiency, higher power density, superior thermal management and low bill-of-material (BOM). The PQFN addresses applications including motor drives, SMPS for server and telecom and OR-ing, as well as battery management systems.

Compared to the standard Drain-Down concept, the latest Source-Down package technology enables a larger silicon die in the same package outline. In addition, the losses contributed by the package, limiting the overall performance of the device, can be reduced. This enables a reduction in R DS(on) by up to 30 percent compared to the state of the art Drain-Down package. The benefit at the system level is a shrink in the form factor with the possibility to move from a SuperSO8 5 x 6 mm 2 footprint to a PQFN 3.3 x 3.3 mm 2 package with a space reduction of about 65 percent. This allows for the available space to be used more effectively, enhancing the power density and system efficiency in the end system.

www.infineon.com

High-Performance Thermal Gap Filler Pads

The Chomerics division of Parker Hannifin Corporation is introducing its next generation of thermal gap filler pads - THERM-A-GAPTM PAD 30 and 60 - for all heat transfer applications between electronic components and heat sinks. With a dependable thermal performance of 3.2 W/m-K, the cost-effective THERM-A-GAP PAD 30 reliably conforms to rough surface irregularities and air gaps on heat generating components. For higher performance applications, THERM-A-GAP PAD 60 offers the enticing combination of excellent thermal conductivity at 6.0 W/m-K, while being 40% softer than current high-performance thermal gap pad offerings from Parker Chomerics. With their special formulation, THERM-A-GAP PAD 30 and 60 ensure complete conformability (with low clamping forces) and the lowest outgassing, thus providing an effective thermal interface wherever uneven surface irregularities, air gaps or rough textures are prevalent. The products are ideal for use in general industrial, life science and consumer markets. Typical applications extend from telecommunications equipment, automotive electronics, and lighting LEDs, through to power conversion systems, consumer electronics, desktop/laptop computers, servers, handheld devices and memory modules. THERM-A-GAP PAD 30 and 60 are also highly effective in vibration-dampening applications. "Thermal gap filler pads continue to be designed and used in greater capacities for price-sensitive markets, as well as those requiring high-performance materials," says Brian Mahoney, thermal business unit manager, Chomerics Division. "We're thrilled to expand our already impressive family of thermal gap filler pads with these next-generation offerings."



Manufactured globally, THERM-A-GAP PAD 30 and 60 come in a range of standard sheet sizes and thicknesses, although custom dimensions are available upon request. Parker Chomerics can also supply the products with various carrier options for ease-of-application and use.

www.parker.com

180W AC/DC Power Supply in a 2x3 Inch Package

P-DUKE has announced the latest extension of it's high-power density power supply to the existing range of 15W to 450W. The TAD180 series deliver with forced air cooling up to180W or 150W at natural convection cooling. Additionally, an up to 220W peak output power for 5 seconds is available. This series is featured with 3000Vac reinforced insulation and over-voltage category OVCIII (up to 2000m operating altitude) which make these power supplies suitable for many industrial applications, especially heavy-duty industry. This series comes in compact 2 x 3 Inch open frame versions or optional encased versions and DIN-rail versions with universal input range of 85 to 264 Vac or 120-370 Vdc. It provides

12, 15, 18, 24, 28, 36, 48, 53 Vdc single output voltage. The output voltage can be easily adjusted up to ±8% with the integrated potentiometer. They have the following protection functions: over-voltage protection (latch mode), over-current protection (hiccup mode and auto-recovery), short-circuit protection (continuous and auto-recovery) and over-temperature protection (sensed by an internal thermistor; hiccup mode and auto-recovery).

TAD180 series is equipped with long-life electrolytic capacitors, efficiencies up to 94%, power factor correction is 0.95, no-load power consumption of less than 150mW and IEC protection types of class I and class II. The power supplies can be operated at an altitude up to 5000m and with its superior performance at an operating temperature of -40°C to +85°C.

www.pduke.com

Isolated Single Channel Gate Driver

Inventchip Technology (IVCT) announced that it started shipping 3.75kVrms isolated single channel Gate driver IC IVCO1A01D engineering samples and will release the product to the market in Q1 2022. IVCO1A01D is a 36V 10A driver. The output side VCC2 UVLO is below 10V, which makes it capable of effectively and safely driving SiC/Si MOSFETs and Si IGBTs. The 10A output peak current makes it easy to use in high power applications. It has split outputs, OUTH and OUTL, so that pull-up and pull-down current can be adjusted independently to optimize EMI and switching loss. The low propagation delay and high common-mode transient immunity (CMTI) enables MOSFETs to reliably switch at hundreds of kHz with high dv/dt. It is in an 8-pin SOIC package with 3.75kVrms isolation. The IVCO1A01D helps engineers solve critical design challenges and reduce system cost in many high density applications, such as the server and telecom power supply, motor drive and inverter designs, etc.

www.inventchip.com.cn

Compact High-Voltage Contactors

TDK Corporation has extended its range of bipolar DC high-voltage contactors to include the HVC43 (B88269X3**0C011) series. These products complete the existing range by offering continuous currents from 150 A DC to 250 A DC and operating voltages of up to 1000 V DC. The contactors are available in 12 V or 24 V coils with a power consumption of 6 W.

The HVC43 series types provide compact dimensions of 78 x 40.4 x 74.5 mm (L x W x H), weigh 300 g, and are 30 per cent smaller and lighter than the HVC200, HVC300, and HVC500 types, designed for voltages of up to 1200 V DC and continuous currents of 500 A DC. The contactors include a hermetically sealed gas-filled ceramic arc chamber, offering outstanding extinguishing properties, and are specially designed to quickly shut down high direct currents of lithium-ion batteries in vehicles, charging stations, or energy storage systems.

www.tdk-electronics.tdk.com

Advertising Index

The Premier Global Event in Power Electronics
APEC®
2★22
REGISTRATION IS NOW OPEN
MARCH 20-24
HOUSTON, TX
IAS IEEE INDUSTRY APPLICATIONS SOCIETY Linking Research to Practice
IEEE Advancing Technology for Humanity
pels IEEE POWER ELECTRONICS SOCIETY Powering a Sustainable Future
PSMA