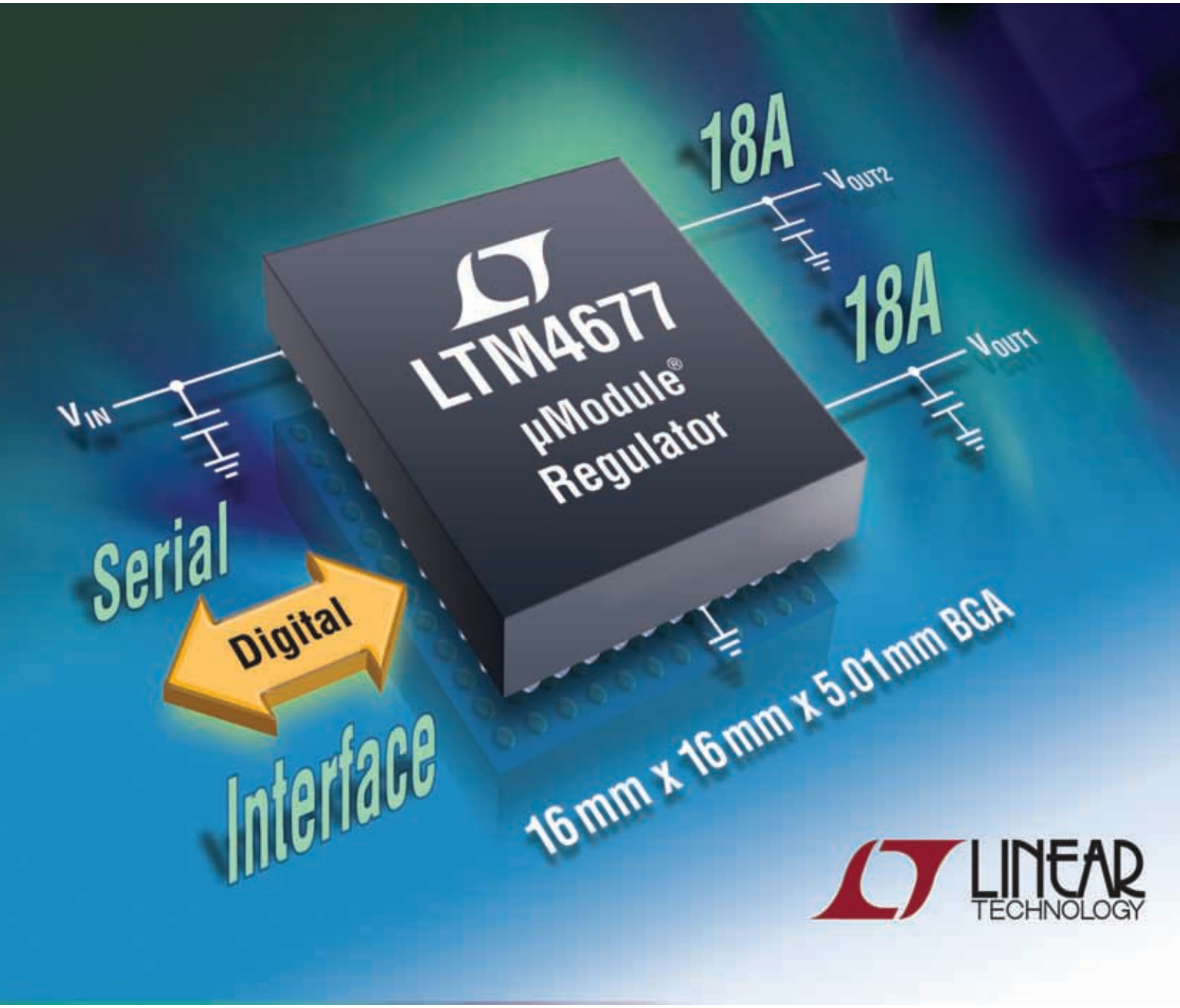
POWER ELECTRONICS EUROPE

ISSUE 5 – September 2016 www.power-mag.com

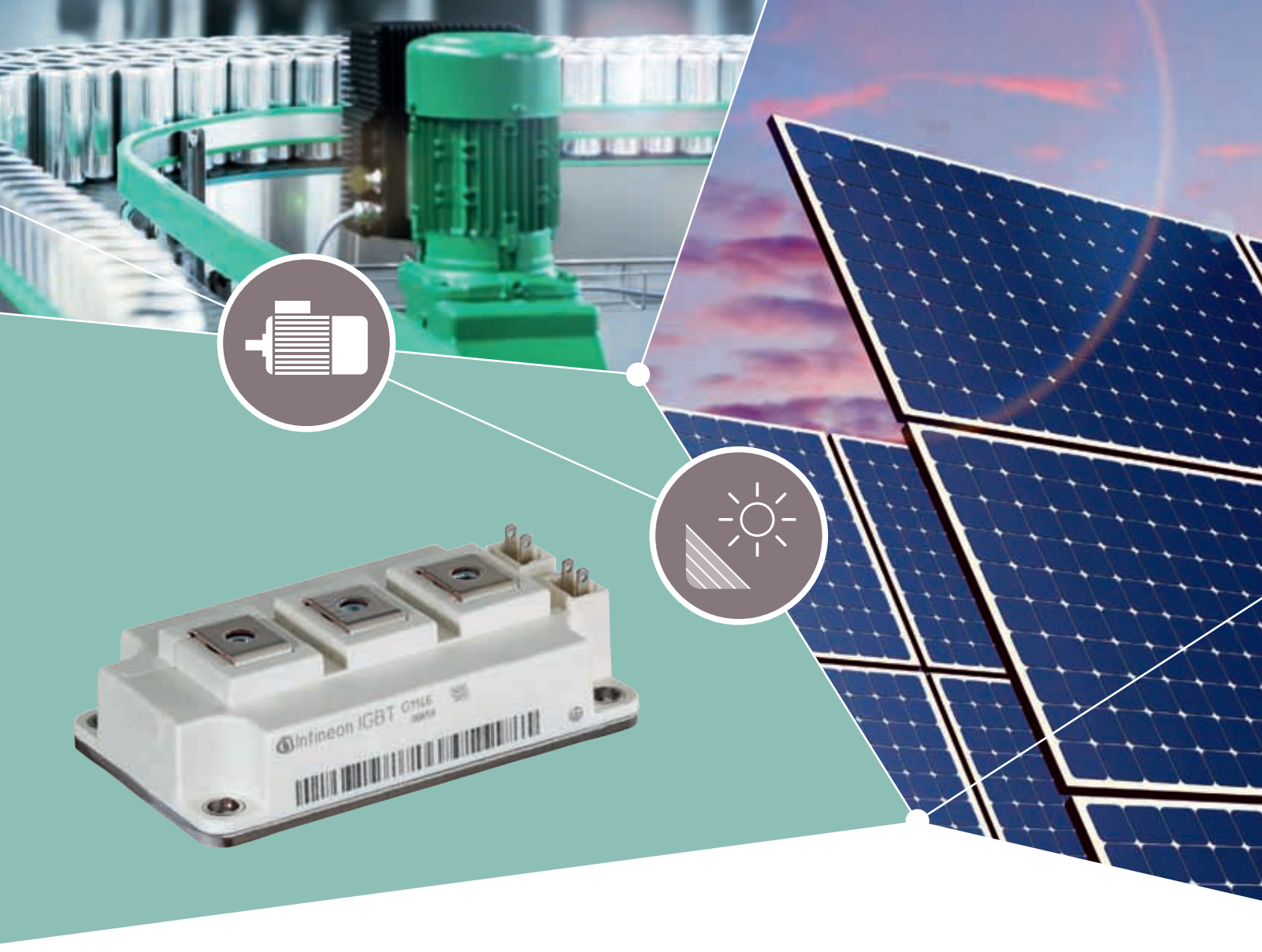
DIGITAL POWER

High Power with Complete Digital Control



THE EUROPEAN JOURNAL FOR POWER ELECTRONICS AND TECHNOLOGY

Also inside this issue



Be BEST IN CLASS

with our NEW 62 mm module

Benefits

› Highest power density
› Allows to increase inverter output power with same frame size

Main features

› 1200 V: 600 A
› 1700 V: 400 A / 500 A
› Also available in ‘Common Emitter’ configuration for 3-level topologies
› Available with thermal interface material TIM
› Add value with the new 34 mm and 50 mm bipolar modules in solder bond technology

www.infineon.com/new62mm

Editor Achim Scharf
Tel: +49 (0)892865 9794
Fax: +49 (0)892800 132
Email: achimscharf@aol.com

Production Editor Chris Davis
Tel: +44 (0)1732 370340

Financial Manager Clare Jackson
Tel: +44 (0)1732 370340
Fax: +44 (0)1732 360034

Reader/Circulation Enquiries
Perception-MPS Ltd.
Tel: +44 (0) 333 577 9202
Email: dfamedia@pmps.info

INTERNATIONAL SALES OFFICES
Mainland Europe:
Victoria Hufmann, Norbert Hufmann
Tel: +49 911 9397 643 Fax: +49 911 9397 6459
Email: pee@hufmann.info

Armin Wezel
phone: +49 (0)30 52689192
mobile: +49 (0)172 767 8499
Email: armin@eurokom-media.d

Eastern US
Karen C Smith-Kernc
email: KarenKCS@aol.com
Western US and Canada
Alan A Kernc
Tel: +1 717 397 7100
Fax: +1 717 397 7800
email: AlanKCS@aol.com

Italy
Ferruccio Silvera
Tel: +39 022 846 716 Email: ferruccio@silvera.it

Japan:
Yoshinori Ikeda,
Pacific Business Inc
Tel: 81-(0)3-3661-6138
Fax: 81-(0)3-3661-6139
Email: pbi2010@gol.com

Taiwan
Prisco Ind. Service Corp.
Tel: 886 2 2322 5266 Fax: 886 2 2322 2205

Publisher & UK Sales Ian Atkinson
Tel: +44 (0)1732 370340
Fax: +44 (0)1732 360034
Email: ian@dfamedia.co.uk
www.power-mag.com

Circulation and subscription: **Power Electronics Europe** is available for the following subscription charges. **Power Electronics Europe**: annual charge UK/NI £80, overseas $150, EUR 140.
Contact: DFA Media, 192 The High Street, Tonbridge, Kent TN9 1BE Great Britain.
Tel: +44 (0)1732 370340.
Fax: +44 (0)1732 360034. Refunds on cancelled subscriptions will only be provided at the Publisher's discretion, unless specifically guaranteed within the terms of subscription offer.

Editorial information should be sent to The Editor, **Power Electronics Europe**, PO Box 340131, 80098 Munich, Germany.

Printed by: Garnett Dickinson.

ISSN 1748-3530

COVER STORY

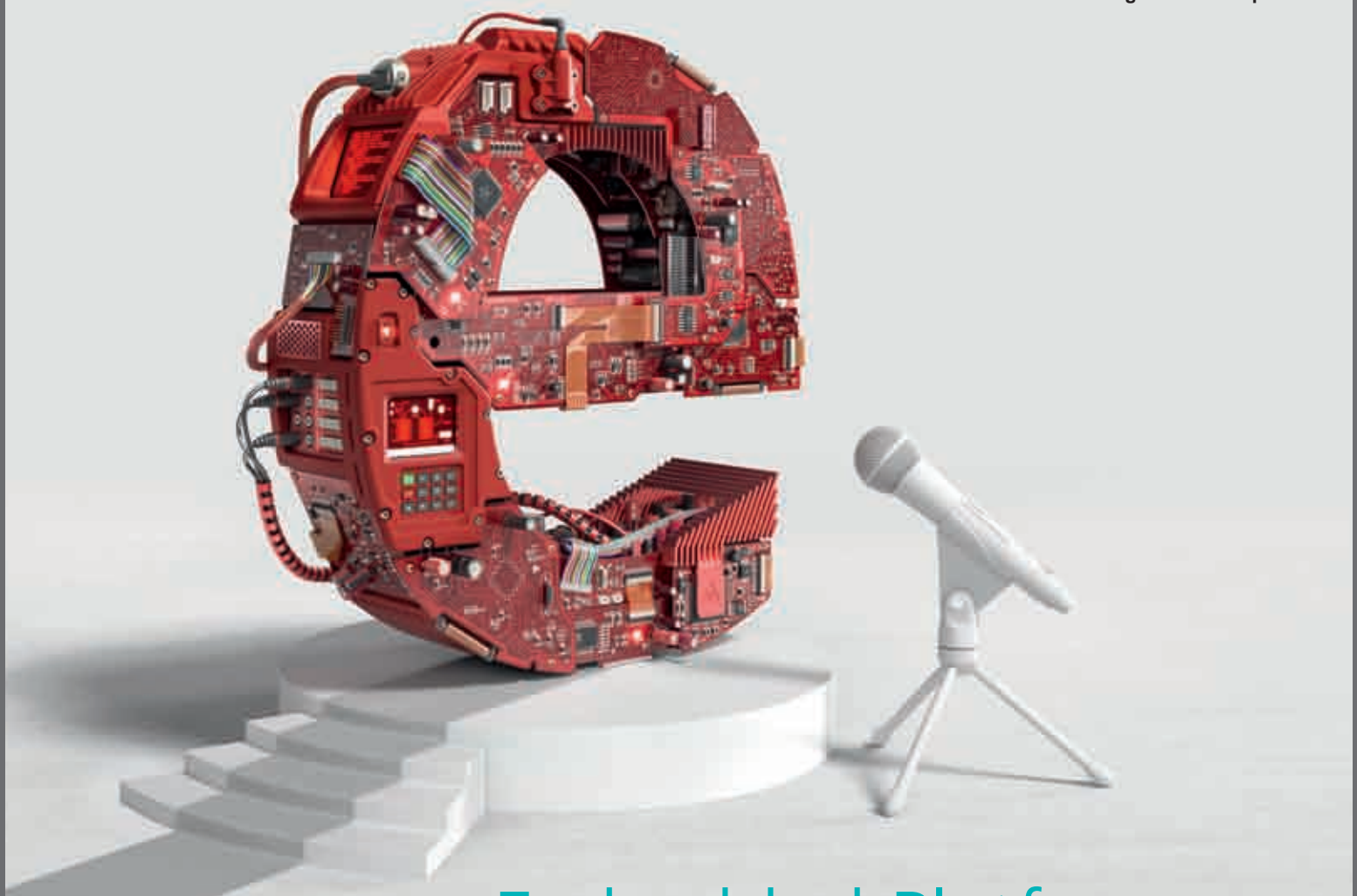
High Power with Complete Digital Control

It should come as no surprise to anyone that a the continuing adoption of Digital Power System Management (DPSM) within the communications and computer industries continues to be driven, in large part, to the high current levels demanded by the sub-20 nm ASICs and/or FPGAs that are at the core of their system architecture. By way of example, consider the newest ASICs being used in the next generation data center switches; they enable a more flexible set of interfaces for ports carrying 100 Mbit to 100 Gbit/s Ethernet and 32 Gbit/s fiber channel traffic. This allows higher density of 100G ports to be placed into a single rack unit. Coupled with this, these sub-20 nm processes allow 20 plus Mbytes of memory to be placed on the ASIC itself, thereby potentially eliminating the need for external memory, saving board space and cost. Having DPSM capability in today's datacom and telecom systems provides a system architect with an simple and powerful way to deliver over 180 W of power to the 1.xV core voltages of the newest sub-20 nm ASICs and FPGAs with just 4 µModule regulators. Utilizing a combination of the LTM4677 and 3 LTM4650s in a multiphase configuration not only saves expensive PCB real estate, but reduces the amount of required cooling due to its overall operating efficiency. Furthermore, the software programmability of DPSM significantly reduces the debug time normally associated with such endeavors. This reduces infrastructure costs, as well as the total cost of ownership over the life of the product. More details on page 26.

Cover supplied by Linear Technology Corporation, USA

Messe München

Connecting Global Competence



Embedded Platforms Conference.

International conference on future-proof hardware and software platforms.

Topics:

- IoT and security
- Microcontrollers and peripherals
- Power and sensors (incl. wireless charging)
- Embedded communication

Information & Registration:
electronica.de/en/embeddedplatforms

Embedded Platforms Conference
November 9–10, 2016 | Messe München

The conference is held within the scope of electronica, the World's Leading Trade Fair for Electronic Components, Systems and Applications.

electronica 2016
inside tomorrow

Mergers for higher Efficiency Levels

The global market for power semiconductors fell 2.6 % to $34 billion in 2015. Discrete power semiconductor product revenue declined 10.1 %, while power module revenues decreased by 11.4 % and power integrated-circuit (IC) revenues increased by 4.5 % overall. The global value of power ICs , power modules and discrete components decreased from $ 15.7 billion to $ 15.2 billion. This 3 % decrease is mainly explained by the strong average selling price (ASP) decrease at IGBT module level. The automotive market will strengthen its position, as the EV/HEV market segment is expected to represent a major part of the IGBT module market by 2021. Over this time the power MOSFET market is expected to grow slightly for all applications, going from $1 billion to $1.2 billion value.

Under these conditions the industry consolidation is still moving on. End of July, Analog Devices, Inc. and Linear Technology Corporation entered into a definitive agreement under which Analog Devices will acquire Linear Technology in a cash and stock transaction that values the combined enterprise at approximately $30 billion. Just after the Analog Devices / Linear Technology merger, Infineons acquisition of International Rectifier and recently Wolfspeed, now Japaneses Renesas is to acquire Intersil, a leading provider of power management and precision analog solutions. Renesas acquires Intersil for $22.50 per share in cash, representing an aggregate equity value of $3.2 billion. The acquisition combines two long-standing industry leaders in their respective segments. Together, Renesas' and Intersil's expertise across a number of state-of-the-art technologies and end markets will enable the combined company to become a complete solution provider of embedded systems. By combining Renesas' microcontroller and system-on-chip products and technologies and Intersil's power management and precision analog capability, Renesas will be well positioned to address some of the most exciting opportunities in key areas such as automotive, industrial, cloud computing, healthcare, and the Internet of Things (IoT). And Littelfuse has acquired the product portfolio of transient voltage suppression (TVS) diodes, switching thyristors and IGBTs for automotive ignition applications from ON Semiconductor for a combined purchase price of $104 million. This portfolio has annualized sales of approximately $55 million. All these acquisitions were announced in the name of more efficient corporations.

Designers are well aware of the advantages of wide bandgap devices such as SiC and GaN, but they also know the challenges they face: a new product with WBG devices means not a direct replacement. It involves R&D investments, higher device cost, differences between Si devices they're already familiar with, and lack of field data. All of these factors present barriers to using WBG. To accelerate adoption, it is necessary to continue to educate end-users about the benefits at system level; and more importantly, to support them in using these new devices. The emergence of 150 mm SiC wafers has been a critical element to explain the wide market adoption of this technology, allowing economy of scale at a manufacturing standpoint together with the use of depreciated 150 mm Silicon production lines that could be converted to accommodate the Silicon Carbide specificities. And with GaN-on-Si the move from 150-mm to 200-mm wafers is underway, leading also to price erosion of the final devices.

