Solving the challenges of driving SiC MOSFETs with new packaging developments

White paper

Silicon carbide (SiC) MOSFETs offer tremendous new characteristics and capabilities, but they also present new challenges. ROHM semiconductor devices allow engineers to take full advantage of SiC MOSFETs, while also overcoming the challenges of driving them.

Expanding the Capabilities of MOSFETs

Transistors are sometimes thought of as the building blocks of digital electronics. The invention of the semiconductor-based transistor, replacing the vacuum tube for electrical switching, enabled some of mankind's greatest leaps forward in technology.

The most common transistor type in electronics is the MOSFET transistor, or metal oxide semiconductor field effect transistor. These transistors take advantage of the peculiar properties of semiconductor materials to allow small electrical current signals to control the switching of sometimes much larger current signals. One type of MOSFET is used as a switch in power electronics circuits, and it is specially optimized to withstand high voltages and pass load current with minimal energy loss.

A new extremely hard compound semiconductor material, silicon carbide (SiC), provides a number of advantages over silicon for making these power switching MOSFETs.. SiC has 10x the breakdown electric field strength, 3x the bandgap, and enables a wider range of p- and n-type control required for device construction. SiC also has 3x the thermal conductivity, meaning 3x the cooling capability of silicon.

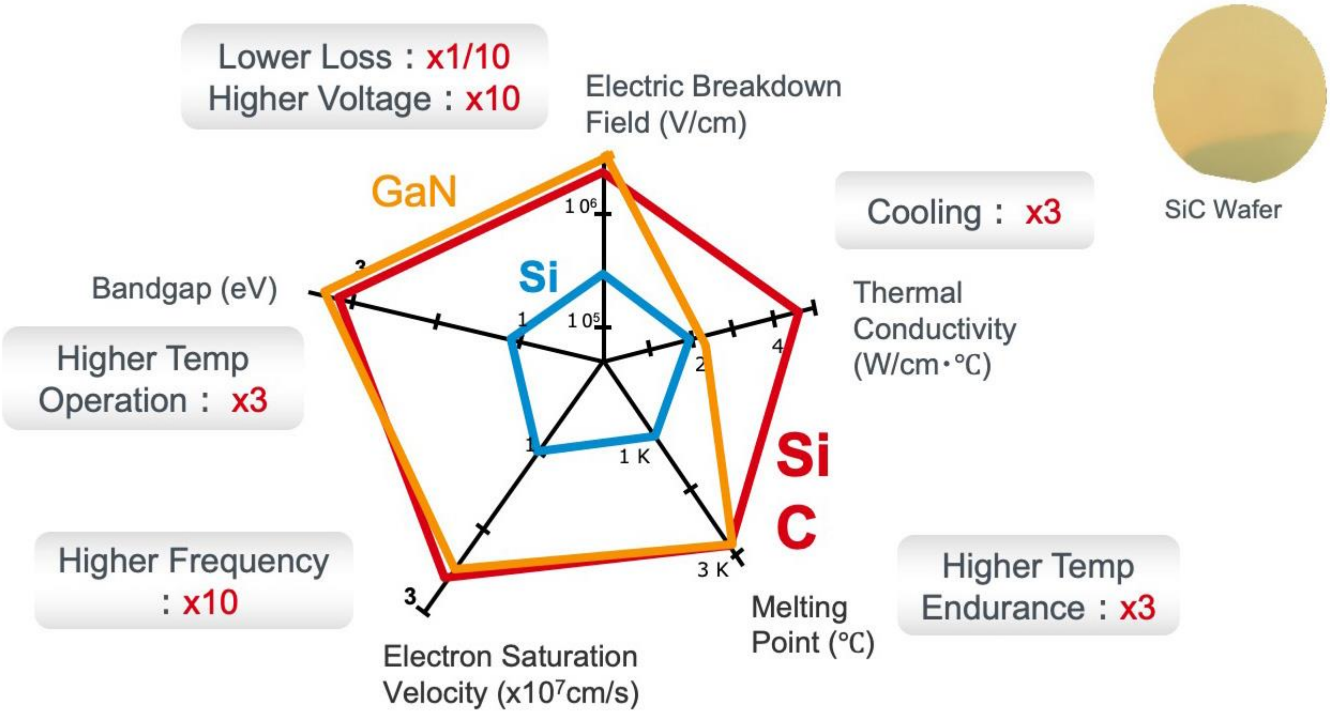

Figure 1: Semiconductor Material comparisons (Silicon Carbide vs Silicon vs Gallium Nitride)

