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POWER SUPPLY DESIGN
94%-Efficient Offline Flyback Switcher IC Family

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Also inside this issue

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COVER STORY

94%-Efficient Offline Flyback Switcher IC Family

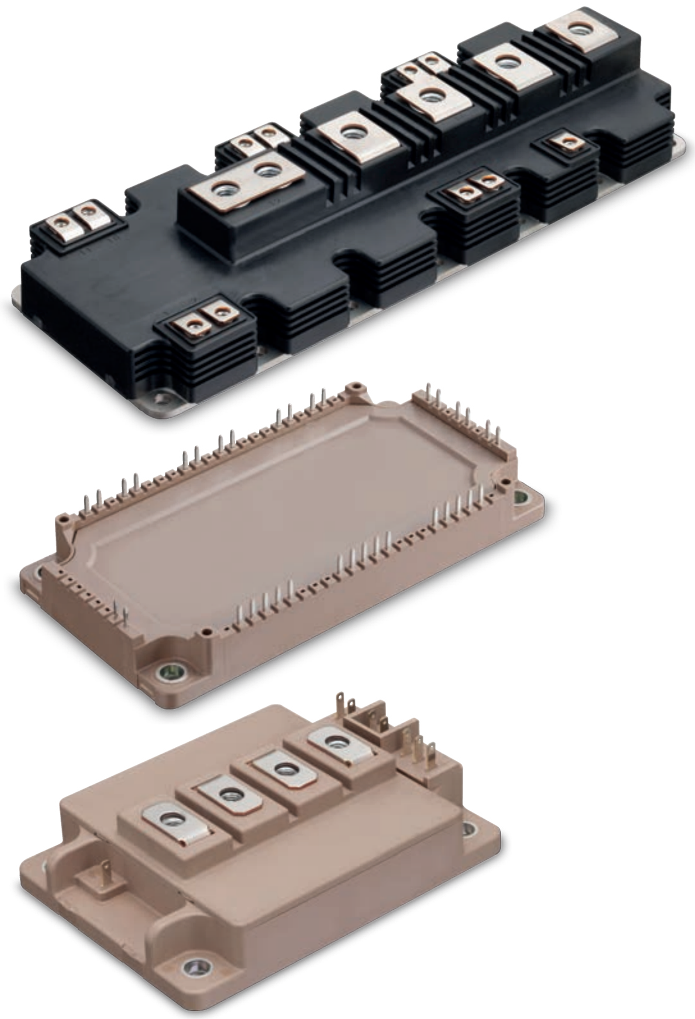
Power Integrations announced its InnoSwitch™3 family of offline CV/CC flyback switcher ICs. The new devices achieve up to 94 % efficiency across line and load conditions, slashing power supply losses by a further 25 % and enabling the development of compact power supplies up to 65 W without heatsinks. InnoSwitch3 devices are intended for power supplies with challenging energy consumption, footprint or thermal constraints, particularly those targeting mandatory Total Energy Consumption (TEC) specifications. These flyback switcher ICs employ isolated digital communications technology, called FluxLink™, plus synchronous rectification, quasi-resonant switching and a precise secondary-side feedback sensing and control circuit. This results in highly efficient, accurate, reliable power supply circuits without the need for optocouplers. InnoSwitch3 devices are CCC, UL and VDE safety-certified to bridge the isolation barrier, and the InSOP™-24 package provides a low-profile, thermally efficient solution with extended 11.5 mm creepage and clearance between primary and secondary sides for high reliability, surge and ESD robustness. More on page 16.

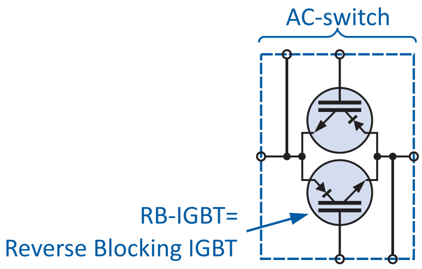
Cover image supplied by Power Integrations, USA

Fuji Electric

3-Level IGBT-Modules

Highest Efficiency in Class





FEATURES

- Lower system costs
- Less harmonics
- Higher efficiency
- Reduction of noise

REVERSE BLOCKING-IGBT (RB)

- FUJI RB-IGBT implements RB capability without additional diode
- Lower losses
- Higher power density per module
- Authentic RB-IGBT technology is only available by FUJI
- Available as 600 V, 900 V, 1200 V

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A Changing Landscape

Power electronics markets are steady evolving and are continuously diffusing its innovations through the overall semiconductor industry. Thus the power semiconductor industry reached $28 billion in 2016. The IGBT market grew 8 % from 2015 to 2016. In 2017, it is expecting spectacular growth, higher than 10 %. Solar and EV/HEV power converter markets have again increased by over 20 % in2016, driving the growth of the power electronics market. Thus it is not a surprise that Chinese companies are trying to acquire know-how in IGBT and power MOSFET manufacturing through M&A.

At the semiconductor level, the power semiconductor market grew by 3.8 % compared to 2015. Among all the different types of power devices including thyristors, MOSFETs, IGBTs and power ICs, IGBTs made the greatest progress, with around 8 % growth. Power devices fuel and enable industry mega-trends reaching almost $35 billion in 2022. Yole expects the IGBT market to go over $ 5 billion by 2022 with a major growth coming from IGBT power module. The high performance that SiC and GaN materials can afford is already creating a battlefield with Silicon based IGBT. To overcome this thread, Si IGBT manufacturers need to look for prompt solutions as technologically update their systems for better efficiency or to increase their IGBT portfolio offer. The IGBT industry will follow power electronics' growth pattern, mainly caused by the high volume automotive market, especially for the electrification of powertrains in EV/HEV. This sector has great growth prospects because it is still an emerging market with tremendous volume potential. Another big sector for IGBTs is clearly motor drives, which keep on growing, thanks to aggressive regulation targets. Yole forecasts a 4.6 % CAGR for motor drives from 2016 to 2022. Photovoltaics and wind are very dynamic markets with growth from huge installations being installed during the last few years. It is worth to say that China led the solar panel implementation in 2016, with an impressive 35 GW installed.

According to market leader Infineon demand is particularly strong for the power semiconductors for various applications ranging from renewables to data centers. The market for electro-mobility also continues to accelerate. "During the nine-month period ended June 2017 we acquired almost twice as much new business in this area for the coming five to ten years as in the entire previous fiscal year. We are a leader in IGBTs for hybrid and electric cars, a technology which will prevail in this application for years to come. We are further expanding our strong position in this market. Overall, we confirm our outlook for the current fiscal year, despite strong headwinds caused by the weaker US dollar", so Reinhard Ploss, CEO of Infineon. The Automotive revenue declined by 2 percent to €766 million in the third quarter of the 2017 fiscal year, compared with €783 million in the previous three-month period. Demand for the segment's products remained stable, with the slight quarter-on-quarter dip in revenue reflecting mainly the weaker US dollar. Revenue generated with products for hybrid and electric vehicles continued to grow quarter-on-quarter. Demand for components installed in driver assistance systems was also slightly higher than in the preceding quarter. The Industrial segment revenue rose by 10 percent from €293 million in the second quarter to €321 million in the third quarter. Demand continued to develop very positively for products used in home appliances, photovoltaics, uninterruptible power supplies, traction, electric drives and wind power. The Power Management segment revenue grew by 7 percent from €520 million to €557 million quarter-on- quarter, mainly reflecting rising demand for products in the fields of AC/DC and DC/DC conversion.

Even if the IGBT has almost reached its technological limit, new designs and new materials can still be used to improve system performance to overcome the WBG devices arrival. In coming years, there will be new IGBT designs from Infineon, Fuji or ABB coming into the market. Packages are being improved by different manufacturers to decrease parasitics and improve system efficiency. A clear example is the introduction of the embedded techniques for discrete IGBTs and overmolded solutions for IGBT modules to reduce size or increase functional density. As IGBTs is a mature technology, the supply chain is well established, with strong partnerships and companies well positioned in each level. However, more companies are entering the IGBT market in order to capture added value, like Littelfuse, who just announced the agreement on the acquisition of IXYS Corporation. Today, much power device novelty comes from a new family of WBG semiconductors, SiC and GaN. WBG benefits such as the performance and market needs accelerate their adoption in more and more applications. Yole expect an increase of WBG market revenues reaching with over 30 % CAGR between 2016 and 2022.

PV applications seem to accept widely SiC products. Indeed SiC solutions propose a better performance/cost ratio at the system level for string PV inverters. In parallel, for xEV applications, leading Chinese xEV supplier BYD has confirmed that they are using SiC on their on board charger. SiC is on the road, but not only for the trial. On-board charger is embracing SiC technology and SiC devices' pre-2020 market volume in automotive applications will mainly be for on-board chargers. On the other hand, the situation remains the same as 2016 for main inverters: almost all the OEMs and Tier-1s are testing SiC devices. Some pioneers like Toyota, Nissan, and Honda will probably release SiC-based solutions around 2020. After 2020, due to the high power rating of main inverter, even low adoption rate will contribute to important revenue after 2020. Together with the development of xEV market, charging infrastructure is emerging as an interesting market for SiC.

We are on the forefront of these developments and keep our readers informed on-time. Enjoy reading of the following pages!

Achim Scharf
PEE Editor

Power Semiconductors Approaching 30 Billion Dollars

The power electronics industry is a key part of the semiconductor history. Power electronics markets are steady evolving and are continuously diffusing its innovations through the overall semiconductor industry. Thus the power semiconductor industry reached $28 billion in 2016.

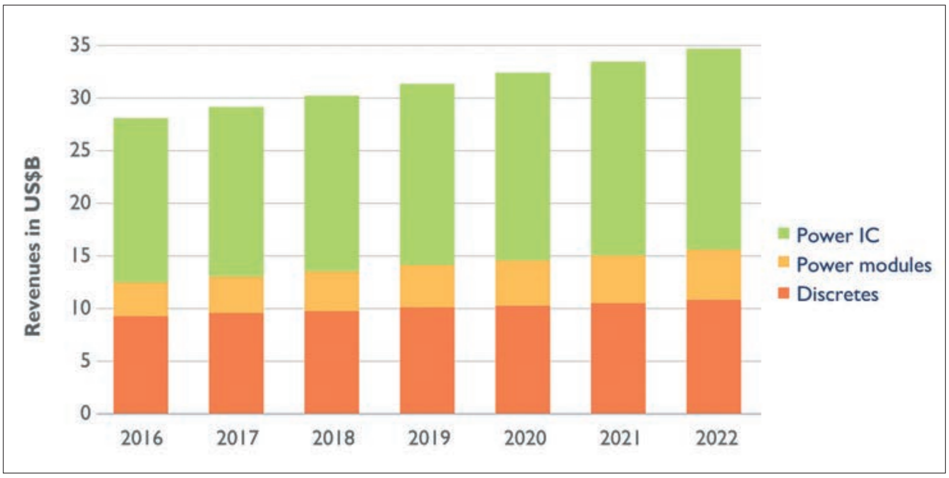
The IGBT market grew 8 % from 2015 to 2016. In 2017, it is expecting spectacular growth, higher than 10 %. Solar and EV/HEV power converter markets have again increased by over 20 % in2016, driving the growth of the power electronics market. Thus it is not a surprise that Chinese companies are trying to acquire know-how in IGBT and power MOSFET manufacturing through M&A.

Numerous mergers and acquisitions (Fairchild Semiconductor and On Semiconductor, Linear Technology and Analog Devices, both in 2016), the emergence of GaN technology, the adoption of SiC solutions (BYD is now proposing SiC-based on-board chargers) illustrate quite well the dynamism of the power electronics industry. This evolution starts with the development of new active devices and goes through the new packaging techniques up to the performance improvement of the power systems. "The power electronics sectors continue to expand their presence almost everywhere, renewable energies and e-mobility, including EV/HEVs, are especially boosting this market. Both solar and EV/HEV converter markets grew by over 20 % between 2015 and 2016," stated Mattin Grao Txapartegi, Technology & Market Analyst at Yole.

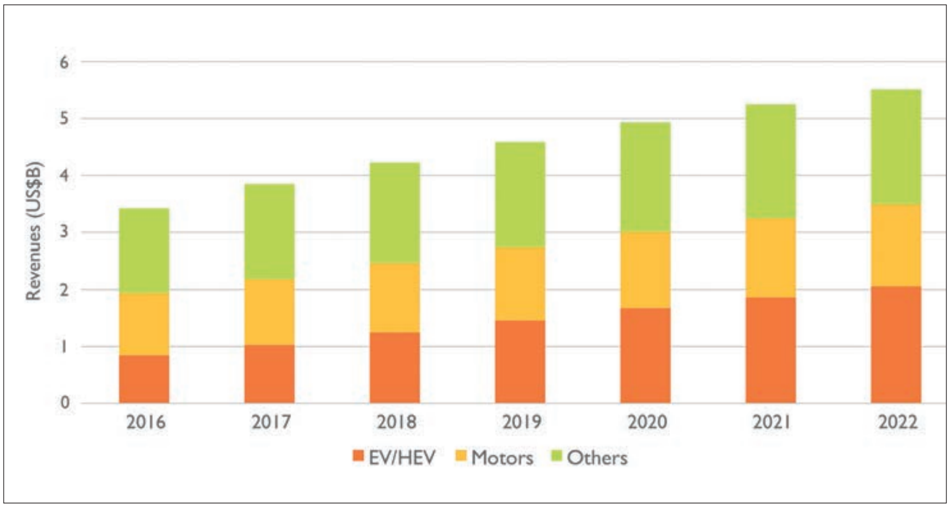
At the semiconductor level, the power semiconductor market grew by 3.8 % compared to 2015. Among all the different types of power devices including thyristors, MOSFETs, IGBTs and power ICs, IGBTs made the greatest progress, with around 8 % growth. Power devices fuel and enable industry mega-trends reaching almost $35 billion in 2022. Yole expects the IGBT market to go over $ 5 billion by 2022 with a major growth coming from IGBT power module. The high performance that SiC and GaN materials can afford is already creating a battlefield with Silicon based IGBT. To overcome this thread, Si IGBT manufacturers need to look for prompt solutions as technologically update their systems for better efficiency or to increase their IGBT portfolio offer.