At Taiwan Semiconductor Manufacturing Corp. (TSMC) a 0.5 µm GaN-on-Silicon-Enhancement-Mode-process was qualified for power 650 V applications. in late 2015, customers for this process was at a first stage GaN Systems for discrete power devices and most recently UK-based Dialog Semiconductor for an integrated 650-V half-bridge design intended for travel notebook adapters. Though the pricing of such components is significantly higher than for Silicon devices, the savings in passive components lead to smaller size of the charger and even to slightly lower pricing – an advantage due to lower losses of GaN technology and higher switching frequency. Here efficiency matters on a system level – it's not the individual component cost which matters on the system's level, it's the efficient composition of such devices in the end product which matters. Thus design engineers need to confirm the purchasers within their organizations not to look for the least cent of a price but for the added value a higher individual price can give on the system price!

Achim Scharf
PEE Editor

Infineon Tops Global Power Semiconductor Market

Overall revenue for the power semiconductors market globally dropped slightly in 2015, due primarily to macroeconomic factors and application-specific issues, according to new reports.

The global market for power semiconductors fell 2.6 % to $34 billion in 2015. Discrete power semiconductor product revenue declined 10.1 %, while power module revenues decreased by 11.4 % and power integrated-circuit (IC) revenues increased by 4.5 % overall. The report identifies Infineon Technologies as last year's leading power semiconductor manufacturer, with 12 percent of the market, Texas Instruments with 11 percent and STMicroelectronics with 6 percent. "While Texas Instruments previously led the market in 2014, the company was overtaken by Infineon Technologies in 2015, following its acquisition of International Rectifier and LS Power Semitech," said Richard Eden, senior analyst, IHS Markit. "Infineon was the leading global supplier of both discrete power semiconductors and power modules, and the fourth-largest supplier of power management ICs. Infineon has been the leading supplier of discretes for several years, but overtook Mitsubishi Electric to lead the power module market for the first time in 2015, again, due to the International Rectifier and LS Power Semitech acquisitions." while Infineon Technologies' acquisition of International Rectifier was the largest acquisition last year, several other deals also changed the terrain of the power semiconductor market landscape. Key deals in 2015 included the following: MediaTek acquired RichTek; Microchip acquired Micrel; NXP Semiconductors acquired Freescale Semiconductor; NXP Semiconductors also created WeEn Semiconductors, a joint venture with Beijing JianGuang Asset Management Co. Ltd (JAC Capital); CSR Times Electric merged with China CNR Corporation to form CRRC Times Electric; and ROHM Semiconductor acquired Powervation.

Regarding absolute figures, the power semiconductor market have been contracted while most indicators were pointing out on the direction of the 2014 recovery. Indeed, 2015 has been a difficult year with the global value of power ICs , power modules and discrete components decreasing from $ 15.7 billion to $ 15.2 billion. This 3 % decrease is mainly explained by the strong average selling price (ASP) decrease at IGBT module level. "We expect this ASP trend to continue, mainly because of price pressure from the automotive market", explains Coralie Le Bret, Technology & Market Analyst at Yole."But overall IGBT module and global power electronics market value should increase, as volume growth outweighs this ASP fall".

Indeed the automotive market will strengthen its position, as Yole is expecting EV/HEV market segment to represent a major part of the IGBT module market by 2021. Over this time the power MOSFET market is expected to grow slightly for all applications, going from $1 billion to $1.2 billion value. In the "Status of Power Electronics Industry 2016" report Yole's analysts forecast the power electronics market's evolution, with two different scenarios depending for instance on the future of electrified vehicles. Thus many applications within the power electronics industry is depending on political decisions. These applications include renewable energies and electrified vehicles for instance. It is complex to estimate the evolution of the market: according to Yole's nominal scenario, the power semiconductor market will reach US$27 billion by 2030; with a more pessimistic approach, such figure will be totally different.

www.ihsmarkit.com, www.yole.fr

World Top 10 Power Semiconductor Supplier Market Share Estimates
(US $ Revenues)

2015 Rank	Manufacturer	2014r share	2015 share	Change
1	Infineon Technologies*	9%	12%	3.1%
2	Texas Instruments	10%	11%	0.7%
3	STMicroelectronics	6%	6%	-0.1%
4	Maxim Integrated	5%	5%	0.1%
5	Qualcomm	4%	4%	0.1%
6	ON Semiconductor	4%	4%	0.0%
7	NXP	3%	4%	0.4%
8	Fairchild Semiconductor	4%	4%	-0.2%
9	Renesas Electronics Corporation	4%	3%	-0.7%
10	Linear Technology	3%	3%	0.0%
	International Rectifier*	3%	N/A	N/A
	Others	43%	43%	-0.5%
	Total Market Size =	**$34,910.1 m**	**$34,011.4 m**	**-2.6%**

Notes

* Infineon Technologies acquired International Rectifier in Jan 2015. Both companies are reported seperately in 2014 and combined as Infineon in 2015.

r= revised since 2015 edition

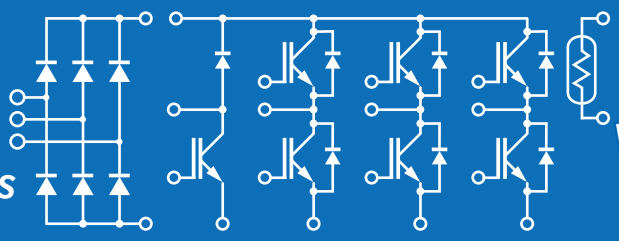
Source: IHS

Fuji Electric

Innovating Energy Technology

Think Easy...

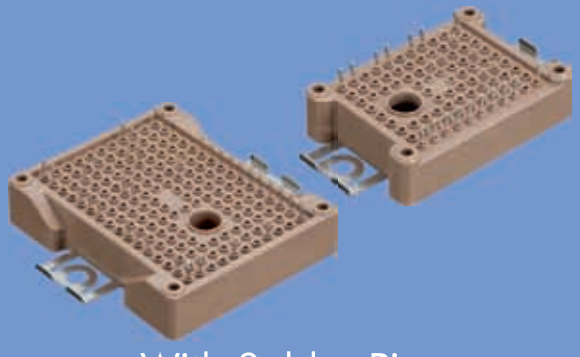
Small PIMs for low power applications



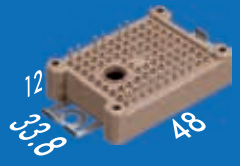
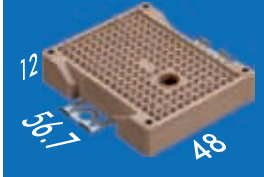
With V-series/6th & X-series/7th Generation IGBT

InnoTrans

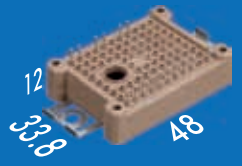
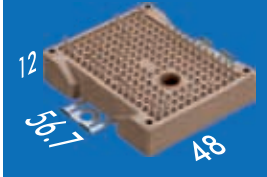
Visit us at the **InnoTrans** in Berlin
20. - 23.Sept.2016
Hall 10.1, booth 211



With Solder Pins

Package	I_c	600V	650V	1200V
	10A	6	7	6 7
	15A	6	7	6 7
	20A	6	7	
	25A			7
	30A	6	7	
	15A			6 7
	25A			6 7
	35A			6 7
	50A	6	7	

With PressFit Contacts

Package	I_c	600V	650V	1200V
	10A	6	7	6 7
	15A	6	7	6 7
	20A	6	7	
	25A			7
	30A	6	7	
	15A			6 7
	25A			6 7
	35A			6 7
	50A	6	7	

6 : V-series/6th Generation IGBT

7 : X-series/7th Generation IGBT

Fuji Electric Europe GmbH
Goethering 58
D-63067 Offenbach

Fon: +49(0)69-66 90 29 0
info.semi@fujielectric-europe.com

www.fujielectric-europe.com

Analog Devices Acquires Linear Technology

End of July, Analog Devices, Inc. and Linear Technology Corporation entered into a definitive agreement under which Analog Devices will acquire Linear Technology in a cash and stock transaction that values the combined enterprise at approximately $30 billion. The transaction is expected to close by the end of the first half of calendar year 2017. Thus the concentration in the (power) semiconductor industry is accelerating.

Following the transaction close, Vincent Roche, President and CEO of Analog Devices will continue to serve as President and CEO of the combined company, and David Zinsner, SVP and CFO of Analog Devices, will continue to serve as SVP and CFO of the combined company. Analog Devices and Linear Technology anticipate a combined company leadership team with strong representation from both companies across all functions. The Linear Technology brand will continue to serve as the brand for Analog Devices' power management offerings. The combined company will use the name Analog Devices, Inc. and continue to trade on the NASDAQ under the symbol ADI.

Under the terms of the agreement, Linear Technology shareholders will receive $46.00 per share in cash and 0.2321 of a share of Analog Devices common stock for each share of Linear Technology common stock they hold at closing. The transaction values Linear Technology at approximately $60.00 per share, representing an equity value for Linear Technology of approximately $14.8 billion. Post-closing, Linear Technology shareholders will own approximately 16% of the combined company on a fully-diluted basis. Analog Devices intends to fund the transaction with approximately 58 million new shares of Analog Devices common stock, approximately $7.3 billion of new long-term debt, and the remainder from the combined company's balance sheet cash. The new long-term debt is supported by a fully underwritten bridge loan commitment and is expected to consist of term loans and bonds, with emphasis on pre-payable debt, to facilitate rapid deleveraging.

"ADI will acquire Linear for $14.8 billion, continuing the trend of big consolidations within the semiconductor sector. ADI reported annual semiconductor revenue of $3.4 billion in 2015, while LLTC revenue was $1.4 billion. After examining the potential margin improvement, product portfolio, and end market focuses of these two companies, the acquisition will increase the competitiveness of ADI in several end markets", comments IHS market researcher Jonathan Liao.

Over 80 percent of ADI's products are general-purpose analog devices used in various end markets in the industry, including computing, communications, industrial, automotive, and consumer electronics. Within the analog products segment, ADI specializes in converters, amplifiers, radio frequency (RF), signal processing, and power management devices. It also invests in high volume manufacturing processes for both analog and digital products. While some ADI products are created for the high performance market and compete directly with LLTC, most of their goods are general-purpose devices made for medium- to high-volume customers. ADI has a massive customer base with over 100,000 customers globally. Similar to ADI, LLTC specializes in analog products, particularly in voltage regulators, RF, data converters, and amplifiers/comparators. Contrary to ADI, LLTC typically focuses on high-margin, high-performance, and lower-volume products in emerging applications, to maximize its return on investment. Analog products typically have larger feature sizes and less dependence on cutting-edge process technologies, and capital investments in analog manufacturing facilities (fab) are typically magnitudes lower than their digital counterparts. As a result, LLTC invests less in manufacturing and achieves higher operating margins. "Overall, ADI will become a much stronger player in the analog market, with the acquisition of LLTC. This move will create a ripple effect for other large suppliers to re-evaluate their scaling strategies and may result in additional acquisitions", Liao expects.

www.analog.com, www.linear.com

Renesas to Acquire Intersil

The merger & acquisition carousel is still turning around. After the Analog Devices / Linear Technology merger, Infineons acquisition of International Rectifier and recently Wolfspeed, now Japaneses Renesas is to acquire Intersil, a leading provider of power management and precision analog solutions. Renesas acquires Intersil for $22.50 per share in cash, representing an aggregate equity value of $3.2 billion. The transaction has been unanimously approved by the boards of directors of both companies. Closing of the transaction is expected in the first half of 2017.

The acquisition combines two long-standing industry leaders in their respective segments. Together, Renesas' and Intersil's expertise across a number of state-of-the-art technologies and end markets will enable the combined company to become a complete solution provider of embedded systems. By combining Renesas' microcontroller (MCU) and system-on-chip (SoC) products and technologies and Intersil's power management and precision analog capability, Renesas will be well positioned to address some of the most exciting opportunities in key areas such as automotive, industrial, cloud computing, healthcare, and the Internet of Things (IoT). The acquisition is also expected to grow Renesas' served product lines, particularly for analog devices, where the market is expected to increase by approximately $3.9 billion by 2020. "Renesas is accelerating its focus of resources in automotive, industrial, infrastructure, and the rapidly growing IoT segments to grow its global business and maintain its position as a leading provider. Intersil's extensive portfolio of analog and power devices as well as its strength in the automotive, industrial, and broad-based segments complement many of our initiatives in these areas," said Bunsei Kure, CEO of Renesas Electronics Corporation. "We believe that this compelling and complementary combination will bring significant synergies and cross selling opportunities as well as system solution proposition which will pave the way for Renesas to strengthen its position as a leader in the global semiconductor market".

www.renesas.com, www.intersil.com

EpiGaN Expands to Asia

EpiGaN, an European supplier of commercial 150 mm- and 200 mm- GaN-on-Silico7¶7n epi-wafers for 600V HEMT (High Electron Mobility Transistor) power and RF (Radio Frequency) devices, announced that the Brussels/Beijing-based European private equity fund ACAPITAL has joined the initial investors in EpiGaN to fund the company's expansion in particular to Asian markets.

EpiGaN,operating out of Hasselt, Belgium, is a global player in developing and delivering GaN-on-Si and GaN-on-SiC material solutions. Gallium Nitride, the most important semiconductor after Silicon, started to revolutionize the energy sector by enabling significant energy loss reduction in power handling, smaller and lighter systems, such as for example for consumer power supplies, photovoltaic inverters, industrial sensors and more generally all products linked with IoT.

EpiGaN offers solutions for epitaxial GaN layer structures on 150 mm and 200 mm Si substrates in particular with its in-situ SiN (Silicon Nitride) passivation, enabling more robust devices. EpiGaN was founded in 2010 by Marianne Germain (CEO), Joff Derluyn (CTO) and Stefan Degroote (COO), as a spin-off from renowned Belgian micro- and nano-electronics research center imec. "We are very pleased to support the growth of EpiGaN and to join its board of directors. EpiGaN has developed a unique expertise, which will allow to build the next generation of energy-efficient devices. Applications are massive: power-electronics, internet of things, smart grid applications, mobile communications and electric mobility: most areas linked with Industry 4.0 and Energy Transition, which are core investment areas for us", commented Andre Loesekrug-Pietri, founder and managing partner of ACAPITAL. "We look forward to help scale EpiGaN internationally and in Asia and China in particular, the largest market in the world."

www.epigan.com

Dialog Semiconductor Enters Gallium Nitride Market

Dialog Semiconductor plc announced end of August its first gallium nitride (GaN) power IC product offering, using Taiwan Semiconductor Manufacturing Corporation's (TSMCs) 650 V GaN-on-Silicon process technology. Dialog Semiconductor plc is headquartered in London. In 2015, it had approximately $1.35 billion in revenue and was one of the fastest growing European public semiconductor companies.

The DA8801 together with our digital Rapid Charge™ power conversion controllers will enable more efficient, smaller, and higher power density adapters compared to traditional Silicon FET-based designs today. Dialog is initially targeting the fast charging smartphone and computing adapter segment with its GaN devices. "The exceptional performance of GaN transistors allows customers to deliver more efficient and compact power adapter designs that meet today's market demands," said Mark Tyndall, SVP Corporate Development and Strategy, Dialog Semiconductor. "GaN technology offers the world's fastest transistors, which are the core of high-frequency and ultra-efficient power conversion. Our DA8801 half-bridge integrates building blocks, such as gate drives and level shifting circuits, with 650V power switches to deliver an optimized solution that reduces power losses by up to 50 percent, with up to 94 percent power efficiency. The product allows for a seamless implementation of GaN, avoiding complex circuitry, needed to drive discrete GaN power switches. The new technology allows a reduction in the size of power electronics by up to 50 percent, enabling a typical 45 W adapter design today to fit into a 25 W or smaller form factor. This reduction in size will enable true universal chargers for mobile devices."

www.dialog-semiconductor.com

"Our GaN activity is now focused on travel adapters, which we will sell for slightly less prices than conventional bulky adapters. Later powering servers might be possible", comments Mark Tyndall, SVP Corporate Development at Dialog Semiconductor Photo: AS

Avnet Silica Signs Distribution Agreement with Dialog

Avnet Silica, an Avnet, Inc. company, announced that it has signed a distribution agreement with Dialog Semiconductor to stock the complete range of products.

By offering the full range of Dialog's power management and connectivity solutions worldwide, our customers have access to a full range of IoT enabling products and services in one place, reducing time to market for low-power, differentiated products," said Mario Orlandi, President Avnet Silica. "By collaborating with Avnet Silica, Dialog is iincreasing the exposure of our mixed-signal products to a much broader set of customers in EMEA," said Dipak Raval, Director of Sales - EMEA at Dialog. "Avnet's sales and expert technical support will enable us to capture business in fast growing and emerging markets across Europe."

Avnet Silica is the European semiconductor specialist division of Avnet, Inc., one of the leading global technology distributors, and acts as the smart connection between customers and suppliers. The distributor simplifies complexity by providing solutions, technology and logistics support. Avnet Silica is a partner of leading semiconductor manufacturers and solution providers over many years. With a team of more than 200 application engineers and technical specialists, Avnet Silica supports projects all the way from the idea to the concept to production.

www.avnet-silica.com

Knowles Opens UK-Based R&D Center

Knowles (UK), formally Syfer Technology, have recently made the short step to new facilities at the Hethel Engineering Centre, Norwich. The move reflects Knowles' commitment to UK-based R&D for its portfolio of ceramic based electronic components.

Knowles (UK) R&D facility has a traceable history back to the 1940's under Erie Electronics Ltd, before becoming Syfer Technology in the 80's. The company was later acquired by the US Dover Corporation and is now part of Knowles, a recent spin-off from Dover. The spin-off also included the DLI, Novacap and Voltronics brands manufacturing capacitor products, EMI filters and EMC solutions that span high reliability, military specification and space level through to volume commercial products. Today the remit is to support all four operating brands in developing new products. "This is the start of a new chapter for Knowles (UK) Ltd. The Hethel Engineering Centre cultivates an environment for world-class hi-tech innovation and this is something we're looking forward to working within. The Knowles UK team will focus on global R&D including product development and customer support", said Knowles UK Director Steve Watts.

www.knowlescapacitors.com

Littelfuse Acquires Select Product Portfolio from ON Semiconductor

Littelfuse Inc. announced has acquired the product portfolio of transient voltage suppression (TVS) diodes, switching thyristors and IGBTs for automotive ignition applications from ON Semiconductor for a combined purchase price of $104 million. This portfolio has annualized sales of approximately $55 million.

"The acquisition of this portfolio aligns with our strategy to expand in power semiconductor applications as well as increase our presence in the automotive electronics market," said Ian Highley, CTO for Littelfuse. "These products have strong synergies with our existing circuit protection business, will strengthen our channel partnerships and customer engagement, and expand our power semiconductor portfolio." Littelfuse also plans to invest approximately $30 million in its semiconductor fabrication locations to enhance its production capabilities, add significant capacity to its China fabrication facility and transfer the production of the acquired portfolio. "Once we complete the transfer of these products, we expect this acquisition to have EBITDA margins of more than 30 percent," added CFO Meenal Sethna.

www.littelfuse.com

Power Supply Safety & Compliance Database as Free Resource

The Power Sources Manufacturers Association (PSMA) offers free access to a new on-line Safety & Compliance Database. The continually updated resource lists the many state, national and worldwide organizations currently active in establishing and maintaining safety, electromagnetic compatibility, material toxicity and environmental standards for power supplies used in commercial applications.

