Reliable Galvanic Isolation, Simplified
Automation is essential to efficiency and productivity in today’s fast-changing industrial scene. High automation unites warehouses, filling operations, rolling mills and conveyor belt systems. These systems monitor and collect data on temperatures, voltages and speeds using a complex network of sensors “in the field.” This vital data is sent across tens of meters of wires to a central control unit for crucial operation-optimization choices. This seemingly simple operation is complicated by the hostile industrial environment’s strong transient-voltage fluctuations and electromagnetic interference. Compact digital isolators may solve these issues and ensure data flow. In this issue, Timur Uludag, senior technical marketing manager at Würth Elektronik eiSos Group in the MagI3C Power Modules business unit, simplifies galvanic isolation and explains how it ensures data transmission in industrial intralogistics systems. Moreover, in this issue, we analyze optical fiber probes and how they boost wide-bandgap power electronics development, a comparative analysis of conventional and SiC-based ANPC topologies based on thermal models and device losses, and a framework for wireless communication and power transfer in industrial IoT and hydrogen electric vehicles. Automakers are tackling various technological issues in vehicle electrification. Electronic designers and engineers of powertrain and high-voltage technology systems for a sustainable future want to increase EV range while decreasing design complexity and external component prices. Modern automotive vision focuses on maximizing EV autonomy by minimizing complexity and design expenses. In this issue, we describe how SiC power electronic components, which improve system performance, greatly affect the EV ecosystem. SiC power devices find extensive utilization in various domains, including power supplies, battery EVs, power-conversion systems for battery charging and traction drives, industrial motor drives and renewable-energy-generation systems like solar and wind inverters. Furthermore, an article will delve into the intricacies of a novel three-phase current-source rectifier (CSR) with an asymmetrical configuration, examining how it distinguishes itself from the conventional CSR. This exploration will encompass the advantages and disadvantages of the proposed CSR in relation to power loss, output filtering, voltage stress and current stress. Analog Devices Inc.’s Erik Lamp, product applications engineer, and Xinyu Liang, application engineering manager, showcase the merits of utilizing the high-performance Silent Switcher 3 architecture. This architecture boasts remarkable attributes, such as ultra-low noise and rapid transient response, particularly in multiphase buck applications. In today’s dynamic technological landscape, our world is witnessing groundbreaking innovations across various domains. From the imperative need for a capillary public charging infrastructure to accelerate the widespread adoption of EVs in urban areas to the revolutionary advancements in wireless EV charging and the transformative influence of quantum computing on industries like power electronics, other articles included in this issue explore the frontiers of innovation and their profound impact on our daily lives.

Yours Sincerely,
Maurizio Di Paolo Emilio
Editor-in-Chief, Power Electronics News

Delving Into Innovations in Power Electronics Engineering
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Reliable Galvanic Isolation, Simplified

By Timur Uludag, senior technical marketing manager at Würth Elektronik eiSos Group in the MagIC Power Modules business unit

Transmitting data over cables in industrial applications comes with the challenges of a high-transient-voltage environment and high EMC interference. Compact digital isolators can be a solution. For a better understanding of the situation, the application of an industrial intralogistics system with various functional units is used.

Industrial environments, such as warehouses, filling plants, rolling mills or conveyor belt systems, all have one thing in common: They are characterized by a high degree of automation. Temperatures, voltages, speeds and other physical variables are measured by sensors “in the field” and forwarded to a central location. Here, actions are initiated that, for example, reduce the speed of a motor to decrease a temperature reading that is too high. Due to the large space these systems occupy, there can be tens of meters of cable between a sensor and the central control unit.

Figure 1 provides an example of an industrial system, though to scale. Interference-free data communication and personal safety are two major challenges for electronics in this type of industrial environment. Strong electromagnetic fields, surge voltages, transient voltages and high EMC noise are commonplace. If, for example, the communication line is laid unfavorably close to a control line of a frequency converter, the pulses will be capacitively coupled and the signals in the communication line will oscillate with the pulse pattern of the frequency converter. These disturbances can quickly reach a level where significant malfunctions occur and even personal safety can be compromised.

Figure 1: Typical industrial application—warehouse logistics

FUNCTIONS OF AN ISOLATOR

Clustering the described phenomena, the following four challenges emerge:

▶ A safety barrier between hazardous voltages and a user
▶ Separation of ground loops between spatial circuits
▶ Minimization of common-mode interference
▶ Interference-free data transmission
Figure 2 graphically illustrates the situation of the data-transmission system. In order to meet the requirements of blocking dangerous voltages from the user while still guaranteeing interference-free data transmission, galvanic isolation must be used that separates the zones electrically—i.e., their potentials from each other—so that they can work separately and thus without interference.

In general, there are three types of isolation technologies that can be used to separate systems galvanically from each other:

▶ Optical
▶ Inductive
▶ Capacitive

An optocoupler consists of a transmitting LED on the primary side and a phototransistor on the secondary side. Both units are galvanically isolated from each other by an optically conductive medium.

An inductive isolator consists of a primary and a secondary transformer winding positioned at a defined distance from each other. Both windings are galvanically isolated from each other by an insulator, such as a polyimide.

A digital isolator based on the capacitive effect consists of two metal plates separating primary from secondary. Both sides are galvanically separated from each other by an insulating material, such as a polyimide.

All three types of isolators mentioned fulfill the basic requirements of galvanic isolation. However, when we consider the challenges of an industrial application—such as harsh environmental conditions, EMC interference and transient voltages, and data rate—the electrotechnical differences of the three technologies become more significant.

Optocouplers have a limited data-transmission rate inherently due to their transmission technology, LED emission and phototransistor reception. Usually, data rates of a few tens of kilobits per second are possible for standard optocouplers. Data transmission is also very temperature-dependent, as the CTR changes with the temperature.

Depending on how the windings are implemented, inductive isolators can be sensitive to magnetic fields; they then act like antennas and can thus additionally couple interference into the desired signal. Additionally, the insulation material between the primary and secondary windings tends to retain water when exposed to high humidity.

Digital isolators based on the capacitive effect, such as the digital isolators of the CDIS and CDIP series from Würth Elektronik, are inherently less sensitive to magnetic fields because they use electrical fields for transmission. The structure, shown in Figure 3, enables data-transmission rates of up to 150 Mbps because the capacitors are constructed using a CMOS process. The insulation barrier consists of amorphous silicon dioxide (SiO$_2$), which is insensitive to humidity.

Please note that this comparison is specifically for the described application and does not claim to be a complete evaluation taking into account all possibilities.

In the next section, we will take a look at the digital isolators of the CDIS and CDIP series from Würth Elektronik.

**CAPACITIVE DIGITAL ISOLATORS**

The digital isolator consists of an oscillator and a modulator on the primary side. On the secondary side are a demodulator and a buffer. The primary-side components are galvanically separated from the secondary-side components by a capacitor structure with an isolation barrier made of SiO$_2$. Signal transmission through the isolation barrier is realized by a modulation method known as on/off keying. The oscillator integrated in the chip is used to modulate the Schmitt-triggered input signal. The modulator generates a differential signal that is transmitted via the capacitive insulation lines. The demodulator is located on the secondary side and is used to amplify, filter...
evaluation. Therefore, ground loops can disturb the communication. The CAN bus has a data rate of up to 8 Mbps.

Digital isolators are placed between the CAN transceiver and the local CAN controller (Figure 5). This allows the system to be isolated from the lines. A single external isolated DC/DC power module, such as the FIMM 1769205132, is required as a power supply for both the primary and the secondary side of the digital isolator, maintaining galvanic isolation with only one component. The digital isolators can operate with a supply of 3.3 V or 5 V—i.e., both standard logic levels.

Digital isolators and isolated power supplies in combination eliminate ground loops and efficiently protect the system from damage due to overvoltage. More information about the two-channel digital isolator WPME-CDIS series can be found in the datasheet.

APPLICATION EXAMPLE: SPI BUS

The serial peripheral interface (SPI) bus is a standard for synchronous serial communication designed to provide a simple and low-cost high-speed interface for microcontrollers (MCUs) and peripherals. The SPI bus can transmit at a data rate of up to 60 Mbps over short distances. SPI interfaces are most commonly used for communication between the analog-to-digital converter and MCU. The most common configuration for isolation is three forward channels (CS, SCLK, SDI) and one reverse channel (SDO).

The best solution for this type of task is to use the 18024115401x digital isolator, as shown in Figure 6. The digital isolator 18024115401x has a three-/one-channel configuration (three forward channels, one reverse channel) and provides an isolation voltage of 5 kVrms and a data rate of up to 100 Mbps. It also has an integrated DC/DC converter, which makes it possible to significantly reduce the number of components in the design and save space on the PCB. In this way, it helps to ensure the required level of isolation and reliable transmission of high-speed signals required when designing an SPI bus.

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Table 1: Overview of the Würth Elektronik digital isolator portfolio

APPLICATION EXAMPLE: CAN BUS

Originally, the controller area network (CAN) bus was developed for automotive applications, but it has become indispensable in industrial plants with functional units that are several tens of meters away. The bus connects the data nodes and the central unit, which takes over the
More information about the four-channel digital isolator WPME-CDIS and WPME-CDIP series can be found in the datasheets.

**SOLUTION FOR HARSH INDUSTRIAL ENVIRONMENTS**

The WPME-CDIS and WPME-CDIP series transmit high-speed digital signals (up to 150 Mbps) safely ($V_{ISO}$ up to 5 kV) in harsh industrial environments. In this way, both the signal integrity and the safe functionality of the system can be guaranteed. Digital isolators also offer interesting circuitry possibilities, as will soon be demonstrated by Würth Elektronik in upcoming application examples, such as for sensors.

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**References**

- WPME-CDIS Capacitive Digital Isolator Standard
- WPME-CDIP Capacitive Digital Isolator Powered
- Power Modules (MagI³C Series)
- REDEXPERT

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**Optical Fiber Probes Boost WBG Power Electronics Development**

By Stefano Lovati, contributing writer for Power Electronics News

Wide-bandgap (WBG) power devices, such as gallium nitride and silicon carbide, can switch at high voltages in a few nanoseconds. Due to the high dV/dt, WBG power devices produce waveforms containing high-frequency harmonics, thus posing unique challenges to designers when accurate measurements must be performed.

*Micsig Technology*, a company that specializes in manufacturing signal test and measurement instruments, has developed a series of optical fiber-isolated scope probes, called SigOFIT, that allow the performance of measurements on devices operating at voltages up to 60 kV and frequencies up to 1 GHz.