IGBTs to stay

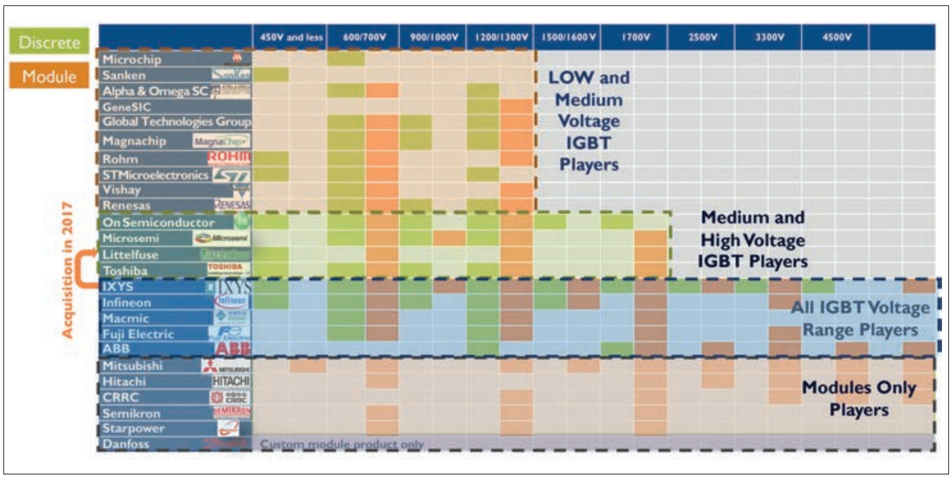
Currently, IGBT manufacturers can have wide voltage ranges in their portfolios, going from 400 V to 6.5k V. The 400 V IGBTs will directly compete with MOSFETs, whereas IGBTs with voltages higher than 600 V will compete with SJ MOSFETs and WBG devices, which exhibit advantages over IGBTs. Lower voltage IGBTs will not be developed



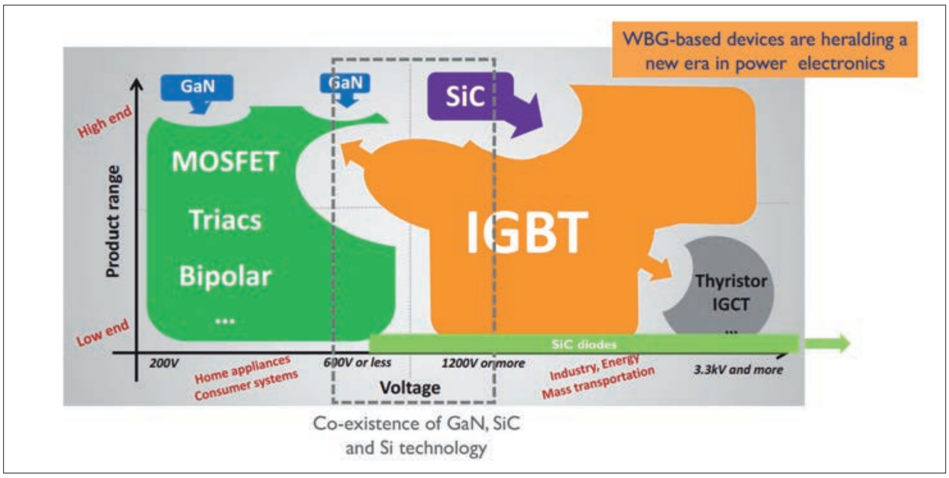
Market size for power semiconductors 2016 – 2022 Source: Yole Juli 2017



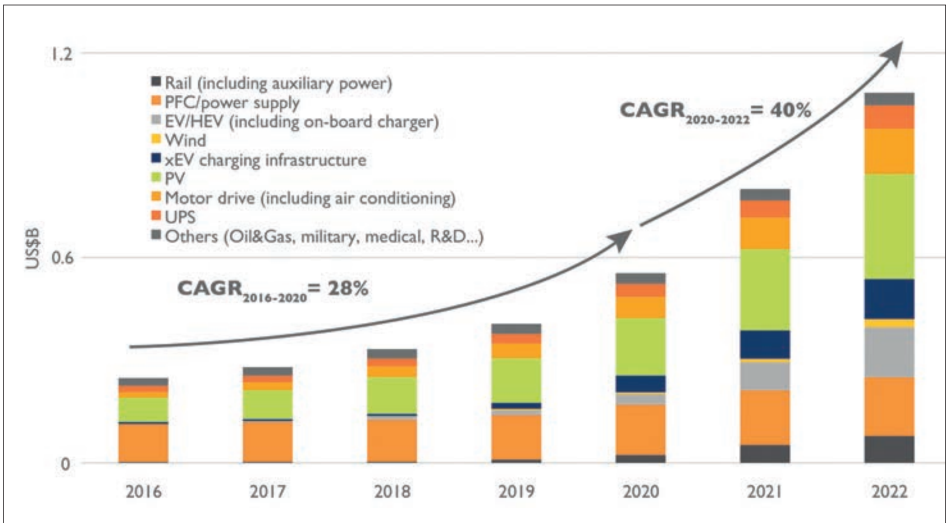
IGBT market evolution by application 2016 – 2022 Source: Yole August 2017



IGBT supply chain and players by voltage Source: Yole August 2017



Power semiconductor market positioning by 2023 **Source: Yole Juli 2017**



SiC device market size by application 2016 – 2022 **Source: Yole August 2017**

Current full SiC power module examples **Source: Yole August 2017**

since they do not show any advantage compared with MOSFETs.

"The IGBT industry will follow power electronics' growth pattern, mainly caused by the high volume automotive market, especially for the electrification of powertrains in EV/HEV ", asserted Ana Villamor, Technology & Market Analyst, Power Electronics. "The EV/HEV sector has great growth prospects because it is still an emerging market with tremendous volume potential." Another big sector for IGBTs is clearly motor drives, which keep on growing, thanks to aggressive regulation targets. Yole forecasts a 4.6 % CAGR for motor drives from 2016 to 2022. Photovoltaics and wind are very dynamic markets with growth from huge installations being installed during the last few years. It is worth to say that China led the solar panel implementation in 2016, with an impressive 35 GW installed.

Even if the IGBT has almost reached its technological limit, new designs and new materials can still be used to improve system performance to overcome the WBG devices arrival. In coming years, there will be new IGBT designs from Infineon, Fuji or ABB coming into the market. Packages are being improved by different manufacturers to decrease parasitics and improve system efficiency. A clear example is the introduction of the embedded techniques for discrete IGBTs and overmolded solutions for IGBT modules to reduce size or increase functional density.

As IGBTs is a mature technology, the supply chain is well established, with strong partnerships and companies well positioned in each level. "Therefore, the main IGBT manufacturers that we included in our 2015 report are still in the IGBT best sellers, except ON Semiconductor, which has become one of the top five IGBT vendors after the acquisition of Fairchild at the end of 2016", explained Villamor. "However, more companies are entering the IGBT market in order to capture added value, like Littelfuse, who just announced the agreement on the acquisition of IXYS Corporation."

SiC is coming

"Today, much power device novelty comes from a new family of WBG semiconductors, SiC and GaN", said Villamor. "WBG benefits such as the performance and market needs accelerate their adoption in more and more applications. At Yole, we expect an increase of WBG market revenues reaching with over 30 % CAGR between 2016 and 2022." Yole's analysts announced a 6 % SiC CAGR between 2016 and 2022 . Moreover, new applications are driving the adoption of SiC solutions.

"The total SiC device market will be worth more than $1 billion in 2022", said analyst Hong Lin. "Indeed the market growth is going to accelerate after 2020, with a 40 % CAGR from 2020 to 2022." Applications like PFC /power supplies and photovoltaic inverters are driving the SiC market growth today. In the future, xEV related applications, rail and others will also contribute to the market evolution. PFC/power supply market segment is still the leading SiC application. However, its market share is expected to decrease gradually because of the penetration of new applications within the SiC industry.

Besides WBG devices, many other innovations are also emerging, as in power module packaging. Needs for higher power density and more highly integrated products have made some traditional technologies and materials outdated. Package evolution is responding to stricter requirements at the system level, and as ever here the automotive industry is driving innovation and growth.

PV applications seem to accept widely SiC products. Indeed SiC solutions propose a better performance/cost ratio at the system level for string PV inverters. In parallel, for xEV applications, leading Chinese xEV supplier BYD has confirmed that they are using SiC on their on board charger. SiC is on the road, but not only for the trial. On-board charger is embracing SiC technology and SiC devices' pre-2020 market volume in automotive applications will mainly be for on-board chargers.

On the other hand, the situation remains the same as 2016 for main inverters: almost all the OEMs and Tier-1s are testing SiC devices. Some pioneers like Toyota, Nissan, and Honda will probably release SiC-based solutions around 2020. After 2020, due to the high power rating of main inverter, even low adoption rate will contribute to important revenue after 2020. Together with the development of xEV market, charging infrastructure is emerging as an interesting market for SiC. Globaly, charging infrastructure are deployed fast in EU, US and Japan. However, the development is especially impressive in China.

Norstel Completes 150 mm SiC Wafer Development

Norstel AB, Sweden, announces the development of low defect density 150 mm Silicon Carbide (SiC) n-type substrates.

"With a micropipe density (MPD) below 0,2 cm² and a Threading Screw Dislocation (TSD) density below 500 cm², our first 150 mm conductive 4H SiC substrates demonstrate our commitment to quality as an enabler for high yield device processing" said CTO Alexandre Ellison. The company states that it has prioritized wafer quality over time to get to the next wafer size. As a result, emphasis was given in R&D to first decrease the dislocation density in the SiC wafers prior to diameter expansion from 100 mm to 150 mm. First 150 mm samples will be available by 1st quarter 2018. "We now have achieved to preserve the high quality during the expansion to 150 mm. In light of the growing market demand for SiC based energy efficient power electronics solutions in applications like PVs, EVs/HEVs, charging infrastructure, trains, energy storage and many more the SiC device and module industry scales up to meet such demand. Larger diameter and lower defect SiC wafers will enable them to increase production efficiency, device yields and volume supply capability to meet their customers' expectations", added CCO Ronald Vogel. Norstel manufactures conductive and semi-insulating silicon carbide wafers and SiC epitaxial layers deposited by CVD. The company produces state-of-the-art n-type and semi-insulating SiC substrates and provides services such as epitaxy, wafer characterization and polishing. Target applications include SiC diodes and switches for Power Electronics and GaN/SiC devices for RF components.

Positive Outlook for Global Electric Motor Market

The global electric motor market is looking up as favourable economic conditions, a recovery in machinery production, and a focus on premium efficiency designs provide a much-needed boost to the industry.

According to IHS Markit, a longstanding contributor to CWIEME exhibitions, global economic growth is expected to increase from 2.5 % in 2016 to 2.9 % in 2017. In a seminar at the recent CWIEME Berlin exhibition, IHS senior analyst Andrew Orbinson revealed how the US economy, in particular, is set to accelerate as capital spending growth resumes, corporate and personal income tax rates decrease in 2018, and the US dollar strengthens against most other currencies in early 2018. This growth signals good news for participants at CWIEME Chicago, North America's leading exhibition for coil winding, transformer and electric motor manufacturing, which has been held in Rosemont, Il. October 3-5. Elsewhere, the outlook is less assured with continued economic uncertainty in Europe. IHS does not anticipate Brexit to restrain UK growth but political instability and banking problems are risks to both UK and Eurozone growth. In Western Europe, interest rates are expected to remain low as governments and central banks look to boost the economy. China's economic slowdown is set to continue despite increased commodity prices due to imbalances in credit, housing, and industrial markets. Russia and Brazil will begin to recover in 2017.

Following the decline in machinery production between 2015 and 2016, IHS anticipates a slow recovery between 2017 and 2021. Machinery production growth is predicted to reach 3.9 % in 2021 in the US and 4 % in the Americas as a whole. This compares to 2.4 % in Germany and 2.5 % in Europe, as well as 7.5 % in China and 6 % in Asia Pacific. Germany and China are slightly ahead of the curve, registering growth in 2016 but all major markets are forecast to increase.

According to IHS data, a total of 39.8 million electric motors are expected to be shipped in 2017, with ABB, Siemens and WEG claiming the top three spots as the world's leading suppliers. Asia is set to account for 42 % of electric motor revenue, while EMEA (Europe, Middle East, and Africa) takes 31 % and the Americas 27 %. Between 2016 and 2021, revenue is expected to achieve a compound annual growth rate (GAGR) of 3.0 % in Asia, 1.7 % in the Americas, and 1.6 %

CWIEME North America reflected the anticipated growth in the global electric motor market

in EMEA. These figures show a significantly better picture than in 2016.

Prices for electric motors are predicted to remain competitive as regional players develop their efficiency capabilities over the coming years. IHS reports that prices for electric motors in the IE3 efficiency class are 20 % higher than for IE2 motors, and as the higher-priced premium-efficiency IE3 motors become more prevalent, average selling prices will increase. IHS also anticipates that as steel prices see a return to growth in late 2017, motor manufacturers will pass higher supply chain costs onto their customers. This is likely to have a long-term impact on pricing.

The US was the first market to introduce a requirement for IE3 efficiency level motors (controlled by frequency inverters) in 2011. In 2015, the European Union passed legislation that 2.5 kW-375 kW electric motors must reach IE2 if they have a variable frequency drive; otherwise, they must reach IE3. In 2017, this requirement was extended to electric motors in the 0.75 kW-7.5 kW category. By 2020, the EU plans to require IE3 efficiency for all motors in its Lot #30 Proposal. IHS does not expect US and EU requirements for IE3 efficiency class motors to restrict the global IE2 motor market before 2020, however, as the majority of regions still accept IE2 motors.

In 2016, IE2 motors accounted for 35 % of the global low-voltage motors market. By 2021, IHS predicts this share to grow to 43 %. IE1 motors, meanwhile, are gradually being phased out due to the increased focus on efficiency in Western Europe, North America, and China. Shipments of IE1 motors reduced significantly between 2014 and 2016 from 44 % of the total market to 38 %. By 2021, this share is expected to drop further to 24 %. The fastest growing class is IE4, which is predicted to grow from less than 1 % in 2016 to 2 % in 2021. The small starting point means that it is set to grow at a much quicker pace.

Transition from DC brushed to DC brushless motors

When it comes to motor type, IHS expects DC brushless motors to overtake DC brushless motors as the most common design over the next five years. DC brushed motors currently account for 46.2 % of the global electric motor market, while DC brushless motors account for 44.8 %. Between 2016 and 2021, DC brushed motors are expected to achieve a CAGR of 2.7 % but DC brushless motors are predicted to grow by 5.4 %. This transition trend is primarily observed in powertrain, chassis, and airflow applications. For example, electric power steering (EPS) has replaced hydraulic power steering in many new vehicles due to the fuel economy adavantage. Brushed DC motors are still the preferred type, however, for inexpensive, reliable applications, such as power seating and power locks, although some motor suppliers are collaborating with OEMs to develop DC brushless motors for these applications as well.

The market for stepper motors – currently 7.1 % of the total – is also set to grow at a CAGR of 4.5 % by 2021, while the biggest growth category is set to be traction motors, again because of their low starting percent of 2.0 % global market share. These motors are expected to achieve a CAGR of 43.1 % 2016-2021.

"The anticipated growth in the global electric motor market spells excellent news for members of the coil winding and electric motor manufacturing community – both in selling more products and commanding a higher price for them," said Haf Cennydd, CWIEME portfolio director. "We are committed to supporting this growth by faciliting the right business connections and sharing the knowledge that drives positive change."

Littelfuse Acquire IXYS

Littelfuse will acquire all of the outstanding shares of IXYS in a cash and stock transaction. The transaction represents an equity value of approximately $750 million. Under the terms of the agreement, each IXYS stockholder will receive per IXYS share either $23.00 in cash or 0.1265 of a share of Littelfuse common stock, subject to proration. In total, 50 % of IXYS stock will be converted into the cash election option and 50 % into the stock election option.

"As the largest acquisition in our 90-year history, this is an exciting milestone for Littelfuse," said CEO Dave Heinzmann. "IXYS' extensive power semiconductor portfolio and technology expertise fit squarely within our strategy to accelerate our growth within power control and industrial OEM markets. The combination of Littelfuse and IXYS unites complementary capabilities, cultures and relationships." The transaction is expected to close in the first calendar quarter of 2018 and is subject to the satisfaction of customary closing conditions, including regulatory approvals and approval by IXYS stockholders. Littelfuse expects to finance the cash portion of the transaction consideration through a combination of existing cash and additional debt.

IXYS acquisition by Littelfuse turns again the IGBT landscape upside down. Therefore, the leading position of Infineon Technologies forces IGBT players to reinforce their technical expertise and their market position and consider collaborations and/or acquisitions. Littelfuse is developing circuit protection with growing global platforms in power control and sensing. IXYS is strongly involved in the development of power semiconductors, solid-state relays, high voltage integrated circuits, and microcontrollers. Both companies have strong synergies: they have for example the same customers' portfolio composed of the electronics, automotive and industrial companies. Under this merger, their aim is to propose a relevant combination of their technical expertise and create value for their common customers' portfolio to become a key IGBT player. With this acquisition, Littelfuse gradually enlarges its role within the IGBT market and takes clearly part in the market consolidation. This acquisition is also supporting Littelfuse's activities in power module design. Low inductance and good thermal performance become today a "must-have" to sell power devices.

"Power packaging is now a key knowledge that must be optimized to obtain good performance at the module level", commented Pierric Gueguen, Business Unit Manager at Yole. "Power packaging management will clearly accelerate the adoption of innovative technologies including WBG . Thus it is not a surprise to see many leading power electronics companies to move towards this level of the power electronics supply chain. Thus Littelfuse confirms its penetration within the SiC industry, initially initiated with its strong investments in Monolith Semiconductors in March 2017. "Today's SiC market is still dominated by discrete devices. However, that situation will soon change, explained Yole's analysts. "Hybrid modules are already penetrating some applications and full SiC modules are coming with dedicated packaging solutions. Today a comprehensive analysis of IXYS and Littelfuse patent portfolios reveals the complementarity of their expertise and positioning focused on IGBT market segment as well as their strategy to offer dedicated SiC-based products in a near future."

Superjunction MOSFETs and SiC Diodes Optimise Power Conversion Performance

The latest advances in superjunction MOSFETs and Silicon Carbide diodes give designers extra freedom to optimize performance and efficiency in cost-sensitive power-conversion applications.