Silicon carbide, also known as carborundum, is a compound semiconductor made up of silicon and carbon. It occurs in nature as an extremely rare mineral called moissanite, but has been mass produced since the 19th century as an abrasive. SiC has only recently entered mass production for high temperature, high voltage semiconductor devices capable of high speed operation.

The Increasing Popularity of SiC MOSFETS

A MOSFET constructed with silicon carbide, therefore, presents a significant step improvement over silicon alone. SiC MOSFETs have much higher breakdown voltages, better cooling and temperature endurance, and can be made physically much smaller as a result. IGBTs (insulated-gate bipolar transistors) are primarily used for switching voltages above 600V, but silicon carbide materials make MOSFETs usable to 1700V and higher voltages. SiC MOSFETs also have significantly less switching losses than IGBTs, and they can operate at higher frequencies.

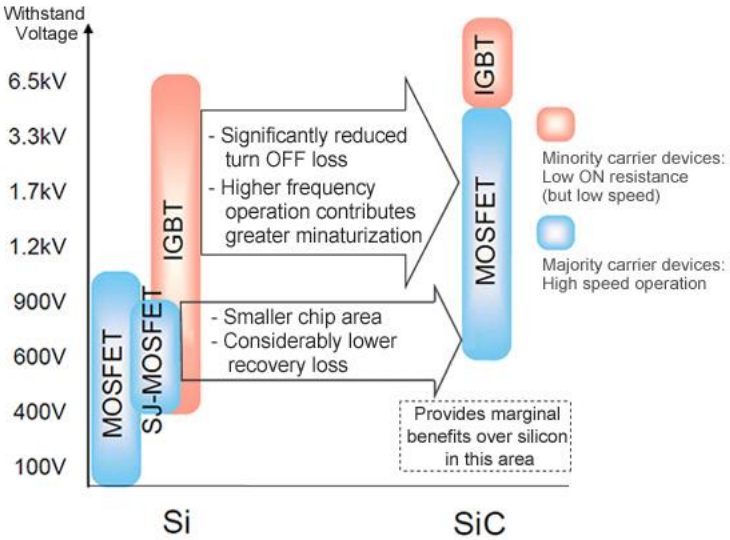

Figure 2: SiC MOSFET Advantages vs Si MOSFET and IGBTs

Because of these and other benefits, SiC MOSFETs are increasingly being used in power supplies for industrial equipment and inverters / converters for high-efficiency power conditioners.

ROHM's Solutions to the Challenges of Driving SiC MOSFETS

But SiC MOSFETs also present new circuit design challenges. Most significantly, they require a high current gate drive to quickly supply the full required gate charge (Q_G). SiC MOSFETs exhibit low on-resistance only when driven by a recommended 18V to 20V gate to source (V_{GS}) voltage, which is significantly higher than the 10V to 15V V_{GS} needed to drive silicon MOSFETs or IGBTs.

ROHM offers two complementary solutions to the challenge of driving these SiC MOSFETs. The first is new package innovations in their latest SiC MOSFET devices. The second is their MOSFET gate driver device capable of driving up to 20A. Together, these ROHM solutions allow engineers to realize all the advantages that SiC MOSFET devices have to offer.

SiC MOSFETs with Driver Source Pin

ROHM's new SiC MOSFET packaging innovations add an additional pin to provide a driver source separate from the power source. In a traditional 3-pin FET, the electromotive force that occurs at the source pin due to the inductance of the pin and the high load currents through the device effectively reduces the V_{GS} seen by the transistor. This lower V_{GS} inhibits the full turn-on of the transistor. In the new devices with a separate driver source pin, that pin provides direct access from the gate driver to the internal transistor source. The inductance effects on the power source pin are thus avoided.