Intended users of the Safety & Compliance Database are those who design power systems for products that will be offered in the global marketplace, and who therefore need to comply with current and evolving safety and standards for their target markets. The database can be searched by specific applications; giving the most recent status of standards, identifying key documents, meetings and milestones associated with each standard, and providing links to the appropriate websites of controlling organizations. "As companies design their new products for global markets, they have to grapple with current, new – and sometimes conflicting – safety standards and regulations," reported Kevin Parmenter and Jim Spangler, co-chairs of the PSMA Safety & Compliance Committee. "Our new Safety & Compliance Database provides a vital resource for engineers and product planners as they keep abreast of standards, including ongoing activities, proposed changes and updates, and information on the latest versions."

The PSMA contracted with Anagenesis Inc. to create and provide continual updates to the database. Interested users can opt in to receive weekly email alerts about new information and changes. The database also features the ability for users to request permission to direct and track information on emerging standards, which enables the database to evolve and improve.

www.psma.com

Improving Power Quality to Meet Future Energy Demands

Future airline and ships will be powered by data, but many more will be powered by electricity. The electric car has made its flashy debut and hit the road; the solar-powered electric plane recently completed its round-the-world trip. More energy and electricity will be needed to fuel the higher levels of activity and living standards.

According to World Energy Outlook report, energy demand is set to grow by nearly a third between 2013 and 2040. "To achieve this growth in a fast and cost-effective way, the 21st century's major energy challenge is delivering electricity as efficiently as possible. The focus should not be purely placed on building new plants and facilities, but rather on producing energy in the most efficient way. The aim to have the lowest losses possible while maintaining a high-quality level will, in turn, help provide more energy for these economies to continue to grow and prosper", states Cavin Pietzsch, global power solutions leader, GE's Power Conversion business. The electricity grid is a complex system in which power supply and demand must be equal at any given moment. Constant adjustments to the supply are needed for predictable changes in demand, such as the daily patterns of human and industrial activity, as well as unexpected changes from equipment overloads and storms.

Combating the unexpected is the rise of renewable energy. According to IEA, renewable electricity additions will top 700 GW by 2020, equalling the share of renewable energy in global power generation rising to over 26 percent. But renewable energy is unpredictable in nature, leading to overloads and the potential for blackouts. This has been a particular problem in countries such as China and the US, where either weak or patchwork grid infrastructure has led to the curtail of renewable production. To maintain reliability and quality of power supply in this environment, economical and efficient solutions are needed to provide dynamic voltage support and fast reactive power compensation. Developments in battery storage are key to ensuring renewables become a viable long-term power source by allowing excess power generated to be stored for use at a time when power demand is higher, creating a more flexible and reliable grid system. In addition, flexible alternating current transmission systems (FACTS) help grid operators maximize power flow along existing lines and improve steady state and dynamic stability with the grid.

"The retirement of baseload plants, increasingly stringent environmental regulations, alongside greater cross-border trading are all making grid stability and productivity more complex. This trend is widespread, and in a society where our consumption of energy shows no sign of slowing down, logic dictates that the energy deficit must be made up. This means that new solutions are needed to provide voltage support and fast reactive power compensation", adds Patrick Plas, HVDC and FACTS General Manager, GE's Grid Solutions business. Dynamic voltage control as well as increased power transfer capabilities are needed to help maximize grid productivity, which can translate directly to a plant's productivity and customer's revenue. GE developed SVC (Static VAr Compensator) and STATCOM (Static Synchronous Compensator) to contribute to meet these needs. They are easy to integrate into both new and existing grid structures and can help improve grid reliability and avoid upgrade costs for grid connections. Synchronous Compensation Machines can additionally provide short circuit power and transient inertia. A STATCOM offers a fast response time as well as the ability to generate or absorb reactive power when the grid voltage drops, helping to increase the reliability and availability of grid operation.

"Additionally, high voltage direct current (HVDC) is the answer to one of the biggest challenges faced by energy managers: move more power more efficiently with the lowest losses possible. Compared to AC systems, HVDC is more energy efficient over long distances, while the real power and reactive power flow is fully controllable, fast and accurate", GE's Pietzsch and Plas conclude.

www.ge.com

Growing SiC Market Generates New Opportunities

In the early 1980's, industry pioneers such as International Rectifier transformed the Silicon bipolar transistor into the mass production MOSFET. The 1990's saw the adoption of IGBT, and the 2000's brought superjunction MOSFET into volume. Now, an even more fundamental transition is underway as Silicon is overtaken by the introduction of wide bandgap (WBG) devices and here in particular Silicon Carbide power semiconductors, especially MOSFETs.

In high power (multi-kW) applications like electric vehicle drive and solar string inverters, IGBTs are being surpassed by 1,200V SiC-FETs which utilize a cost-effective vertical structure to enable high efficiency, simplified architectures, stated Navitas' (**www.navitassemi.com**) CTO Dan Kinzer i. e. in his PCIM keynote.

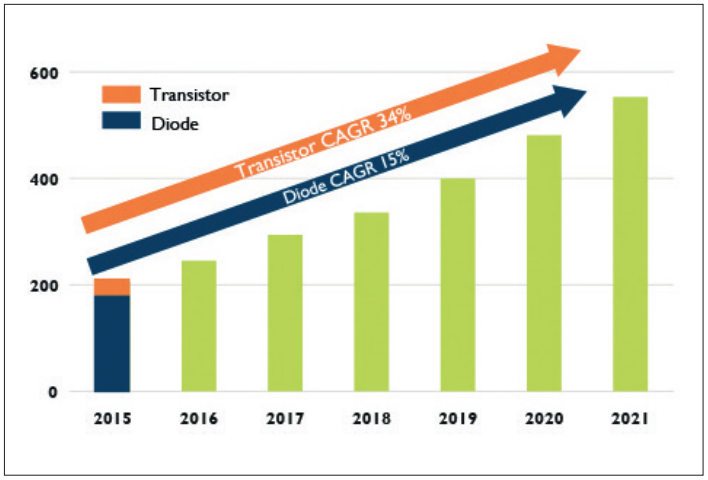
According to market researcher Yole Développement (**www.yole.fr**), the adoption of SiC solutions will be generalized: most of players are already offering devices off-the-shelf and are involved in different R&D projects. "SiC devices are used in some applications thanks to the high energy density they offer and their efficiency", asserts analyst Coralie Le Bret. "In the future we expect multi-sourcing and price decrease to favor the WBG materials penetration. Packaging will have to be developed in accordance with the device in order to take the best of it".

Additionally, the emergence of 150 mm SiC wafers has been a critical element to explain the wide market adoption of this technology, allowing economy of scale at a manufacturing standpoint together with the use of depreciated 150 mm Silicon production lines that could be converted to accommodate the Silicon Carbide specificities.

SiC power is diffusing into multiple application segments

When the first SiC diode was launched in 2001, the industry questioned the future of the SiC power business: Will it grow? Is this a real business? Fifteen years later, in 2016, people don't ask these questions anymore. The SiC power business is concrete and real, with a promising outlook. The SiC power market (diode and transistor included) is estimated to be more than $200 million in 2015 and forecasted by Yole to be more than $550 million in 2021, with a 2015 - 2021 CAGR of 19 %. Not surprisingly, the power factor correction (PFC) power supply market is still the leading application, consuming a large volume of diodes, according to Yole figures.

Photovoltaics (PV) inverters are close behind. SiC diodes and MOSFETs are now used by various PV inverter manufacturers in their products. It has been confirmed that SiC implementation provides several performance benefits:

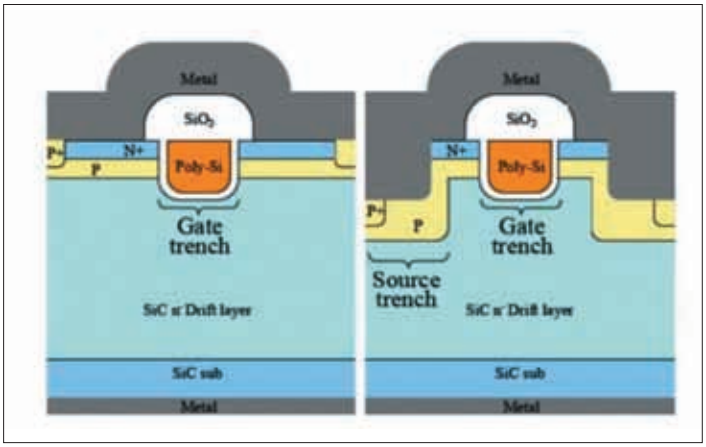


SiC device market 2015-2021 **Source: Yole Développement June 2016**

increased efficiency, reduced size and weight. In addition, it allows to low cost at the system level in certain power range. The benefits enabled by SiC, the continuous performance improvement, and the cost erosion of SiC power devices will fuel the implementation of SiC in more applications such as EV/HEV, uninterruptible power supplies (UPS), motor drives, wind, and rail.

Designers are well aware of SiC's advantages, but they also know the challenges they face: a new product with SiC devices means not a direct replacement. It involves R&D investments, higher device cost, differences between Si devices they're already familiar with, and lack of field data. All of these factors present barriers to using SiC. To accelerate SiC's adoption, it is necessary to continue to educate end-users about the benefits at system level; and more importantly, to support them in using these new devices.

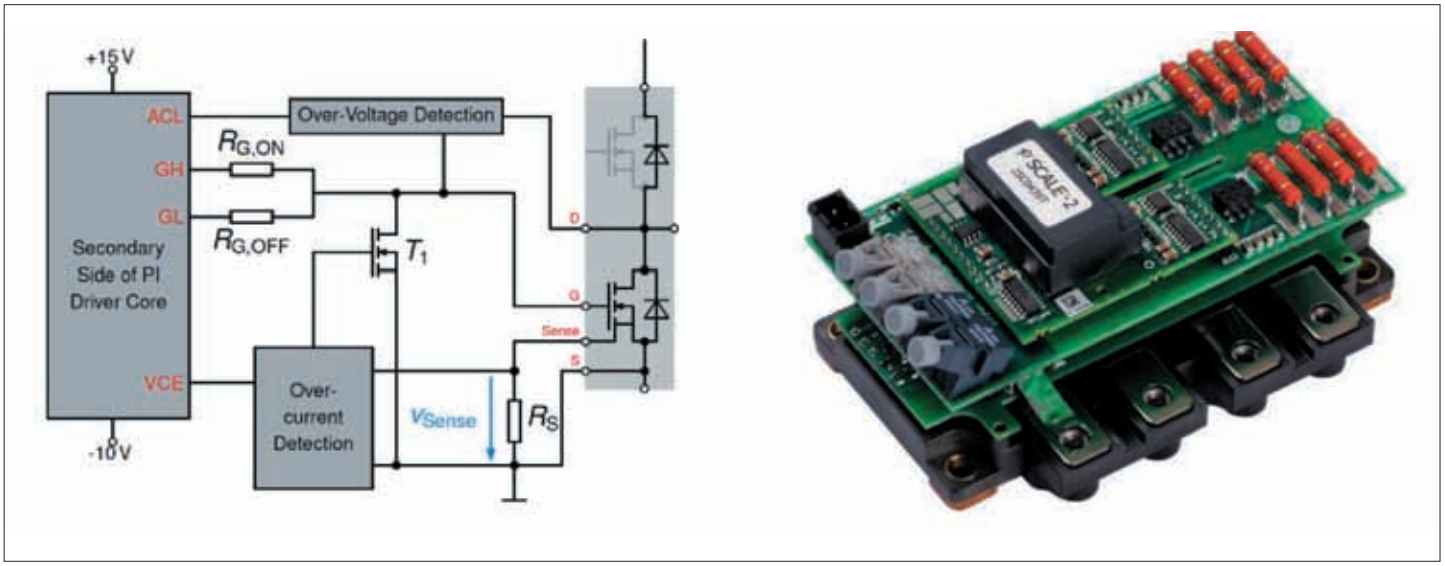
Japanese ROHM Semiconductor (**www.rohm.com**) pioneered besides US-based Cree (now named Wolfspeed and recently acquired by Infineon) the



Schematic cross section of conventional single-trench SiC-MOSFET structure (left) and double-trench structure with source trench and gate trench

SiC-MOSFET. SiC devices have been a focus of the power semiconductor market due to the realization of improved material characteristics over Silicon. As SiC market commercialization accelerates, we are well situated to introduce the combination of controller IC and 1700 V SiC-MOSFET for industrial power supplies and contribute to improved efficiency in these applications. Additionally, expanding on our line-up of robust devices for high temperature and high humidity environments has led to the evolution of a new generation of devices which is realized in the lower on-resistance trench-gate SiC-MOSFET", said Product Planning Engineer Naoyuki Kizu. "The most noteworthy product release in our SiC product line-up in 2015 was the world-first commercialization of the SiC "Trench" MOSFET, our 3rd gen SiC-MOSFET. We developed a double-trench, SiC MOSFET structure, which has both gate and source trench. A conventional trench device structure suffers from poor gate oxide reliability due to high electric field concentration at the bottom corners of the trench structure."

Infineon presented at PCIM 2016 its first SiC-MOSFET rated 1200 V (**www.infineon.com/coolSiC**) with an on-resistance of 45 mΩ and rated current of 25 A. "Compared with our SiC-JFET, the new SiC-MOSFET allows a significant reduction of the switching losses. The device concept shows considerably suppressed parasitic turn-on under typical operating conditions. This results in drastically reduced recovery losses leading to very low total switching losses", underlined Peter Friedrichs, Senior Director SiC. "First products will be available in 3-pin and 4-pin TO-247 packages targeted at photovoltaic inverters, UPS, battery charging and energy storage applications. A



Gate driver for Mitsubishi's SiC-MOSFET protection (right) and its corresponding equivalent circuit diagram (left)

challenge in the development of SiC-Power-MOSFETs is to balance gate-oxide reliability and low on-resistance. This SiC-Trench-MOSFET-concept combines an attractive on-resistance and an optimization against too high gate oxide field stress, Infineon underlined. "SiC is seen as the major innovation for industrial power applications up to several hundreds of kilowatt. After the successful market introduction of SiC diode technologies, SiC based transistors will be the next major step", Friedrichs stated more recently in his EPE 2016 keynote on the "future of WBG devices".

Facing questioning about reliability, SiC device suppliers thus are offering more and more reliability data, supported by internal and third-party testing, Yole expects.

Are SiC MOSFETs reliable?

This question has been raised frequently, particularly regarding the gate oxide of SiC MOSFETs. Formerly favored SiC JFETs or SiC BJTs do not have a gate oxide and thus do not fell in this category – but these devices require special driving and therefore lack in popularity over the last two years.

At PCIM Europe 2016 a session on SiC reliability tried to give answers to this question, particularly the paper "Breakdown of gate oxide of 1.2 kV SiC-MOSFETs under high temperature and high gate voltage" prepared by the Technische Universität Chemnitz, Professorship of Power Electronics and EMC, Josef Lutz. The onset of gate oxide breakdown of different discrete 1.2 kV SiC MOSFETs for different gate voltage steps has been analyzed. The devices were tested at the same high temperature and the gate voltage was increased step by step. The research on this breakdown distribution is necessary to prove if SiC MOSFETs can fulfill the same reliability requirements for power electronic devices, which are also applicable for current IGBTs. Important for the reliability of SiC MOSFETs is the gate oxide quality. The commonly used material for gate oxide in Si and SiC devices is SiO_2. For SiC MOSFETs the gate oxide is thinner in comparison to Si MOSFETs due to the impact of oxide thickness on the channel resistance. Therefore, the reliability of the gate oxide for high gate voltages must be well known.

Devices of three manufactures were tested, with manufacturer 1 set to M1, manufacturer 2 set to M2 and manufacturer 3 set to M3. The authors did not disclose the real manufacturers. Devices from M1 and M2 are commercial devices, whereas M3 devices are up to now not available in the market. Hundred unstressed devices per manufacturer were tested at a constant test temperature of 150°C. The applied gate voltage of the devices was increased during the test for every 168 h. After every 168 h, the test was interrupted for a re-measurement of the threshold voltage at room temperature. The gate voltage at the first step is the rated gate voltage according to the data sheet. At the second step, the voltage was set to the maximum use gate voltage. After this step, the gate voltage was increased in defined steps.

Two manufacturers presented gate oxide breakdown for a gate over-voltage of 12 V. The failure rate ppm for 168 h and the rated gate voltage for M1 and M2 were calculated. M1 shows a 62190 ppm compared to of 4100 ppm of M2. The ppm rate of M3 could not be calculated up to now due to the running test without any failure. Differences of the threshold voltage drift were found during the threshold voltage drift investigation for the three manufacturers. M1 indicates the greatest standard deviation. In summary, the devices demonstrate a high difference in reliability. One manufacturer shows a high extrinsic failure rate for low gate over-voltages of 10 V. Further investigations for gate oxide reliability should be done and screening test with longer time and higher gate voltage are needed, concludes the paper.

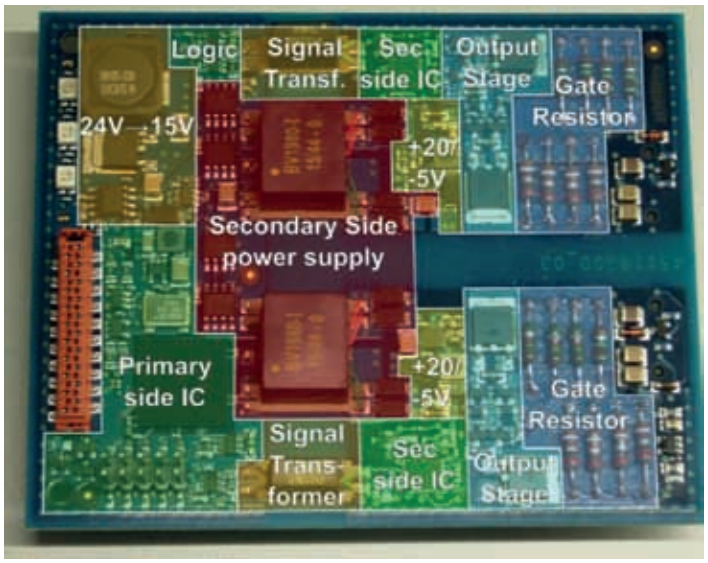
Driving SiC modules properly

Also, the announcement of a new module is frequently associated with the release of a driving solution, assisting the designer in surmounting the difficulties linked to the driver. Although SiC-MOSFETs have superior characteristics, they need optimized gate drive control.

An example for this attempt is over-current detection and short circuit protection method for large current full-SiC Mitsubishi modules using current sense source terminals, presented by this company and Power Integrations (**www.power.com**). This new driver incorporates over-current detection, soft-shut-down and active over-voltage clamping.