With this kind of isolated probe, which has no electrically conductive path between the probe tip and the oscilloscope, Micsig addresses the needs of WBG semiconductor–based high-voltage power electronics development, involving bandwidths up to 1 GHz and rise times down to less than 350 ps. These probes help ensure that measurements are both reliable and safe in the challenging operating conditions of these advanced semiconductor technologies.
BENEFITS OF OPTICAL FIBER-ISOLATED SCOPE PROBE

Optical fiber-isolated scope probes, also known as optical isolation probes or fiber-optic probes, offer several advantages in electronic test and measurement scenarios. Here are some key advantages of optical fiber-isolated scope probes:

▶ Electrical isolation between the measurement instrument (oscilloscope) and the device under test (DUT). This isolation prevents ground loops and eliminates the risk of unwanted electrical interference that could distort measurements or damage sensitive components.

▶ High bandwidth. Optical fibers can convey signals with high-bandwidth capabilities, allowing accurate measurements of high-frequency signals without significant signal degradation.

▶ High-voltage tolerance. Optical fiber probes can tolerate higher voltage differentials compared with traditional electrical probes.

▶ Noise immunity. Electrical isolation through optical fibers minimizes the susceptibility to electromagnetic interference (EMI), leading to cleaner and more accurate measurements.

▶ Operator safety. Optical fiber isolation prevents the flow of potentially harmful high-voltage currents between the instrument and the DUT. This is especially crucial when working with high-voltage or high-power circuits.

Additionally, optical fibers can span longer distances compared with traditional electrical cables without signal degradation, and they have minimal loading effects on the DUT. Traditional electrical probes can introduce capacitance and resistance, altering the behavior of the circuit being measured. Optical fiber probes mitigate this issue, providing a more accurate representation of the circuit’s behavior.

Figure 1: Application example of the SigOFIT probe (Source: Micsig Technology)

SigOFIT PROBE’S FEATURES

With the SigOFIT probe shown in Figure 1, the scope end of the probe and the probe’s head are connected by optical fibers along which an analog optical representation of the signal is transmitted down to the scope end, while power is transmitted up to the head, in this case by a laser.

An amplifier at the head presents 1M in parallel with 10 pF to the probe tip via an SMA connector, and probe tips ranging from 10× to 2,000× are available for connecting to the signal of interest. The capacitance at the signal interface is 3 pF, and 1 pF in the case of 2,000×. In contrast with conventional differential probes, which can only test high-voltage signals, the SigOFIT probe can be used with various attenuator tips to test differential-mode signals from ±1.25 V to ±2,500 V, achieving full-range output and a very high signal-to-noise ratio.

As a result of signal and power transmission being electrically isolated, the utmost common-mode withstanding voltage is 60 kV. The company claims that the SigOFIT instrument provides a high common-mode-rejection ratio (CMRR) of 112 dB at 100 MHz and over 100 dB at 500 MHz.

Measuring the ability of the equipment to reject unwanted common-mode signals while accurately amplifying the desired differential signals, CMRR is important for several reasons:

▶ Noise rejection: Unwanted common-mode noise and interference can couple onto both the signal and the ground. CMRR helps to ensure that such noise is rejected or attenuated, allowing the instrument to accurately capture and measure only the differential signals of interest.

▶ Accuracy: CMRR minimizes the impact of common-mode noise, which can otherwise distort the measurement results.

▶ Balanced and differential signal processing: CMRR is particularly crucial in differential signal processing and balanced circuits, ensuring that the equipment amplifies the difference between two signals while rejecting the common-mode components.

▶ Minimizing distortion: Common-mode signals can cause distortion in measurement equipment, affecting linearity and fidelity. A high CMRR helps to prevent distortion and maintain the integrity of the measured signals.

The DC gain accuracy of the SigOFIT probe is higher than 1%, while the amplitude-frequency characteristics of the probe are outstanding. After warming up, the zero drift is less than 500 µV, and the highest noise floor in the range is 1.41 mVrms.

SigOFIT is the best choice for latest-generation semiconductor test and measurement. Because of its short test leads and coaxial cable transmission, the SigOFIT probe has an input capacitance of less than 3 pF and is hence an extremely reliable tool for testing power devices based on WBG materials like GaN and SiC.
Because the SigOFIT probe receives its power from a laser, it can achieve total galvanic isolation from the DUT. The main technical features of the probe can be summarized as follows:

- Up to 1-GHz bandwidth
- 160-dB CMRR at DC
- Over 100-dB CMRR at 500 MHz
- 60-kVpk common-mode voltage range
- Up to ±2,500-V differential input voltage range
- 1% DC gain accuracy
- Autozero in less than 1 second
- Support all BNC-type oscilloscopes

As shown in Figure 2, the SigOFIT probe perfectly suppresses the oscillation caused by high-frequency common-mode noise and therefore is an ideal solution for SiC and GaN power devices. The yellow plot has been obtained using a conventional differential probe, whereas the blue plot has been obtained using the SigOFIT probe.

Key applications for the SigOFIT probe include:

- Design of motor drive and power converter
- Design of GaN, SiC and half-/full-bridge devices
- Design of inverter, UPS and switching power supply
- High-voltage, high-bandwidth safety test
- Power device evaluation
- Current-shunt measurements
- EMI and ESD troubleshooting
- Floating measurements
Comparison of SiC-Based ANPC Topologies

By Stefano Lovati, contributing writer for Power Electronics News

Silicon carbide devices are gaining popularity as a result of their numerous benefits for modern power electronic applications.1-3 To compensate for the higher cost of SiC-based power devices, hybrid Si–SiC topologies have been proposed.4-6 In such topologies, such as the active neutral-point–clamped (ANPC) converter, Si devices are switched either at their fundamental frequency or at a lower frequency than SiC devices, which are switched at a high frequency. However, the device losses are unevenly distributed, which is essential for the converter’s operation.

This article will provide a comparative analysis of conventional and SiC-based ANPC topologies based on thermal models and device losses.7

ANPC TOPOLOGIES Three SiC-based ANPC converter topologies are represented in Figure 1. Figure 1a shows the SiC-based ANPC converter. It consists of six SiC MOSFETs per phase leg to attain high efficiency. In this topology, the modulation scheme applies the switching state during the null-state operation such that all SiC MOSFETs (S2, S3, S5, and S6) in the middle are activated. This results in decreased conduction losses. In addition, because all of the devices are SiC MOSFETs, the switching losses are minimal. Consequently, this converter obtains a high level of efficiency at a high switching frequency. However, the excessive cost is due to the use of six SiC MOSFETs per phase leg.
Figures 1b and 1c show the hybrid ANPC converter with four and two SiC devices, respectively, to reduce the cost of the converter and obtain performance comparable to that of the SiC-only ANPC. Si IGBTs are switched at the fundamental frequency, while SiC MOSFETs are switched at a higher frequency in these topologies. Due to the reduced switching loss characteristic of SiC MOSFETs, greater efficiency at a lower cost can be attained. Unevenly distributed switching stress among the converter switches is a problem with the hybrid ANPC topologies described previously.

Figures 1a, 1b, and 1c show the hybrid ANPC topologies with four and two SiC devices, respectively, to reduce the cost of the converter and obtain performance comparable to that of the SiC-only ANPC. Si IGBTs are switched at the fundamental frequency, while SiC MOSFETs are switched at a higher frequency in these topologies. Due to the reduced switching loss characteristic of SiC MOSFETs, greater efficiency at a lower cost can be attained. Unevenly distributed switching stress among the converter switches is a problem with the hybrid ANPC topologies described previously.

**LOSS ANALYSIS**

The converter device losses include conduction and switching losses. The conduction losses $P_c$ for all SiC ANPC converters in active and null states, for positive direction of load current $i_L$, are given by the following two equations:

$$P_c(\text{active}) = 2 \times (P_{c(Si-MOS)} + P_{c(Si-IGBT)})_{at \, i_L} = 2 \times i_L^2 \times r_{ds}$$

$$P_c(\text{null}) = 2 \times (P_{c(Si-MOS)} + P_{c(Si-diode)})_{at \, 0.5 \, i_L} = 2 \times \left( \frac{i_L}{2} \right)^2 \times r_{ds} + \left( \frac{i_L}{2} \right)^2 \times r_d$$

where $r_{ds}$ and $r_d$ are the on-state resistances of the SiC MOSFET and SiC diode, respectively.

The conduction losses for the four SiC ANPC converters in active and null states for the positive direction of load current are given by the following two equations:

$$P_c(\text{active}) = \left( P_{c(Si-MOS)} + P_{c(Si-IGBT)} \right)_{at \, i_L}$$

$$P_c(\text{null}) = \left( P_{c(Si-MOS)} + P_{c(Si-diode)} \right)_{at \, 0.5 \, i_L}$$

where $P_{c(Si-MOS)}$, $P_{c(Si-IGBT)}$, and $P_{c(Si-diode)}$ represent the conduction losses, on-state drop at zero current and on-state resistances, respectively, for the Si IGBT.

Likewise, the conduction losses for the two SiC ANPC converters in active and null states for the positive direction of load current are given by the following two equations:

$$P_c(\text{active}) = \left( P_{c(Si-IGBT)} + P_{c(Si-MOS)} \right)_{at \, i_L}$$

$$P_c(\text{null}) = \left( P_{c(Si-IGBT)} + P_{c(Si-diode)} \right)_{at \, 0.5 \, i_L}$$

The switching losses can be determined using the characteristics obtained using the double-pulse tests, at different load-current values, for the respective devices. Using these characteristics, the turn-on ($P_{sw-on}$) and turn-off ($P_{sw-off}$) power losses at the given value of the switch current ($i_{sw}$) can be determined using the following two equations:

$$P_{sw-on} = \frac{1}{T_s} \times E_{on}(i_{sw})$$

$$P_{sw-off} = \frac{1}{T_s} \times E_{off}(i_{sw})$$

where $T_s$ is the switching time and $k_x$ ($x = 1, 2, 3, 4, 5, 6$) are the curve-fitting constants.
The relation between device losses and junction temperature, for the selected switching devices, is given by the following equation:

\[ P_{\text{loss}}(T_{jx1}) = P_{\text{loss}}(T_{jx0}) \times (a_1 \times e^{-a_2 \times T_{jx1}}) \]  

where \( T_{jx1} \) and \( T_{jx0} \) are the new and old values of the junction temperatures, respectively, \( a_1 \) and \( a_2 \) are the curve-fitting constants and \( P_{\text{loss}}(T_{jx0}) \) represents the total switch losses, including the conduction and switching loss.

\( T_{j} \) also depends on the switch losses, as in the following equation:

\[ T_{jx1} = T_{ho} + P_{\text{loss}}(T_{jx0}) \times (R_{(j-c)x} - R_{(c-h)x}) \]  

where \( R_{(j-c)x} \) and \( R_{(c-h)x} \) represent the thermal resistances between the junction to case and case to heatsink, respectively, \( x \) is the switch number and \( T_{h} \) is the temperature of the heatsink given by the following equation:

\[ T_{h} = P_{\text{total}} \times R_{(h-a)} + T_{a} \]  

where \( T_{a} \) is the ambient temperature, \( R_{(h-a)} \) is the thermal resistance of the heatsink and \( P_{\text{total}} \) indicates the total device losses of the converter.