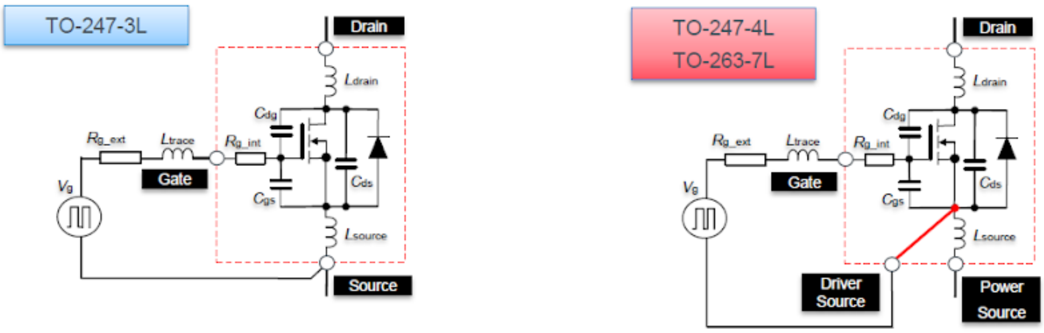

Figure 3: Traditional 3 Lead MOSFET vs New Package with Separate Driver Source Pin

SiC MOSFETs with a separate driver source pin are available in 4-pin or 7-pin packages. The 4-pin package is the TO-247-4L, and is designated by ROHM part numbers SCT3xxxAR or SCT3xxxKR. The 7-pin package is the TO-263-7L, and is designated by ROHM part numbers SCT3xxxAW7 or SCT3xxxKW7.

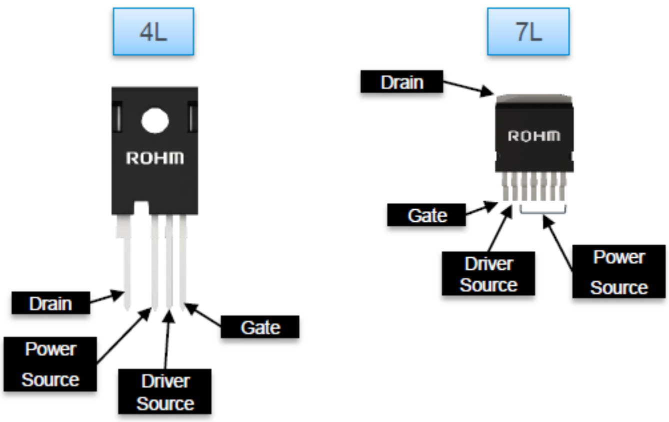

Figure 4: SiC MOSFET Package with Separate Driver Source Pins

High Current Gate Driver

ROHM's new transistor gate driver with galvanic isolation (BM6112) is ideally suited for the unique challenges of driving SiC MOSFETs. It can drive high currents up to 20A, drive gate voltages up to 20V, and do it all with an I/O delay of less than 150ns, max. With an impressive set features and qualifications, including 3750 Vrms isolation, under-voltage lockout (UVLO), and short circuit protection, this gate driver empowers the designer to take full advantage of SiC MOSFETs.

Most traditional FET gate drivers are not capable of directly driving SiC MOSFETs, so they require the use of a buffer between the gate driver and the FET. The BM6112, however, can directly drive single SiC MOSFETs under most conditions. When driving power modules, however, a gate drive buffer will almost always be required.

The BM6112 is automotive qualified (AEC-Q100), and is suitable for automotive, industrial inverter, and UPS system applications.

Packaging Innovation to Solve Problems

The use of SiC semiconductor materials presents a leap forward in technology for MOSFET devices, and ROHM is leading the way. SiC MOSFETs are fast, high voltage, and high temperature. They are poised to replace IGBTs in many applications, with faster operation, smaller size, and lower losses. But those benefits come with some challenges — challenges that ROHM provides solutions for. With the packaging innovation of adding a separate driver source pin and isolated gate driver ICs for driving the SiC MOSFET gates, designers can take full advantage of the SiC MOSFET benefits in their designs.

For more information, visit rohm.com and check out these resources:

Resources

1. What are SiC Semiconductors?
2. SiC Power Devices and Modules Application Note (PDF)
3. SiC MOSFET ordering information
4. BM6112FV-C Gate Driver Providing Galvanic Isolation datasheet (PDF)

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