The new 800 A/1200 V full SiC module (FMF800DX-24A) was developed for high power applications allowing either high switching frequencies (in the range of 30 to 100 kHz) or high efficiency or high power densities. efficiency or high power densities. Employing SiC technology facilitates a drastic reduction in the switching losses compared to the Si IGBT. On the other hand, the static losses should be carefully adjusted without sacrificing the ability to handle short circuit conditions. The low on resistance of the SiC MOSFET is inversely proportional to the chip short circuit capability. For this full SiC module, Power Integrations has developed a gate driver reference design (RDHP-1417). It uses the current mirror source terminal of FMF800DX-24A for providing over-current detection in short circuit conditions. Active clamping and soft shut down functions are able to limit over-voltage spikes when high currents are turned-off.

A high power, high frequency gate driver with high integration density using ASICs allowing to drive very low inductive 1200 V, 400 A SiC-MOSFET half bridge modules in both-side sinter technology (SKiN) was develoed by Semikron (**www.semikron.com**). Because of its low propagation delay, low dead times and very strong output stages of +40/-78 A, the driver for normally-off SiC-MOSFET is suited to switch the 400 A devices up to 200 kHz with extremely low switching losses and low over-voltages. It provides a nominal gate-source voltage of 20 V in the on-state which reduces the on-resistance. In the off-state negative voltages of -3 V...-5 V are needed to prevent parasitic turn-on due to high dv/dt at the parasitic capacitance



Front side of Semikron's new SiC-MOSFET gate driver board with primary side IC, 2 x secondary side ICs; secondary side power supply and gate driver output stages

between gate and drain and in order to reduce the switching losses. The driver uses transformers for bidirectional signal transmission between primary and secondary side (modem), can handle chips with breakdown voltages up to 1700 V and positive and negative offset voltages, respectively. A temperature and short circuit monitoring of the MOSFET switch, as well as differential primary side inputs are used. A galvanic isolated power supply for the secondary sides and a monitoring of all operating voltages of the driver are implemented. The whole driver functionality is integrated in primary and secondary side ASICs. Power supply, output stages and only very few discrete components had to be placed on the PCB, the backside could be completely reserved for shielding and cooling.

Simplifying SiC designs

Similarly, Wolfspeed proposes a new SiC-dedicated online design simulation tool (**www.wolfspeed.com/speedfit**) to simplify the designer's task.

"The SpeedFit™ simulation tool allows designers to determine the right SiC device for their power system in seconds, a process that previously required hours examining datasheets and making calculations," said Guy Moxey, Wolfspeed's senior director of power marketing. It is based on the proven PLECS® web-based simulation platform from Plexim (**www.plexim.com**), which is suited for high-speed simulations of power electronic systems. It is available in two editions: PLECS Blockset for seamless integration with MATLAB®/Simulink®, and PLECS Standalone, a completely independent product. The SpeedFit circuit simulation tool features a simple, intuitive interface that power electronics design engineers can use to simulate any SiC-based power converter circuit topology: DC/DC, AC/DC, or DC/AC. Users input their specific application parameters, and the SpeedFit tool generates a comprehensive analysis of SiC device performance, including: voltage and current waveforms, average switching and conduction losses, and maximum junction temperature for specific operating conditions. Additionally designers can select a topology, specify their recommended SiC power device or choose one from the library, define their thermal interface parameters and cooling method, and see the results immediately. The Speedfit simulation tool also allows users to specify external gate resistance, as well as major passive component values present in the circuit, allowing them to compare performance results for several different circuit configurations and devices. The tool quickly, easily, and accurately summarizes system parameters, device part numbers, and simulation results in a single, concise report.

Wolfspeed has made files containing loss and thermal impedance information for their SiC devices available on their website so current PLECS platform users can download and access models for SiC power devices. "Our PLECS Standalone tool features a free demo mode that provides access to a collection of pre-built designs, and can be accessed, along with free PLECS trial licenses for custom model development, on the Plexim website." said Kristofer Eberle, business development manager, Plexim.

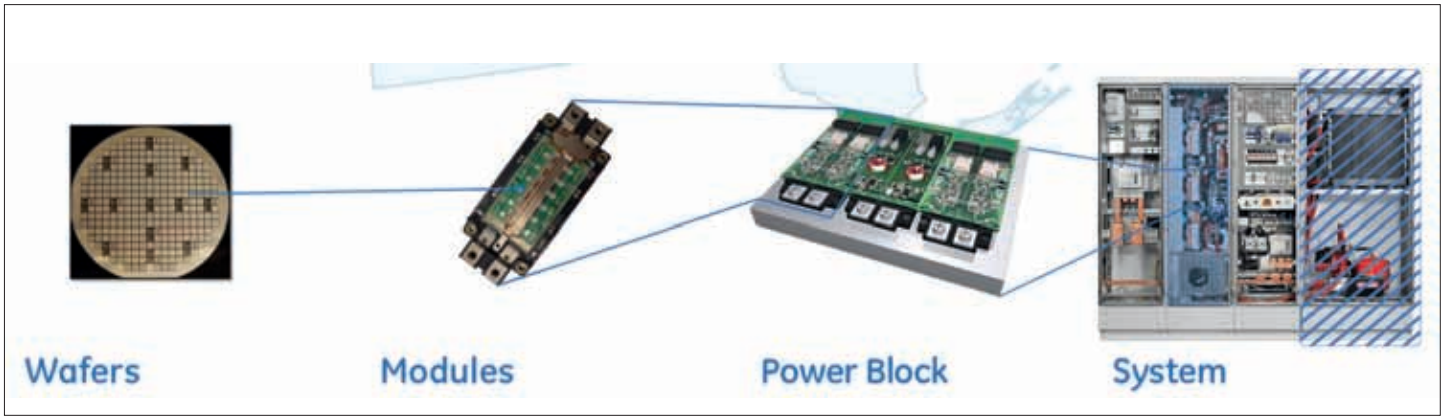
SiC power block approach

Additional integrated solutions like power stack (also called "power assembly" or "power block") are appearing on the market. For example, GE (**www.geglobalresearch.com/impact/the-building-blocks-of-silicon-carbide-a-rising-star**) has proposed a power block designed to be a kind of "plug-and-play" solution, with the objective to avoid integration difficulties that designers may encounter.

In 1986, GE ushered in a new era in electricity consumption with the invention of Insulated Gate Bipolar Transistor (IGBT). For IGBTs and predecessor switching devices, Silicon has been the workhorse material. But recent advances in SiC are promising a better material that will set new standards of efficiency and performance.

GE recognized the great potential of SiC technology more than 50 years ago, but early progress was stymied by the material's immaturity. As the material improved over decades, the race was on to develop industrially ready SiC devices. This was not as simple as it might sound. Research groups around the world quickly discovered that it was difficult to make stable and reliable SiC MOSFETs.

"When we started this work in 2005, the prevailing view was that industrially ready SiC MOSFETs would never be feasible," said Ljubisa Stevanovic, GE Global Research's Technology Leader for SiC. "We knew, however, that they would be the ideal device for a majority of applications, so we focused our efforts on solving the challenge of making industrially ready SiC MOSFETs. Our entry into SiC was originally motivated by high-value, low-volume aviation applications, but as the technology matured and the decision was made to keep it in-house, GE's focus has shifted to expanding opportunities on the application side and scaling up manufacturing. Today's SiC efforts are two-pronged: identifying applications for SiC in existing GE products while also selling SiC devices to other companies, even competitors."



GE's SiC value chain

In 2009, the team demonstrated the first stable, industrially ready SiC MOSFET. In 2013, GE partnered with New York State and State University of New York's Polytechnic Institute to answer a call for proposals by the U.S. Department of Energy. The DOE wanted one of its new manufacturing institutes to focus on SiC. Although the New York SiC bid was not selected, the experience still proved to be fruitful. The first public announcement about GE's SiC development came in July 2014 when GE and the SUNY Polytechnic created the New York Power Electronics Manufacturing Consortium (NY-PEMC). This partnership will boost production by creating a manufacturing line at SUNY Polytechnic in Albany and drive down manufacturing costs by scaling up from 4" wafers to 6" wafers. In August 2015, GE and SUNY Polytechnic announced that the modules and power blocks (assembly of multiple modules) will be manufactured at a new facility in Utica. These higher level assemblies are specially designed to harness the full power of SiC and will be integral to the success of SiC as a product. The power block assemblies will reduce the time to market by optimizing assembly of multiple modules, controls, and cooling. In March 2016 GE Aviation has been awarded a $2.1 million contract from the US Army to develop and demonstrate SiC-based power electronics supporting high-voltage next generation ground vehicle electrical power architectures. It involves an 18-month development program to demonstrate the benefits of SiC MOSFET technology combined with GaN devices in a 15 kW, 28 VDC/600 VDC bi-directional converter which will provide twice the power in half the volume of Silicon-based power electronics.

SiC power is creating many opportunities

More and more players are entering at different levels of the value chain:

- At the module packaging level, Starpower just showed their SiC module in May 2016.
- At the device level, after investing in Monolith Semiconductors in 2015, Littlefuse released its SiC diode products in May this year, with the intention to develop a full product range. We've also identified other newcomers: Brückewell, YangJie Technology, Gengol, each with different backgrounds and different business models.
- On the materials side, Aymont, the SiC growth furnace supplier, has started to supply SiC wafers

Furthermore, existing players will expand their products. Infineon released in May 2016 at the PCIM Conference its 1200V trench SiC MOSFET and plans to go into mass production in 2017.

Also, Fuji's full SiC module will be available. As more and more products reach the market, Yole expects an acceleration of SiC. This growing market is generating plenty of opportunities for different types of suppliers: passive components, materials suppliers, test equipment suppliers, and more. **AS**

Literature

"Status of the power electronics industry 2016", Yole Market Report
"Power SiC 2016", Yole Market Report
"High Quality 150 mm SiC Substrates for Power Electronic Applications, Power Electronics Europe 4-2016, pages 16-17
"More Power for PCIM Europe", Power Electronics Europe 3-2016, pages 9-15
"Infineon Acquires Cree/Wolfspeed", Power Electronics Europe 4-2016, page 8
"Breakdown of gate oxide of 1.2 kV SiC-MOSFETs under high temperature and high gate voltage", PCIM Europe 2016 Proceedings, pages 172 – 179
"Advanced protection for large current full SiC-modules", PCIM Europe 2016 Proceedings, pages 48 - 52

Optimizing Battery Accuracy for EVs and HEVs

Intersil's new ISL78610 12-cell lithium-ion (Li-ion) battery pack monitor provides cell balancing and accurate voltage and temperature monitoring to safeguard Li-ion battery packs in hybrid electric vehicles, plug-in hybrid electric vehicles, and pure electric vehicles. System designers can use the ISL78610 as a standalone battery-pack monitor or as a redundant back-up device when combined with the high accuracy ISL78600 multi-cell battery manager. This powerful combination enables automobile manufacturers to achieve the higher ISO 26262 automotive safety integrity level (ASIL) D rating.

Automotive battery management system (BMS) technology has advanced considerably over the last decade. Today, several multi-cell balancing (MCB) IC features play a key role in meeting the stringent safety, reliability and performance requirements of battery systems in electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs), and hybrid electric vehicles (HEVs). IC manufacturers are now focusing their efforts on further functional optimization by integrating key features such as internal cell balancing and current measurement.

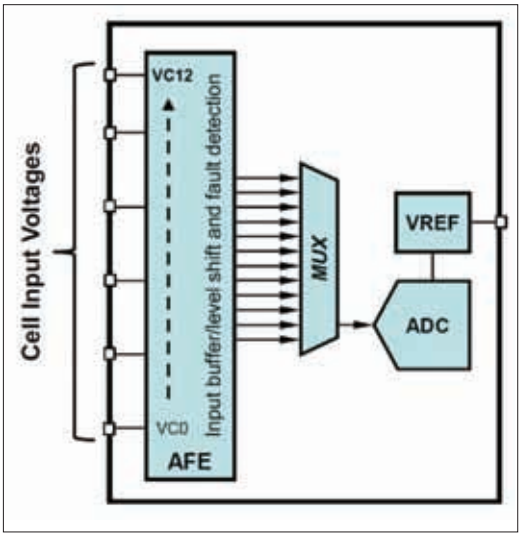
One of the critical functions of a BMS IC is the accurate measurement of individual cell voltages, which has a direct influence on battery life and range over the vehicle's service life. Accuracy is particularly important for battery cell types that have a flat discharge curve, like lithium-iron phosphate cells, which benefits smaller packs due to their low internal impedance. These cell types make it necessary for system engineers to detect small changes in cell voltage as the battery discharges. Measuring small cell voltage changes requires a sophisticated combination of accurate and stable voltage reference, an analog front end (AFE), and a precision ADC, which is a considerable design challenge for MCB IC designers. Adding to the system design challenge is the fact that detecting these changes has become critical for accurate state of charge (SOC) and state of health (SOH) calculations.

Key elements in a multi-cell balancing IC

At the core of any MCB IC is a precision reference. The types of reference topologies employed can vary, although bandgaps tend to be the most commonly used due to their optimal trade-off in accuracy versus die area. For example, the ISL78600 multi-cell Li-ion battery manager uses a precision bandgap reference design that has a solid track record, and is well suited for demanding automotive applications. The technology is stable, mature, well characterized, and has been optimized over many years of use, nderpinned by a substantial amount of real-world performance data. Its excellent performance characteristics make the precision bandgap reference very stable and linear over an MCB IC's deployed lifetime. This is a key consideration when designers make vehicle battery-life calculations, and it directly influences an automaker's warranty and cost of ownership metrics.

Along with a precision reference, the ADC is another key functional block for measuring accuracy. IC

The ISL78610 monitors and balances up to 12 cells with accurate voltage readings and diagnostics



Simplified diagram of the ISL78600's three functional blocks and their interconnection

designers must now decide which type of ADC to use as the main cell-voltage-measurement block. Two of the most popular and commonly used types of ADCs are successive approximation register (SAR) and delta-sigma. Having the fastest sampling rate of the two technologies, the SAR offers high-speed voltage conversion and excellent noise immunity, but tends to require a larger die area. SAR ADCs also offer the best combination of data acquisition speed, accuracy, robustness and immunity to the effects of EMI.

On the other hand, IC designers like delta-sigma ADCs because they typically require less die area, and are relatively easy to implement. However, they tend to be slower because they use a decimation filter, which reduces the sample rate and data acquisition speed. To overcome this issue, designers will use two or more delta-sigma ADCs in an interleaved configuration. Another consideration when implementing delta-sigma ADCs is their tendency to saturate when subjected to EMI, which causes the misreporting of cell voltages.

The individual cells' interface is managed by the AFE, which integrates input buffers, level shifters and fault detection circuitry. The AFE is key to handling hot plug transients when the cells are initially connected to the BMS. The ISL78600 is designed with a fully differential AFE that enables negative input voltages to be measured without affecting the adjacent cell measurements. This is advantageous in systems where bus bar interconnection is required. To improve robustness under transient conditions, an external low-pass filter is added to the cell voltage inputs. The input filtering requirements have been optimized for maximum EMI and hot plug immunity, without compromising speed or accuracy. By contrast, ICs that use a bipolar AFE rather than a charge coupled AFE can have their accuracy detrimentally affected by the component values selected for the input filter.

The combination of a stable and linear bandgap reference, SAR ADC and fully differential AFE gives a multi-cell Li-ion battery manager fast data acquisition capability combined with robustness and precision accuracy. Rather than relying simply on the measured accuracy values as it leaves the factory, the ISL78600's high accuracy is independently verified after mounting on a PCB.

Accuracy over a range of cell voltages and temperatures (see graph) is of critical importance to battery system designers, because they work with a system error budget for the vehicle's

service life, and-must be able to factor in reliable and predictable accuracy figures. Therefore, a careful examination is recommended, and a detailed comparison should be made between each IC vendor's data sheets, particularly in the areas of accuracy, data acquisition speed, and input filter requirements, including their effect on accuracy.

Achieving ISO 26262 ASIL-D compliance

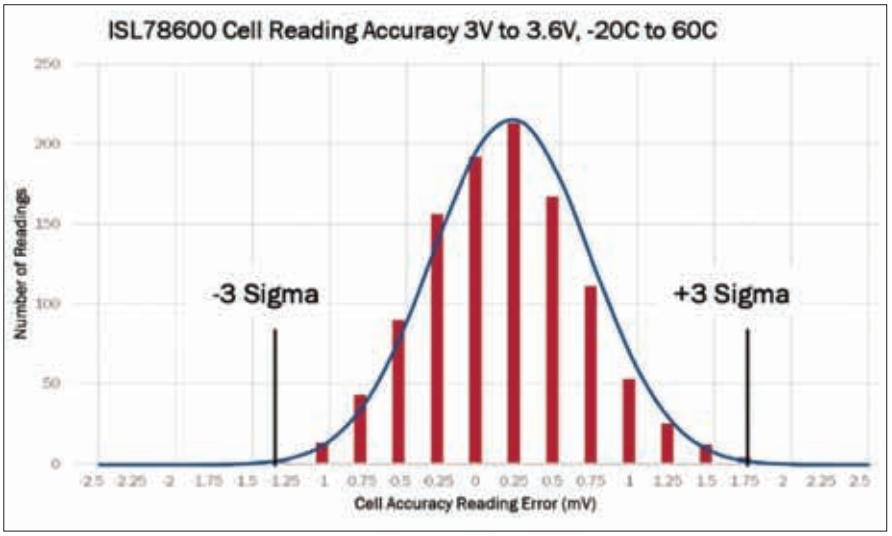
For hybrid and electric vehicles that require a redundant back-up battery management device, the ISL78610 battery pack monitor can be combined with the high accuracy ISL78600 multi-cell battery manager. This powerful combination enables automobile manufacturers to achieve the higher ASIL- D rating.

The ISL78610 monitors and balances up to 12 cells with accurate voltage readings and diagnostics. This lets system designers make informed decisions based on absolute voltage levels rather than simply receiving a "system not OK" signal indicating an out-of-range condition. The ISL78610 includes a voltage reference, 14-bit analog-to-digital converter and registers for control and data, while connecting directly to a microcontroller through its 2 Mbps SPI interface. The device also offers four external temperature inputs, and includes fault detection and diagnostics for all key internal functions.

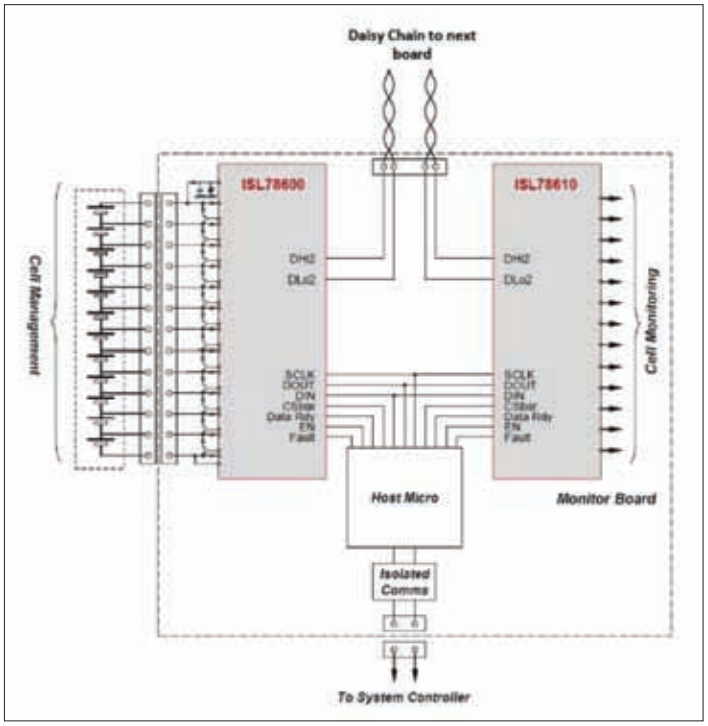
Together, the ISL78610 and ISL78600 offer internal and external fault detection such as open wire, over- and under-voltage as well as temperature and cell balancing faults to mitigate battery pack failures. Multiple devices can be daisy-chained together to support systems with up to 168 cells using a proprietary communications system that provides excellent transient and EMC/EMI immunity, which exceeds automaker requirements.