To compute the steady-state values of the device losses and junction temperatures, a closed-loop method coupling the loss equations with the junction temperature values has been employed. After determining the switching losses, the temperature of the heatsink is evaluated using the given parameters and Equation 11. Figure 2 depicts the computed device losses for the discussed topologies.

Evidently, the distribution of device loss is not homogeneous across all considered topologies. In addition, the two SiC ANPC topologies have relatively higher device losses because the SiC MOSFET S2 was overstressed (Figure 2c). In all considered topologies, the junction temperatures of the devices are also non-uniform and follow the same trajectory as the device losses.

THERMAL ANALYSIS

Using simulation based on the finite element method (FEM), a 3D model of a heatsink has been developed to examine the influence of uneven loss dissipation. The device losses are computed and used as inputs to this FEM model, and closed-loop simulations are carried out.

The heatsink temperature of individual devices can be computed using the following equation:

\[ T_{hx} = P_{\text{loss}(x)} \times (R_{(j-c)} + R_{(c-h)}) + T_{jx} \]  

Where \( T_{hx} \) represents the heatsink contact temperature for the provided switch \( x \) and \( P_{\text{loss}(x)} \) represents the computed loss corresponding to the same switch. These \( T_{hx} \) values are then input into the 3D FEM model of the heatsink to calculate the steady-state temperature caused by heat dissipation. The resulting values of the heatsink contact temperatures are then applied to Equation 10 to determine the updated junction temperatures.

In the two SiC-based ANPC topologies, the switching losses are concentrated on the interior switches, which are the SiC MOSFETs that conduct for the majority of the time and have higher

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junction temperatures. Therefore, in these hybrid topologies, the switches with the highest switching stress can be maintained in locations that allow for the greatest heat transfer to the ambient.

In topologies containing a combination of Si/SiC devices and an asymmetrical distribution of losses, conventional thermal models are unsuitable for producing accurate results. The results of conventional thermal models may cause some of the designed converters' switches to be overstressed and malfunction. Consequently, the effect of the different heatsink contact temperatures must be considered during the design of the converter, which is feasible with the presented method.

References


Why SiC Is at the Heart of E-Mobility

Vehicle electrification is a sector that still has many technical challenges that automakers are focusing on. Electronic designers and engineers of powertrain systems and high-voltage technology systems for a sustainable future are interested in achieving greater range for EVs, reducing design complexity and costs of external components.
Maximizing the autonomy of EVs by reducing complexity and design costs is the main objective of the modern automotive vision. The EV ecosystem is strongly influenced by the presence of SiC power electronic devices, which allow the system to obtain multiple performance advantages.

By Giordana Francesca Brescia, contributing writer for Power Electronics News

The automotive industry is going through a phase of technological transformation. Indeed, the evolution from internal-combustion-engine (ICE) vehicles to electrically powered vehicles is spreading rapidly. In parallel, innovations in the semiconductor market for traction inverter systems and power conversion help overcome critical barriers to ever more widespread use. Driven by regulations around the world to reduce CO$_2$ emissions, electric vehicles will achieve widespread adoption by 2030. As such, designers of high-voltage applications, such as traction inverters, are faced today with addressing a variety of challenges to optimize system efficiency and reliability in a small space. Automotive research further reduces components and speeds prototyping of an efficient system using the silicon carbide EV traction inverter reference design.

Today, automakers can build reliable SiC-based traction inverters and insulated-gate bipolar transistors (IGBTs) with advanced SiC monitoring and protection and diagnostics for functional safety. The latest-generation and highly integrated SiC gate drivers make it possible to maximize the autonomy of EVs. To achieve the goal of increasing the autonomy of EVs, it is also necessary to design more efficient traction inverters. Automotive engineers must design safer and more efficient traction inverters that can increase the range of EVs by up to a few thousand kilometers per year. SiC gate drivers, thanks to their features, allow designers to improve power density, reduce system design complexity and the number of external components, lower costs, achieve strategic objectives in terms of functional safety and overall performance, maximize autonomy and design increasingly efficient traction inverters.

TECHNICAL SPECIFICATIONS AND REFERENCE MARKETS OF POWER DEVICES

With SiC gate drivers, you can do much more while consuming less power. This has made them ideal devices suitable for multiple markets, especially in what the automotive market requires today, with advantages in various applications. The new SiC gate drivers offer outstanding characteristics in terms of increased power density, performance and safety.

Efficient power conversion depends on the power semiconductor devices used in the system. High-power applications are becoming more efficient and smaller in size due to improvements in power device technology. These devices include IGBTs and SiC MOSFETs, which are well-suited to high-power applications due to their high voltage ratings, high current ratings and low conduction and switching losses. Applications with voltages greater than 400 V require device voltage ratings greater than 650 V to allow sufficient headroom for safe operation. Applications like industrial motor drives, EVs and hybrid vehicles, traction inverters and solar inverters for renewable energy have a power level from a few kilowatts to a megawatt and beyond.

The applications for SiC MOSFETs and IGBTs have very similar power levels; however, they vary as the frequency increases. SiC MOSFETs are becoming increasingly common in power-factor-correction power supplies, solar inverters, EVs and hybrid vehicles, traction inverters for EVs, motor drives and railways. On the other hand, IGBTs are more common in motor drives, uninterruptible power supplies, string and central solar power inverters below 3 kW and EV/hybrid-vehicle traction inverters.

There are also several system advantages of SiC MOSFETs over silicon MOSFETs and IGBTs. First, silicon MOSFETs and IGBTs have been used in power converters for a long time. However, SiC MOSFETs have emerged as a new technology, displaying important advantages that surpass those
of other devices due to their inherent material properties. In fact, a wide-bandgap (WBG) material has extremely interesting characteristics. The material properties of SiC translate directly into system-level advantages over systems using Si devices. Key benefits include reduced size, cost and weight. As a result, SiC MOSFETs are increasingly replacing silicon power devices.

Si MOSFETs, Si IGBTs and SiC MOSFETs are used in power applications but differ in power levels, drive methods and operating modes. Power IGBTs and MOSFETs are voltage-driven at the gate, as the IGBT is internally a MOSFET driving a bipolar junction transistor. As a result of the bipolar nature of IGBTs, they carry a large amount of current with a low saturation voltage, resulting in low conduction losses.

MOSFETs also have low conduction losses but depend on the device’s drain-source on-resistance \( R_{\text{DS(on)}} \). Silicon MOSFETs carry less current than IGBTs, so IGBTs are used in high-power applications. MOSFETs are used in high-frequency applications in which high efficiency is paramount.

As for SiC MOSFETs, we can say that they are similar to Si MOSFETs in device type. However, SiC is a WBG material with properties that allow these devices to operate at the same high-power levels as IGBTs while still being able to switch at high frequencies. These properties translate into important benefits, including higher power density, higher efficiency and lower heat dissipation. As power levels increase—for example, in traction inverters that drive EV motors—thermal management of silicon power devices like IGBTs becomes more complicated due to high-limit operating temperatures and allowable junction temperatures. This involves incorporating cooling components into drive systems, especially in a traction inverter, where power levels can exceed 100 kW. However, these cooling components increase the size, weight and cost of the vehicle. In contrast, SiC has a much higher allowable junction temperature. Additionally, for a given battery capacity, SiC circuit breakers offer a 10% efficiency improvement over IGBTs in the traction inverter system.

**THE IMPORTANCE OF SiC IN AUTOMOTIVE POWER ELECTRONIC SYSTEMS**

SiC, a third-generation broadband semiconductor, has established itself in recent years as a successful technology that has the potential for a global impact on the sustainable transport ecosystem. The use of SiC for power switches enables higher power densities and switching efficiencies in EV powertrains. There are several advantages to derive from the adoption of SiC, which can be obtained by exploiting the highly differentiated set of SiC material properties to design more efficient, robust and compact propulsion systems.

We can thus summarize the main advantages of power electronics based on SiC as follows:

- Increased power density for improved performance of EV powertrains
- Ability to operate at higher temperatures than traditional silicon-based devices
- Increased current-carrying capacity
- Higher switching frequencies
- High withstand voltage
- A 2× to 3× higher thermal conductivity than that of silicon
- Increased driving range
- Faster charging
- Cost reduction

SiC power devices can carry current densities up to 5× higher than silicon power devices. This allows for higher per-chip power density, leading to smaller devices and more compact packages. While research is continuing to reduce battery cost by increasing battery capacity—i.e., energy density—EV powertrains are also increasing power density (defined as the ratio of energy efficiency to overall size) by decreasing size, weight and cost. This is achieved by maximizing the use of SiC power switches, especially in on-board chargers (OBCs) and traction inverters in propulsion systems.

Additionally, SiC-based power devices are also capable of achieving switching frequencies 10× faster, up to at least 20 kHz in traction inverters and hundreds of kilohertz in OBCs. At these higher frequencies, the size of passive components like capacitors and inductors can be significantly reduced, allowing for smaller overall systems. SiC allows for higher withstand voltage, power and switching efficiency, simplifying the design of high-power traction inverters with significantly reduced losses.
EV system engineers are challenged to make the most of the potential of high-voltage technology through innovations involving power conversion and WBG semiconductors. The need for greater reliability and higher-power performance for EVs is continuously growing, as efficiency gains have a direct effect on increasing range per charge. However, it is still too difficult for EV designers to achieve a large increase in efficiency, given that most traction inverters are already operating at 90% or higher efficiency. The use of SiC for power switches enables higher power densities and switching efficiencies in EV powertrains.

Additionally, SiC-based power electronics enable EVs to achieve longer driving range, faster charging and lower total cost of ownership. The reduced power loss of SiC devices can also be exploited to reduce battery cost and size. Also, higher voltages reduce the need for large amounts of copper in the motor windings, resulting in smaller motor designs. These reductions in component size and weight help reduce the cost of EVs, significantly contributing to EVs’ cost parity, or even better, than traditional ICE vehicles. For a given power level and battery capacity, SiC power devices can be smaller in size, which results in clusters of EV subsystems with integrated propulsion systems. At the design level, the cost of the system can be minimized by eliminating or reducing the mechanical blocks for cooling and the amount of material for the passive elements and the case.

Overall, SiC power electronics are having a large global impact. The largest market segment for SiC in the coming years is definitely EVs, suggesting that the SiC technology market will grow faster than the EV market.

References


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An Innovative Solution to Address Energy-Efficiency Problems in SWIPT-NOMA Systems

Researchers at KMOU have developed a framework for wireless communication and power transfer in industrial IoT.