In the drive to continue increasing energy efficiency in switching power-conversion systems such as PFC and switching power supplies, superjunction MOSFETs and wide-bandgap Silicon Carbide (SiC) diodes have become favored solutions for energy-conscious designers. Both technologies have allowed smaller die sizes in relation to key parameters such as MOSFET on-resistance and diode reverse voltage, enabling designers also to reduce circuit size and increase current density. As market adoption of these device technologies continues to grow, new demands are coming to the fore, such as improved noise performance.

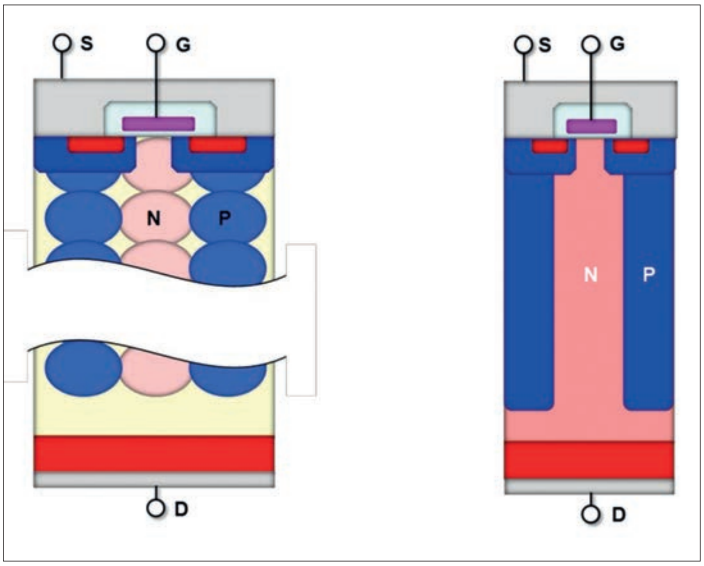
Reducing electromagnetic noise emission is desirable in high-end power supplies for equipment such as LCD TVs, LED lighting, medical power supplies, notebook power adapters and power supplies for tablets. Resonant switching topologies, such as the LLC converter with zero-voltage switching, are popular for these types of applications for their inherently low electromagnetic emissions. Primary-side switching in an LLC circuit as shown (MOSFETs Q1 and Q2), is often now handled by superjunction transistors to achieve a compact and energy-efficient power supply.

Superjunction transistor progress

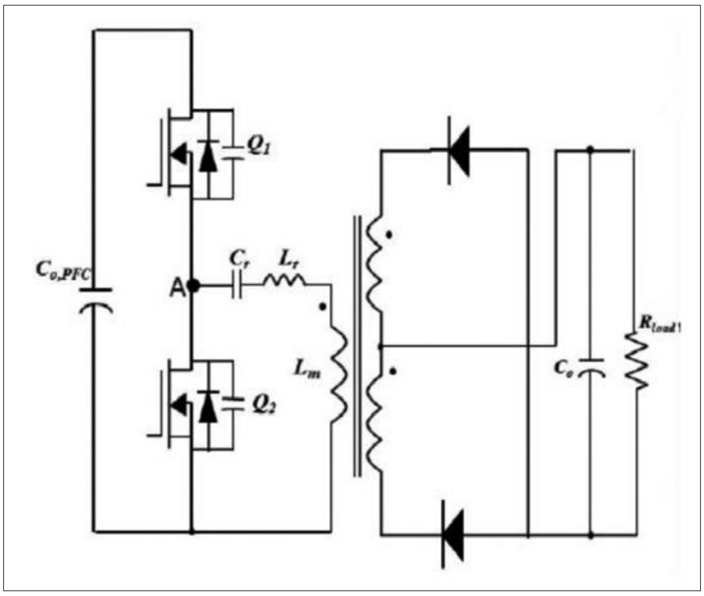
The superjunction MOSFET has enabled power supply designers to benefit from significantly lower conduction loss for a given die size than is achievable using conventional planar Silicon MOSFETs. Because the device architecture also allows low gate charge and capacitance, superjunction MOSFETs also exhibit lower switching losses than conventional silicon transistors.

Early superjunction devices have traditionally been fabricated using a multi-epitaxial process. Rich doping of the N-region allows much lower on-resistance than is achievable in conventional planar transistors. The P-type regions bounding the N channel are architected to achieve the desired breakdown voltage.

The N- and P-type structures of these devices have been fabricated using multi-epitaxial processes that have resulted in dimensions that are larger than



Multi-epitaxial superjunction MOSFET (left) and single-epitaxial MOSFET



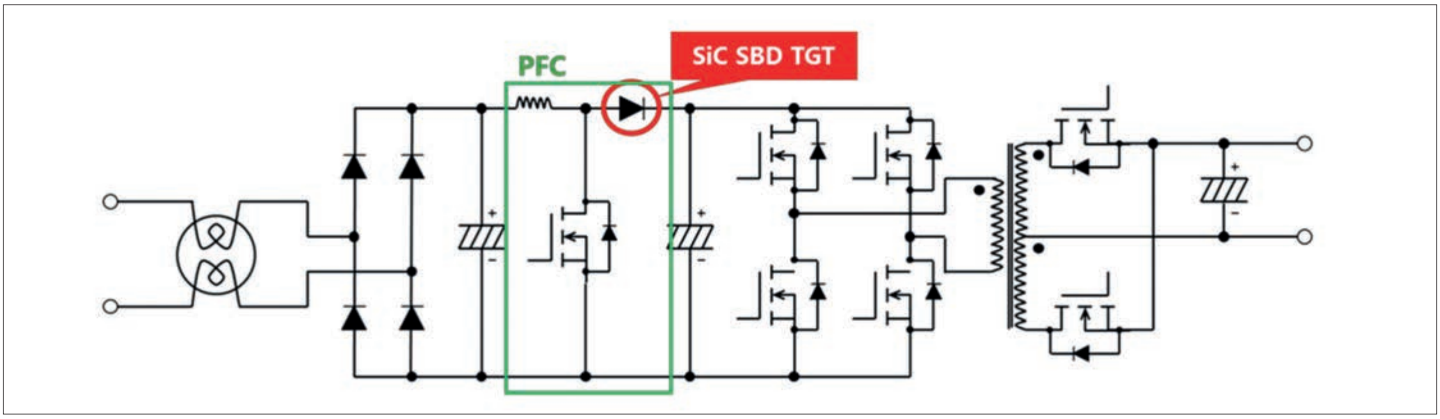
Primary-side superjunction transistors boost the efficiency of high-end LLC-resonant PSUs

ideal and have an associated impact on overall device size. The nature of the multi-epitaxial fabrication also restricts engineering of the N-channel to minimize on-resistance. Improved fabrication processes, such as deep trench filling that enables single-epitaxial fabrication, now give designers greater freedom to optimize the aspect ratio of N- and P-channels and so further minimize on-resistance while also reducing MOSFET size.

Toshiba's fourth-generation DTMOS IV takes advantage of single epitaxy to achieve a 27 % reduction in device pitch at the same time as reducing on-resistance per die area by 30 %. Also DTMOS V is based on the deep trench process, with further improvements at cell structure level. The single-epitaxial process also enables superjunction MOSFETs to deliver more stable performance in relation to temperature change. Ultimately, this helps to counter the typical reduction of efficiency experienced in power converters at higher operating temperatures.

Meeting demands for lower EMI

With the arrival of fifth-generation DTMOS V devices, designers can now choose superjunction MOSFETs that deliver low-noise performance suitable for use in power converters. DTMOS V FETs also display a well-balanced ratio of lower noise performance and switching performance. This is achieved through a modified gate structure and patterning, which results in increased reverse transfer capacitance seen between the gate and drain (C_{rss} or C_{gd}). Emitted noise is comparable to that experienced with competing low-EMI devices, while at the same time the devices deliver the superior on-resistance that



SiC diode technology can be used in conjunction with a high-speed superjunction MOSFET to boost the efficiency of PFC circuitry

characterizes superjunction technology.

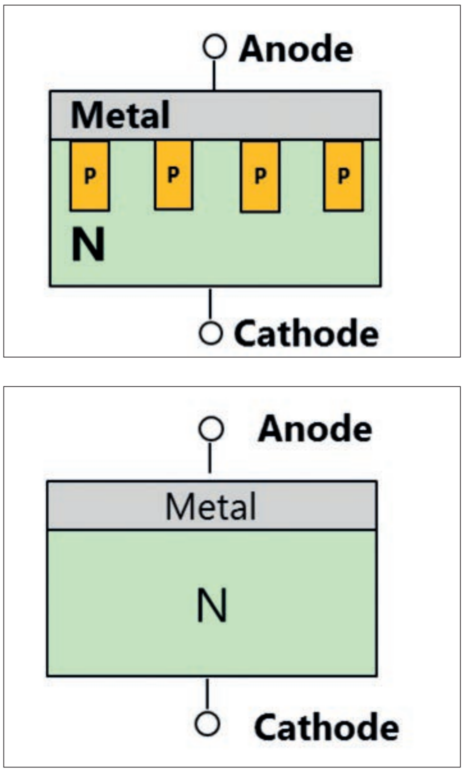
The superjunction process itself, and DTMOS technology in particular bring other substantial benefits to designers of power electronics. The fundamental figure-of-merit (FOM) of resistance x chip size shows a 30 % improvement over DTMOS III, leading to smaller $R_{DS(ON)}$ chips in the same package.

By applying the new, single epitaxial process to DTMOS, the effects of temperature on RDS(ON) are reduced, thus ensuring better and more consistent performance in power applications. When compared to the previous generation of DTMOS, $R_{DS(ON)}$ is some 15 % lower at maximum operating temperature. This saves costs by allowing for less stringent heat management requirements.

The fast body diode built in to DTMOS IV achieves fast recovery times in the range of 140 ns, even at high temperature. This results in lower power losses, less heat generation and a more thermally efficient design. The superjunction process also reduces the output capacitance, C_{OSS}, by 12 %, leading to a reduction in the waste energy being stored in the device (that has to be dissipated during each and every switching cycle). This makes DTMOS IV ideal for the fast-switching and resonant topologies commonly found in power designs. Hard-switching applications such as Power Factor Correction (PFC) benefit in terms of increased efficiency from the 45 % reduction in gate-drain charge (Q_{gd}) found in the X-Series.

DTMOS product range

The fifth-generation of Toshiba's DTMOS range, DTMOS V, was announced in December 2016, adding further performance improvements to the DTMOS IV range, including a further 17 % improvement in $R_{DS(ON)}$ and greater



Enhanced architecture of the SiC SBD (top) in comparison with the standard Silicon SBD architecture (bottom)

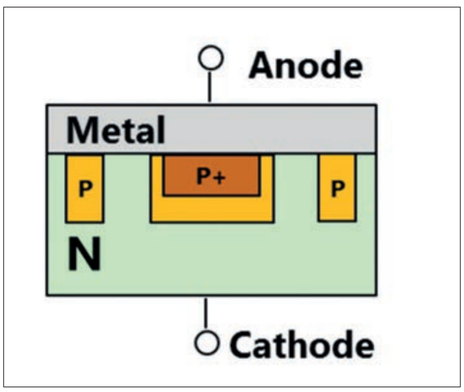
optimization of the trade-off between switching performance and EMI noise. The DTMOS range encompasses a wide variety of package type options offering both pin-in-hole and surface mount options, giving convenience and compatibility with a wide variety of manufacturing processes. The range includes industry-standard options such as D-PAK, D2-PAK, TO-220 and TO-247 as well as other types.

The DTMOS IV series offers VDSS options from 500 to 650V with 800V versions currently under development. Current handling capability extends to 100 A in the high-performance TK100L60W, available in a TO-3P(L) package, approaching 800W. Unsurprisingly, the TK100L60W also offers the best RDS(ON) value in the range - an ultra-low 0.018 Ω. The trade-off in this device is the relatively high output capacitance (C_{oss}) and gate charge (Q_g) of 320 pF and 360 nC, respectively.

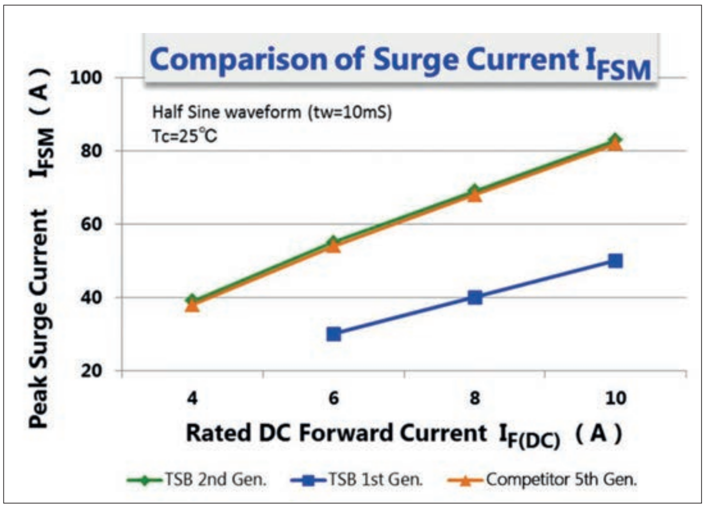
However, many devices in the series offer far lower switching loss performance with the TK5Q60W standing out with C_{oss} and Q_g values of 10 pF and 10.5 nC. The recently announced DTMOS V series offers a more focused range, initially packaged in the highly popular TO-252 (DPAK) and TO-220SIS formats. In moving to the latest series, the product naming conventions have changed and the $R_{DS(ON)}$ value now replaces the drain current (I_D) in the part number. While, at one level, this is a detail, it also communicates the importance Toshiba places on continually reducing this critical parameter for future, high-performance, power systems.

Diodes toughen up with SiC advances

Complementing the high efficiency and current density of deep-trench



Optimising the SiC P+ region in the second-generation 650V SiC SBD



IFSM capability comparison between 1st gen and 2nd SiC generation

superjunction power switches, new generations of SiC diodes combine inherently superior energy efficiency compared to standard silicon devices with increased current density, higher current ratings and greater robustness, and enhanced cost-performance ratio.

The properties of SiC enable SiC Schottky Barrier Diodes (SBDs) to deliver fast and temperature-stable reverse-recovery comparable to that of conventional Silicon diodes. The latter can result in thermal instability if reverse-voltage derating is not applied. In addition, the wide bandgap property of SiC allows the device to have a higher voltage rating in relation to die size, enabling 650 V and 1200 V devices to be housed in industry-standard surface-mount and through-hole packages. This combination of characteristics makes SiC diodes ideal for applications such as power-factor correction, in conjunction with a high-speed superjunction MOSFET.

Emerging generation

The key targets for the latest generation of 650V SiC SBDs have been to increase performance in relation to device cost, and to raise the maximum forward-current surge capability and thus deliver more robust devices that are capable of surviving harsh exception conditions.

As with LSI semiconductors, power semiconductor die size is a key determinant of device cost. Development of the second-generation SiC SBD architecture has focused on reducing the die thickness. The result has been to reduce thickness by two-thirds, bringing an attendant cost saving, while also raising current density by a factor of up to 1.5.

To increase the surge-current capability and hence deliver more robust devices for power switching applications, the first-generation architecture has been modified to minimize modulation of the conductivity (as measured using the diode forward-voltage, V_F) thereby allowing higher maximum forward surge current, I_{FSM}. This has been achieved by optimizing the area of the P+ region.

The second generation of SiC SBD diodes from Toshiba offers designers performance benefits based upon the new technology as well as additional current ratings and package types. While the second generation retains the two TO-220 packages, including the TO-220-2L with metal tab and TO-220F-2L with full plastic encapsulation, for pin-in-hole applications, the new range includes SMD options for the first time. The industry-standard DPAK package offers benefits in automated manufacturing environments across the current range from 2 A to 10 A, while the 4 A to 10 A devices have the added option of an 8x8DFN package. Both packages are available in tape-and-reel packaging for convenience and include a metal pad for better thermal conductivity.

www.toshiba.co.jp

www.power-mag.com

94%-Efficient Offline Flyback Switcher IC Family

Power Integrations announced its InnoSwitch™3 family of offline CV/CC flyback switcher ICs. The new devices achieve up to 94 % efficiency across line and load conditions, slashing power supply losses by a further 25 % and enabling the development of compact power supplies up to 65 W without heatsinks, according to the introduction of the new device family by **Andy Smith, Senior Product Marketing Manager, Power Integrations, Milpitas, USA[1]**

InnoSwitch3 devices are intended for power supplies with challenging energy consumption, footprint or thermal constraints, particularly those targeting mandatory Total Energy Consumption (TEC) specifications.