PCB layout and configuration considerations

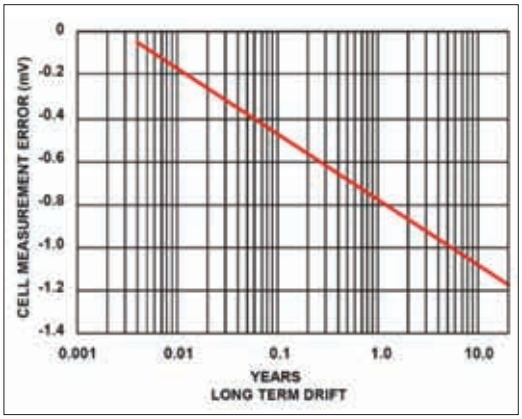
Soldering induces stresses across the



1080 total readings collected from 10 MCB evaluation boards with a voltage scan rate of 240 ?s for all 12 cells



LEFT: The ISL78610 12-cell battery pack monitor serves as the redundant back-up device in an ASIL-D-compliant HEV/PHEV/EV system



RIGHT: MCB IC cell error vs. lifetime

PCB, which "flexes" the MCB IC in the X and Y plane, and results in sub-atomic changes in the silicon's properties. This effects the IC's behavior and, in particular, the reference circuit block. Since the reference is a critical part of the measurement circuitry, any variation in its characteristics has a direct effect on the accuracy of the ADC. This is a well-known and understood phenomenon in the precision IC industry, and designers make allowances for this by carefully placing sensitive circuitry in areas of the die less likely affected by soldering and other manufacturing stresses.

Alternatively, there are more costly reference design techniques available to designers, such as placing a separate reference circuit on its own die within the same IC package, or using a completely separate discrete reference IC. No matter which technique is used, the PCB design and manufacturing stage are both critical, so making use of standard precision part PCB layout and careful consideration for IC mounting and soldering profiles can help mitigate any issues.

For example, if designers follow the ISL78600's recommended PCB layout guidelines and soldering reflow profiles, the IC's board-level cell reading accuracy and long-term drift characteristics are logarithmic and predictable. This results in a typical cell reading error of only 1.2mV over 10 years of service life.

www.intersil.com/products/isl78600

Is Faster Always Better?

In assembly operations, it pays to be fast. Spend less time putting a product together, and that product will cost less to produce. This bit of conventional wisdom explains the growing popularity of fast cure adhesives, which can save significant amounts of assembly time.

How much time? The fastest two-part epoxies have fixture or handling times as low as 1 to 2 minutes, while comparable conventional epoxies could require 15 minutes or more. Fast curing one-part epoxies can fully cure in minutes at 125°C, which can save an hour or more of cure time versus conventional one-parts. Similar savings can be achieved with speedy silicones that set up in minutes rather than the more typical 1 to 2 hours or more. Other types of adhesives, including cyanoacrylates and UV curables, are also inherently fast with cure times measured in seconds or minutes. All these time savings can improve assembly throughput by a large margin, which gives fast cure products a compelling value proposition.

Even so, engineers should always question the need for speed when selecting adhesives. For all their benefits, fast cure adhesives have physical property trade-offs that make them inappropriate for certain kinds of bonding, sealing and potting applications. What's more, there are some usage scenarios where too fast a cure will actually complicate assembly operations and require the use of automated mixing and dispensing equipment.

Fast cure families

Like their slower curing counterparts, fast cure adhesives are available in a wide range of one- and two-part formulations. Beyond their potential to save handling and full cure time, each formulation has its own set of strengths and weaknesses.

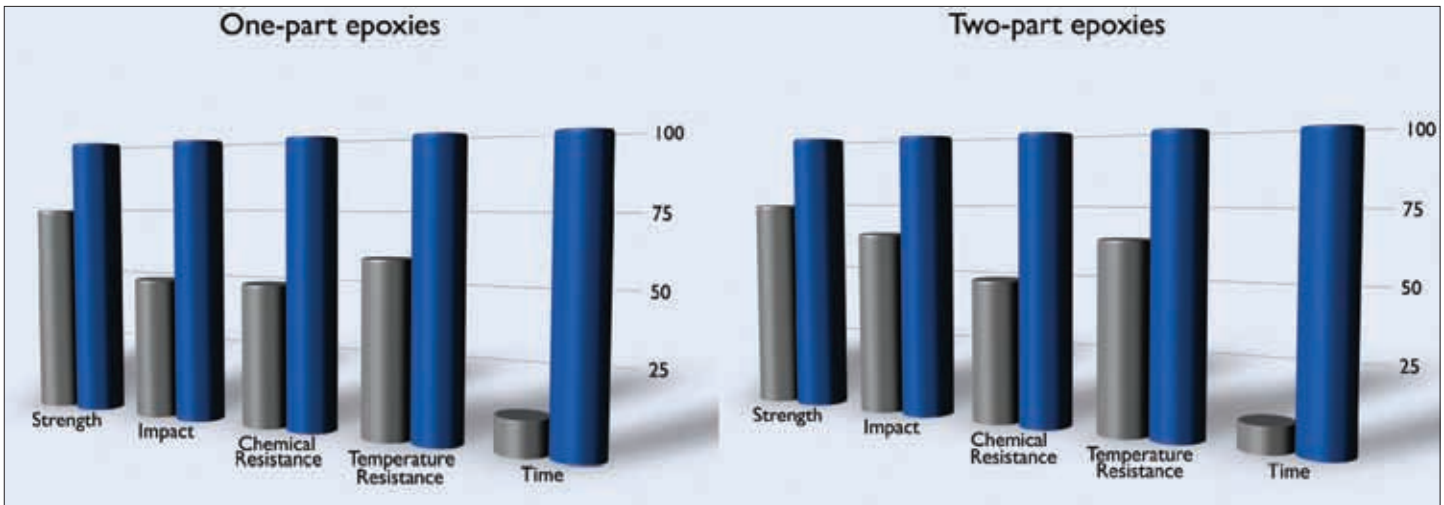
In general, though, one-part fast cure adhesives earn high marks for ease of use since they eliminate the need for mixing and cut fixturing time significantly. On the other side of the balance sheet, they have a more limited range of physical and mechanical properties than comparable two-part formulations. And because their cure reaction is exothermic, or heat generating, one-part fast cure products are not the best choice for many potting applications.

Two-part fast cure products are also not a good fit for most potting applications, owing to their exothermic cure mechanism. Moreover, two-part products sacrifice some ease of use because they do require precise mixing on the factory floor. In high production volumes, they may not be compatible with manual mixing and dispensing methods. On the plus side, two-part products are far more versatile and offer a broader range of properties than the one-part fast cure products—though not nearly as broad as standard two-part epoxies.

Fast cure adhesive products do tend to trigger capital equipment costs. So their use should hinge on an economic decision that balances the savings from shorter cure times against the added expense of higher adhesive costs. In many assembly applications, the economics will make sense. In others, they may not. Applications with very low production volumes, for example, may not be able to justify higher adhesive costs through improvements to assembly throughput. The same reasoning goes for applications in which adhesive bonded joints are few in number or simply don't represent a significant bottleneck in the overall production process.

The most commonly used fast cure products include:

- One-part epoxies. Capable of fully curing in 2 to 10 minutes upon exposure to heat, these fast curing adhesives can save hours of cure time versus a standard one-part epoxy. In addition to the speedy cure, they also offer a controllable working time.
- One-part silicones. These adhesives can typically reach a tack-free state in a speedy 3 to 15 minutes. Comparable moisture-curing standard silicones, by



Fast Cure Properties

Fast cure formulations of one- and two-part epoxies tend to have mechanical and physical properties that are nearly, but not quite, on par with their conventional counterparts.

Note that concept of handling and cure time differ between one- and two-part fast cure epoxies.

One-part formulations cure with the application of heat. So they have a virtually unlimited open time until they take a trip through the oven. They emerge fully cured—or very close to it—from their oven cycle.

Two-part formulations cure upon the reaction of their chemical components. The fastest versions can set up in minutes, allowing them to be handled or removed from fixtures. To reach their fully cured state can take hours longer. Like conventional two-part epoxies, fast cure versions will reach their maximum properties if subjected to a heat cycle.

contrast, can take hours to setup and days to fully cure. One-part fast cure silicones are room temperature vulcanizing, so they can be valuable option in applications where a heat cycle would be damaging.

- Cyanoacrylate (CA) adhesives. Capable of setting up in less than a minute and reaching a full cure in a few minutes, CA adhesives certainly qualify as fast curing. They are also among the simplest to apply, with no need for ovens and no inherent need for specialized dispensing equipment. Over the years, they've staked out a place in fast moving assembly lines for medical devices, electronics and industrial applications. Their main drawback is that they have a somewhat limited range of properties such poor resistance to impacts, thermal cycling and high temperatures.
- UV curables. Once exposed to a UV light source, these one-part adhesives can cure almost instantly. And once they do, they have a number of beneficial properties including optical clarity, moisture resistance and strong bonds to many different substrates. They also have superior chemical resistance, though not quite up to the level of standard epoxies. Because they require UV light to fully cure, they offer good control of open time. But they can be problematic in applications where the joint design or depth creates shadows that light cannot reach.
- Two-part epoxies. With set up times as fast as a minute and no heat cycle to initiate the cure, two-part fast cure epoxies can be a good choice in applications that cannot use a one-part epoxy for reasons of thermal sensitivity. The two-part epoxies also have the very best balance of strength, thermal, chemical and electrical properties in the entire fast cure class. So they can be a good choice in applications that run up against mechanical or physical property limitations with other fast cures.
- Two-part silicones. They also cure in a matter of minutes and offer a favorable balance of mechanical and physical properties, though not quite on the same level as epoxies. The same issues associated with mixing apply here too. They have achieved success in electronics and other thermally sensitive bonding applications.

Curing common mistakes

In their zeal to lower assembly costs, it's understandable that engineers will sometimes overemphasize cure speed. This tendency, however, can lead to the use of fast cure products where they are not the ideal choice based on the application's functional requirements or assembly methods. Those who focus too much on cure speed most often get into trouble with CAs. We've seen these fast curing adhesives specified for some of the worst usage scenarios for this type of adhesive - including medical devices that require autoclaving or assemblies subjected to high impact loads. Fast cure epoxies can likewise be misapplied if they are specified without regard to the property trade-offs.

These epoxies perform well enough that these trade-offs don't come into play in most applications, but there are times when application requirements require a slower curing epoxy that maximizes properties.

The misuse of fast cure adhesives doesn't always come down to their end-use properties. One common mistake involves a failure to account for open time needs during the assembly process. It's counter-intuitive, but a fast cure can actually hinder smooth, cost-effective assembly operations if it leaves no time to position parts correctly in a fixture. Savvy engineers will intentionally pick slower curing adhesives with longer open times when confronted with difficult fixturing processes. In these cases fixturing difficulties, not cure time, drives the cost.

www.masterbond.com

To receive your own copy of

Power Electronics Europe

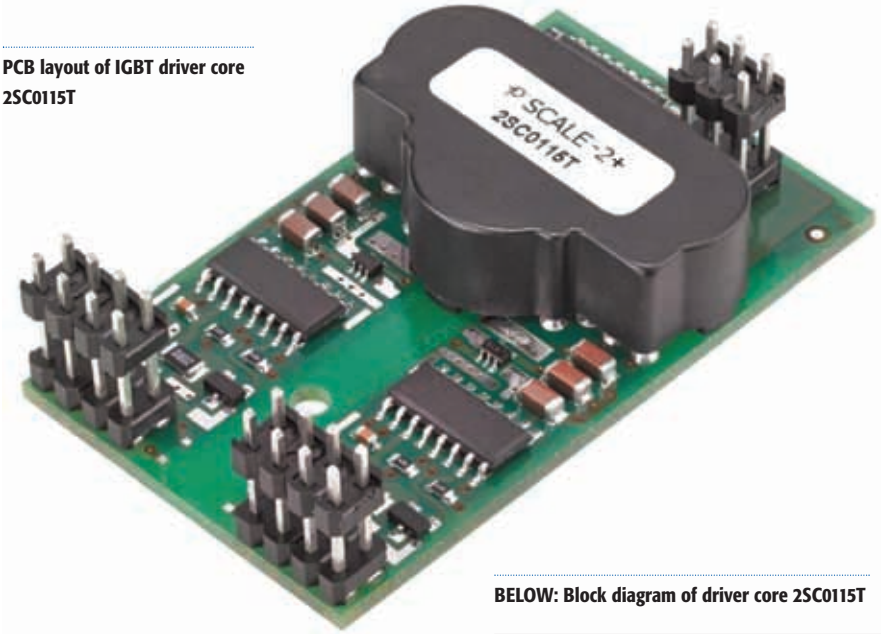
subscribe today at:

www.power-mag.com

Dual-Channel Compact Driver Core for 1200 V IGBTs

Designers of 10 to 500 kVA inverter systems can now take advantage of the reduced size and increased reliability offered by a new dual-channel gate driver core from Power Integrations. The use of proprietary SCALE™-2+ technology lowers the overall total component count and enables soft shutdown (SSD) in the event of a short circuit.

A footprint of 53.2 x 31 mm and a profile of just 13 mm make the 2SC0115T gate driver core the most compact of its type and is suitable for 90 kW to 500 kW inverters and converters. Leveraging SCALE-2+ integrated circuit and isolated transformer technology for DC/DC power and switching signal transmission, the core improves system reliability and performance by eliminating the need for an optocoupler. Reinforced electrical isolation targets systems with a working voltage of 900 V, which is typical for 1200 V IGBT modules and complies with the PD2 and OV II requirements of IEC 60664-1 and IEC 61800-5-1.



PCB layout of IGBT driver core 2SC0115T

IGBT driver properties

SCALE-2+ chipset consists of two application-specific integrated circuits (ASICs) that cover the main range of functions needed to design intelligent gate drivers. The driver supports switching frequencies up to 50 kHz. It comprises all functionality for an advanced dual-channel IGBT gate driver including an isolated DC/DC converter, short-circuit protection, advanced active clamping, and primary- and secondary-side supply-voltage monitoring.

The primary-side and secondary-side pin grid pitch is 2.54 mm with a pin cross section of 0.64 mm x 0.64 mm. Total outline dimensions of the board are 53.1mm x 31mm. The total height of the driver is 13 mm measured from the bottom of the pin bodies to the maximum point of the driver.

The gate driver core has to be mounted onto the carrier board with the transformer upside down. The header stacks must not be pressed together. The driver top side is free of components.

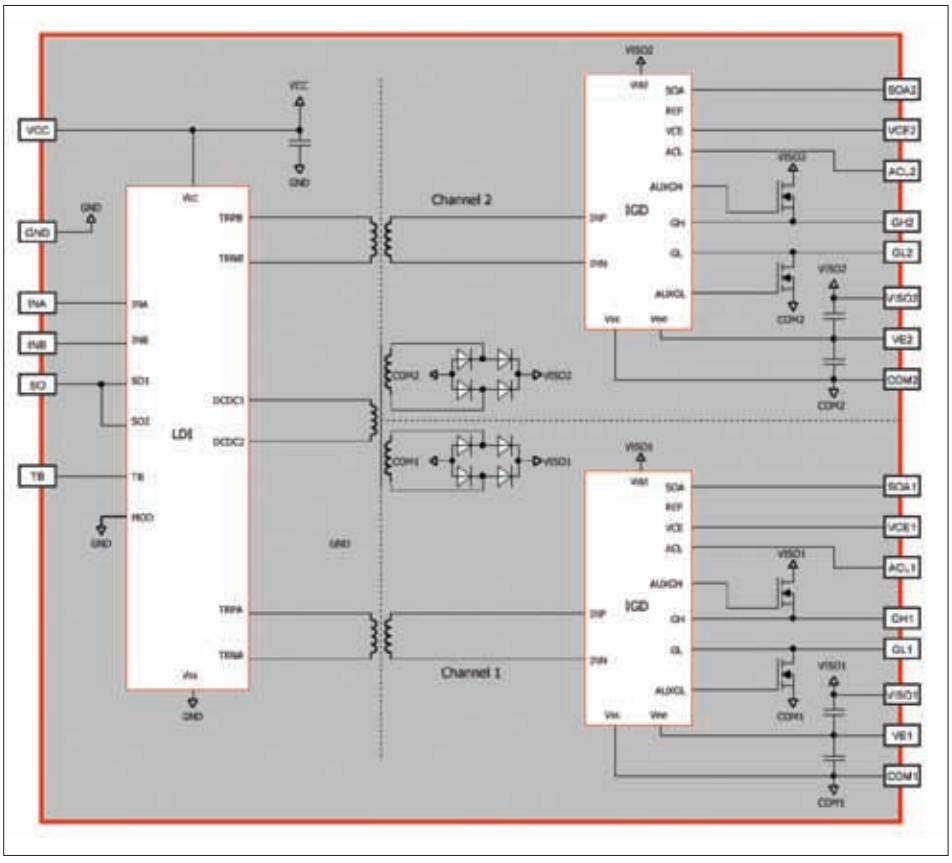
The driver has one V_{CC} terminal on the interface connector. It supplies the primary-side electronics as well as the DC/DC converter to supply the secondary sides with 15 V. The driver limits the inrush current at startup and no external current limitation of the voltage source for V_{CC} is needed for this purpose.

INA and INB are drive inputs. They safely recognize signals in the whole logic-level range between 3.3 V and 15 V. Both input terminals feature Schmitt-trigger characteristics. An input transition is triggered at any edge of an incoming signal at INA or INB.

The output SO has an open-drain transistor. When no fault condition is detected, the output has high impedance. An internal current source of 1 mA pulls the SO output to a voltage of about 4 V when left open. When a fault condition (primary-side supply under-voltage, secondary-side supply under-voltage, IGBT short circuit) is detected, the status output SO goes to low (connected to GND).