By Abhishek Jadhav, contributing writer for Power Electronics News

Managing power supplies for smaller IoT devices has always been challenging. As these devices are designed to consume relatively little power, replacing or recharging batteries in many IoT devices can become impractical. To address the power supply challenge, wireless-power-transfer (WPT) technology is considered a promising solution, which uses radio-frequency (RF) signals to transmit energy wirelessly to these small IoT devices.

Simultaneous wireless information and power transfer (SWIPT) has attracted significant interest in the field of IoT because it allows devices not only to receive information but also to harvest energy from the same RF signal. SWIPT combines two functions into a single RF signal: energy harvesting (EH) and information decoding (ID). One approach to implementing SWIPT involves time-switching receivers, as they decode information and harvest energy in different timeslots. Another approach is power-splitting (PS) receivers, which split the received RF signal into two parts with an appropriate PS ratio.

Researchers have been discussing the integration of non-orthogonal multiple access (NOMA) with SWIPT to enhance the efficiency of mobile communication systems. NOMA allows multiple users to share the same frequency band and offers higher spectral efficiency and increased system throughput. There has been a challenge with existing SWIPT-NOMA systems: As the distance between the transmitter and receiver increases, the efficiency of WPT decreases.

A team of scientists from Korea Maritime and Ocean University (KMOU) have developed an innovative solution to address the energy-efficiency problems in SWIPT-NOMA systems. They applied the SWIPT-NOMA concept to a distributed antenna system (DAS). A DAS includes multiple antennae distributed relatively close to the end user, along with a central base station. By using this DAS setup, the energy and spectral efficiencies of the devices are significantly improved.

"By applying a DAS with supporting antennas relatively close to edge users alongside a central base station, SWIPT-NOMA’s loss with growing distance can be reduced efficiently," said Dong-Wook Seo, associate professor from the Division of Electronics and Electrical Information Engineering at KMOU. "This improves information decoding and energy-harvesting performance."

THREE-STEP ITERATIVE ALGORITHM

Researchers aimed to maximize the energy efficiency of the SWIPT-NOMA-DAS system.

▶ Power allocation for the central IoT controller. In the first step, the researchers optimized power allocation for the central controller of the IoT system. This optimization involves determining how much power is directed toward the central controller to facilitate both data-communication and power-transfer functions.

▶ Power allocation for NOMA signaling and the PS assignment. In the second step, the researchers optimized the distribution of power for NOMA signaling (used for communication) and the assignment of PS for SWIPT (used for power transfer). This optimization aimed to minimize both data rates and the energy required for harvesting.

▶ Extending optimization to a multi-cluster scenario. Finally, the researchers analyzed scenarios in which the system might not provide sufficient energy and data rates. In response to this challenge, they extended their approach of optimizing power allocation and the PS assignment to include situations involving multiple clusters of devices or users.
“This technology ensures very efficient energy consumption and offers various advantages, such as convenience, low power and battery life extension,” Seo said. “Thus, it can be applied to smartphones, laptops, wearable devices and electric vehicles. Most importantly, the SWIPT-NOMA-DAS system can optimize resource allocation and efficiently perform wireless charging and information transmission for users in an IoT environment.”

RESULTS

The chart above presents the comparisons between the proposed scheme and other schemes regarding average PS ratios and energy efficiency. PS ratios indicate the distribution of power between EH and ID. As the available power budget increases, all PS ratios increase because there is a greater power reserve available for both EH and ID functions.

The efficiency of EH from the IoT controller to the weak user (User 1) is noted to be very low due to the long communication distance. Consequently, the PS ratio ($\alpha_1$) for User 1 is smaller than the PS ratio ($\alpha_2$) for User 2. The PS ratio ($\alpha_1$) of the weak user under the SWIPT-NOMA scheme is smaller than that of other schemes. This indicates the positive impact of using a DAS in improving both EH and ID for the weak user.

Although the proposed scheme uses more power for ID (larger PS ratios), its energy efficiency is better than that of SWIPT-OMA in DAS. This is attributed to the fact that NOMA can increase data rates compared with orthogonal multiple access (OMA) with the same power budget, allowing more power to be allocated for EH.

The research shows:

▶ The proposed SWIPT-NOMA-DAS system is 5× more energy-efficient than SWIPT-NOMA without the use of a DAS.
▶ The scheme shows a more than 10% improvement in performance compared with SWIPT-OMA-DAS.

References


Hydrogen EVs: The Future of Sustainable Mobility?

In recent years, interest in sustainable and clean energy sources has led to an incessant search for alternative solutions to traditional internal-combustion–engine vehicles.

By Giordana Francesca Brescia, contributing writer for Power Electronics News

Usually, e-mobility is associated with vehicles with a large battery charged by electricity. However, other exciting drive technologies have emerged recently. Among the most promising solutions are electric vehicles with hydrogen infrastructure, which use fuel cells to generate electricity, an alternative without emissions and without long charging times. Specifically, this refers to hydrogen-electric drive, also called fuel-cell drive. Hydrogen EVs represent an ecological solution for the future of sustainable mobility. Using fuel cells, these vehicles convert hydrogen into electrical energy, eliminating harmful emissions and reducing their environmental impact. Furthermore, they offer a greater range than traditional EVs, allowing for longer journeys without the need for frequent charging. While maintaining the same driving experience as that of electric cars, in terms of dynamic acceleration and silence, there are notable differences in operation between a battery EV (BEV) and a hydrogen EV.

HOW DO FCEVs WORK?

EVs have multiple advantages for both customers and the environment—think, for example, of the reduction of pollutants and noise, as well as dynamic driving. Cars with hydrogen infrastructure are powered by an electric motor and are therefore classified as electric cars. Fuel-cell EVs (FCEVs) use the same electric drive as BEVs but differ in the way energy is stored.

In fact, FCEVs use a propulsion system similar to that of EVs, in which the energy stored as hydrogen is converted into electricity by the fuel cell. However, there is a substantial difference compared with other EVs: Hydrogen vehicles produce their own electricity, which means that their power does not come from an integrated battery, as is the case with purely electric vehicles or plug-in hybrid vehicles, which can be charged from an external power source.

Hydrogen cars are equipped with their own on-board power plant, which converts the hydrogen in the fuel tank into electricity. This power plant is the fuel cell itself. In an FCEV, hydrogen and oxygen generate electrical energy that is routed into the electric motor and/or battery if necessary. Unlike other EVs, therefore, FCEVs produce electricity using a hydrogen-powered fuel cell rather than just drawing electricity from a battery.

A process commonly known as reverse electrolysis takes place inside a fuel cell. Hydrogen reacts with oxygen in the process. The hydrogen comes from one or more tanks in the car, while the oxygen comes from the ambient air. The only things this reaction produces are electricity, heat and water, which exits through the exhaust as water vapor, with no emissions.

The electricity generated in the fuel cell takes two paths, depending on the specific driving situation. It flows to the electric motor and directly drives the vehicle and charges a battery that serves as temporary storage until the energy is needed for driving. This battery is significantly smaller than the battery of a fully electric car, which implies that it is also lighter. The battery is also constantly recharged by the fuel cell.
FCEVs also feature other innovative technologies to increase efficiency, such as regenerative braking systems that capture energy lost during braking and store it in a battery. In fact, most FCEVs use the battery to recover energy from regenerative braking, providing extra power during short acceleration events; smooth the power output of the fuel cell; and shut down the fuel cell during low power demands. The amount of energy stored onboard is determined by the size of the hydrogen tank. This operating scheme is very different from that of a fully electric vehicle, in which the amount of power and energy available are both closely related to the size of the battery pack.

ZERO EMISSIONS AND LOWER ENVIRONMENTAL IMPACT

Hydrogen cars are powered exclusively by electricity and operate with zero harmful tailpipe emissions. This category of vehicles is much more efficient than conventional internal-combustion-engine (ICE) vehicles and produces no emissions. Unlike conventional ICE vehicles, which emit greenhouse gases and air pollutants, hydrogen vehicles help reduce air pollution and overall environmental impact, as they are powered by fuel cells that produce energy electricity through the reaction between hydrogen and oxygen. For example, the city of Los Angeles has introduced a fleet of hydrogen buses, significantly reducing CO₂ emissions and improving air quality for its citizens. This demonstrates how hydrogen EVs can be an effective solution to combat urban pollution, promote a sustainable lifestyle and accelerate the ecological transition.

GREATER AUTONOMY AND REDUCED CHARGING TIMES

Another important competitive advantage of hydrogen EVs is their greater autonomy compared with traditional EVs. Hydrogen EVs can therefore overcome the range limitations of BEVs, making them a more practical choice for long journeys and everyday mobility needs. Another advantage is shorter refueling time. While electric cars take a longer time to recharge their batteries, hydrogen vehicles can be refueled with hydrogen in just a few minutes, similar to the refueling process of an ICE vehicle.

CONCLUSION

Hydrogen EVs represent a promising solution for the future of sustainable mobility. To date, hydrogen drives are considered among the most environmentally friendly solutions, despite still being in the implementation phase. Thanks to their ability to eliminate harmful emissions and thus reduce environmental impact, they represent an ecological alternative for road transport. Furthermore, their greater autonomy and reduced charging times make them a practical choice for everyday mobility needs.

The U.S. Department of Energy leads research efforts to make hydrogen-powered vehicles an affordable, green and safe transportation option that can increase energy resilience through diversity and strengthening the economy. With further technological developments and greater infrastructure support, hydrogen EVs could become a common reality in our cities and streets, contributing to a cleaner and more sustainable future. Hydrogen is also one of the most efficient ways to store and transport renewable energy. For this reason, it will play an important role in future energy supply methods.

References


Study Reveals Lack of Public Infrastructure Limits EV Adoption

By Stefano Lovati, contributing writer for Power Electronics News

The widespread use of electric vehicles raises a number of important concerns that must be addressed to achieve a seamless transition to a transportation system that is more environmentally friendly.

One of the major challenges for large-scale adoption of EVs is indeed the charging infrastructure. Based on a study conducted by Juniper Research, this article emphasizes the need for a capillary public charging infrastructure to enable the widespread adoption of EVs, especially in urban environments.

THE PUBLIC VS. RESIDENTIAL DILEMMA

Limited charging accessibility is one of the major factors hindering widespread EV adoption. Without an extensive network of charging stations, it may be inconvenient for EV owners to charge their vehicles. This can be especially problematic for apartment occupants and drivers without off-street parking who lack access to private charging stations. To ease range anxiety and make EV ownership more practical, it is vital to develop a network of charging stations that include urban, suburban and rural areas, as well as high-traffic routes.