The InnoSwitch3 IC family is optimized into three application-specific series:

- CE: Current External. Includes accurate CC/CV regulation with external output current sense for optimum design flexibility. Targets compact single-voltage chargers, adapters, IoT and building automation.
- CP: Constant Power. Ideal for USB Power Delivery (PD), rapid charging and other applications where a dynamic output voltage is required.
- EP: Embedded Power. Features the family's highest-rated MOSFET (725 V) and provides full line and load protection with excellent multi-output cross-regulation for demanding industrial applications and appliances.

These flyback switcher ICs employ isolated digital communications technology, called FluxLink™, plus synchronous rectification, quasi-resonant switching and a precise secondary-side feedback sensing and control circuit. This results in highly efficient, accurate, reliable power supply circuits without the need for optocouplers. InnoSwitch3 devices are CCC, UL and VDE safety-certified to bridge the isolation barrier, and the InSOP™-24 package provides a low-profile, thermally efficient solution with extended 11.5 mm creepage and clearance between primary and secondary sides for high reliability, surge and ESD robustness. The new devices also incorporate protection features as well as output rectifier short-circuit protection and feature on-chip high-voltage MOSFETs.

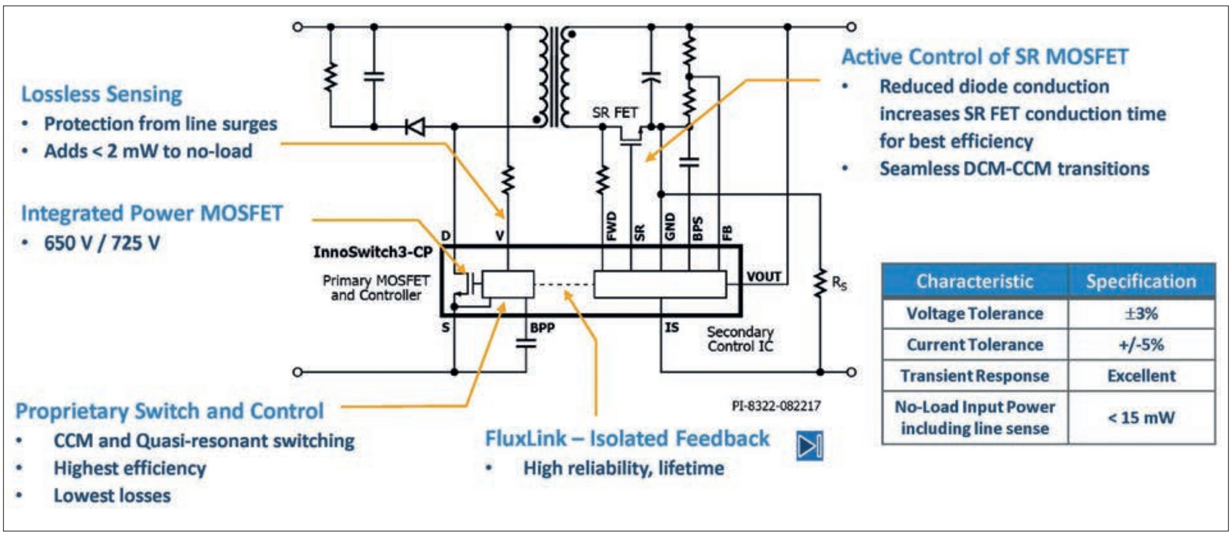
Samples are available now, priced at $1.11 (CE) and $1.15 (CP), in 10,000-piece quantities. InnoSwitch3-EP parts will be available in November 2017 at $1.18 per 10,000-pieces.

Innovative architecture

The InnoSwitch3-EP combines a 1 Ω high-voltage power MOSFET switch (rated at 650 V for the CP and CE series and 725 V for the EP series), along with both primary-side and secondary-side controllers in one device. Typical switching frequency is in the range of 100 MHz.

The architecture incorporates the novel inductive coupling feedback scheme (FluxLink) using the package lead frame and bond wires to provide a safe, reliable, and cost-effective means to transmit accurate, output voltage and current information from the secondary controller to the primary controller.

The primary controller is a Quasi-Resonant (QR) flyback controller that can operate in continuous conduction mode (CCM), boundary mode (CrM) and discontinuous conduction mode (DCM). The controller uses both variable frequency and variable current control schemes. The primary controller consists of a frequency jitter oscillator, a receiver circuit magnetically coupled to the secondary controller, a current limit controller, 5 V regulator on the PRIMARY BYPASS pin, audible noise reduction engine for light load operation, bypass over-voltage detection circuit, a lossless input line sensing circuit, current limit selection circuitry, over-temperature protection, leading edge blanking, secondary output



Characteristic	Specification
Voltage Tolerance	±3%
Current Tolerance	+/-5%
Transient Response	Excellent
No-Load Input Power including line sense	< 15 mW

Figure 1: Innoswitch3 properties – eliminating optocouplers via FluxLink digital feedback

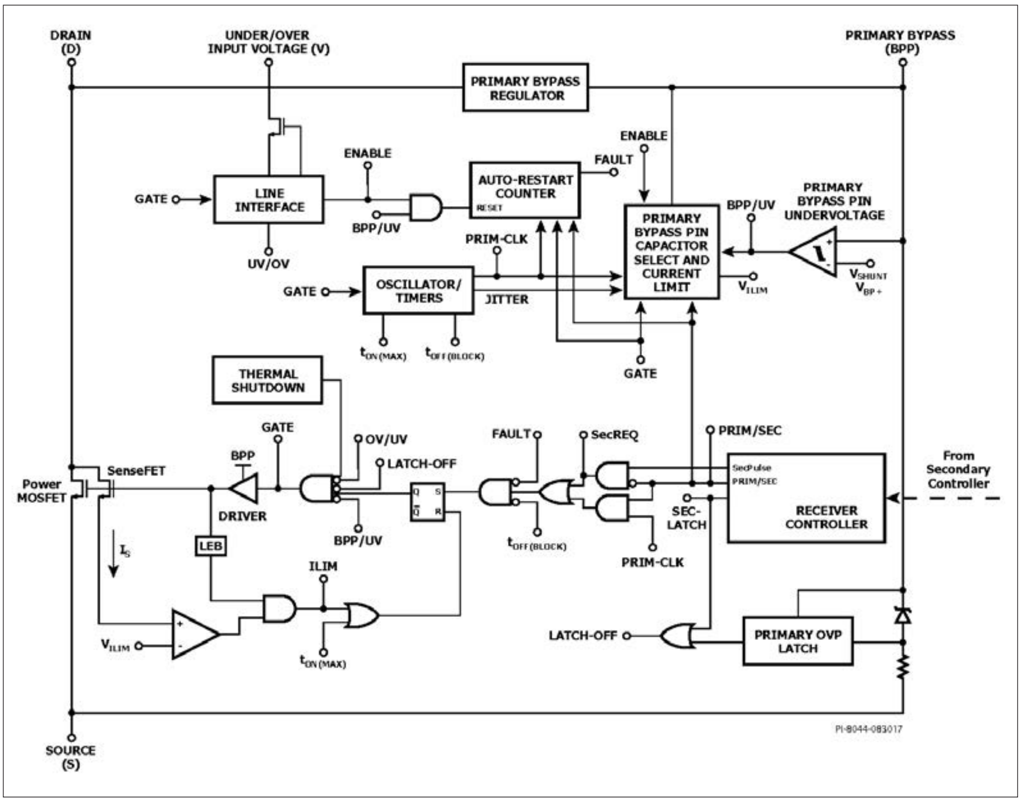


Figure 2: Primary controller block diagram

diode / SR FET short protection circuit and a 650 V / 725 V power MOSFET.

The secondary controller consists of a transmitter circuit that is magnetically coupled to the primary receiver, a constant voltage (CV) and a constant current (CC) control circuit, a 4.4 V regulator on the SECONDARY BYPASS pin, synchronous rectifier FET driver, QR mode circuit, oscillator and timing circuit, and numerous integrated protection features. Figures 1 and 2 show the functional block diagrams of the primary and secondary controller, highlighting the most important features.

Primary controller

The variable frequency QR controller plus CCM/CrM/DCM operation is intended for enhanced efficiency and extended output power capability.

The PRIMARY BYPASS pin has an internal regulator that charges the pin capacitor to V_{BPP} by drawing current from the DRAIN pin whenever the power MOSFET is off. The PRIMARY BYPASS pin is the internal supply voltage node. When the power MOSFET is on, the device operates from the energy stored in the PRIMARY BYPASS pin capacitor. In addition, a shunt regulator clamps the PRIMARY BYPASS pin voltage to V when current is provided to the PRIMARY BYPASS SHUNTpin through an external resistor. This allows the InnoSwitch3-(EP) to be powered externally through a bias winding, decreasing the no-load consumption to less than 15 mW in a 5 V output design.

The user can adjust current limit (I_{LIM}) settings through the selection of the PRIMARY BYPASS pin capacitor value. A ceramic capacitor can be used, sizes of 0.47 µF and 4.7 µF for setting standard and increased ILIM settings respectively are selectable.

The PRIMARY BYPASS pin under-voltage circuitry disables the power MOSFET when the respective pin voltage drops below ~4.5 V (V_{BPP} - $V_{BP(H)}$) in steady-state operation. Once the PRIMARY BYPASS pin voltage falls below this threshold, it must rise to V_{SHUNT} to re-enable turn-on of the power MOSFET. This pin has also a latching OV protection feature. A Zener diode in parallel with the resistor in series with the PRIMARY BYPASS pin capacitor is typically used to detect an over-voltage on the primary bias winding and activate the protection mechanism. In the event that the current into the pin exceeds I_{SD}, the device will latch-off or disable the power MOSFET switching for a time t $_{AR(OFF)}$, after which time the controller will restart and attempt to return to regulation. V_{OUT} OV protection is also included as an integrated feature on the secondary controller.

The thermal shutdown circuitry senses the primary MOSFET die temperature. The threshold is set to T_{SD} with either a hysteretic or latch-off response. If the die temperature rises above the threshold, the power MOSFET is disabled and remains disabled until the die temperature falls by $T_{SD(H)}$ at which point switching is re-enabled. A large amount of hysteresis is provided to prevent over-heating of the PCB due to a continuous fault condition.

Latch-off response: If the power MOSFET is disabled, latching is reset by bringing the PRIMARY BYPASS pin below $V_{BPP(RESET)}$ or by going below the U_V (I_{UV-}) threshold.

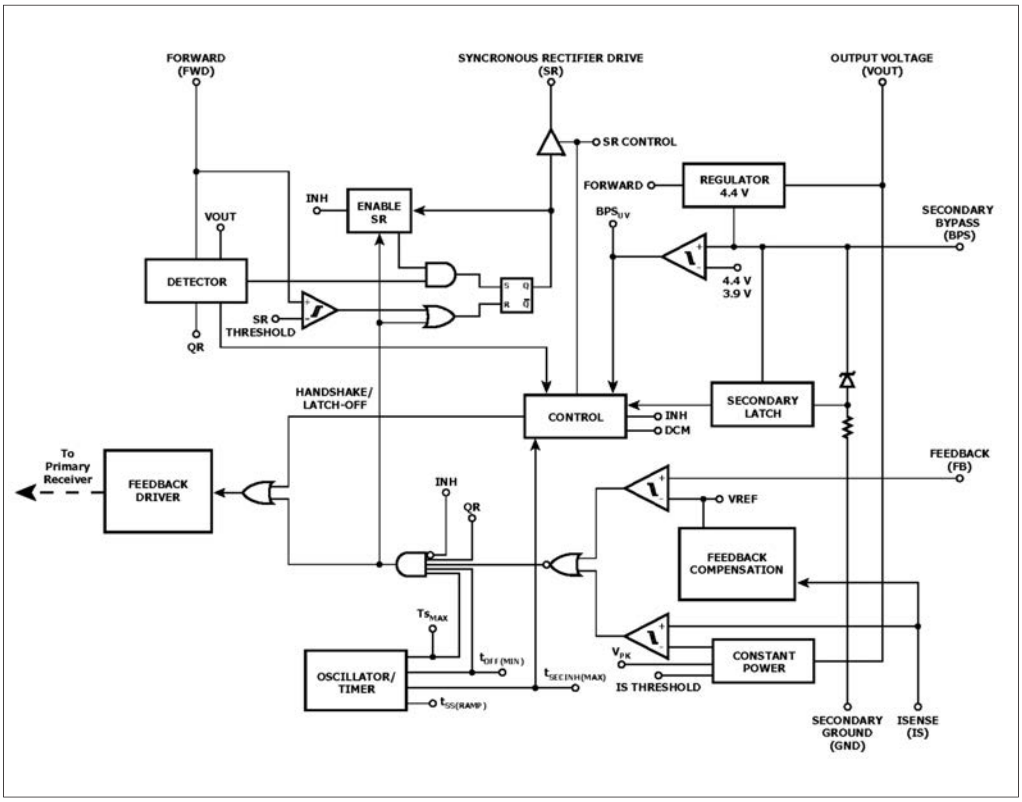
The current limit threshold ramp is inversely proportional to the time from the end of the previous primary switching cycle (i.e. from the time the primary MOSFET turns off at the end of a switching cycle). This characteristic produces a primary current limit that increases as the switching frequency (load) increases (Figure 4). This enables the most efficient use of the primary switch with the benefit that this algorithm responds to digital feedback information immediately when a feedback switching cycle request is received.

At high load, switching cycles have a maximum current approaching 100 % I_{LIM}. This gradually reduces to 30 % of the full current limit as load decreases. Once 30 % current limit is reached, there is no further reduction in current limit (since this is low enough to avoid audible noise). The time between switching cycles will continue to increase as load reduces.

The normalized current limit is modulated between 100 % and 95 % a modulation frequency of fM this results in a frequency jitter of ~7 kHz with average frequency of ~100 kHz.

In the event a fault condition occurs (such as an output overload, output short-circuit, or external component/pin fault), the IC enters auto-restart (AR) or latches off. The latching condition is reset by bringing the PRIMARY BYPASS pin below ~ 3 V or by going below the UNDER/OVER

Figure 3: Secondary controller block diagram



INPUT VOLTAGE pin U_V (I_{UV-}) threshold.

In the event that there are two consecutive cycles where the I_{LIM} is reached within ~500 ns (the blanking time + current limit delay time), the controller will skip 2.5 cycles or ~25 µs (based on full frequency of 100 kHz). This provides sufficient time (SOA protection) for the transformer to reset with large capacitive loads without extending the start-up time.

Secondary controller

As shown in Figure 3, the IC is powered by a 4.4 V (V_{BPS}) regulator which is supplied by either V_{OUT} or FWD. The SECONDARY BYPASS pin is connected to an external decoupling capacitor and fed internally from the regulator block.

The FORWARD pin also connects to the negative edge detection block used for both handshaking and timing to turn on the SR FET connected to the SYNCHRONOUS RECTIFIER DRIVE pin. The FORWARD pin voltage is used to determine when to turn off the SR FET in discontinuous mode operation. This is when the voltage across the $R_{DS(ON)}$ of the SR FET drops below zero volts.

In continuous conduction mode (CCM) the SR FET is turned off when the feedback pulse is sent to the primary to demand the next switching cycle, providing excellent synchronous operation, free of any overlap for the FET turn-off. The mid-point of an external resistor divider network between the OUTPUT VOLTAGE and SECONDARY GROUND pins is tied to the FEEDBACK pin to regulate the output voltage. The internal voltage comparator reference voltage is V_{FB} (1.265 V). The external current sense resistor connected between I_{SENSE} and SECONDARY GROUND pins is used to regulate the output current in constant current regulation mode.

Innoswitch3-EP application example

Innoswitch3 ICs target adapters and open-frame power supplies for consumer, computer, communication and industrial applications. The circuit shown in Figure 5 is a low cost 5 V, 0.3 A and 12 V, 0.7 A dual output power supply which features high efficient design satisfying cross regulation requirement without post regulator.