Each channel of the 2SC0115T driver is equipped with a V_{CE} monitoring circuit. The turn-off threshold is internally set to 9.3 V. The driver will safely protect the IGBT against short-circuit, but not necessarily against over-current. Over-current protection has a lower timing priority and is recommended to be realized within the host controller. In order to ensure that the 2SC0115T can be applied as universally as possible, the response time capacitor is not integrated in the

BELOW: Block diagram of driver core 2SC0115T



driver, but must be connected externally. During the response time, the V_{CE} monitoring circuit is inactive. The response time is the time that elapses after turn-on of the power semiconductor until the collector/drain voltage is measured. Both IGBT collector-emitter voltages are measured individually. V_{CE} is checked after the response time at turn-on to detect a short circuit. If the measured V_{CE} at the end of the response time is higher than the threshold V_{thx}, the driver detects a short circuit. The driver then switches off the corresponding power semiconductor. The fault status is immediately transferred to the SO output. The power semiconductor is kept in off-state (non-conducting) and the fault is shown at pin SO as long as the blocking time T_b is active. The blocking time is applied independently to each channel. T_b starts as soon as V_{CE} exceeds the threshold of the V_{CE} monitoring circuit outside the response time span.

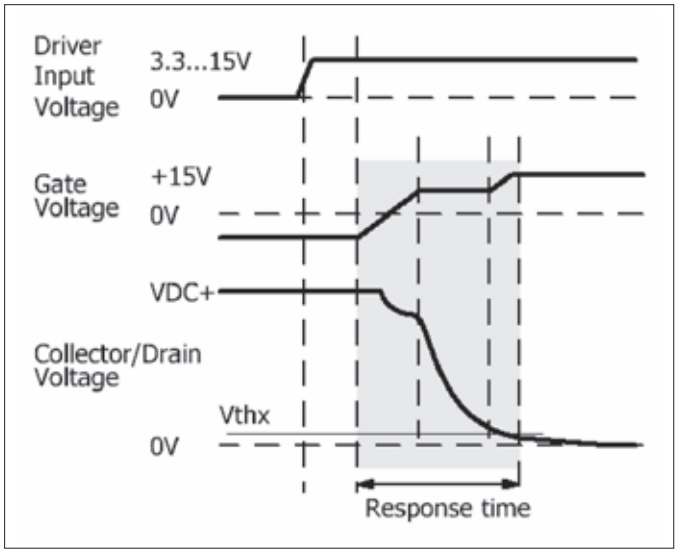
The driver is equipped with blocking capacitors on the secondary side of the DC/DC converter. Power semiconductors with a gate charge of up to 3 µC can be driven without additional capacitors on the secondary side. For IGBTs or MOSFETs with a higher gate charge, a minimum value of 3 µF external blocking capacitance is recommended for every 1 µC gate charge beyond 3 µC.

Active clamping is a technique designed to partially turn on the power semiconductor as soon as the collector-emitter (drain-source) voltage exceeds a predefined threshold. The power semiconductor is then kept in linear operation. Basic active clamping topologies implement a single feedback path from the IGBT's collector through transient voltage suppressor devices (TVS) to the IGBT gate. The 2SC0115T supports Power Integrations' Advanced Active Clamping, where the feedback is also provided to the driver's secondary side at pin ACLx.

Gate turn-on (GHx) and turn-off (GLx) terminals allow the turn-on (GHx) and turn-off (GLx) gate resistors to be connected to the gate of the power semiconductor. The GHx and GLx pins are available as separated terminals in order to set the turn-on and turn-off resistors independently without the use of an additional diode.

The new cost-effective SCALETM-2+ dual-driver core 2SC0115T combines compactness with broad applicability. The driver was designed for universal applications requiring high reliability. The 2SC0115T drives all IGBT modules up to 1400A/1200V and provides reinforced isolation between primary and either secondary sides.

www.power.com/igbt-driver



Turn-on characteristic of an IGBT or MOSFET

Reference Design adds Wi-Fi to EV Charging Stations

Texas Instruments has issued a reference design that adds Wi-Fi connectivity to an electric vehicle (EV) charging station. EV owners will now be able to remotely monitor and control the charging of their vehicles from just about anywhere with Wi-Fi, presenting dozens of potential use cases from home automation to checking the availability of nearby public charge points.

Battery technology advancements and government regulations have resulted in a growing number of new electric vehicles around the world. But EV makers still need more charging stations to make it easier for drivers to charge their vehicles. The new reference design uses TI's SimpleLink™ Wi-Fi wireless microcontroller (MCU) technology that allows design engineers to create stations that intelligently charge at non-peak times or detect and communicate when a charging station is available.

Faster charging

One barrier to widespread EV charging station adoption is the amount of time it takes to charge a vehicle. The reference design supports Level 1 charging, which is compatible with household outlets, as well as Level 2 EV charging, which helps vehicle owners tap into higher current (15 A to 30 A and higher) connections available in commercial office buildings. Level 2 chargers typically take up to eight hours to fully charge the vehicle. Later this year TI plans to introduce a Level 3 EV DC charger reference design scalable to 600 V and 400 A that cuts charging time down to only 20-30 minutes – enough time to stop at a Wi-Fi enabled restaurant that has a charging station and charge the vehicle during lunch.

EV chargers are broadly classified into three categories, Level 1, 2 and 3 chargers based on their power and charging capabilities (see Table 1). These three types can be further classified into alternating current (AC) chargers and direct current (DC) chargers based on charging technology. Level 1 AC chargers employ a slow rate of charging, using low battery-charge currents to avoid damaging the battery cells; a slow charging rate also facilitates alignment with the energy capacity of the local grid connection. Level 2 AC chargers, typically located at public charge stations, tap into the higher current connections available in commercial buildings. Technology innovations in power-handling capabilities and cell topology have led to the advent of Level 3 DC chargers. A Level 3 charger contains its own high-voltage AC/DC power supply, bypassing the on-board charger (AC/DC) on the vehicle to provide very high power charge levels.

Although Level 3 chargers have relatively faster charging times compared to Level 1 & 2 chargers, the former makes up for less than 10 % of the total deployments worldwide. Such extended charging time (Level 3 chargers included) has been a major deterrent in adoption of electric vehicles. Adding remote monitoring and control capabilities to EVSE can help alleviate the inconvenience caused to EV owners from such extended charging times. For example, being able to remotely monitor and reserve a slot with EVSEs in the office parking lot, or at a public charging station in a mall or a freeway can eliminate the uncertainty associated with finding an EV charger at the next stop. Automatic text message when an EV charging is complete can ensure that the user makes space for the next user without added delay. Being able to automate the charging times and conditions for an EV when it's plugged in at home would allow for EV to be charged during off peak hours when the grid tariff is lower.

Public charge stations help tap into higher

SEMIKRON
innovation+service

Power Electronic Stacks

When Time to Market Counts

You want to...

- **reduce time to market**
- **limit your financial investment**
- **control your cost of development**
- **save costs on manufacturing of stack assemblies**

We are the global market leader in power electronic stacks with over 200,000 assemblies in the field. Five global stack centers provide optimized, pre-qualified and field-tested stack assemblies. Our stacks feature short lead times while still easy to customize for your needs. Our global stack centers provide worldwide coordination, engineering, manufacturing and test to localize manufacturing of your stack assemblies.

Further information: www.semikron.com/power-stacks

Electric Vehicle Service Equipment (EVSE) reference design controls the charging current and adds Wi-Fi connectivity

EVSE Type	Power Supply	Charger Power	Charging time* (Approx.) for a 24kWH Battery
Level 1 (AC Charging)	120VAC 12 A to 16A (Single Phase)	~1.44kW to ~1.92kW	~17 Hours
Level 2 (AC Charging)	208 ~ 240VAC 15 A ~ 80A (Single/ Split Phase)	~ 3.1kW to ~19.2kW	~8 Hours
Level 3 (Combo Charging System or DC Charging)	300 to 600VDC (Max 400A) (Poly Phase)	From 120kW up to 240kW	~ 30 Minutes

* Charging time does not scale linearly with EVSE charge capacity.

Charging levels and associated charging times

current connections that are available in commercial buildings, but these stations must be able to charge all varieties of electric vehicles.

These problems are mitigated through EVSE that controls the power flow that goes into EVs. Many vehicle manufacturers have adopted the J1772 SAE standard for AC electrical connections to a vehicle. This standard translate into international localizations, and only the form factors differ.

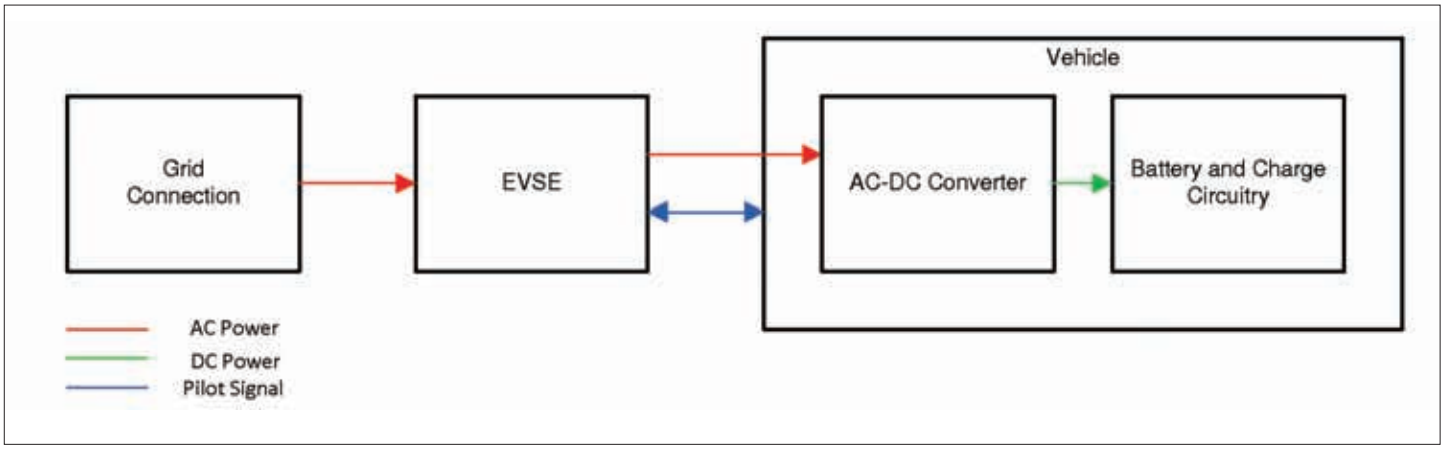
The reference design meets the remote monitoring and control requirements discussed in the use cases above (and many more). Adding Wi-Fi allows for monitoring of the EVSE from any Wi-Fi connected device by a standard web browser. Some of the primary functionalities included in this design are:

- Level 1 and Level 2 charger operation (120V to 240V).
- Power delivery up to 30A (expandable by using larger relays).
- Pilot signal-wire communication support.
- Latched-relay detection.
- High-precision energy metering.
- Communication enabled using SimpleLink™ technology over a Wi-Fi transceiver.

Reference design details

The verified design details how to implement J1772-compliant level 1 and level 2 electric vehicle service equipment (EVSE) with added Wi-Fi functionality. The CC3100 network processor enables highly embedded devices like the EVSE to easily connect to an existing wireless network or directly to a device. By integrating this functionality in an EVSE, the design is capable of remote-power monitoring and control of the charging state of the connected electric vehicle. The MSP430F6736 performs all energy measurements and EVSE control functions and controls the Wi-Fi transceiver. The data can be displayed on any Wi-Fi connected device by using a standard Web browser.

The core of the EVSE operation for AC power delivery is communication with the vehicle through a single-line pilot wire, which enables negotiation with the vehicle for power status, available power, and charge state. The EVSE must be able to control AC power delivery to the plug (up to a



EVSE position in charging power flow

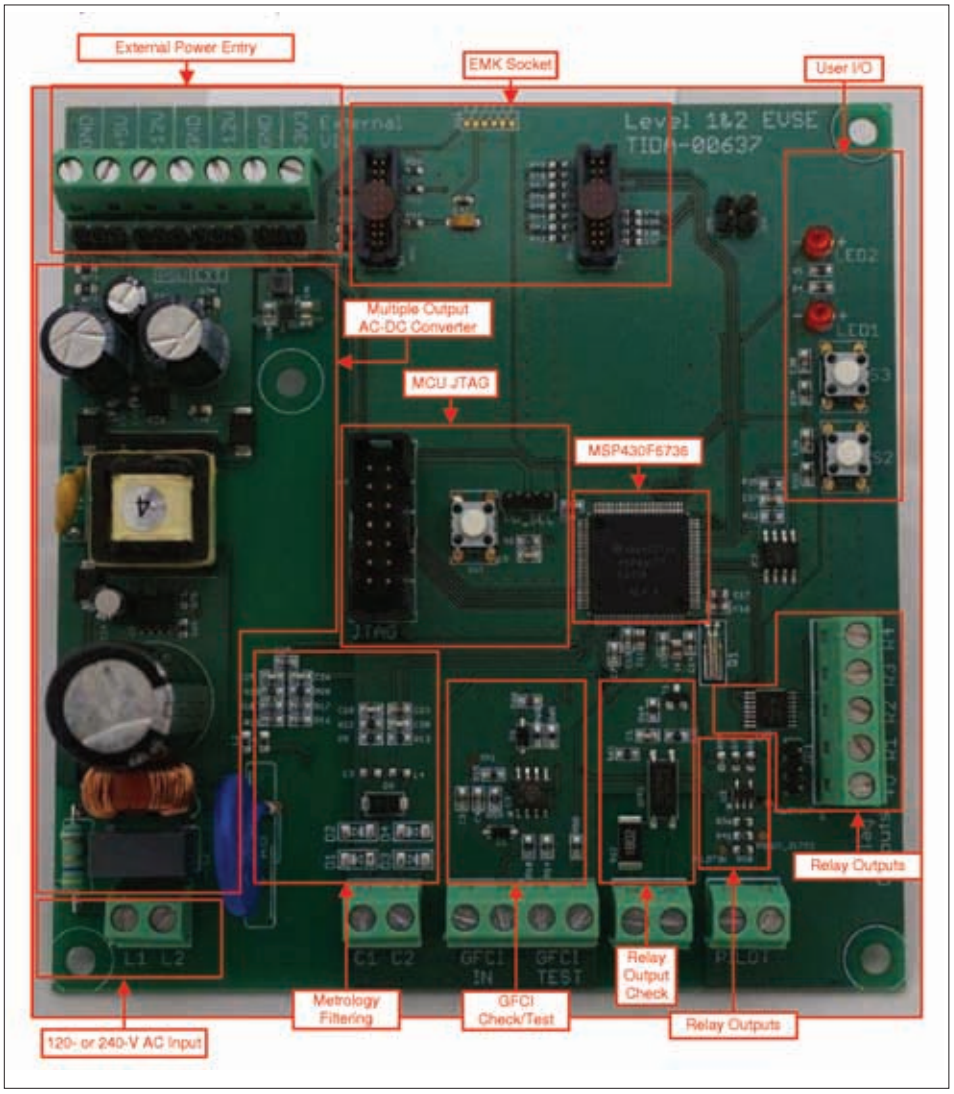
240-V AC and 80 A) for robust relay or contactor driving.

The pilot signal is the primary method that a J1772 compliant EVSE uses to communicate with a vehicle. The pilot signal is based on a 1-kHz, ±12-V PWM signal that is transmitted to a vehicle through the charge cord. The vehicle can then respond by placing various loads on the line, affecting the voltage (the EVSE measures this). The duty cycle of the pilot signals communicates the limit of current the EVSE is capable of supplying to the vehicle, it is set in steps to 8.3 % for charge current of 5 A and 96 % for 80 A. The vehicle then uses up to the limit of current for the charging circuitry. This current rating is determined by the electromechanical components in the EVSE, such as conductors, relays, contactors, and the service connection.

The PWM is generated by a timer module on the MSP430 MCU. Because the current rating is tightly coupled to the external hardware, the current rating can be set as the permanent value in the firmware. Advanced EVSEs with a human machine interface (HMI) can enable the current to be derated if the service line cannot provide sufficient current with a stable voltage. A significant voltage drop is possible because of wire loss in high-current applications.

The primary functionality of the EVSE is the reliable control of large currents that are directed toward an EV at the voltage of the main. In a normal-use case, the relay must be held closed for several hours to fully charge a vehicle, but the relays cannot be latching type because of safety concerns. If something fails in the control system, the relays must fail open. These high-current relays can draw tens to hundreds of milliamps as an inductive load, requiring specific drive architectures.

Because of the amount of time that a relay requires to remain powered on, an efficient-drive solution is preferred instead of the Darlington array or a discrete transistor configuration. The used TPL7404L has high-efficiency, integrated-diode protection for inductive loads and has a wide-voltage output capability to match most electromechanical relays. The design defaults to a 5-V output, but an external voltage can be used depending on the relay configuration. The relay configuration used for design testing contains a two-stage approach. The EVSE board controls the first relay through a 12-V signal from the TPL7404L device. This relay switches a 120-V signal into a larger relay that is capable of supporting the



The control system for the EVSE-WIFI reference design is fully implemented in a single PCB (top view of the board is shown)

required currents of the EVSE. This configuration is not uncommon because many large contactors or high-amplifier relays are 120 V. This configuration also reduces power-supply requirements because a lower current is required to drive a smaller first relay.

The energy measurement section has been emulated from the existing portfolio of residential e-meter designs, specifically the Class 0.2 Single-Phase E-Meter. It offers a high-accuracy energy measurement through the MSP430F6736 MCU. The MCU is fully programmable and has been adopted to run the software that controls the EVSE system.

The software package provided implements the basic structure of the J1772 signaling protocol and to evaluate the functionality of design features. The software was built on top of the existing MSP430-Energy-Library. This library has been proven for use in electricity meters and provides a framework for adding the EVSE application state machine.

For more details on the reference design visit: **www.ti.com/tool/tidc-evse-wifi**

High Power with Complete Digital Control

It should come as no surprise to anyone that a the continuing adoption of Digital Power System Management (DPSM) within the communications and computer industries continues to be driven, in large part, to the high current levels demanded by the sub-20 nm ASICs and/or FPGAs that are at the core of their system architecture. **Tony Armstrong, Director of Power Product Marketing, Linear Technology Corporation, USA**

By way of example, consider the newest ASICs being used in the next generation data center switches; they enable a more flexible set of interfaces for ports carrying 100 Mbit to 100 Gbit/s Ethernet and 32 Gbit/s fiber channel traffic. This allows higher density of 100G ports to be placed into a single rack unit. Coupled with this, these sub-20 nm processes allow 20 plus Mbytes of memory to be placed on the ASIC itself, thereby potentially eliminating the need for external memory, saving board space and cost.

Nevertheless, the system architects of this type of communications equipment are constantly being pushed to increase the data throughput and performance of their systems as well as add functionality and features. Simultaneously, pressure is being applied to decrease the systems overall power consumption. For example, a typical challenge is to reduce overall power consumption by rescheduling the work flow and moving jobs to underutilized servers, thereby enabling shutdown of other servers. To meet these demands, it is essential to know the power consumption of the end-user equipment. Thus, a properly designed digital PSM can provide the user with power consumption data, allowing for smart energy management decisions to be made. This is a key requirement for data centers where the electricity costs for the HVAC systems that keep the internal ambient temperatures under control are significant.

System challenges

When digital power is done correctly, it can reduce equipment power consumption, shorten time to market, have excellent stability and transient response, and increase overall system reliability.