THE STUDY’S RESULTS

A recent study conducted by Juniper Research found that the absence of public infrastructure is a significant barrier to the widespread adoption of EVs in metropolitan locations. According to the findings of the survey, homeowners who live in flats and apartments cannot have home chargers installed on their properties. This is only one of the challenges that the automobile industry is facing as it embarks on the most significant transformation in its entire history, moving from vehicles powered by internal-combustion engines (ICE) to fully electric fleets of vehicles.

According to projections made by Juniper, the number of EV charging points that are operational worldwide will increase from 14.2 million in 2023 to 45 million in 2027. However, the market research company found that there is a substantial discrepancy between the adoption of public and home chargers, with more than twice as many home chargers as public chargers expected to be in service by the year 2027.

In addition, the research concludes that actions taken by regulators, such as mandating the installation of charging stations in newly constructed buildings, are insufficient on their own to roll out charging infrastructure on a large-enough scale to generate environmental advantages.

OMNION POWER ENTERS EV MARKET WITH EV100/EV101 RECTIFIERS FOR DC FAST CHARGING

As the consumer market for electric vehicles grows, the need for faster, more reliable and available charging infrastructure becomes increasingly prevalent. OmniOn Power is helping to meet the power, reliability and efficiency needs of the EV industry with the introduction of its new 30-kW power supplies: the EV100H3NK and EV101H3NK. The new EV100 and EV101 rectifiers are purpose-built for use in fast DC-powered EV charging stations and leverage high-quality components to help ensure charger reliability and uptime. The plug-and-play power supplies enable large, multi-charger applications, with 12 or more rectifiers able to operate in parallel to power high-capacity charging stations. The rectifiers feature a space-saving 13.23 × 3.3 × 17.25-inch footprint, a 480-V three-phase input and an adjustable DC output range of 50–1,000 V, which is settable by the host charger.

These rectifiers integrate CAN automotive communications protocols and include inherent safety features, such as an emergency power off to help ensure user safety. This feature is available as a discrete circuit if required to comply with local and regional regulations. Additionally, the rectifiers allow for remote firmware downloads to support field upgrades and meet UL, VDE and CE safety requirements. Learn more about OmniOn Power’s EV100 and EV101 rectifiers here.
Researchers from Juniper believe that EV charging networks, as well as city authorities and each other, need to collaborate to figure out how to effectively fill gaps in the infrastructure for charging EVs; otherwise, EV adoption will remain limited.

ONGOING INITIATIVES

Different organizations are working on this issue and several initiatives are ongoing as well. At the end of July, the U.S. Department of Energy selected the J.D. Power EV Index to support EV infrastructure growth initiatives. The J.D. Power EV Index is an analytics tool that is suited for tracking the increasing market for EVs in the U.S. It will assist in the establishment of benchmarks and will monitor the ongoing development of EV infrastructure across the country. It gives essential data on regional patterns of growth in infrastructure as well as potential obstacles to the mainstream adoption of EVs by consumers.

The J.D. Power EV Index (Figure 1) collects and analyzes millions of data points that are then grouped into six categories: interest, availability, adoption, affordability, infrastructure and experience. These categories are used to measure the degree to which EVs in the U.S. have attained parity with ICE vehicles. It is revised every month, and its findings have shown that consumers’ primary concern regarding EV adoption is a dearth of publicly available charging stations. In addition, the EV Index demonstrates the considerable variance in the availability and accessibility of charging infrastructure that exists across the country in its many regions.

The automotive branch of J.D. Power claims that the EV Index was developed to assist key stakeholders in making educated decisions based on the most comprehensive data that is currently available. This involves monitoring EV adoption, pricing and infrastructure, in addition to several other criteria that provide a comprehensive perspective of the EV landscape in real time. Data on the infrastructure at the level of a zip code can be utilized as useful building blocks to measure the progress that is being made toward the establishment of infrastructure for a variety of different participants.

At roughly the same time, it was announced that seven of the most significant car manufacturers in the world will join forces to establish a groundbreaking charging network joint venture that will greatly increase the number of locations that offer high-power charging in North America.

It is the goal of the BMW Group, General Motors (GM), Honda, Hyundai, Kia, Mercedes-Benz Group and Stellantis to build at least 30,000 high-power charge points in urban and highway sites. This will ensure that consumers may charge their vehicles whenever and wherever they need to.

All EV customers will have access to charging stations, which will be equipped with connectors compatible with both the Combined Charging System (CCS) and Tesla’s North American Charging Standard (NACS). The opening of the first stations is anticipated to take place during the summer of 2024 in the U.S. and in Canada at a later date. Each location will feature multiple high-power DC chargers, making long-distance travel more convenient for consumers. In accordance with the sustainability strategies of all seven manufacturers, the joint venture intends to use only renewable energy to power the charging network.

Another significant step toward EV charging infrastructure deployment is the imminent standardization, by SAE International, of Tesla’s NACS connector (Figure 2). Following Volvo, Rivian, Mercedes-Benz, Ford and GM announcements, the support for Tesla’s NACS has been disclosed by most EV charging companies and software developers. That will allow access to 12,000 fast-charging stations around North America.

The transaction will result in an increase not only in the total number of chargers but also in access to faster chargers, with the expectation that more consumers will be persuaded to buy EVs in the foreseeable future.

The new SAE NACS connector standard will be developed expeditiously and is one of several important initiatives to strengthen the EV charging infrastructure in North America. This incorporates the public key infrastructure developed by SAE-ITC for cybersecure charging.

However, Juniper Research asserts that these initiatives are insufficient. Government initiatives are not enough to accelerate EV adoption, and new business models are required. Juniper concluded that the variety of charging rates, payment systems and access requirements dampens consumer enthusiasm for EVs. EV charging networks should simplify and develop interoperability to facilitate an easier ownership experience.
SiC Drives Efficiency in Industrial and Automotive Applications

By Stefano Lovati, contributing writer for Power Electronics News

Silicon carbide is a wide-bandgap semiconductor material that has enhanced performance characteristics compared with traditional silicon-based devices. This facilitates enhanced energy efficiency and improved power management across a wide range of applications.

A SiC power device has enhanced operational capabilities in terms of temperature tolerance and efficiency due to its reduced power losses and increased bandgap. This enables the device to operate reliably across a broader range of temperatures without experiencing any detrimental effects on its performance or efficiency. These characteristics, together with the property of chemical inertness, enhance the significance of SiC in the realm of power electronics, hence promoting its utilization and dissemination across many applications. SiC power devices find extensive utilization in various domains, including power supplies, battery electric vehicles, power-conversion systems for battery charging and traction drives, industrial motor drives and renewable-energy–generation systems like solar and wind inverters.

This article centers its attention on the use of SiC in the industrial and automotive sectors, specifically highlighting the activities of WeEn Semiconductor, an international corporation that specializes in the research, production and distribution of SiC power devices.

THE RELEVANCE OF SiC

With its proficiency in SiC and bipolar power devices, WeEn Semiconductor endeavors to provide a valuable contribution to the advancement of sustainable energy solutions, efficient power management systems and sophisticated electronic products. SiC power devices possess several advantageous characteristics over traditional silicon-based devices, such as a larger bandgap, lower intrinsic carrier density, higher thermal conductivity and higher saturation velocity. Consequently, these material properties enable SiC power devices to offer numerous benefits when compared with other alternatives.

These advantages encompass a reduced specific on-resistance (R_{DS(on)}) at a given voltage level, a higher-voltage capability compared with silicon (e.g., up to 15 kV for SiC MOSFETs, in contrast with the 6.5 kV of silicon IGBTs) and significantly lower capacitances owing to the compact package size associated with a given R_{DS(on)}.

The integration of reduced conduction and switching loss, increased switching frequencies and simplified cooling demands can yield decreased power-conversion losses, enhanced efficiency, streamlined converter topologies and notable advancements in high-temperature capabilities and performance, as well as diminished system dimensions, weight and expenses.

SiC can operate at temperatures higher than silicon without suffering a discernible drop in performance. This demonstrates that SiC components can function in high-temperature conditions without suffering any performance degradation. In addition, SiC devices can manage a greater amount of power within a smaller package than silicon devices can. This enables both an increase in power density as well as a reduction in the size and weight of the system. Silicon has a higher resistance to both electric shock and the damaging effects of the environment, while SiC has an even higher resistance. As a consequence, the resulting devices are sturdier and more trustworthy, making them appropriate for a wider variety of mission-critical applications.

There have been several technological hurdles along with the commercialization and evolution of planar technology SiC MOSFETs. However, over time, the dependability of the gate oxide has also greatly improved. The gate oxide, as well as the methods that can be used to protect it from high electric fields, continues to be a primary area of emphasis in device development.
It is also vital to improve screening tests to filter out dies that have the potential to have parametric drifts over time.

To manufacture dependable SiC MOSFETs, the density of gate oxide defects must be reduced to a minimum throughout the production stage. In addition, novel screening procedures need to be developed to discover and eliminate potentially compromised devices.

The next generation of WeEn's SiC devices will make use of a structure known as a "trench," which is characterized by the precise etching of trenches into the SiC material. Within this structure can be found the active zone of the device as well as the channel. The gate electrode is often positioned within the trench, which encircles the channel and allows for superior control over the distribution of the electric field in comparison with planar devices. The use of trench devices has several advantages, including a lower ignition resistance and an increased switching performance because of better gate control. Figure 1 shows the technological advancements that have been made in the SiC MOSFET throughout the years.

SiC MOSFETs have found an optimal application space in EV traction inverters. The efficiency and size of the inverter system have increased due to their increased switching frequency, decreased leakage and enhanced performance at high temperatures. Customers can benefit from an increased driving range per battery charge. The total addressable market for SiC was approximately $1 billion in 2022. By 2028, analysts anticipate growth to reach $5 billion. Silicon IGBTs currently dominate the low- and medium-power (150 kW) inverter market, but this is swiftly changing as the use of SiC increases, particularly in the >80-kW market. SiC devices dominate the market for EVs, SUVS and high-performance trucks with power ratings above 200 kW.

WeEn's first planar technology SiC MOSFETs have a voltage of 1,200 V and have $R_{\text{DS(on)}}$ Values of 160 mΩ, 80 mΩ and up to 12 mΩ. TO247-3L and TO247-4L packages are available, along with other industry-specific ones. Other solutions are 650 V and 1,700 V.

The short-circuit capability of SiC MOSFETs depends on the gate-to-source voltage ($V_{gs}$) and drain-to-source voltage ($V_{ds}$) at the time of short-circuit. WeEn proposes that the short-circuit capability of a SiC MOSFET is affected by the voltage levels provided at its $V_{gs}$ and $V_{ds}$ during the short-circuit event. These voltage levels affect the behavior of the MOSFET during the short-circuit event.