Bridge rectifier BR1 rectifies the AC input supply. Capacitors C2 and C3 provide filtering of the rectified AC input and together with inductor L1 form a pi-filter to attenuate differential mode EMI. Y capacitor C10 connected at the power supply output with input help reduce common mode EMI. 0Thermistor RT1 limits the inrush current when the power supply is connected to the input AC supply. Input fuse F1 provides protection against excess input current resulting from

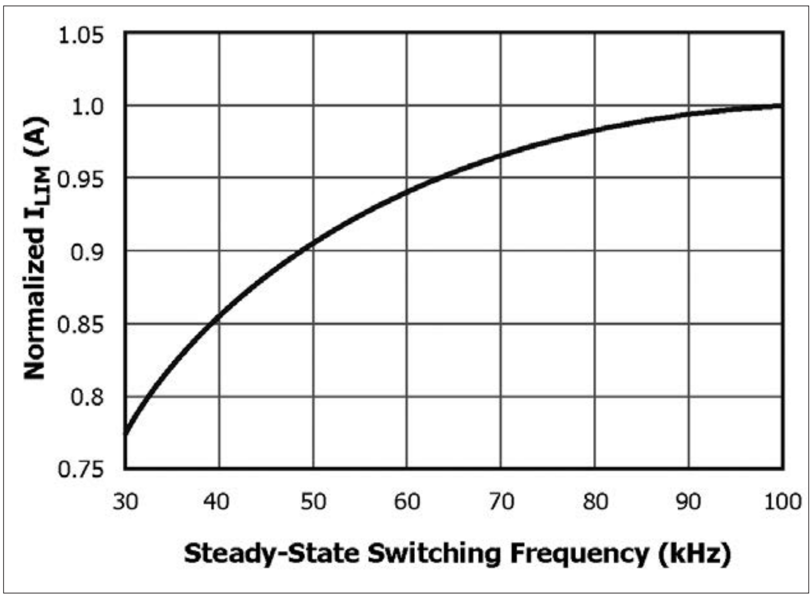


Figure 4: Normalized primary current vs. frequency

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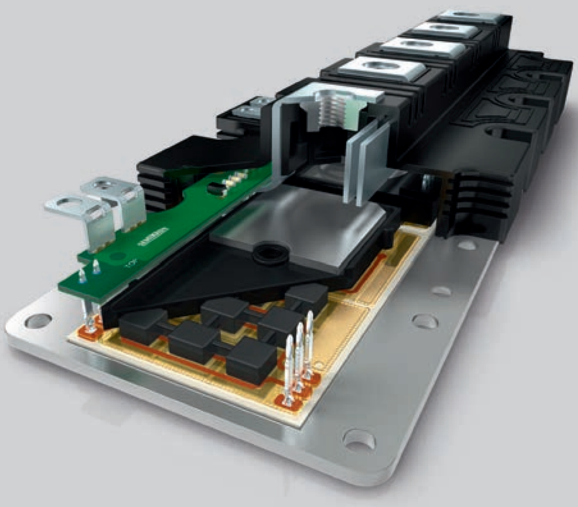

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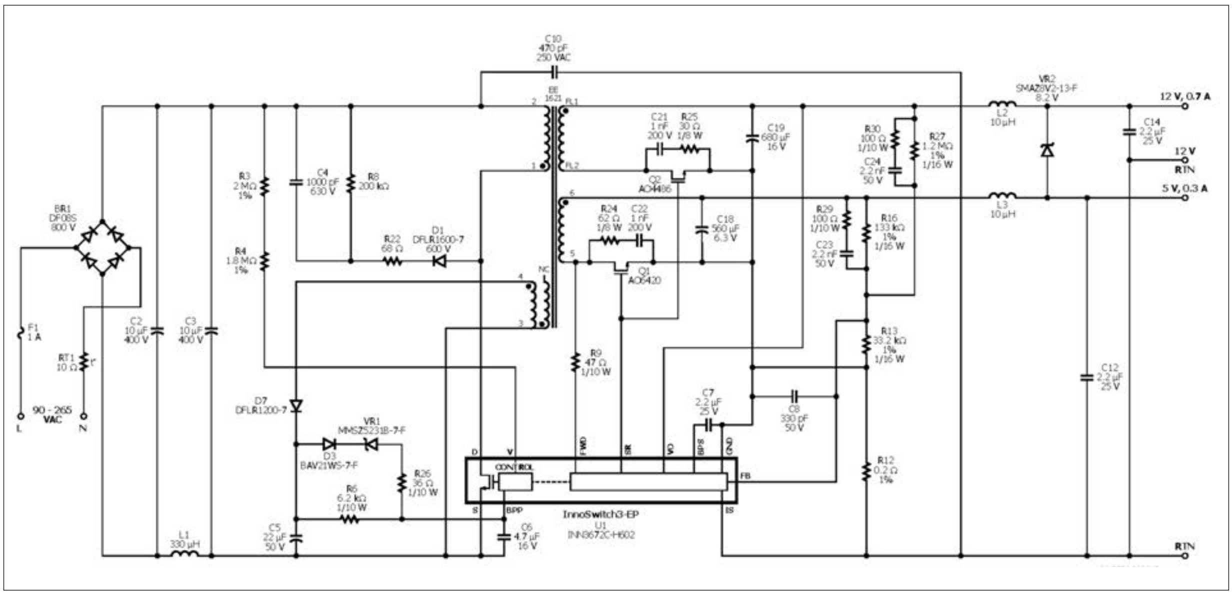


Figure 5: **Schematic of a 5 V/0.3 A and 12 V/0.7 A dual-output power supply for HVAC application**

catastrophic failure of any of the components in the power supply. One end of the transformer primary is connected to the rectified DC bus; the other is connected to the drain terminal of the internal MOSFET (U1).

A low-cost RCD clamp formed by diode D1, resistors R22, R8, and capacitor C4 limits the peak drain voltage of U1 at the instant of turn-off of the MOSFET inside U1. The clamp helps to dissipate the energy stored in the leakage reactance of transformer T1.

The InnoSwitch3-EP IC is self-starting, using an internal high-voltage current source to charge the PRIMARY BYPASS pin capacitor (C6) when AC is first applied. During normal operation the primary-side block is powered from an auxiliary winding on the transformer T1. Output of the auxiliary (or bias) winding is rectified using diode D7 and filtered using capacitor C5. Resistor R6 limits the current being supplied to the PRIMARY BYPASS pin of U1. The latch off primary-side over-voltage protection is obtained using Zener diode VR1 with current limiting resistor R26.

The secondary-side of U1 provides output voltage, output current sensing and drive to a MOSFET providing synchronous rectification. 5 V secondary of the transformer is rectified by SR FET Q1 and filtered by capacitors C18. High frequency ringing during switching transients that would otherwise create radiated EMI is reduced via a snubber (resistor R24 and capacitor C22). 12 V secondary of the transformer is rectified by SR FET Q2 and filtered by capacitors C19. High frequency ringing during switching transients that would otherwise create radiated EMI is reduced via a snubber (resistor R25 and capacitor C21).

Synchronous rectifications (SR) are provided by MOSFETs Q1 and Q2. The gates of Q1 and Q2 are turned on by secondary-side controller inside IC U1, based on the winding voltage sensed via resistor R9 and fed into the FORWARD pin of the IC. In continuous conduction mode of operation, the MOSFET is turned off just prior to the secondary-side commanding a new switching cycle from the primary. In discontinuous mode of operation, the power MOSFET is turned off when the voltage drop across the MOSFET falls below 0 V. Secondary-side control of the primary-side power MOSFET avoids any possibility of cross conduction of the two MOSFETs and provides extremely reliable synchronous rectification.

The secondary-side of the IC is self-powered from either the secondary winding forward voltage or the output voltage. Capacitor C7 connected to the SECONDARY BYPASS pin of U1, providing decoupling for the internal circuitry.

Total output current is sensed by R12 between the IS and GROUND pins with a threshold of approximately 35 mV to reduce losses. Once the current sense threshold is exceeded the device adjusts the number of switch pulses to maintain a fixed output current. The output voltages are sensed via resistor divider R13, R16, and R27, and output voltages are regulated so as to achieve a voltage of 1.265 V on the FEEDBACK pin. The 12 V phase boost circuit, R30 and C24, in parallel with 12 V feedback resistor, R27, and 5 V phase boost circuit, R29 and C23, in parallel with 5 V feedback resistor, R16, reduce the output voltage ripples. Capacitor C8 provides noise filtering of the signal at the FEEDBACK pin. Zener VR2 was added for tighter cross-regulation to limit the 12 V output when it is unloaded.

Resistor R3 and R4 provide line voltage sensing and provide a current to U1, which is proportional to the DC voltage across capacitor C3. At approximately 100 VDC, the current through these resistors exceeds the line under-voltage threshold, which results in enabling of U1. At approximately 435 VDC, the current through these resistors exceeds the line over voltage threshold, which results in disabling of U1.

An online selection tool, Build Your Own InnoSwitch, help designers customize device features for their particular design specifications. Technical support for InnoSwitch3 ICs, including the PI ExpertTM Online design tool, is available from the Power Integrations website

www.power.com/products/innoswitch/

No Inductors Required

It is well known that EMI considerations require careful attention during the initial design process in order to ensure that they will pass EMI testing once the system is completed. Until now, there has been no sure fire way to guarantee that this could easily be attained with the right power IC selection for all but very low power systems. However, with the recent introductions of low EMI regulators an alternative choice is now available. **Tony Armstrong, Director of Product Marketing Power Products, Linear Technology Corp., Milpitas, USA**

A fundamental axiom for switching power supplies is that they must not generate a lot of noise. Accordingly, quiet, well-regulated power supplies are important for optimum performance in many circuit applications. In order to attain this level of performance it is critical to be able to mitigate any noise generated as part of this conversion process. An obvious way to attain this is to simply use a linear regulator. However, although they supply quiet power supply rails, their conversion efficiencies are poor at high step-down ratios and this can lead to thermal issues with the design in high output current applications.

Of course, magnetic-based switching regulators can alleviate the usual thermal issues since they generally have high efficiency of conversion, leading to simpler thermal design when high output currents are required by the end application. It is well understood that component selection and circuit board layout can play a significant role in determining the success or failure of virtually all power supplies. These aspects set their functional EMI and thermal behavior. For the un-initiated, switching power supply layout may seem like a "black" art, but it is in fact a basic aspect of a design often overlooked in the early stages of the process. Since functional EMI requirements always have to be met, what is good for functional stability of the power supply is also usually good for its EMI emissions, too. Furthermore, good layout from the beginning does not add any cost to the design and can actually provide cost savings by eliminating the need for EMI filters, mechanical shielding, EMI test time and board revisions.

Moreover, the potential problems of interference due to noise can be exacerbated when multiple DC/DC switchmode regulators are used in a design to generate multiple rails of if they are paralleled for current sharing and higher output power. If all are operating (switching) at a similar frequency, the combined energy generated by multiple regulators in a circuit is then concentrated at one frequency. Presence of this energy can become a concern, especially if the rest of the ICs on the printed circuit boards, as well as other system boards are close to each other and susceptible to this radiated energy. This can be particularly troubling in industrial and automotive systems that are densely populated and are often in close proximity to electric noise generating sources, such as mechanically switched inductive loads, PWM drive power outputs, microprocessor clocks and contact switching. Furthermore, if switching at different frequencies, intermodulation products can alias into sensitive frequency bands.

Switching regulator emissions

Switching regulators usually replace linear regulators in areas where low heat dissipation and efficiency are valued. Moreover, the switching regulator is typically the first active component on the input power bus line, and therefore has a significant impact on the EMI performance of the entire product design.

Conducted emissions ride on the wires and traces that connect up to a product. Since the noise is localized to a specific terminal or connector in the design, compliance with conducted emission requirements can often be assured early in the development process with a good layout or filter design. Radiated emissions are a different matter altogether. Everything on the board that carries current radiates an electromagnetic field. Every trace on the board is an antenna and every copper plane is a resonator. Anything, other than a pure sine wave or DC voltage, generates noise all over the signal spectrum. Even with careful design, a power supply designer never really knows how bad the radiated emissions are going to be until the system is tested. And radiated emissions testing cannot be formally performed until the design is essentially complete.

Filters are often used to reduce EMI by attenuating the strength at a certain frequency or over a range of frequencies. A portion of this energy that travels through space (radiated) is attenuated by adding metallic and magnetic shields. The part that rides on PCB traces (conducted) is tamed by adding ferrite beads and other filters. EMI cannot be eliminated but can be attenuated to a level that is acceptable by other communication, signal processing and digital components. Moreover, several regulatory bodies enforce standards to ensure compliance in both industrial and automotive systems.

Modern input filter components in surface mount technology have better performance than through-hole parts. However, this improvement is outpaced by the increased demands created by today's high frequency switching regulators. The low minimum on- and off-times required at higher operating frequencies result in higher harmonic content due to the faster switch transitions, thereby increasing radiated noise. However, these high switch edge rates are needed to get higher conversion efficiencies. A switched capacitor charge pump does not exhibit this behavior since it operates at much lower switching frequencies and most importantly can tolerate slower switching transitions without degradation in efficiency.

Savvy PCB designers will make the hot loops small and use shielding ground layers as close to the active layer as possible. Nevertheless, device pin-outs, package construction, thermal design requirements and package sizes needed for adequate energy storage in decoupling components dictate a minimum hot loop size. To further complicate matters, in typical planar printed circuit boards, the magnetic or transformer style coupling between traces above 30 MHz will diminish all filter efforts since the higher the harmonic frequencies are, the more effective unwanted magnetic coupling becomes.

Switched capacitor charge pumps

Charge pumps have been around for

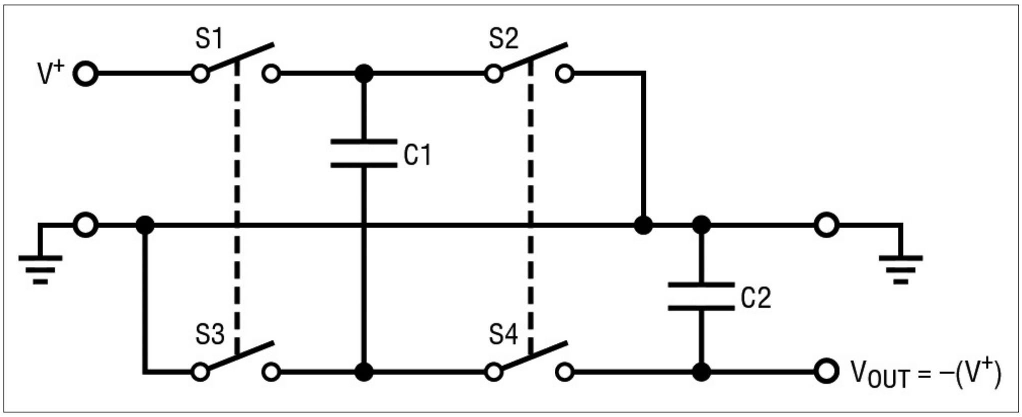


Figure : Simplified charge pump block diagram of a voltage inverter

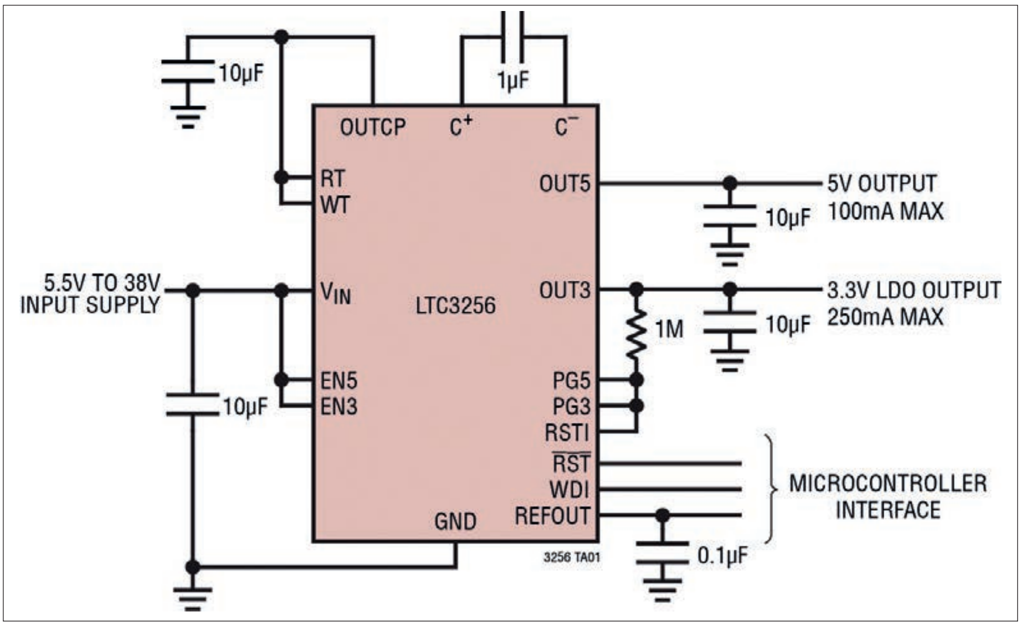


Figure 2: LTC3256 has a 5 V/100 mA Output & a 3.3 V/250 mA output

decades, and they provide DC/DC voltage conversion, using a switch network to charge and discharge two or more capacitors. The basic charge pump switch network toggles between charge and discharge states of the capacitors. As shown in Figure 1, C1 the "flying capacitor" shuttles charge, and C2 the "reservoir capacitor" holds charge and filters the output voltage. Additional "flying capacitors" and switch arrays enable multiple gains.