Complex multi-rail systems can be efficiently developed using a comprehensive development environment with intuitive graphical user interface (GUI). Such systems also simplify in-circuit testing (ICT) and board debug by enabling changes via the GUI instead of soldering in "white wire" fixes. Another benefit is the potential to predict power system failures and enable preventive measures, thanks to the availability of real-time telemetry data. Perhaps most significantly, DC/DC converters with digital management functionality enable designers to develop "green" power systems that meet target performance (compute speed, data rate, etc.) with minimum energy usage at the point of load, board, rack and even installation levels, reducing infrastructure costs and the total cost of ownership over the life of the product.

Many telecom and datacom systems are powered via a 48 V backplane. This voltage is normally stepped down to a lower intermediate bus voltage of typically 12 V to 3.3 V to power the racks of boards within the system. However, most of the sub-circuits or ICs on these boards are required to operate at voltages ranging from sub-1 V to 3.3 V at currents ranging from tens of milliamps to hundreds of amps. As a result, point-of-load (PoL) DC/DC converters are necessary to step down from the intermediate bus voltage to the desired voltage required by the sub-circuits or ICs. These rails have strict requirements for sequencing, voltage accuracy, margining and supervision.

There can be as any many as 50 PoL voltage rails in a telecom system and system architects need a simple way to manage these rails with regards to their output voltage, sequencing and maximum allowable current. Certain processors demand that their I/O voltage rise before their core voltage, alternatively certain ASIC and DSPs require their core voltage rise before their I/O. Power down sequencing

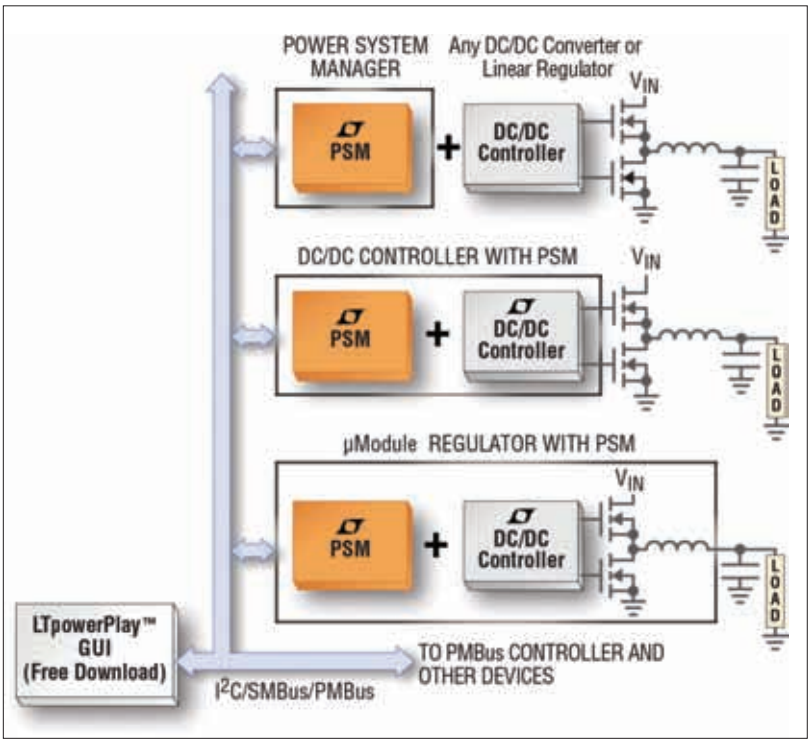


Figure 1: Typical digital power system management system configuration

is also necessary. Designers need an easy way to make changes to optimize system performance and to store a specific configuration for each DC/DC converter in order to simplify the design effort.

Furthermore, in order to protect expensive FPGAs, ASICs and DSPs from the possibility of an over-voltage condition, high-speed comparators must monitor the voltage levels of each rail and take immediate protective action if a rail goes out of its specified safe operating limits. In a digital powered system, the host can be notified when a fault occurs via the PMBus alert line and dependent rails can be shut down to protect the powered devices such as an FPGA. Achieving this level of protection requires reasonable accuracy and response times on the order of tens of microseconds.

It was because of these challenges that a PSM product line that includes synchronous step-down DC/DC controllers with integrated power FET gate drivers and comprehensive power management features accessed via the I²C-based PMBus has been developed. These include precision references and temperature-compensated analog current-mode control loops offering ±0.5% DC accuracy, easy compensation that is calibrated to be independent of operating conditions, cycle-by-cycle current limit, and fast and accurate current sharing and response to line and load transients without any of the ADC quantization-related errors found in products utilizing "digital" control. Some of these also incorporate 16-bit data acquisition systems that provide digital read back of input and output voltages and currents, duty cycle and temperature. Also included is a fault logging capability via an interrupt flag along with a "black box" recorder that stores the state of the converter operating conditions just prior to a fault. Finally, multi-rail system development is facilitated though LTpowerPlay® development software and GUI interface.

Simple solutions for complex problems

So what does the system architect have to do in order to configure a digital power

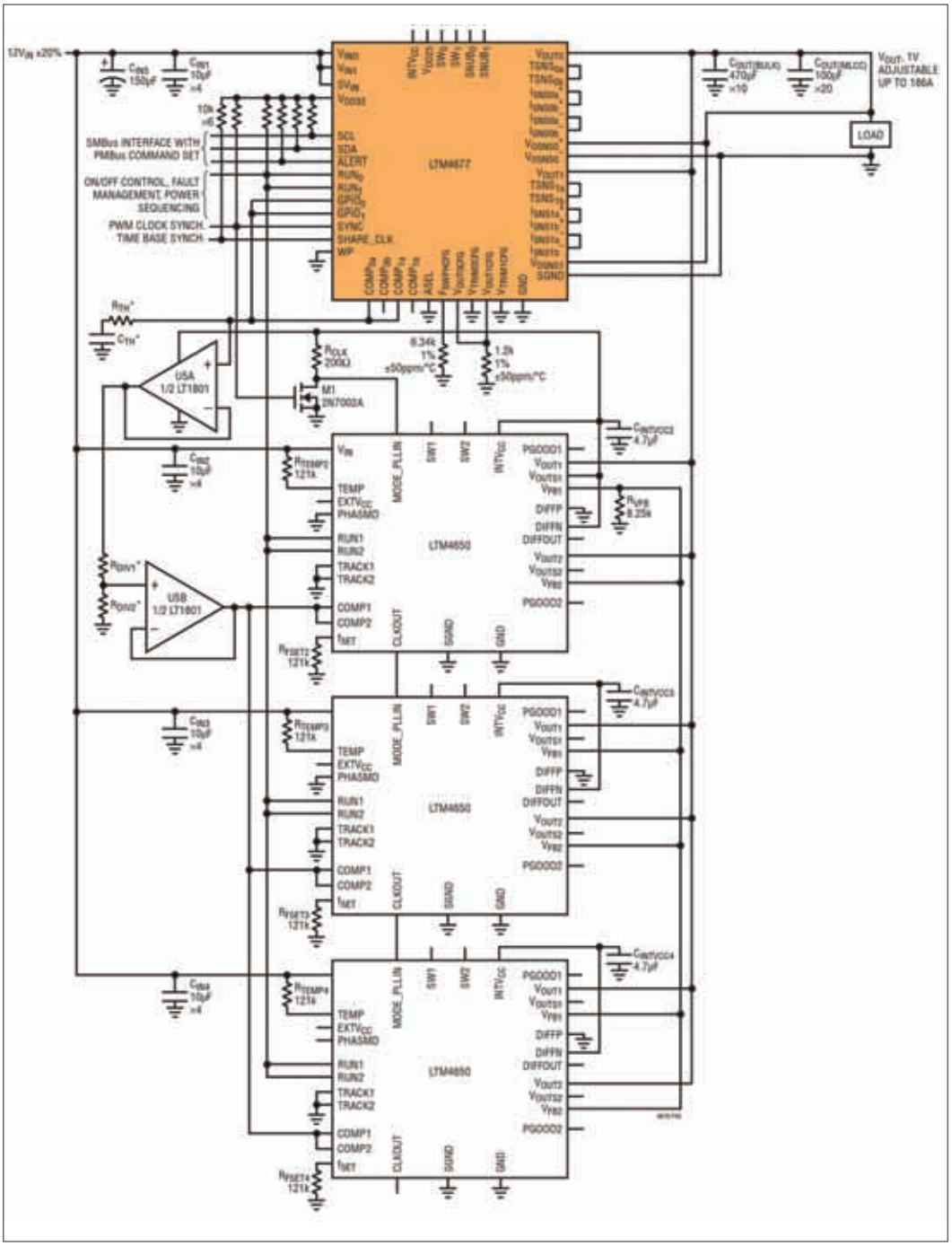


Figure 2: A combination of 1 LTM4677 DPSM module & 3 LTM4650 modules delivers 186 A at 1 V from a nominal 12 V input

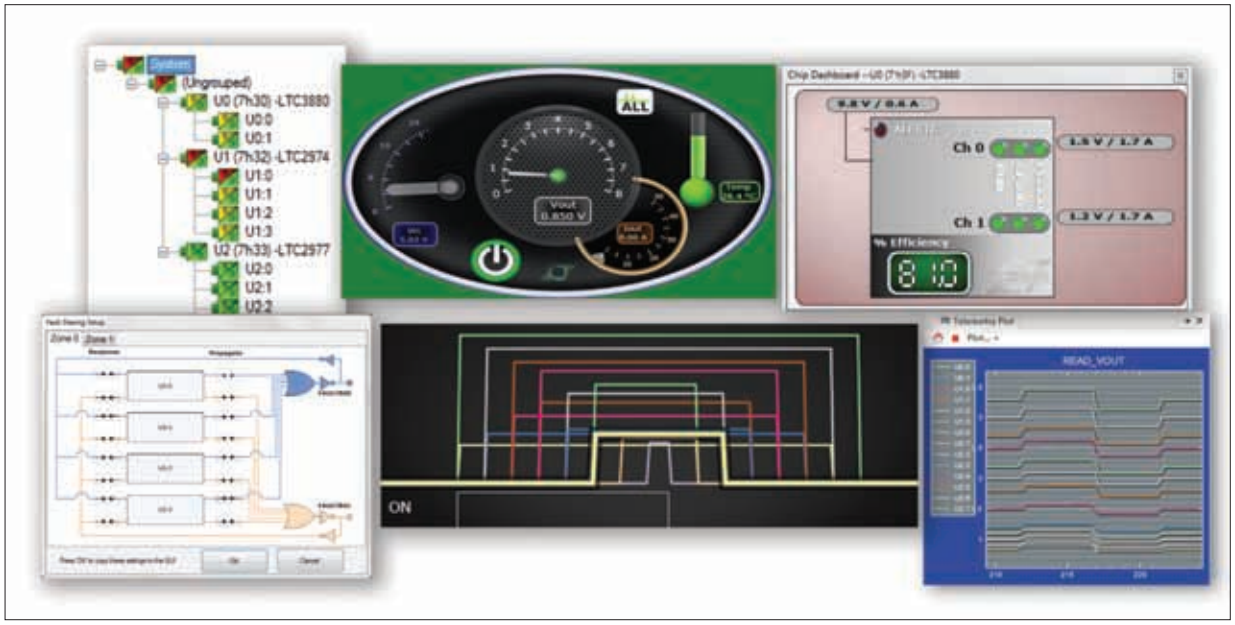


Figure 3: A snapshot of a typical dashboard screen shot of the LTpowerPlay GUI

system management solution for their end product? One of the primary objectives will be to design a system so that it can be easily configured and monitored via a digital communications bus. This will be achieved by utilizing one of the following; I^2C, SMBus or PMBus. Either of these buses can enable on-demand telemetry capability to set, monitor, change and log power parameters of any PoL converter configuration within the system. A simplified snapshot of such a system is shown in Figure 1.

As can be seen in this example, the PoL converters illustrate 3 different topology configurations. At the top of the figure, a power system manager chip is used alongside a conventional DC/DC converter. The DC/DC converter can be of any topology and have any degree of integration since it is the power system manager that will allow it to be interfaced, controlled and monitored via the communication bus. The middle PoL converter demonstrates an increased level of integration, namely, that the DC/DC converter has the power system management built-in (in the same package). And finally, the bottom PoL converter is a compact module which incorporates the power system manager, the DC/DC converter and all its associated external components into a single form factor (Linear calls these a µModule® regulator).

Linear's µModule DC/DC regulators can provide a simple and effective way to deliver both high power outputs and DPSM capability. Since many of the regulators can be easily paralleled for high current outputs with per channel current matching within a nominal 1 % of each other, thereby mitigating the potentials for hot spots. Moreover, only one of the µModule regulators needs to contain DPSM capability, since it can supply the complete digital interface even if the uModules in parallel does not have DPSM inherent within them. Figure 2 shows an application schematic of one LTM4677 (36 A DPSM µModule) in parallel with 3 LTM4650s (50 A µModules).

Universal GUI for DPSM

A key advantage of a system architected with DPSM products is that with the right GUI it is easy to communicate with each individual PoL converter within in the system. So, from the onset, Linear decided to develop a GUI that was a complete development platform which could be easily used with all of the different types of products it offered in its DPSM product portfolio – the LTpowerPlay windows based development environment.

Not only does this software make is easy to control and monitor multiple Linear PMBus-enabled devices simultaneously, it also allows modification of the DC/DC converters configurations in real time be downloading system parameters to the internal EEPROM of the individual devices. This reduces design development time by allowing system configurations to be adjusted in software rather than resorting to the time honored tradition of swapping out components and rewiring boards. Once an end system has been deployed in the field, such as a data center, then the system can be adjusted real time by an overseer by simple updating operation parameters of the PoL converters via an applicable interface using this GUI. Figure 3 shows a typical screen shot of LTpowerPlay dashboard that a user would see when interrogating their system.

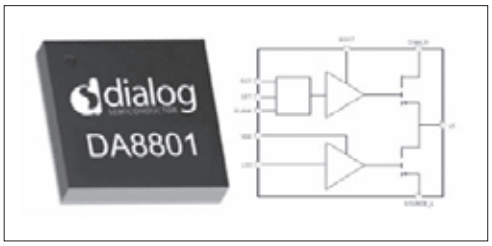
All Linear PMBus products are supported by this software development system which can help designers quickly debug systems both during initial development and then when they are installed at a user's site. It quickly and easily allows monitoring, control and adjustment of supply voltages, limits and sequencing. Furthermore, production margin testing is easily performed using a couple of standard PMBus commands.

Conclusion

Having DPSM capability in today's datacom and telecom systems provides a system architect with an simple and powerful way to deliver over 180 W of power to the 1.xV core voltages of the newest sub-20 nm ASICs and FPGAs with just 4 µModule regulators. Utilizing a combination of the LTM4677 and 3 LTM4650s in a multiphase configuration as shown in Figure 2, not only saves expensive PCB real estate, but reduces the amount of required cooling due to its overall operating efficiency. Furthermore, the software programmability of DPSM significantly reduces the debug time normally associated with such endeavors. This reduces infrastructure costs, as well as the total cost of ownership over the life of the product. And while it might take the fun out of the traditional solder iron and rewiring approach to debugging hardware systems, its convenience and time saving attributes are too compelling to be ignored.

Integrated 650 V GaN Half Bridge Power IC

The DA8801 from Dialog Semiconductor is a highly-optimized, high-voltage GaN half bridge which integrates 650 V high-side and low-side power switches with analog, logic, and protection. It enables power supplies to shrink in half and cuts power losses in half. GaN high electron mobility transistors (HEMTs) are 10x faster than Silicon MOSFETs, enabling high frequency power electronics to deliver much higher efficiency. GaN power switches require 5x lower Q_G, C_{OSS}, and Q_{RR}, resulting in extremely low switching and charging loss. So-called SmartGaN monolithically integrates GaN HEMTs with crucial analog and logic blocks, providing a complete half-bridge solution, tuned for performance and cost. The simple low voltage inputs make GaN much easier to implement. Moreover, parasitic elements, which are detrimental to low-noise and efficiency, are virtually eliminated. The 500 mΩ power switches, rated at 650 V, are well suited for AC/DC applications.



www.dialog-semiconductor.com

Wireless Power Kit at Mouser

Mouser Electronics is now stocking the WP3W-RK wireless power reference kit from Integrated Device Technology (IDT). The new IDT Qi-based transmitter and receiver reference kit helps make integrating wireless charging into compact electronics easy and affordable, targeting designs requiring 3 W or less. The reference kit is comprised of both a P9235A-R transmitter and a P9027LP-R receiver, with three different coil size options supporting various applications, form factors and power levels. Delivering peak 80 % system efficiency at 3 W, the kit offers integration with the drop-in reference layout provided and an optimized thermal design. The kit's associated layout module allows for direct instantiation on to a system board, while an optimized and fully tested bill-of-materials (BOM) takes the guesswork out of component selection. In addition, a digital library of layout guides, schematics, Gerber files, and more eliminates traditional design and support barriers regardless of application volume.