This suggests that decreasing $V_{gs}$ and $V_{ds}$ can increase the SiC MOSFET's short-circuit withstand time (SCWT). SCWT is the MOSFET's short-circuit resistance before injury or thermal runaway. At 18 V and 800 V, the SCWT of WeEn's second-generation MOSFETs is 3.5 µs with secure shutdown and no thermal runaway. WeEn's second-generation SiC MOSFET is functional under these conditions. When $V_{gs}$ is 18 V and $V_{ds}$ is 800 V, the SiC MOSFET can tolerate a short-circuit for 3.5 µs without thermal runaway.

WeEn's SiC MOSFET has a competitively low $R_{\text{on}}$ (2.6 m-$cm^2$), demonstrating the technology's benefits. A low $R_{on}$ value indicates reduced power losses and increased switching efficiency, highlighting the benefits of SiC technology.

WeEn's SiC MOSFET employs a transparent naming convention to indicate $R_{\text{on}}$ at 15-V gate-drive voltage. The optimized gate oxide enables the device to operate normally with a 15-V gate-drive voltage, making it simpler to implement in conventional designs. The optimized gate oxide enables MOSFETs to operate reliably at this gate-drive voltage, easing their incorporation into existing conventional designs. WeEn conducted the corresponding reliability test using a range of $V_{gs}$ from 12 to 24 V to ensure the robustness of the gate in wide drive scenarios.

The N-channel SiC MOSFET WNSC2M20120B7 has a low on-resistance of 20 mΩ. High switching speeds enable rapid transitions between the on and off states. This feature is advantageous for applications requiring operation at a high frequency. Additionally, the MOSFET can be turned off with a 0-V gate voltage, which simplifies the gate-driver circuit and reduces the complexity of the control circuit. Because of the high efficiency and low power losses of SiC MOSFETs, system cooling requirements can be decreased, resulting in smaller and less expensive cooling solutions.
Typical applications include:

▶ Switch-mode power supplies (SMPS): SMPSes are used in a variety of electronic devices, including computers, televisions, audio systems and more, as independent power supplies. They convert AC power from the mains to the DC voltage efficiently required for electronic circuits.

▶ Uninterruptible power supplies (UPSes): UPS systems provide reserve power during power outages and voltage fluctuations using SMPS technology. SMPS-based UPSes are more efficient, more compact and provide superior power management than transformer-based UPS systems.

▶ Solar string inverter and solar optimizer: Solar PV systems use string inverters and optimizers based on SMPSes. Inverters transform the direct current produced by solar panels into alternating current for grid connection, while optimizers increase energy efficiency by monitoring and optimizing the output of each solar panel. SMPS technology facilitates maximum power-point tracking and ensures high conversion efficiency.

▶ EV battery chargers: These use SMPS technology to convert the grid’s alternating current into direct current to charge the EV battery. SMPS-based chargers offer high efficiency, compact size and the ability to provide the requisite power levels for rapid charging, thereby promoting the adoption of EVs.

▶ Motor drives: SMPS technology is widely used to govern the speed and torque of electric motors in motor drives. By utilizing SMPS-based motor drives, the efficacy of motor control can be significantly enhanced, resulting in energy savings, precise control and enhanced motor performance overall.

WeEn Semiconductor provides its customers with efficient, dependable and high-quality power devices. To satisfy the changing demands of a variety of industries, the company prioritizes continuous innovation and technological advancement. Increased efficiency and the resulting decrease in application temperature will enhance the project's dependability.

Multiphase Solutions for High-Current, Fast-Transient, Noise-Sensitive Applications

By Erik Lamp, product applications engineer, and Xinyu Liang, applications engineering manager, both at Analog Devices Inc.

Power consumption for CPUs, FPGAs and ASICs in today’s computing environment is increasing. And in some more specific applications, such as 5G transceivers, beamformers and other high-speed RF applications, the power requirements are even more strict in terms of the bandwidth and RF noise level. Due to the high output current, the traditional two-stage (buck + LDO) solution that is widely used by RF applications is bulky, inefficient and requires more heatsinking. The growing requirement for the output-current capability makes it uneconomical to use a single buck regulator to power the high-demanding load, too. Multiphase buck regulators are widely used in this area thanks to the high performance in current-delivering capability benefiting from the scalability and ripple interleaving advantage. However, to achieve fast transient and ultra-low RF noise requirements, a multiphase buck regulator will require many output capacitors and multiple stages of LC filters to fulfill the purpose of powering high-speed RF ASICs. The additional components...
usually use up a significant portion of board space and can potentially increase the solution cost. This article demonstrates the benefits of using a high-performance Silent Switcher 3 architecture, which features ultra-low noise and ultra-fast transient in multiphase buck applications. Different ASIC load requirements will be addressed with different design considerations.

The Silent Switcher 3 architecture features an ultra-low-noise design (typically 4 μVrms from 10 Hz to 100 kHz), ultra-low EMI emissions and an ultra-fast transient response with a high-gain-error amplifier. Among this new product family, the LT8627SP features the highest, 16-A current rating, which makes it a perfect candidate for a multiphase buck configuration in any high-current, noise-sensitive applications. Due to the low-supply-voltage nature of all ASIC loads (<1 V) and the widely used 12-V power distribution system, a multiphase buck is very sensitive to the minimum on time. The innovative architecture of Silent Switcher 3 technology provides the smallest on time (15 ns), which allows the LT8627SP to easily operate at a switching frequency of >1 MHz that benefits the ripple, size, noise and bandwidth.

**TRANSIENT RECOVERY TIME MINIMIZATION FOR A 50-A CURRENT RF DIGITAL LOAD**

An important characteristic of a power supply’s performance is its recovery time. This is the time it takes for its output voltage to return to its regulated value when a load transient happens. Every power supply has a limit to how fast it can recover, which is related to its control loop bandwidth. A higher control loop bandwidth means the inductor current can ramp up/down faster during the transient to compensate for the charge change on the output capacitors to recover in a shorter time.

One example of using a four-phase LT8627SP is to power a 1.8-V, 50-A RF digital load with a maximum load current of 50 A, as shown in Figure 1. The power supply was designed to output 1.8 V with a switching frequency of 2 MHz. This high switching frequency reduces the EMI emissions and allows the output capacitors to be smaller. The use of low-ESR ceramic capacitors and high-ESR polymer capacitors is avoided in the design. Interleaving PWM technology (90° per phase) is applied to increase the equivalent ripple frequency so that the control bandwidth can be pushed higher.

The compensation network is adjusted with the aim of achieving at least a 45° phase margin and a gain margin greater than 8 dB while pushing the bandwidth as high as possible. As a result, its control loop was tuned to its highest bandwidth of 280 kHz with 45° of phase margin and 9 dB of gain margin, as shown in the bode plot in Figure 2. As a comparison, a single-phase LT8627SP with equivalent output capacitance per phase ([2 × 100 μF] + [1 × 1 μF] + [1 × 0.1 μF]) was tested at a 1.8-V, 12-A output. The bode plot is also shown in Figure 2 with the same stability criterion.
To comparatively test the recovery time, a 50% load transient was performed for both the our-phase and one-phase LT8627SP, with a slew rate of 6 A/µs per phase. Results (see Figure 3) showed a recovery time of about 2.5 μs at the rising edge of the transient. This is almost a tenfold reduction in recovery time, shown in Figure 4, for the one-phase LT8627SP.

**TRANSIENT $V_{PP}$ MINIMIZATION FOR HIGH-CURRENT WIRELESS APPLICATIONS**

The multiphase operation of the Silent Switcher 3 architecture has been used on many customer power supply designs. Figure 5 shows another example of how the LT8627SP is helping a wireless customer power a fast, high-current–transient SoC with a 0.8-V $V_{OUT}$ and 22-A to 60-A load transient in 1 µs. To prevent the SoC performance from downgrading due to the transient, a $V_{PP}$ of less than 5% (40 mV) is desired.

From the previous section, we already know that for four-phase interleaving the LT8627SP, we can expect a fairly high control bandwidth, which is about 300 kHz. In the time domain, we can roughly model the relationship between the voltage deviation during the load transient and control bandwidth by:

$$\Delta V_{OUT} = \frac{\Delta V_{OUT}}{8C_{OUT}} + V_{RIPPLE}$$

Thus, we can get the minimum output capacitance to be 1,583 µF, giving a 10-mV ripple voltage. The design should select capacitance higher than this value and different from the previous section, as more polymer capacitors are used to provide enough damping during the transient. The final output capacitance is decided by trial and error, as the output capacitance also affects the loop bandwidth and stability.

The four-phase LT8627SPs are interleaved at a 1-MHz switching frequency to a combined 4-MHz ripple frequency. After determining the minimum amount of output capacitance, a 35-mV (4.4%) $V_{PP}$ was achieved in a 22-A to 50-A to 22-A load transient with a 28-A/µs slew rate. The transient waveform is shown in Figure 6. To verify the stability of the control loop, a bode plot measurement was made using a 50-A load. The results are shown in Figure 7. At 50 A, the control loop had a bandwidth of 322 kHz with a 50° phase margin.
For additional performance tests, the efficiency and full-load thermal performance was measured. The efficiency was tested up to a 60-A load at 12 V_IN, 0.8 V_OUT as shown in Figure 8. Including auxiliary losses, the converter’s peak efficiency at a 25-A load was 89%, and the converter’s efficiency at a 60-A load was 84%.

The thermal performance of this four-phase design is shown as a thermal image in Figure 9. At a 60-A load, the hottest IC is 66°C and the coolest IC is 61.6°C. This gives a max temperature deviation of ~5°C between the four ICs, which represents excellent current sharing between phases.

### DESIGN CONSIDERATIONS AND GUIDANCE FOR MULTIPHASE LT8627SP

As a peak-current-mode control IC, the LT8627SP can be easily configured into a multiphase operation. The following design considerations need special care:

- For proper current sharing, the VC pins of each IC should be tied together, as shown in the schematic in Figure 1.
- To evenly interleave for four-phase LT8627SPs, the CLKOUT of each IC is configured to be 90° phase-shifted and fed into the SYNC pin of the next IC. In this configuration, the switch-node waveform for each IC is shown in Figure 10. Interleaving is one of the biggest benefits brought by the multiphase buck. As the evenly interleaved phases multiply the output-voltage ripple frequency, the output capacitance can be significantly reduced. The higher interleaved ripple frequency can also help the control loop be immune to ripple noise at a higher bandwidth. The LT8627SP can operate up to a 4-MHz switching frequency with three phase-shift clock configurations: 180°, 120° and 90°. This means it can achieve up to 12 of interleaving without extra devices.

- For proper voltage sensing, the OUTS pins of each IC should be tied together. It is worth noting that because all of the error amplifiers (EAs) are involved in the control loop, the bode plot injection needs to involve all EAs. As a result, both the sensing point (output voltage) and the OUTS pin sides need to be tied together to make sure perturbation is evenly observed for each EA.