When switches S1 and S3 are on, or closed, and switches S2 and S4 are off, or open, the input power supply charges C1. During the next cycle, S1 and S3 are off, S2 and S4 are on, and charge transfers to C2, generating V_{OUT} = - (V+).

However, until recently, charge pumps have had limited input and output voltage ranges, which has limited their use in industrial and automotive applications where inputs up to 40V or greater are commonplace.

A recent introduction in this area is the LTC3256. It is a highly integrated, high-voltage low noise dual output power supply, which takes a single positive input and generates 5 V and 3.3 V step-down supplies with high efficiency and no inductors. The device features a wide 5.5 V to 38 V input voltage range and includes independently enabled dual outputs: a 5 V 100 mA supply, and a 250 mA / 3.3 V low-dropout (LDO) regulator, for a total of 350 mA output current. This combination of regulators offers much lower power dissipation than a dual-LDO solution. For example, with a 12 V input and a maximum load on both outputs, power dissipation is decreased by over 2 W with the LTC3256 vs. a dual LDO, thus reducing the heat loss and input current. See Figure 2 for its complete schematic.

The device has been engineered for diagnostic coverage in ISO26262 systems and incorporates numerous safety and system monitoring features. It is well-suited for a variety of applications requiring low noise, low power rails from high voltage inputs such as automotive ECU/CAN transceiver supplies, industrial/telecom housekeeping supplies, and general-purpose low-power conversion.

The LTC3256 maximizes efficiency by running the charge pump in 2:1 mode, over as wide an operating range as possible, and automatically switches to 1:1 mode as needed, consistent with VIN and load conditions. Controlled input current and soft switching minimize conducted and radiated EMI. The device offers low quiescent current of only 20 ?A with both outputs in regulation (no load) and 1 ?A in shutdown. The integrated watchdog timer, independent power good outputs and reset input ensure reliable system operation and enable fault monitoring. A buffered 1.1 V reference output enables system self-testing diagnostics for safety critical applications. The LTC3256 also has additional safety features including over-

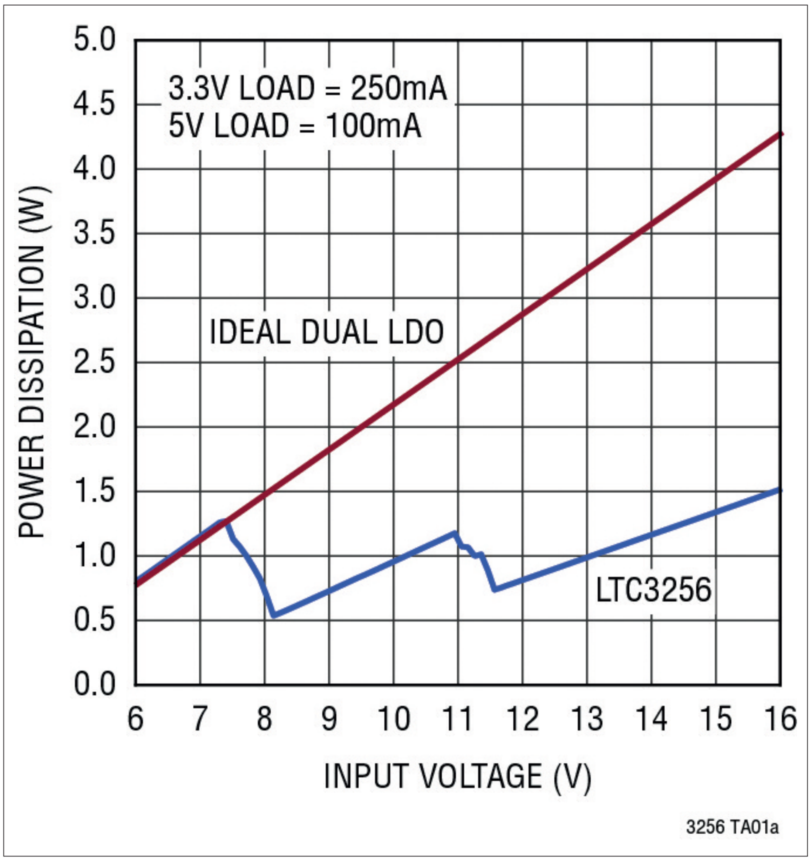


Figure 3. **Power dissipation characteristics of the LTC3256 vs. a dual LDO**

current fault protection, over temperature protection and tolerance of 38 V input transients.

Figure 3 highlights the LTC3256's good power dissipation characteristics. At 12 VIN, the IC with 3.3 V @ 250 mA and 5 V @ 100 mA outputs dissipates about 750 mW, while under these same conditions, a dual LDO would dissipates almost 3 W. That's 2.25 W less for LTC3256, which is a huge benefit for the thermal aspect of the design.

Conclusion

It is well known that EMI considerations require careful attention during the initial design process in order to ensure that they will pass EMI testing once the system is completed. Until now, there has been no sure fire way to guarantee that this could easily be attained with the right power IC selection for all but very low power systems. However, with the recent introductions of low EMI regulators, such as the LTC3256 high voltage charge pump, an alternative choice is now available. It provides much higher efficiency and lower power loss when compared to linear regulators and do not require the compensation, layout, magnetics and EMI issues associated with a switching regulator.

Imaging Detects Cracks in Multilayer Ceramic Capacitors

Multilayer ceramic capacitors (MLCCs) play a vital role in all kinds of power electronic applications, especially the variable speed drives (VSDs) manufactured by ABB. A significant issue for the industry is that the mechanical stresses involved in the assembly, handling and testing of the circuit boards holding MLCCs can cause small cracks in them that present a risk of component failure. **C. Andersson, ABB Corp. Research, Switzerland; J. Ingman, E. Varescon, and M. Kiviniemi, ABB Oy, Finland**

The most common failure mode for cracks in MLCCs is an open connection, which is detrimental to performance, but not catastrophic. However, if a crack reaches through the electrodes from both terminals, and the component is stressed by a combination of humidity and voltage, the failure mode will be an electrical short, which is far more serious for most circuits. Because a flex-cracked MLCC cannot be detected by electrical measurements or be eliminated through burn-in testing, it is crucial to find a screening test which detects the crack before it can turn into a short in the field. One promising method is X-ray imaging. This had been the subject of previous experiments, but not on a large-scale basis. Therefore, ABB decided to investigate the potential X-ray imaging.

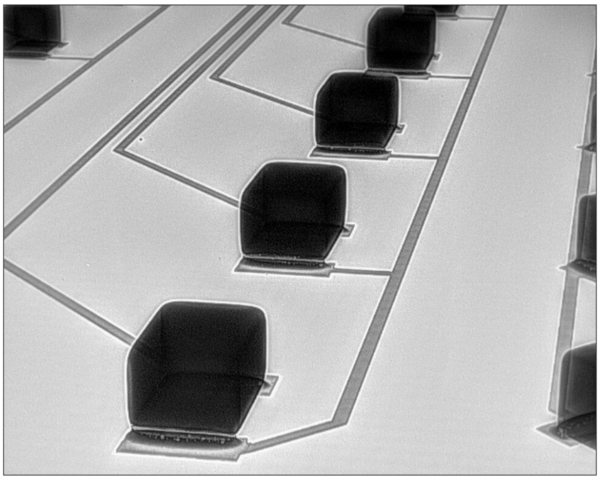
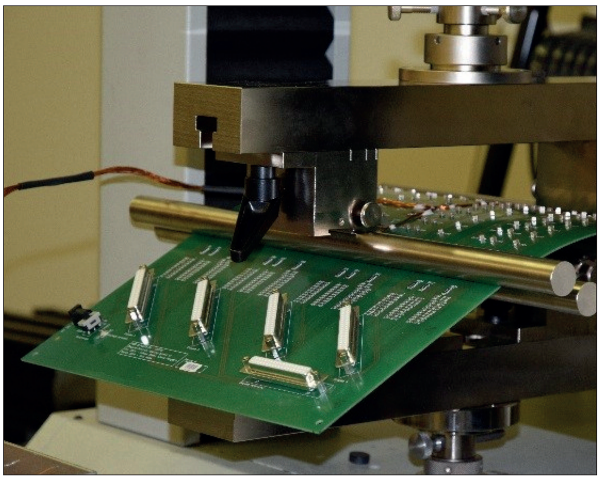


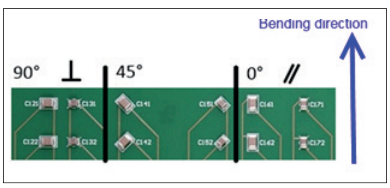
Figure 3: Overview 2D X-ray image showing several 1812-sized MLCCs placed parallel (0°) to the bending direction, where cracks in all five MLCCs can be seen

The test program

Test boards with a thickness of 1.55 mm and two copper traces were manufactured to examine commercially available 1812-sized MLCCs from different manufacturers.



RIGHT Figure 1: Four-point bending test setup



LEFT: Figure 2: Mounting direction of the MLCCs on the test board compared to the bending direction of the individual capacitors

A four-point bending setup was used to provide approximately the same strain level over all the MLCCs arranged in columns of 10 to enable good statistical evaluation of the resulting data (see Figure 1).

Three different orientations of the MLCCs (90°, 45° and 0°) to the axis of bending were examined (see Figure 2) to help understand the impact of bending angle on the cracking of MLCCs. Following the bending tests, the MLCCs were examined in a Phoenix Nanomex X-ray machine that has a resolution of 200 nm.

The test results

Figure 3 shows an example of an overview 2D X-ray image in which the cracks in all of the five MLCCs mounted parallel to the bending direction are can be seen. One MLCC was selected for further magnification under which the crack is even more easily visible, as shown in Figure 4. Several smaller cracks can be seen as well as voids in the solder.

For comparison, the same capacitor was viewed with an optical microscope, which showed no signs of a crack inside the MLCC – see Figure 5. This shows that optical inspection of MLCCs is not effective for the detection of flex cracks. During the test program 300 MLCCs were optically inspected as well as viewed with X-ray imaging and no component showed any external signs of cracks.

To verify the findings of the X-ray imaging, cross-sections were made and Figure 6 shows the same MLCC as in Figures 4 and 5. From the optical microscopy image of the cross-section the

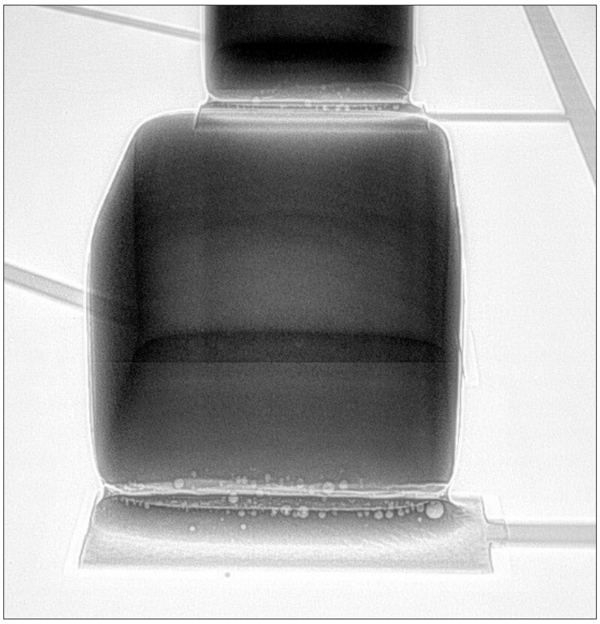


Figure 4: **Magnified 2D X-ray image of an MLCC in which the crack is clearly visible**

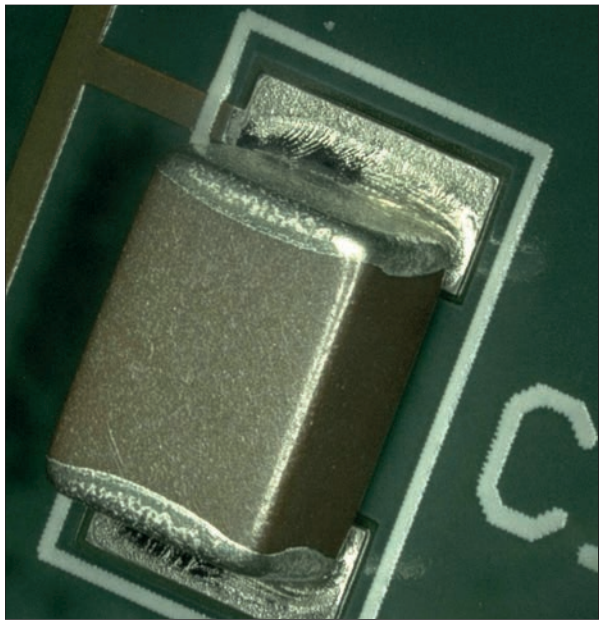


Figure 5: **Optical microscopy image of the same MLCC showing no external sign of a crack**

presence of cracks in the MLCC is confirmed. Furthermore, it could be seen that the flex cracks reach all the way into the active area where the over-lapping electrodes are positioned. There are also smaller cracks seen on the left side (the rear face of the MLCC in Figure 4). The solder looks undamaged which explains its normal external appearance. The probable reason for this is that the relatively soft solder is able to absorb the strain that is applied though the bending test whereas the more brittle ceramic cracks.

The MLCCs mounted 45° to the bending direction produce discontinuous and less obvious cracks than the ones mounted 0° to the bending direction.

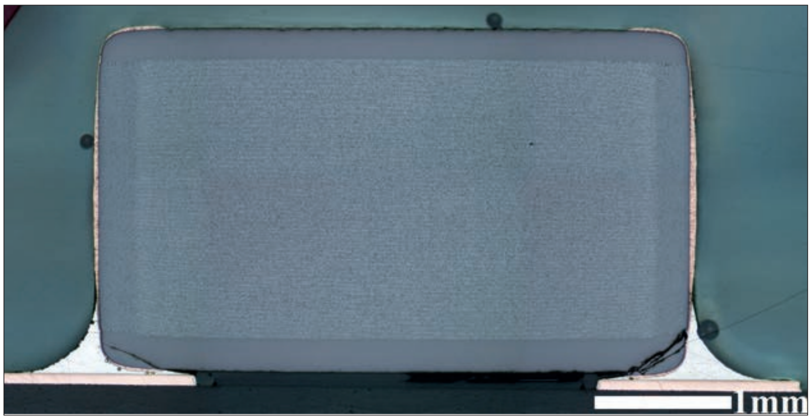


Figure 6: **Cross-section of the MLCC shown in Figures 4 and 5, confirming the presence of a crack into the active electrode area**

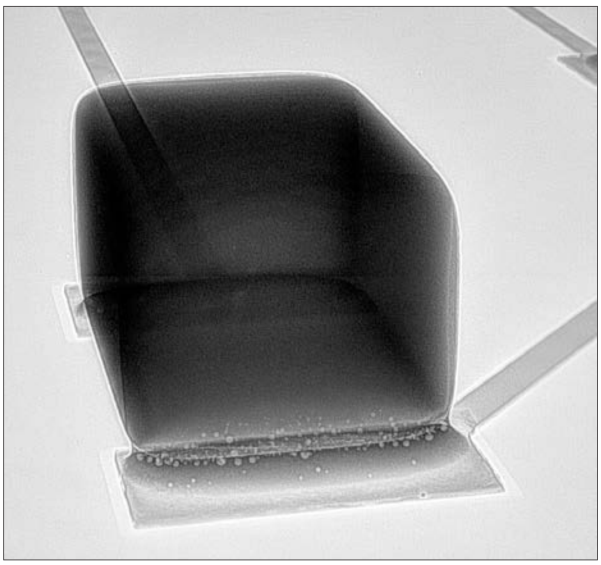


Figure 7: **Zoomed in X-ray image of an MLCC mounted 45° to the bending direction. Several small cracks are identified especially in the magnified inset at the top**