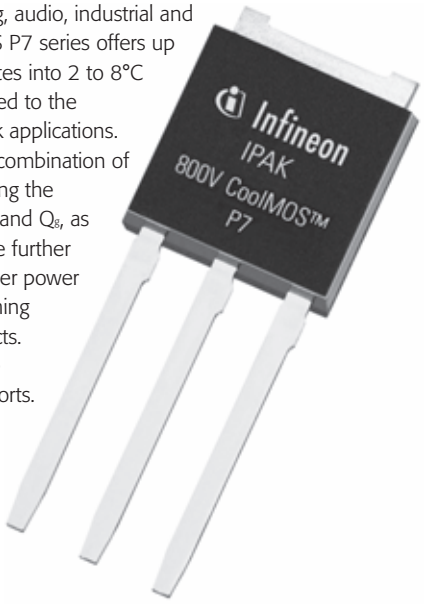
www.mouser.com/new/idt/idt-wp3w-rk-kit/

Intersil offers the new ISL91127 and ISL91128 high efficiency buck-boost regulators. The devices feature 4.5 A switches, efficiency up to 96 %, and aquiescent current of 30 µA for superior light load efficiency. The devices operate in buck, boost or buck-boost mode, depending on the relation between input and output voltages, and provide smooth transitions between modes to prevent noise and glitches. The new buck-boost regulators' wide input voltage range of 1.8V to 5.5V supports multiple battery topologies, and their wide output voltage range of 1 V to 5.2 V combined with 3 A output current provides design flexibility. The ISL91128 also features I?C programmable dynamic output voltage adjustability, which eliminates feedback resistors and allows the reuse of the same design for multiple output voltage needs. In hand-held device applications where the input voltage may be higher or lower than the output voltage, buck-boost regulators improve efficiency and provide longer battery life compared to a boost regulator plus bypass solution. With increasing demands for smaller and smaller footprints, ISL9112x compact QFN and WLCSP packages enable power designs that maximize efficiency while providing flexibility and ease of design. The ISL91127 and ISL91128 can be combined with the ISL9003A, ISL9016, ISL9021A, and ISL9001A LDOs to support multiple output rails with improved ripple. They also work with the ISL9113 sync boost converter and ISL91133 boost regulator if additional higher voltage rails are required, and lower voltage rails are supported with the ISL9104 and ISL9103 sync buck converters.

www.intersil.com/products/isl91127

800 V CoolMOS P7 Series

Infineon introduces the 800 V CoolMOS™ P7 series. Based on the Superjunction technology, this 800 V MOSFET is suited for low power SMPS applications, mainly focused on flyback topologies which are typically found in applications like adapter, LED lighting, audio, industrial and auxiliary power. The 800 V CoolMOS P7 series offers up to 0.6 % efficiency gain. This translates into 2 to 8°C lower MOSFET temperature compared to the CoolMOS C3 tested in typical flyback applications. This new benchmark results from a combination of optimized device parameters including the reduction of more than 50 % in E_{oss} and Q_g, as well as a reduced Ciss and Coss. The further improved performance enables higher power density designs through lower switching losses and better DPAK $R_{DS(on)}$ products. Overall, this helps customers to save BOM costs and reduce assembly efforts. The integrated Zener Diode significantly improves ESD ruggedness, thus reducing ESD related production yield losses.



www.Infineon.com/p7

10 A Current-Compensated Chokes

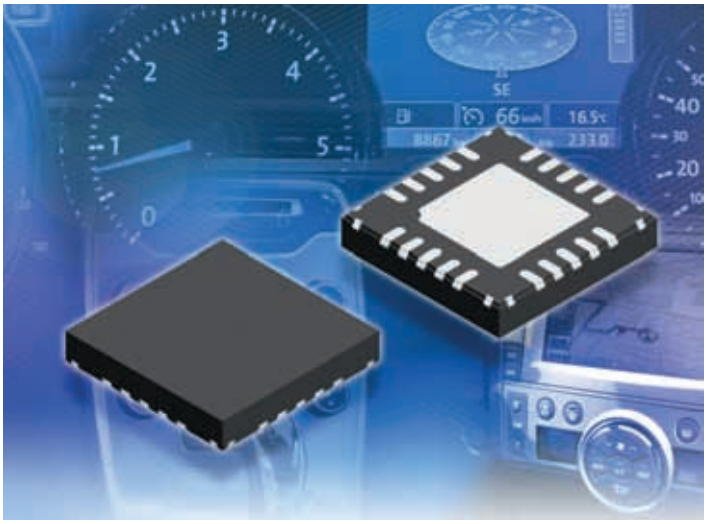
Switzerland-based Schaffner is expanding its range of current compensated EMC correcting chokes with horizontal and vertical mounting options and with additional inductance values between 0.4 and 100 mH for currents between 0.3 and 10 A. The new RN series is now rated up to 300 VAC and the extended product range enables design engineers to optimize their EMC/EMI solutions for performance and PCB layout. RN dual common-mode chokes operate over the frequency range DC to 50/60 Hz and offer 100 kHz to 3 MHz common-mode resonance frequencies. Multiple PCB-mounting options may be specified. The new higher temperature rating offers easier design with an ambient temperature rated at 60°C. Applications include switch mode power supplies and converters, inverters, battery management systems, chargers, dimmers or phase angle control devices.

www.schaffner.com

Railway Certified DC/DC Converters

RECOM introduces the new RP40-FR DC/DC converter series certified for use in rolling stock as well as industrial applications requiring compliance with recognised safety standards. EN50155 certification ensures that the RP40-FR series is suited for harsh environments, additionally the new series is also certified according to UL/cUL 60950-1 and can be used for applications with higher input voltages in industry, telecommunications, and distributed power supply architectures. Along with a wide 4:1 input voltage range, RECOM DC/DC converters deliver 40 W of regulated output power from single or dual outputs and come with an output trim function. The DC/DC converters include on/off remote control with positive or negative logic. The series is available with rated DC inputs of 24 V or 48 V with 1.6 kV DC insulation or 110 V with 3 kV DC insulation. Due to high efficiency up to 92 %, 40 W is available in 2 x 1 inches (50.8 x 25.4 x 10.2 mm without a heatsink). Protection features include short-circuit, over-voltage, over-load, and over-temperature, temperature range is -40° to 105°C.

www.recom-power.com



Buck/Boost Controller with Integrated MOSFET

Allegro MicroSystems Europe has introduced a new automotive AEC-Q100 qualified power management IC. The A4450 can implement either a buck or buck/boost regulator to efficiently convert automotive battery voltages into a tightly regulated voltage, with seamless transition between the buck and boost modes. The A4450 is intended for automotive input environments where battery input voltage supply can vary above and below the required output voltage and a single- inductor/single-stage conversion is desired. The wide input operating voltage range of 3 V to 36 V makes the device suitable for a range of automotive infotainment applications and handles idle stop/start, cold crank, double battery and load dump conditions. The device features a high-voltage battery compatible enable (EN) input to accommodate for switched battery input applications. The A4450 provides regulated output voltage ranging from 3 V to 8 V with load current of up to 1 A DC. The PWM switching frequency range is 250 kHz to 2.4 MHz, and frequency dithering and controlled switching transitions minimise EMI. Protection features include pulse-by-pulse current limit, hiccup mode short-circuit protection, LX short-circuit protection, missing freewheeling diode (buck diode at LX node in A4450).

www.allegromicro.com

Current Sensing Optocoupler

Broadcom offers a new optically isolated sigma-delta modulator device, the Avago ACPL-C799, designed for a wide range of industrial applications including servo drives and motors. The new device features a low differential input range of +/-50 mV allowing designers to reduce power dissipation across a current-sensing shunt resistor in servo drive and motor applications. Compared to previous generation products with an input range of +/-200 mV, the ACPL-C799 enables the use of a smaller shunt resistor with one-quarter the value, thereby eliminating 75 % of shunt resistor's power losses. Despite the reduced input voltage range, the device delivers superb SNR, ENOB and offset drift performance, enabling a high precision motor control in space constrained, high temperature environments.

www.broadcom.com

TARGET YOUR BUYERS

FROM OVER 60,000
QUALIFIED CONTACTS

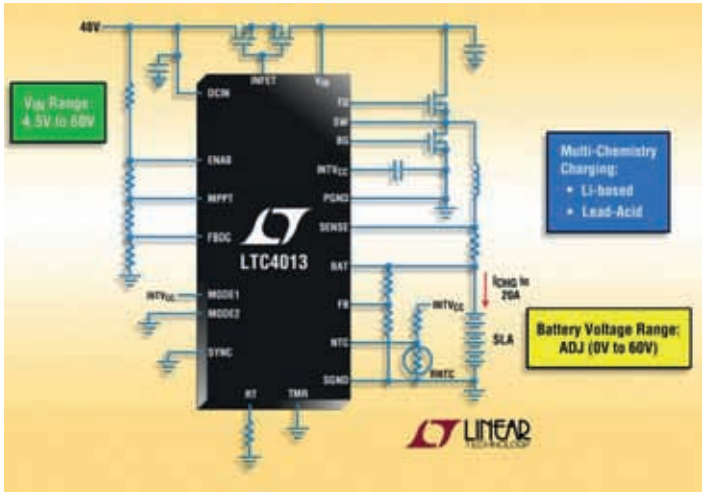
- **E-CAMPAIGN**
- **LIST RENTAL**
- **LEASE**

DFA media **Direct**

Contact: Ian Atkinson
on +44 (0)1732 370340
ian.atkinson@dfamedia.co.uk

Plant&Works Engineering
Drives&Controls
POWER ELECTRONICS EUROPE
Hydraulics&Pneumatics
THE JOURNAL OF FLUID POWER AND SYSTEMS

60 V Synchronous Buck Battery Charger



Linear Technology Corporation introduces the LTC4013, a highly integrated, high voltage multi-chemistry synchronous step-down battery charger controller. With a wide input voltage range that spans up to 60V, the LTC4013 uses temperature-compensated 3- and 4-stage charge algorithms to efficiently charge 12 V and 24 V lead-acid batteries. Alternatively, the LTC4013 will charge a multicell Lithium-based battery stack with float voltages near to the input supply. Mode pins define the float voltage and charge algorithm. Charge current is precision regulated to ±5% and programmable with a single resistor up to 20 A (depending on the selection of external components). The LTC4013 features user-adjustable maximum power point tracking (MPPT) circuitry that enables simple power optimization in the case of power-limited sources such as solar panels. The MPPT open-circuit method corrects for panel temperature changes without the inconvenience of adding a solar panel temperature sensor. Other features include an external input MOSFET driver (INFET) to avoid battery discharge during an input supply short, two open-drain status pins, and an ISMON pin that provides analog information about charge current.

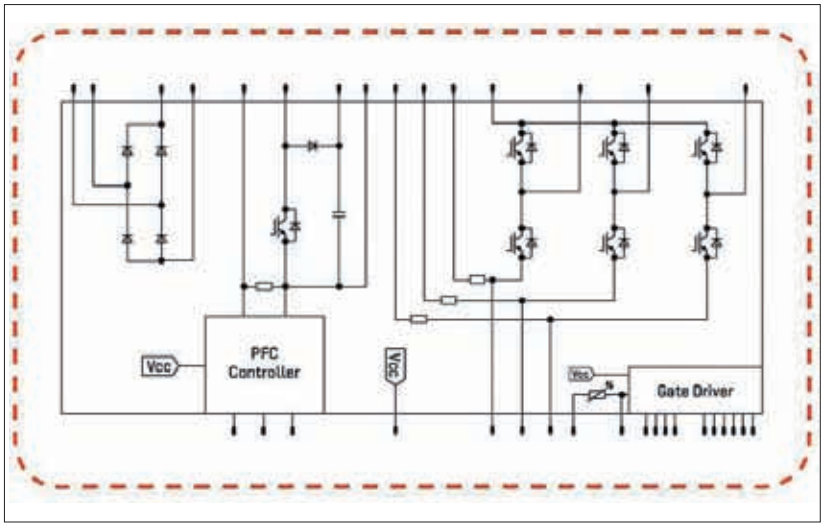
www.linear.com/product/LTC4013

Power Monitoring IC

Mouser Electronics stocks the MAX44299 low-side current, voltage and power monitoring IC from Maxim Integrated. The MAX44299 offers power, current, and voltage monitoring plus reference with precise measurement and programmable current-sensing of full-scale voltages of 5 mV, 10 mV and 20 mV. With its wide single supply voltage range from 3 V to 5.5 V, the MAX44299 allows simple sharing of supplies with either an analog-to-digital converter (ADC) or a microcontroller, and is an ideal solution to improve measurement quality while saving cost and space in a variety of power monitoring applications. The device offers instantaneous power with accurate power measurement of less than 1.1 % of reading total error. The MAX44299 features three outputs, all of which are scaled to a full-scale current of 100 µA. The device's reference output allows an additional output current of 100 µA, which can be set as a reference voltage for an ADC being used to measure power, voltage, and current signals. Having the MAX44299 use currents rather than voltage to convey the measured signals to the ADC also avoids any errors caused by voltage drops across the parasitic resistance of the PCB - a significant factor for high-current systems. The 16-bump, 2.4 mm × 2.4 mm MAX44299 IC is specified at a temperature range from 0 to 85°C.

www.mouser.com/new/maximamplifiers/maxim-max44299-amplifier

New IPM with CIP Topology



Vincotech offers a new Intelligent Power Module for 600 V applications. The flowIPM 1B CIP 600 V features a combination of a high-speed F5 IGBT with the switching performance of a MOSFET and a Silicon Carbide boost diode in the PFC circuit optimized for frequencies up to 150 kHz. The high-speed F5 IGBT, paired with the SiC boost diode in the PFC circuit, not only delivers impressive performance, it also drives down the cost of external passive components. The current rating of this new CIP (converter + inverter + power factor correction) topology housed in an

integrated power module is 10 A at 80°C heat sink temperature. The deeply integrated flowIPM 1B CIP 600 V module also features an inverter gate drive with a bootstrap circuit for high-side power supply, as well as emitter shunts (30 mΩ) for improved motion control. The new flowIPM 1B CIP 600 V modules come in 17 mm flow 1B housings. Versions in the 12 mm housing, with press-fit pins and phase-change material are available on request.

www.vincotech.com/en/products/new-products/2016/flowipm1bcip.html

Arbitrary 4-Quadrant Power Sources

www.rohrer-muenchen.de
Rohrer GmbH
Tel.: +49 (0)89 8970120

Busbars

www.auxel.com
Auxel FTG
Tel: + 33 3 20 62 95 20

Capacitors

www.psl-group.uk.com
PSL Group UK Ltd.
Tel +44 (0) 1582 676800

Certification

www.productapprovals.co.uk
Product Approvals Ltd
Tel: +44 (0)1588 620192

Connectors & Terminal Blocks

www.auxel.com
Auxel FTG
Tel: +44 (0)7714 699967

DC/DC Connverters

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

www.protocol-power.com
Protocol Power Products
Tel: +44 (0)1582 477737

Diodes

www.neutronltd.co.uk
Neutron Ltd
Tel: +44 (0)1460 242200

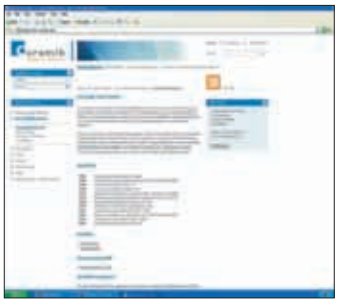
www.microsemi.com
Microsemi
Tel: 001 541 382 8028

www.voltagemultipliers.com
Voltage Multipliers, Inc.
Tel: 001 559 651 1402

Diodes

www.proton-electrotex.com/
Proton-Electrotex JSC/
Tel: +7 4862 440642;

Direct Bonded Copper (DPC Substrates)



www.curamik.co.uk
curamik® electronics GmbH
Tel: +49 9645 9222 0

Discrete Semiconductors

www.digikey.com/europe
Digi-Key
Tel: +31 (0)53 484 9584

www.microsemi.com
Microsemi
Tel: 001 541 382 8028

Drivers ICS

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

EMC/EMI

www.dextermag.com
Dexter Magnetic Technologies, Inc.
Tel: 001 847 956 1140

Ferrites & Accessories

www.dextermag.com
Dexter Magnetic Technologies, Inc.
Tel: 001 847 956 1140

GTO/Triacs

www.mark5.com
Mark 5 Ltd
Tel: +44 (0)2392 618616

Hall Current Sensors

www.dgseals.com
dgseals.com
Tel: 001 972 931 8463

Harmonic Filters

www.murata-europe.com
Murata Electronics (UK) Ltd
Tel: +44 (0)1252 811666

High Voltage and High Power Electronics

Dean Technology, Inc.
www.deantechnology.com
+1 (972) 248-7691

IGBTs

www.microsemi.com
Microsemi Tel: 001 541 382 8028

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

Line Simulation

www.hero-power.com
Rohrer GmbH
Tel.: +49 (0)89 8970120

Magnetic Materials/Products

www.dextermag.com
Dexter Magnetic Technologies, Inc.
Tel: 001 847 956 1140

www.rubadue.com
Rubadue Wire Co., Inc.
Tel. 001 970-351-6100

Mosfets

www.mark5.com
Mark 5 Ltd
Tel: +44 (0)2392 618616

www.microsemi.com
Microsemi
Tel: 001 541 382 8028

www.neutronltd.co.uk
Neutron Ltd
Tel: +44 (0)1460 242200

Optoelectronic Devices

www.digikey.com/europe
Digi-Key Tel: +31 (0)53 484 9584

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

Packaging & Packaging Materials

www.curamik.co.uk
curamik® electronics GmbH
Tel: +49 9645 9222 0

Power Amplifiers

www.rohrer-muenchen.de
Rohrer GmbH
Tel: +49 (0)89 8970120

Power ICs

www.digikey.com/europe
Digi-Key Tel: +31 (0)53 484 9584

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

Power Modules

www.psl-group.uk.com
PSL Group UK Ltd.
Tel +44 (0) 1582 676800

www.fujielectric-europe.com
Fuji Electric Europe GmbH
Tel: +49 (0)69-66902920

www.microsemi.com
Microsemi Tel: 001 541 382 8028

www.proton-electrotex.com/
Proton-Electrotex JSC/
Tel: +7 4862 440642;

Power Protection Products

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

Power Semiconductors

www.psl-group.uk.com
PSL Group UK Ltd.
Tel +44 (0) 1582 676800

www.proton-electrotex.com/
Proton-Electrotex JSC/
Tel: +7 4862 440642;

Power Substrates

www.universal-science.com
Universal Science Ltd
Tel: +44 (0)1908 222211

Resistors & Potentiometers

www.isabellenhuette.de
Isabellenhütte Heusler GmbH KG
Tel: +49/(27 71) 9 34 2 82

RF & Microwave Test Equipment.

www.ar-europe.ie
AR Europe
Tel: 353-61-504300

Simulation Software

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

www.universal-science.com
Universal Science Ltd
Tel: +44 (0)1908 222211

Smartpower Devices

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

Switched Mode Power Supplies

www.biaspower.com
Bias Power, LLC
Tel: 001 847 215 2427

Switched Mode Power Supplies

www.power.ti.com
Texas Instrumments
Tel: +44 (0)1604 663399

Thermal Management & Heatsinks

www.universal-science.com
Universal Science Ltd
Tel: +44 (0)1908 222211

Thermal Management & Heatsinks

www.psl-group.uk.com
PSL Group UK Ltd.
Tel +44 (0) 1582 676800

Thermal Management & Heatsinks

www.abl-heatsinks.co.uk
ABL Components Ltd
Tel: +44 (0) 121 789 8686

www.curamik.co.uk
curamik® electronics GmbH
Tel: +49 9645 9222 0

www.dau-at.com
Dau GmbH & Co KG
Tel: +43 3143 23510

www.power.ti.com
Texas Instrumments
Tel: +44 (0)1604 663399

Thyristors

www.mark5.com
Mark 5 Ltd
Tel: +44 (0)2392 618616

www.proton-electrotex.com/
Proton-Electrotex JSC/
Tel: +7 4862 440642;

ADVERTISERS INDEX

We look forward to seeing you

10-12 April 2018
NEC Birmingham

AIR-TECH EXHIBITION 2018 COMPRESSED AIR • VACUUM • GENERATORS

DRIVES & CONTROLS 2018 THE AUTOMATION, POWER TRANSMISSION & MOTION ENGINEERING EVENT

EUROPEAN OFFSHORE ENERGY 2018

FLUID POWER & SYSTEMS 2018 The Exhibition for Hydraulics & Pneumatics Industries

PLANT&ASSET MANAGEMENT 2018

SMART MACHINES & FACTORIES 2018

DFA Media Ltd · 192 High Street · Tonbridge · TN9 1BE · tel: +44 (0) 1732 370340 · info@dfamedia.co.uk

SEMIKRON
innovation + service

SEMITOP® E1/E2 - 2nd Generation

Industry Standard Packages for Supply Chain Safety

Wide product portfolio up to 55kW

- Highest supply chain safety
- Multiple sources down to chip level on offer
- Optimum thermal footprint/heat spreading
- Low inductance case for optimised switching performance
- Flexible architecture thanks to PinGrid layout philosophy

Motor Drives | Solar Energy | AC | DC Power Supplies | Utility Vehicles

www.semikron.com

shop.semikron.com