- The RT pin needs a resistor to set the frequency. The master IC should have a resistor value that sets the desired switching frequency, and the slave ICs should have a resistor value that sets their frequencies 20% lower than the main IC.

### CONCLUSION

Building power supplies for 5G telecom applications can be challenging. The applications require fast, high-current–transient responses to either achieve minimum peak-to-peak output voltage or minimum recovery time during a load transient. One easy solution to the challenges is to parallel multiple Silent Switcher 3 architecture power converters, such as the LT8627SP, into a single interleaving system. By doing so, the bandwidth and load capability of the power supply can be increased, and thus, its ability to perform fast, high-current transients can be achieved.
Wireless EV Charging
Set to Transform the Automotive Industry

In the constantly evolving landscape of sustainable mobility, research and development of new technologies for charging EVs have become increasingly frequent and necessary. Wireless charging is one of the most promising innovations in this sector.

By Giordana Francesca Brescia, contributing writer for Power Electronics News

Wireless charging is considered a key infrastructure that will lead to an increase in the supply of electric vehicles in the future, optimizing convenience for drivers. However, this way of charging EVs is not an absolute novelty. The roots of this revolutionary technology date back to the pioneering work of Nikola Tesla in the early 20th century, with his famous wireless energy transmission experiment. However, it is only in the last few decades that this technique has made significant progress, thanks to developments in energy transfer and the growing adoption of EVs, which is changing the global landscape of electric mobility (e-mobility). Wireless charging technology is set to grow, as the wireless EV charging market in Europe and North America is expected to reach $2 billion by 2028 and become a mass market.

HOW DOES WIRELESS CHARGING WORK?

Wireless charging is based on the principles of electromagnetism. The technology uses a drive coil mounted on the floor or a parking structure, commonly called a charging station. When an EV equipped with a receiving coil is positioned above this station, an electromagnetic coupling occurs between the two coils, allowing the transfer of energy. This process eliminates the need for physical cables and connectors, making charging more convenient and efficient. It is based on the principle of inductive charging, whereby electricity is transferred through a coil in the charger to another in the car.

Wireless charging transmits electricity through the air in the form of a magnetic field. This means that energy can be sent from one device to another without physical contact, as long as the charger and the car are close by. Once both the emitting and receiving coils are aligned, the charging process can begin.

Wireless charging systems have a very high efficiency, with an efficiency rate of between 90% and 95%, also thanks to the optimized power electronics and coil design, which minimize the energy loss of the charging system. Improving efficiency is key to reducing energy losses. Continuous technological development will lead to further increased efficiency, reaching higher figures and approaching the efficiency rate of conductive charging.

Instead of cables, a wireless system requires charging pads that EVs park on to power the batteries. However, to date, there are several technologies based on wireless charging, each with their own unique characteristics:

▶ Inductive: This is the most common wireless charging technology. It works by using transmitting and receiving coils that create magnetic fields for energy transfer. This technology is suitable for short-distance charging, such as in public car parks.
▶ Resonant: Resonant charging technologies allow for more clearance between the transmit and receive coils, making vehicle placement above the charging station more flexible. This is helpful in ensuring proper coil alignment and optimal transfer efficiency.
▶ Magnetic: Magnetic charging technologies use permanent magnets or oscillating magnetic fields to transfer energy. This technique is best suited for short-distance charging applications.
▶ Laser: Although less common, laser-based wireless charging uses a laser beam to transfer energy to the vehicle. This technology is under development and is best suited for specialized applications.

CAN WIRELESS EV CHARGING TRANSFORM THE GLOBAL AUTOMOTIVE INDUSTRY?

Wireless EV charging could change the rules of the e-mobility game for the automotive industry. Automakers, automotive suppliers and clean technology companies are exploring wireless EV charging systems that are safe and effective, yet fast and affordable. The emerging market for this technology is characterized by huge investments. While it may take some time for wireless EV charging to finally take
off, it is a technology with distinct advantages and is perfect as an alternative to traditional charging methods, simplifying and streamlining the process.

Wireless charging offers a number of significant benefits. First, it eliminates the need to handle cables, reducing wear and tear and the risk of damage. It also makes charging more accessible by allowing the construction of underground or hidden charging infrastructure. This is particularly important for urban environments, where space is limited. Another advantage is vehicle-network connectivity. Demand-driven sales of EVs have seen a sharp increase across the world, and protecting energy ecosystem infrastructure is critical to supporting power systems. Wireless charging can make an important contribution to lightening the load on the network by distributing energy demand throughout the day.

Contactless charging promises to increase reliability, safety and availability while making the user experience more comfortable for drivers of EVs, also looking ahead to autonomous driving.

Wireless EV charging is, in fact, a key point if we want to achieve the mass implementation of autonomous mobility. The technology looks promising, as it aims to make charging more convenient for drivers by eliminating the need for cables to power EVs. Furthermore, it is not necessary to get out of the car, which could attract the interest of more users. This innovative charging mode can also help reduce visual congestion at charging stations.

However, to date, wireless charging faces one of the main obstacles to energy efficiency, as part of the energy can be dispersed into the environment. Furthermore, a global standard is needed to ensure interoperability and global standardization for wireless charging systems between different vehicles and charging stations. In this sense, there are ongoing efforts to develop standards that ensure interoperability between different vehicles and charging stations. Harmonization of standards is essential to enable drivers to use wireless charging stations regardless of vehicle make or model. Finally, charging stations must be designed to prevent risks like overheating, short-circuits and electromagnetic interference.

Despite these partially unresolved issues and barriers to adoption, the industry is making significant progress in overcoming these major challenges.

**PRACTICAL APPLICATIONS OF WIRELESS CHARGING IN E-MOBILITY**

Let’s analyze the practical applications of this revolutionary technology and its impact on e-mobility.

**Public car parks**

One of the most obvious applications of wireless EV charging is in public parking lots. Charging stations can be integrated into the floor of parking lots, allowing drivers to park above them without having to maneuver cables. This makes charging convenient and accessible, encouraging more people to switch to EVs. Additionally, public parking lots equipped with wireless EV charging can help reduce range anxiety, as drivers know they can easily charge their vehicle while out and about.

**Streets**

An even bolder idea is wireless charging integrated into the streets themselves, i.e., dynamic induction charging based on installing charging coils on the street. This technology could allow EVs to charge while driving while on the move. The vehicles would be equipped with special receiving coils, and the streets would have transmitting coils embedded in the pavement. As the vehicles drive along these roads, they would automatically recharge. This application could revolutionize e-mobility, eliminating the need for continuous stops to fully recharge the vehicle's batteries.

**Specialized applications**

In addition to common applications in public parking lots and streets, wireless charging has the potential for specialized applications. For example, it could be used for charging heavy EVs, such as electric buses, or for charging electric drones in flight.

**CONCLUSION**

Wireless EV charging is a promising technology that is changing the way we think about mobility. It has a positive impact on the environment and sustainability, helping to reduce greenhouse gas emissions and dependence on fossil fuels. Furthermore, when the energy used for charging comes from renewable sources, such as solar or wind energy, EVs become even more sustainable. Reducing air pollutant emissions is particularly important in urban areas, where air quality is often a critical issue to address.

Wireless EV charging is constantly evolving and has different facets. As it continues to evolve, it is likely to become more common and accessible. Automotive companies are investing in this technology and governments are encouraging its adoption. In the near future, we may see significant growth in the number of charging stations, along with greater energy efficiency and better interoperability between vehicles and stations.

Wireless charging promises to revolutionize the way we manage energy in EVs, leading to more sustainable and convenient mobility for the electric future. Regardless of the level of development and deployment, it is changing the way the automotive industry approaches powering EVs.
Reducing Stress in Semiconductor Devices: Exploring Asymmetrical Structures

By Saumitra Jagdale, contributing writer for Power Electronics News

A lot of different types of electronics use semiconductor devices, such as those that change power, communicate and process signals. Because stress (such as heat, high voltage, high current or change frequency) can hurt a device’s performance, dependability and efficiency, it is best to make semiconductor gadgets that are stress-resistant. The use of an asymmetrical structure, such as a three-phase current-source rectifier (CSR), is one way to reduce stress. When a structure is asymmetrical, it means that the device's terminals or arms have different shapes or links.

A CSR is a type of power converter that changes alternating current to direct current with a step-down voltage function. It has six switches set up in three bridge arms. Each switch is made up of a transistor and a diode. You can make an asymmetrical structure by changing the inflow or outflow terminal of the CSR. This can lower the voltage and current load on the switches.

ASYMMETRICAL STRUCTURE AND MODULATION SCHEME

The suggested CSR has the same number of devices as a typical CSR, but the connection between the upper and lower arms is not symmetrical. The suggested CSR and a typical CSR are shown in Figure 1 in terms of their topological structure.

Figure 1 shows that the suggested CSR’s outflow terminal is not the same as its inflow terminal. Instead, the outflow terminal is connected between the diode and the transistor on the upper arms. In other words, the body diodes on the upper arms are added to the suggested CSR's current path. The current path in the planned CSR has a small change with this new structure. An easy way to control CSRs is through space-vector pulse-width modulation (SVPWM), which is what the suggested CSR’s modulation scheme is based on. You can use two active vectors and one zero vector from a set of seven swapping states to make the input reference current space vector. This is what SVPWM is all about. The switching states are set by the different ways the switches in each arm can be turned on or off.

The input reference current space vector is made up of a current vector that rotates at a certain angle and has a certain amplitude. The modulation index and the sector angle are used to figure out the duty cycles for each vector. The SVPWM schematic diagram of the suggested CSR can be seen in Figure 2.

This article will talk about a new three-phase CSR with an asymmetrical structure and explore how it differs from a typical CSR, along with the pros and cons of the suggested CSR in terms of power loss, output filter, voltage stress and current stress.
STRESS CHARACTERISTICS AND COMPARATIVE ANALYSIS

One of the best things about using an uneven structure for the CSR is that it makes semiconductor devices less stressed. Stress is made up of voltage stress and current stress, which changes based on how the CSR is working and what state it is in when it switches.

The voltage stress on a switch is the change in voltage between its two ends when it is not in use and current is flowing through its body diode. The voltage stress on a switch changes how well it blocks and how much it switches. The current that flows through a switch when it is on is called its current stress. This current also flows through the switch’s body diode. The current stress on a switch is determined by the current going through its body diode when it is turned on. This stress affects how well it handles heat and electrical loss. The amount of power that flows through a switch affects how well it handles heat and how much it loses.

There are two parts to a switch's power loss: switching loss and transmission loss. The switching loss depends on how often the switches are made and how much power and current are stressed during the changes. There is a link between the conduction loss and the on-state resistance and current stress during conduction times.