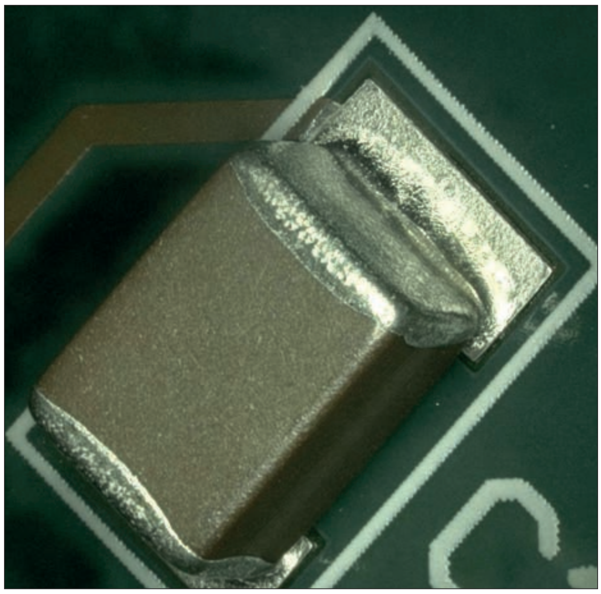


Figure 8: **Optical microscopy image of the same MLCC as shown in Figure 7. No external sign of a crack can be observed**

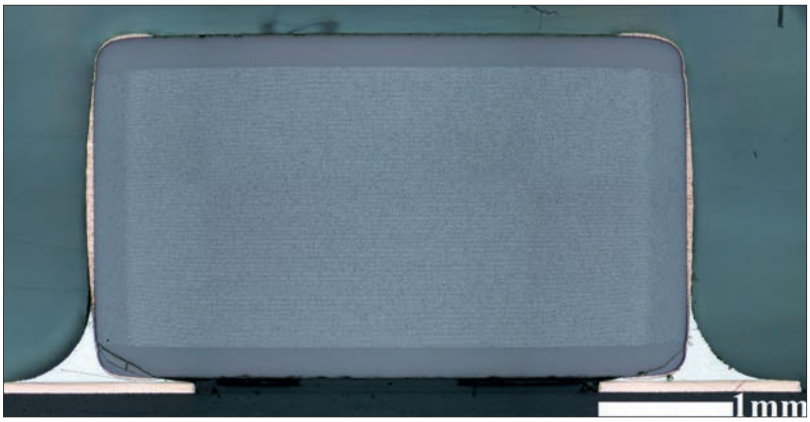


Figure 9: **Cross-section of the MLCC shown in Figures 7 and 8, confirming the presence of a crack into the electrode area**

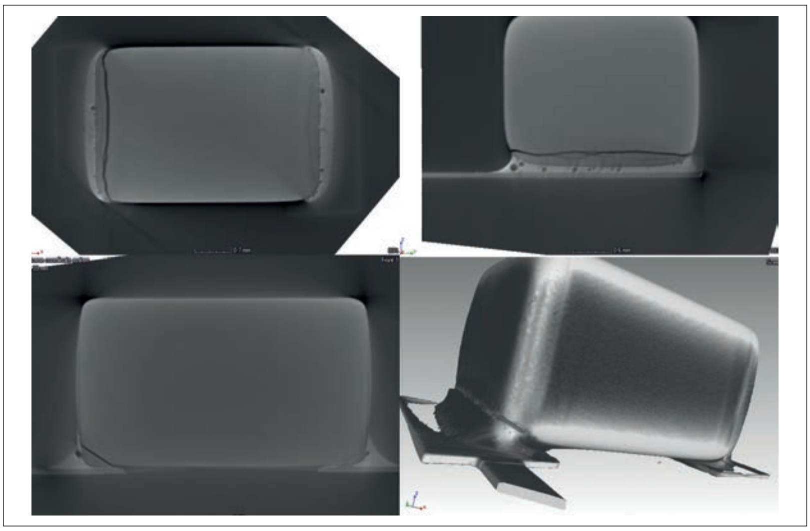


Figure 10: **Non-destructive virtual 3D slicing images and 3D reconstruction of the cracked MLCC from Figures 4 to 6 for even better crack identification**

Figure 11: **3D CT X-ray images of the MLCC shown in Figures 7 to 9 showing a small and discontinuous crack**

However, even these smaller and discontinuous cracks can be seen by 2D X-ray imaging as shown in Figure 7. The cracking profile is different for the MLCCs placed 45° to the bending direction compared to the ones placed parallel. This is most probably because the forces inside the components are different when it is bent at 0° which gives clear and linear cracks, while 45° results in more slanted cracks.

The MLCCs mounted at 45° to the bending direction also showed no external signs of cracks under optical inspection – see Figure 8. A cross-section was made to confirm the finding of small cracks in the X-ray images as seen in Figure 9. It is important to note that a cross-section is at one point of depth in the MLCC. So there is always the risk of not finding a discontinuous crack. While both cross-sectioning and chemical etching are useful techniques to find cracks after an MLCC failure has occurred, X-ray imaging has the added value of being non-invasive as well as non-destructive. It can therefore also be used in screening and sampling as well as failure analysis.

3D CT X-ray analysis

Even better resolution of the cracks can be achieved if a 3D computer tomography (CT) X-ray analysis is performed as shown in Figure 10.

The top-left image shows an X-ray 3D slice from below the MLCC with part of the solder and the continuous crack on the left-hand side. The top-right image shows a slice into the side of the MLCC from one of the end terminals. The lower-left image shows a slice corresponding to the mirror image of the cross-section in Figure 6 with the cracks in both sides visible, and the lower-right image shows the full 3D model. These 3D X-ray images show clearly the presence of cracks as well as making it possible to follow their propagation into the depth of the capacitor.

The same 3D analysis was carried out for the MLCCs mounted 45° to the bending direction as shown in Figure 11. In this case, the cracks are much more difficult to detect due to their non-continuous nature.

3D X-ray analysis definitively has advantages and possibilities which 2D X-ray imaging does not have such as the detection of very small cracks and the possibility to see crack propagation paths from three dimensions. At the same time, it also has some disadvantages in that it is time-consuming, needs a small enough sample in order to rotate at least 220° and it is difficult to capture all the information from the 3D model in a 2D representation.

Impact of strain levels

A total of 300 MLCCs were examined visually and by X-ray after the bending tests. Figure 12 summarises the number of cracked and uncracked MLCCs for the different mounting orientations as a function of the level of bending strain they were subjected too.

MLCCs perpendicular to the bending direction were not found to be cracked. Whereas MLCCs at 45° or 0° orientation started showing cracks as the level of strain increased.

Conclusion

X-ray imaging shows significant potential as a non-invasive method of detecting cracks in MLCCs that could be implemented as a screening test in a production environment.

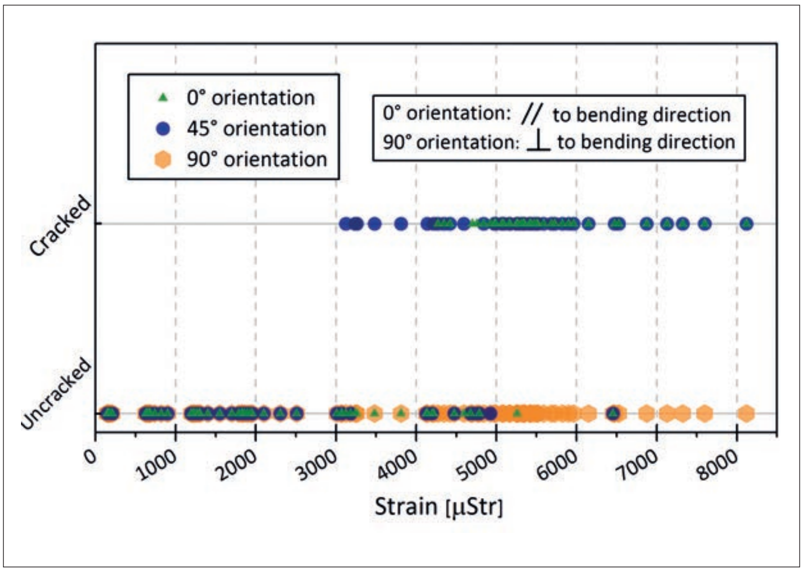


Figure 12: **Indication of cracked or uncracked MLCCs for different strain levels and orientations**

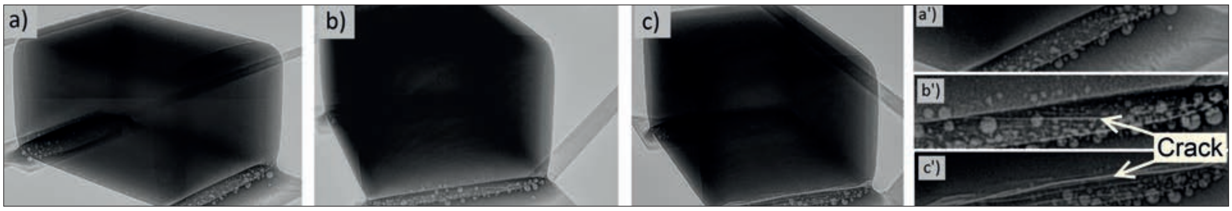


Figure 13: **Cracks of different orientations**

Smart Sensors for Grid Modernization

Grid modernization initiatives are gaining momentum around the globe. Upgraded energy grids enable the integration of conventional energy sources with renewables and energy storage, as well as creating resiliency in the face of cyber-attacks and climate challenges. Low-inductance thick-film resistors play a vital role as sensing elements in these applications. **R. Ratzi, Miba Energy Holding Austria; A. Klein and T. Zimmerman, EBG Austria and USA**

Modernizing the grid is an opportunity for many players across the value chain. A major growth area is in metering and monitoring smart grid applications, which in the long run smooth out the power flowing to and from the grid, and cut waste by enabling optimal generation. If we know how much power is being produced, then less power needs to be produced. Today precise measurements can be taken at the point of transmission and distribution, but to accomplish this, smart grid sensors are needed.

Huge opportunities for sensors

There are a multitude of metering / monitoring points that are being upgraded with smart grid optimization, from point of use to transmission and distribution, both using the same types of technology just on different scales. In regards to transmission and distribution, in the past, very rudimentary tools were used to test and monitor the grid. Flashing lights, for example, were used on Fault Current Indicators, repair personnel had to be dispatched in multiple areas to find one fault by visual confirmation. Then the industry moved to wireless data locators.

These types of locators would give a position of the fault, in return would reduce the time and efforts in locating the fault thus a faster repair. Today precise measurements can be taken at the point of transmission and distribution, but to accomplish this, smart grid sensors are needed.

Market researcher IHS tracked Smart Grid Sensors as a stand-alone category in the Distribution Automation (DA) market and predicted that by 2021, demand for new Smart Grid Sensor technology will grow 1,200 %, making it one of the fastest growing segments in DA. It will surpass its earliest predecessor, non-communicating Fault Current Indicator (FCI) sensor technology.

Another important application of voltage sensors are intelligent transformer substations. There are used in the medium voltage secondary distribution grid. This is a key application which allows the grid to counterbalance voltage variations caused e.g. by local PV systems or fast charging stations for electrical vehicles.

The voltage divider

With this opportunity comes a challenge. The grid typically operates at a high voltage, but measurement equipment such as sensors should not exposed to this high voltage as it could pose both a reliability and a safety issue. So a voltage divider is used to reduce the voltage to a much lower level. If, for example, the grid is at 5,000 volts, you might use a 100:1 divider, so the sensor only sees 50 V maximum.

Voltage dividers can be made with capacitors (a capacitive divider) or with resistors. It is in the voltage dividers that accuracy becomes important. If a capacitor has a tolerance of +/- 2 %, and it used as a component in the divider, at the high end that 2 % error could give 51 V, or at the other end 49 V. Either way, with a 2 % error like this the grid voltage is between 4900 and 5100 V, because the divider is no more accurate than this. A second and even more important factor is thermal stability. Over a typical temperature range of 0 to 50°C, for example, a capacitor may drift by 0,5 %. On a cold day, the voltage is going to measure a different value than on a hot day. This is not because the grid voltage is any different, but because of the inaccuracy of the sensor due to thermal drifts.

Viewing it mathematically, if a resistor has a thermal coefficient of 50 parts per million (ppm) over a 50 K range that is 2500 ppm is an accuracy of 2500/1000000 = 0,25 %. This makes the sensor with a resistive divider is twice as accurate over temperature as a capacitive divider. The more accurate the real-time data is the more efficient and cost effective the grid can become. This is a prerequisite for functionalities like intelligent power grid with active load management or intelligent transformer substations, which are integrated in an overall smart grid power system management by remote signaling and control.

Thick-film resistors

EBG Resistors is a manufacturer of low-inductance thick-film resistors that can be used for high voltages, up to 90 kV on a single resistor. Higher voltage loads are possible if the resistor is potted. The EBG resistor product lines consist of an extensive variety of metal oxide products made with an exclusive METOXFILM formulation (see Figures 1 and 2).

METOXFILM or Thick Film resistors are the main choice for the high voltage needs of smart grid sensors, which will be used to monitor and measure transmission lines that operate at voltages from 20 kV to 230 kV (medium to high voltage grid) and even higher. The other main types of resistor technologies, such as wire wound, carbon film, bulk, etc., are not meant to handle such high continuous voltages. EBG resistors have been used for years with the move to digital and controllable power monitoring, where long-term stability and low-to-no drift is a goal. The resistors used for metering applications are typically flats and smaller cylindrical with tight tolerances and tight temperature coefficients. Typically in these point-of-use metering locations, such as industrial and commercial smart meters, the resistors have the same job as sensing, as voltage dividers, dividing the voltage to a usable and manageable level for all of the other internal circuitry.

In sensing applications, EBG's resistors are used in sensors applied directly to the voltage transmission lines, where it's necessary for them to be able to withstand high voltage loads and maintain tight tolerances and low drift under load. In the past, these sensing applications have been performed with a capacitive load. However, with more precise measurements required by power

Figure 1: **MTX type high-voltage resistor (divider)**

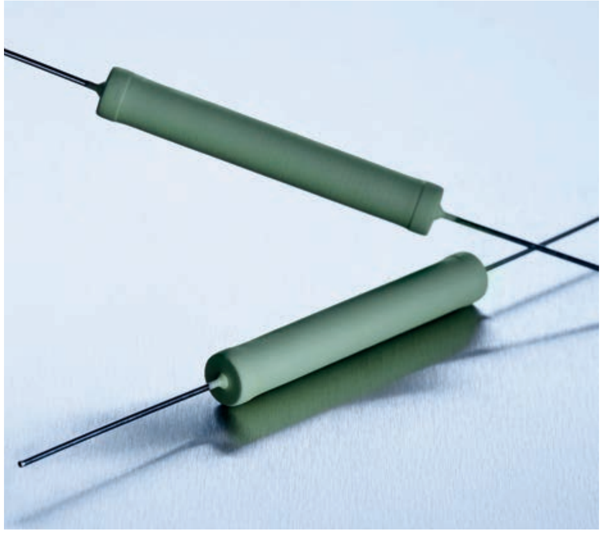


Figure 2: **Ultra-stable SHP high-voltage resistors**

generation companies, the capacitive load divider can no longer be used and resistive loads are now required.

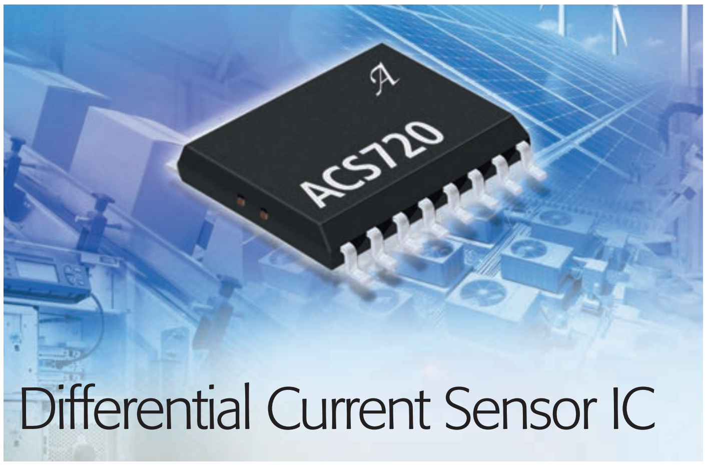
EBG can customize its high voltage resistors for exacting TCR and stability requirements over wide operating temperature range. The company can produce them with tolerances as low as +/-0.1 % and down to 15 ppm on flats - even lower (down to < 5 ppm) on cylindrical parts. Ongoing development aim at even lower thermal coefficients in temperature ranges starting from -10 °C to 85 °C. In addition, EBG can also customize mechanical dimensions of flats and cylindrical resistors as well as producing with custom terminals and terminations with multiple types of protective coatings to fit the application. Therefore, these resistors are made to order and typically highly customized.

Some of these applications are in other areas that are linked to the Grid, such as; E-Mobility in fast charging stations and EV busses, green power generation in Solar and wind, the medical market, (CT scans, MRIs and X-ray machines, to name a few). They're also used in motor drives, welders, power supplies, and instrumentation, within the industrial market where the EBG power resistors absorb high energy pulse loads and protects the machinery from failing due to unexpected voltage spikes.

High Switching Frequency IGBT

Alpha and Omega Semiconductor (AOS) expands its recently launched fast turn-off 650 V H-series IGBT family with a 1200 V rating. The new AOK40B120H1 has been developed to address needs of industrial welding and high-frequency converters with 3-phase AC or high voltage DC input. The AOK40B120H1 has been designed with AOS' patent pending AlphaIGBT™ technology platform and features fast turn-off as well as low $V_{CE(SAT)}$ of 1.8V, which reduces power losses incurred during conduction and switching. Also, the 1200 V minimum BV_{CES} rating and high latch-up ruggedness enable a larger safety application design. The AOK40B120H1 is available in production quantities with a lead-time of 12-14 weeks. The unit price for 10,000 pieces is $3.00.

www.aosmd.com



Differential Current Sensor IC

Allegro MicroSystems Europe has introduced a new high accuracy Hall-effect-based current sensor IC with multiple programmable fault levels intended for industrial and consumer applications with a focus on motor control and power inverter stage applications. One of the key benefits of the ACS720 is to provide high isolation with a reduced bill of materials made possible by the proprietary IC SOIC-16W package. The IC works off a single 5 V supply while maintaining an output voltage swing from 0 to 3 V, with a stable zero current output of 1.5 V. This allows the ACS720 to operate off a 5 V supply while having an output which is compatible with typical 3.3 V ADCs found on many MCUs. Furthermore, the device's high PSRR rejects the noise often found on the supplies in the power section of the PCB or system, maintaining high accuracy in noisy environments. The device has dual fault functions that are user configurable. Fast and slow fault output allow for short-circuit and over-current fault detection. A user-created resistor divider from the power supply of the ACS720 is used to set the fault level. The fault outputs are open drain, allowing the user to pull them up to a compatible voltage for the MCU. The open-drain outputs also allow for implementing a simple logical OR of multiple sensor fault outputs. The ACS720 also integrates differential current sensing, which rejects external magnetic fields, greatly simplifying board layout in three-phase motor applications. Near closed-loop accuracy is achieved in this open-loop sensor IC due to patented, digital temperature compensation, ultimately offering a smaller and more economical solution for many current sensing applications that traditionally rely on closed-loop core based sensors.

www.allegromicro.com

Connector For Greater Power Density In Rail Vehicles

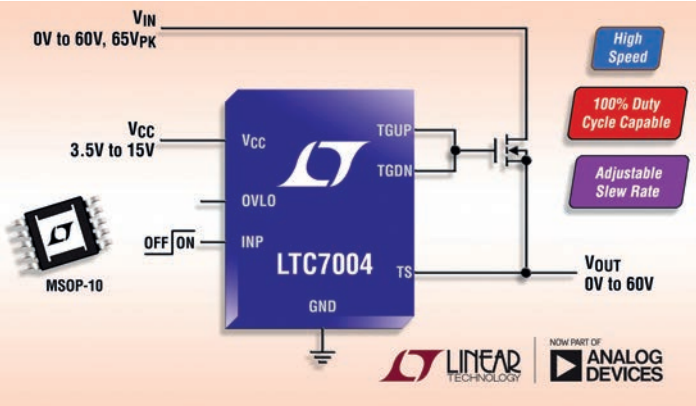
The new Han® 34 HPR EasyCon connector from HARTING is designed for high-current transmission with a high power density, making it ideally suited to use in rail vehicles. Han 34 HPR housings and retaining frames are designed in such a way that a connector is now available that can accommodate four 650 A contacts alongside one another in a single interface. This more than doubles the connector's current-carrying capacity compared to the next HPR connector size down, saving space for the end-user. However, the housing dimensions have not increased to the same degree: the housing width is only a third more than the smaller alternative. The new connector is available in an angled version for inter-car car transitions and a straight version for connections to traction units. The housing also allows 12 individual Han-Modular modules to be inserted as an alternative to the 650 A high-current contacts. Until now, two housings equipped with six Han-Modular individual modules each had to be used to obtain a comparable power supply.

www.HARTING.co.uk

48V Hybrid Electric Battery Test System

Digatron's 48V hybrid electric battery tester is a high current (500 A) cycler, designed for testing batteries for the new 48 V automotive platform. It can also test EV and hybrid modules, up to 100 V, and of course offers all the refinements of its larger brother, the Electric Vehicle Tester: CAN communication to BMS, battery emulation mode, modular structure for higher output (600, 800 & 1000 V) . This summer has been a game changer in the fortunes of the EV market with announcements from several of the auto majors and from China to end combustion engine manufacture in 20 years. It's not a question of "IF" anymore, it's only a question of "When" .
This has created an opportunity for new testing products and new circuit technologies, Digatron expects. Likewise our high current Silicon Carbide powered Regenerative cell tester is becoming the industry standard especially in the booming automotive sector, where 200A, 300A, 500A, 600A cell testing is required as many battery makers need to evaluate their products as efficiently as possible, whilst reducing space, cooling and cost issues – Digatron is the only player in the market to offer this range of power testing in an air-cooled packaging solution.

www.digatron.com



60 V High Side N-Channel MOSFET Driver

Analog Devices/Linear Technology offers the LTC7004, a high-side N-channel MOSFET driver that operates up to a 60 V supply voltage. Its internal charge pump fully enhances an external N-channel MOSFET switch, enabling it to remain on indefinitely. The LTC7004's 1Ω gate driver can drive large gate capacitance MOSFETs with very short transition times and 35 ns propagation delays, well suited for both high frequency switching and static switch applications. The LTC7004 operates from a 3.5 V to 15 V driver bias supply range with an adjustable under-voltage lockout. The fast 13 ns rise and fall times, when driving a 1,000pF load, minimize switching losses. Other features include an adjustable turn-on slew rate and an adjustable over-voltage lockout. The LTC7004 is available in the MSOP-10 package with pins configured for high voltage spacing. It is available in three operating junction temperature ranges of extended and industrial versions from –40°C to 125°C, a high temperature automotive version from –40°C to 150°C and a military grade from –55°C to 150°C. The 1,000-piece price starts at $2.05 each.

www.linear.com/product/LTC7004

Drum Cores for EMI Filtering

Premier Magnetics offers its new line of low-cost, high-performance drum core inductors designed for EMI filtering and switch mode power supply applications. With a product offering of over two dozen models with inductance values from 100 to 10,000 µH, the new PM-R Series boasts low DC resistance (DCR), providing low temperature rise at high peak currents. Their combination of high peak current and high self-resonant frequency (SRF) make the PM-R Series inductors an ideal drop-in replacement for lower-performing drum core devices. And in applications where the devices' maximum height of 10.0 to11.5 mm is acceptable, the PM-R Series offers a cost-effective alternative to surface-mount inductors. They are available with sleeving (+125°C); and without sleeving (+155°C). Standard operating temperature range is -40°C to 130°C, with higher temperatures available. The radial-leaded components are RoHS compliant.

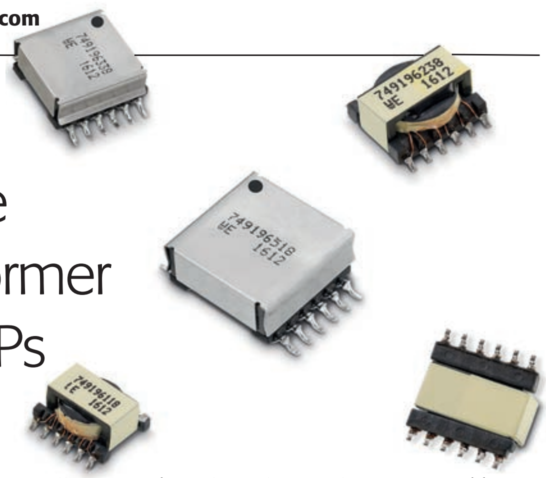
www.premiermag.com

80 V GaN Power Stage

Mouser is now stocking the LMG5200 GaN power stage from Texas Instruments (TI). The device delivers 25 % lower power losses compared to Silicon-based designs, enabling single-stage conversion and providing increased power density and efficiency in space-constrained, high-frequency applications. It consists of a high-frequency driver and two 15 mΩ GaN FETs in a half-bridge configuration. The device significantly reduces EMI while increasing power-stage efficiency by minimizing packaging parasitic inductances in the critical gate-drive loop. The LMG5200 device features advanced multichip packaging technology and is optimized to support power-conversion topologies with frequencies up to 5 MHz. The LMG5200 device's transistor–transistor logic (TTL)-compatible inputs can withstand input voltages up to 12 V regardless of the VCC voltage. This allows the inputs to be directly connected to the outputs of an analog PWM controller with up to 12 V power supply, eliminating the need for a buffer stage. The proprietary bootstrap voltage clamping technique ensures the gate voltages of the enhancement mode GaN FETs are within a safe operating range. Mouser is also stocking the LMG5200EVM-02 evaluation module, designed to provide engineers with a complete working power stage with an external PWM signal. The board can be configured as a buck converter, boost converter, or other converter topology using a half bridge. It can be used to evaluate the performance of the LMG5200 as a hard-switched converter to sample measurements such as efficiency, switching speed and voltage change over time (dV/dt).

www.mouser.com

Flexible Transformer for SMPs



Würth Elektronik eiSos offers a new line of transformers for SMT assembly - WE-FLEX HV (Flexible Transformer High Voltage). Like the WE-FLEX series of transformers, these excel because of their flexible capabilities in various applications making them suited for fast prototyping. Different circuit configurations enable over 375 transformer solutions and around 125 chokes with WE-FLEX HV. Applications include flyback converters, forward converters, push-pull converters, step-up and step-down converters or single-ended primary-inductor converters (SEPIC). Isolation voltage is 1.5 kV AC. The newly developed MnZn core material reduces core losses by up to 30 % compared with classical products and makes the new SMD transformer an attractive solution for all types of isolated DC/DC converters in industrial and telecommunications applications. WE-FLEX HV is available in four sizes, each with five different air gap lengths. The working temperature is specified as -40°C to +125°C. Given suitable circuitry, the large package types of the series have a basic isolation for working voltages up to 250 V RMS.

www.we-online.com

Anti-Stall Stepping Motor Driver IC

Toshiba Electronics Europe (TEE) announced a new stepping motor driver (TB67S289FTG) that automatically detects and prevents stalling during operation. Stable and highly precise control is a basic operating requirement for motors used in printers, office appliances, banking terminals (including ATMs), cash dispensers and home appliances. Motors stall when the motor rotation deviates from the control signal. Avoiding stalls in stepping motor operation is the highest priority for delivering stable and precise motor control and is achieved by providing additional current to ensure an operating margin for the motor. Real-time monitoring of motor torque and current feedback, using additional sensors and highly advanced MCU control, is also required to improve efficiency and heat generation. A further way to improve efficiency and cut down heat generation is to improve the built-in MOSFET's on-resistance thereby reducing power loss during operation.

The TB67S289FTG is the first stepping motor driver to apply Toshiba's original anti-stall and efficiency improvement system, Active Gain Control (AGC). AGC enables the driver to monitor the motor and torque, and automatically optimizes the motor control without additional MCU control. In operation, the new TB67S289FTG prevents step-losses and motor stalls, and automatically optimizes motor current, depending upon the torque needed. Offering step resolutions of full, half, quarter, 1/8, 1/16 and 1/32 steps to cut down noise and vibration, the device includes several built-in, MCU flaggable, error detection functions (thermal shutdown, over-current shutdown, under-voltage lock out, and motor load open detection) that contribute to safety and reliability. It also supports the power-on sequence for a single power drive. The TB67S289FTG reduces motor power by up to 80 %, thereby delivering significant improvements in efficiency and heat without relying on the low on-resistance of 0.46 Ω (upper + lower typ.).

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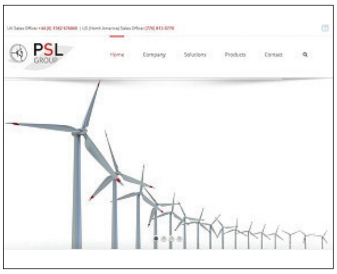

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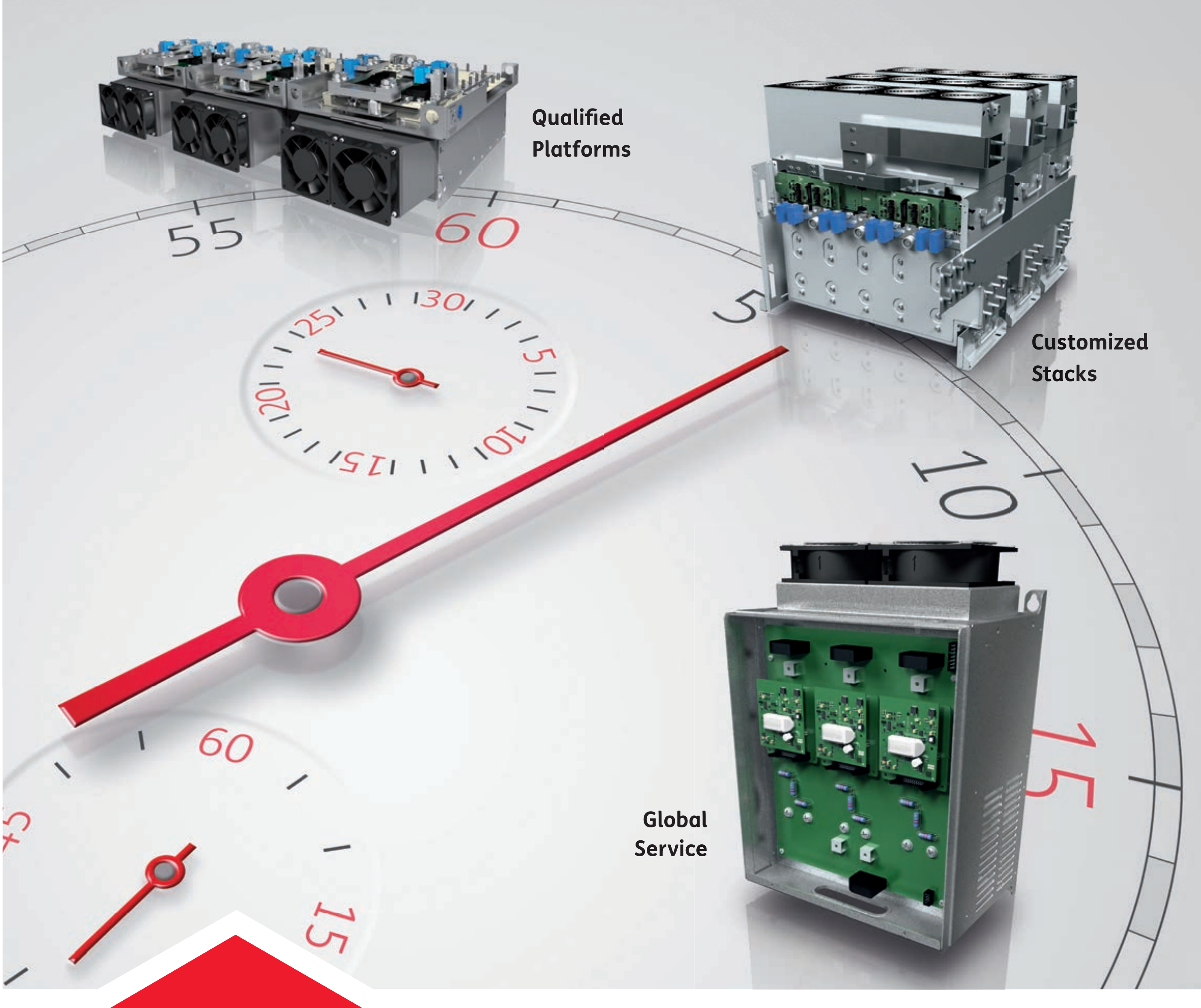
When Time to Market Counts



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