The proposed CSR has a slightly higher switching loss than a typical CSR because it has an extra turn-on and turn-off in each switching period. However, it has a much lower conduction loss because half of the transistors are under less voltage and current stress. This means that the proposed CSR can work better than a typical CSR, especially when the modulation index is low and the freewheeling time is long.

One more good thing about the suggested CSR is that it can make the CSR system’s output filter smaller. The proposed CSR has a smaller output ripple voltage than a typical CSR because it has more than one freewheeling path. As a result, the suggested CSR can make the system more powerful and less expensive.

iDEAL’s SuperQ TECHNOLOGY WITH ASYMMETRICAL STRUCTURE

iDEAL Semiconductor’s SuperQ technology is an example of the asymmetrical CSR system discussed as a new approach to power device architecture. SuperQ, while primarily based on silicon, can also be adapted for use with alternative semiconductor materials like silicon carbide and gallium nitride. One distinguishing feature of SuperQ is its asymmetrical, charge-balanced structure, which facilitates increased doping levels, thinner epitaxial regions and larger conduction areas compared with conventional superjunction devices.

This unique structure translates into notable advantages, including reduced $R_{\text{sp}}$ and lower switching losses, particularly in the 60-V to 850-V voltage range, when compared with currently available products. Additionally, SuperQ’s fabrication process follows a simplified CMOS-like flow suitable for 200-mm and 300-mm wafers, resulting in devices with the industry’s lowest resistances for selected packages.

Examining SuperQ’s potential impact on the power industry, it is evident that this technology could bring substantial benefits. According to available information, SuperQ has the potential to achieve up to a 50% reduction in $R_{\text{sp}}$ and a 70% decrease in switching losses compared with leading market alternatives. Such improvements could enhance the efficiency, reliability and thermal performance of power systems while also streamlining the manufacturing and packaging of power devices, potentially lowering costs.

Notably, SuperQ has progressed beyond the theoretical stage and has been successfully demonstrated across various test conditions and applications by IDEAL Semiconductor. This technology has showcased its prowess with examples like a 650-V/20-A device featuring an $R_{\text{sp}}$ of just 6 mΩ in a TO-247 package and a 100-V/100-A device with an $R_{\text{sp}}$ of only 0.8 mΩ in a D2PAK package.

SuperQ stands out as a notable advancement in the power device sector, offering improved performance and potential cost savings while demonstrating adaptability to various semiconductor materials. These promising developments hint at its potential to reshape the industry and is in line with the novel three-phase CSR. While both SuperQ and the asymmetrical CSR hold significant promise, further independent evaluations and real-world applications are essential to gauge their full impact on the power device landscape.

References


Figure 3: Specific resistance ($R_{\text{sp}}$) for silicon, GaN and SiC vs. SuperQ (mid-voltage) (Source: IDEAL Semiconductor)
Device Modeling in the New Era of Quantum Computing

By Stefano Lovati, contributing writer for Power Electronics News

Leveraging the principles of quantum mechanics, quantum computing has emerged as a cutting-edge technology driving a seismic shift in the world of computing. This has prompted a surge in investments and reshaped the landscape of numerous industries such as power electronics.

THE NEW ERA OF QUANTUM COMPUTING

Quantum computing exploits the peculiar properties of quantum bits (qubits), which can simultaneously exist in multiple states due to the occurrences of superposition and entanglement. This inherent parallelism permits quantum computers to solve complex problems exponentially more quickly than classical computers. Consequently, the potential applications of quantum computation span numerous industries, including the pharmaceutical and healthcare sectors, encryption and cybersecurity, and financial services.

As one of the main components of electronic design automation, device modeling plays a crucial role in understanding, designing and optimizing the behavior of quantum devices. However, device modeling comes with its own set of challenges.

CHALLENGES OF DEVICE MODELING

Quantum noise and decoherence represent one of the fundamental difficulties in modeling quantum devices. Qubits, the fundamental units of quantum information, are extremely environment-sensitive. It is easy for them to become entangled with external factors, resulting in a loss of quantum coherence. This phenomenon, known as decoherence, has a significant impact on the reliability and stability of quantum calculations.

Device modeling must account for various sources of noise and decoherence, including thermal fluctuations, electromagnetic interference and even cosmic rays. Developing accurate models that capture the dynamics of quantum systems is a complex task.

To reduce thermal noise and maintain the stability of quantum states, cryogenic temperatures are used in quantum computing. Several factors make it difficult for devices to operate at cryogenic temperatures, including:

- Thermal effects. At cryogenic temperatures, thermal effects become non-negligible, and accurate modeling of heat dissipation, thermal conductivity and temperature gradients is essential to comprehend the behavior of quantum devices.
- Properties of materials. At cryogenic temperatures, the properties of materials undergo significant transformations. Included in this are electrical conductivity, thermal conductivity and mechanical properties. Additionally, quantum effects like tunneling become more significant, and the behavior of particles can be different from what classical models predict.
- Superconductivity. The use of superconducting qubits is one of the most promising methods for developing quantum computers. Several quantum computers, notably those based on superconducting qubits, typically operate at temperatures near absolute zero (−273.15°C, or 0 K). Certain substances become superconductors at these temperatures, meaning they conduct electricity with zero resistance.

Figure 1: An example of a cryogenic quantum-computing system (Source: Keysight Technologies, 2020)
Historically, device modeling has focused primarily on CMOS models, the technology extensively used in integrated-circuit technology that powers traditional computers. Unlike ICs, qubits are central to quantum computing. Device modeling can still be used in various quantum-computing system components.

Qubit ICs are typically utilized to connect qubits to control and read out signals. Taking a typical cryogenic quantum-computing system as an example (Figure 1), we can see that the control system will go through several levels of interconnects and electronics and finally reach the qubit IC. In qubit ICs, the temperature gradually decreases from the ambient temperature in the control system to less than 100 mK.

The design-to-manufacturing process for qubit ICs is similar to that of traditional ICs. Still, the foundry process design kit is essential to the circuit design process. Devices in the qubit IC may be passive devices or transistors. This will depend on the qubit platform being used.

The foundry device model typically covers temperatures from -40°C to 175°C (233.15 K to 48.15 K), which is based on the vast majority of (classical) IC applications over the past decade. The quantum application, however, can function at temperatures as low as 4 K.

As a result, the device’s behavior at cryogenic temperatures may not be effectively captured by the current industry models used in semiconductor foundries, potentially leading to unexpected design problems. To accommodate deep cryogenic temperatures, device modeling teams are exploring novel approaches to characterization and simulation.

KEYSIGHT’S DEVICE MODELING SOLUTION

To better describe the electrical behavior of novel systems, such as quantum computers, modelers will create a new set of equations. Verilog-A code, the most prevalent method of the past few years, or another sort of script like C code will be used to write the equations. Next, we’ll connect those algorithms to commercial SPICE simulators so we can run simulations and get model parameters. Modeling engineers face a new difficulty when they are tasked with figuring out how to use a newly developed model to extract parameters.

Keysight Technologies, a leading provider of electronic design and test solutions, offers a comprehensive suite for quantum device modeling through its PathWave platform (Figure 2).

Keysight’s solutions utilize and expand upon device modeling from traditional silicon devices to cryogenic devices and new device structures to meet the demands of quantum-computing customers. Then those working with quantum applications might save a lot of time and money by relying on experts’ knowledge of CMOS modeling.

The PathWave platform includes the following:

- The software WaferPro Express automates wafer-level measurements of semiconductor devices, such as transistors and circuit components. It offers drivers and test procedures for a variety of instruments and silicon probes. The tool can conduct automatic wafer-level measurements in both room-temperature and cryogenic conditions, thanks to its collaboration with cryogenic probe station suppliers.

- PathWave Device Modeling (IC-CAP) is the standard in the industry for modeling DC and RF semiconductor devices. IC-CAP extracts precise compact models utilized in high-speed digital, analog and RF applications. The IC-CAP device definition, data processing and simulator interface are highly flexible. In the case of devising a new device structure, that gives users great convenience in customizing new structure devices, models and parameter equations.

- MBP is a one-stop solution for high-volume model generation that offers both automation and flexibility. The software includes automated extraction programs for industry-standard models and an open interface for the customization of modeling strategies. MBP has a more user-friendly interface and can manage the entire foundry library more efficiently than IC-CAP. Users of MBP could easily integrate the foundry model library and fine-tune selected parameters without altering the original structure of the model library. Therefore, MBP is recommended for quantum users who wish to adapt existing foundry models to cryogenic environments.
Infineon and Eatron collaborate to advance automotive battery management systems

Infineon Technologies and Eatron Technologies have partnered to integrate sophisticated machine learning algorithms and solutions into the AURIX TC4x microcontroller (MCU). The partnership aims to advance battery management systems (BMS) for automobiles.

COSEL launches ultra-compact, high efficiency GaN-based power supplies

The TE series from COSEL is a new generation of highly compact power supplies for industrial applications. Using cutting-edge technologies such as wide bandgap Gallium Nitride (GaN) semiconductors, high-frequency planar transformers, and enhanced...

Taiwan Semiconductor Launches New ESD Devices Targeting Wearables

Taiwan Semiconductor unveils its new TESD Series of single-channel ESD clamping diodes with optimized size and performance for wearable applications. The novel design of the new TESD devices includes bidirectional restraining cells (for ESD protection up to ±30kV) housed in...

Power Integrations Releases Innovative 1,250V GaN Switcher IC

Power Integrations released the world’s highest-voltage, single-switch gallium-nitride (GaN) power supply IC, featuring a 1,250 V PowiGaN switch. InnoSwitch3-EP 1,250 V ICs are the newest members of Power Integrations’ InnoSwitch family of off-line CV/CC QR flyback switcher ICs, which feature synchronous rectification, FluxLink safety-isolated feedback and an array of...

References

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"Get Ready for Wi-Fi 7: Applying New Capabilities to the Key Use Cases", a report examining how this new technology will revolutionize people's daily lives throughout the world, was recently released to the public...
Getting Started with Transformers
Transformers are widely used to efficiently transfer both power and data in switching power supplies, MOSFET gate drivers, and isolation circuits.

The Fundamentals of Power Inductors
Understanding the fundamentals of power inductors is critical for both newer engineers and savvy veterans as they attempt to obtain performance data critical to their design.

Challenges in the Development of Next-Generation Motor Control Systems
Many of today's motor control systems are implemented by programming motor control algorithms on the MCU. However, due to the diversification of needs, control algorithms are becoming more and more complicated, and it is required to realize not only motor control but also communication and control of the entire system with one MCU.

How to Design a Simple, Uninterruptible Power Supply with Supercapacitors
How can you more easily ensure a continuous, reliable power supply in power-critical applications? In many applications, it is important for the supply voltage to be continuously available no matter what the circumstances. This isn't always easy to ensure.

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