When Life Presents You with Challenges, Make Them into Opportunities

There's a point in a product's life cycle when design costs have been amortized, all bugs have been ironed out, and production has settled into a happy, profitable routine. The hundreds of hours spent qualifying the product are dimming in the memories of the designers, who are now intently focusing on their latest creations. Buyers have their component supply chain established, and all lead times have been programmed in. Even the chief financial officer is happy.

A pop-up appears. Just another e-mail from one of many suppliers. It is lunchtime, and the buyer nearly files it for later review but out of curiosity opens it—and her heart sinks. That part number is all too familiar, and those words “obsolete—no recommended alternative” and “last time buy” are going to spoil her lunch big-time. A component obsolescence issue causes a potential crisis for a Swedish battery charger manufacturer—but silicon carbide (SiC) cascodes come to the rescue.

The Darkest Hour
This, with some artistic license, is what happened at the Swedish company Micropower Group with one of its flagship products, an 8-kW charger for the materials handling industry. It used a bridge converter with 12 silicon (Si) MOSFETs in four groups of three in parallel. And now they were suddenly obsolete.

With orders on the books and limited MOSFET stocks, a crisis meeting looked at the options and tasked the engineers to report back. Alternative suppliers’ MOSFETs had low current density, and too many in parallel would be needed at a prohibitive cost. Superjunction MOSFETs seemed to be the answer—but, no, their body diodes were failing in prototypes for no apparent reason, providing little confidence in their robustness.

A new design using wide-bandgap SiC or gallium nitride devices looked attractive for performance and long-term benefits but was quickly ruled out; there was simply no time for the extensive redesign and qualification that would be needed for different gate-drive requirements, let alone running them at their potential speeds. Even dropping in IGBTs was considered but discounted when the loss in efficiency was calculated, especially in light of upcoming energy savings standards.

A Break in the Clouds
In the face of diminishing options, a version of a wide-bandgap device came to their attention—the SiC cascode from UnitedSiC. It sounds like it should be a vacuum tube, and originally it was, invented in the 1930s. It has surfaced through the years in bipolar transistor and MOSFET forms, and now the SiC cascode version is a hybrid of a conventional Si MOSFET and an SiC normally on junction gate field-effect transistor (JFET) (Figure 1).

In the cascode, a low-voltage Si MOSFET is connected with its drain to the source of an SiC trench JFET, with the JFET gate sharing a common connection to the MOSFET source. When a positive voltage is applied to the Si MOSFET gate, it turns on, effectively shorting the JFET gate to the source, turning it on. When the Si MOSFET gate is at 0 V, it is off, allowing its drain to rise in voltage. However, when this reaches approximately 7 V, the JFET gate becomes 7 V more negative than its source, turning it off. The MOSFET drain does not exceed 10 V, as it is dynamically clamped by the ratio of the two series devices’ output capacitances. The Si MOSFET can therefore be a low-voltage type with an associated extremely low on-resistance $R_{DS(on)}$ of a few milliohms. The overall on-resistance is then dominated by the JFET channel.

In this combination, one gets many advantages. The gate drive becomes noncritical, and a body diode is formed in the low-voltage MOSFET with very low reverse recovery charge and low forward drop. Also, the short-circuit current is very well controlled by a natural pinch-off effect. The combination has an avalanche rating to make it robust against overvoltages. Because SiC die sizes are relatively small, device capacitances are low, providing high-speed and low-switching
losses, and parts are available in the same TO-247 package as the obsolete Si MOSFET. The low-voltage copackaged Si MOSFET is custom designed to give optimum performance in the cascode application. The overall on-resistance is effectively set by the JFET, which dissipates the bulk of the cascode power so the SiC’s inherent high-temperature rating yields a nice safety margin over the obsolete Si MOSFET solution. The gate-drive ease was a clincher for Micropower Group, as the potential alternatives—IGBTs or SiC MOSFETs—need very particular voltages (Figure 2) for reliable and efficient operation and, in the case of

![Diagram showing SiC cascode compared with other devices. The recommended working voltages are shown in the boxes.](image-url)
IGBTs, significant gate-drive power. The cascode, with its typical drive of +12 V/0 V and maximum of +/-25 V, drops in to an existing Si MOSFET slot with little or no change to the surrounding circuitry.

The first tests were encouraging, and the engineers realized that, with simple adjustments to the gate resistor values and driver dead time, keeping the existing gate-drive voltages and operating frequency, the product worked. Detail tests showed that efficiency had actually increased by 1% at operating loads and by an impressive 10% at light loads, offering real energy savings to the company’s customers to the order of 750 kWh in five years in real applications. The voltage rating of the cascode is 1,200 V, against the obsolete Si MOSFET at 950 V, for increased reliability with the voltage overstress that one might see with inductive loads; its on-resistance is better by a third, at 100 milliohms. The engineers found that even snubber network sizes could be reduced and electromagnetic interference performance maintained with just two extra Y capacitors. With two cascodes replacing sets of three Si MOSFETs, the overall cost was no greater, and Micropower Group became excited about the prospect of achieving similar gains in other products.

The Final Push

With a tentative sigh of relief, Micropower Group embarked on a thorough qualification program to ensure that the results could be duplicated in production and, most important, that the devices would survive the reality of short circuits and overvoltages. In the 12-month test sequence, full functional and environmental tests were performed, including a six-month program of thermal cycling. Abnormals included output short circuits; load disconnections and bouncing phase errors, each performed 20,000 times; voltage surges, according to IEC 61000-4-5; and thermal overloads, simulating a loss of cooling. All of the tests were passed in the time planned, with no failures. As a final precaution, prior to full production, 20 chargers using cascodes were shipped to selected global customers, followed by 100 more, for real-life field testing, again with no issues arising.

From the dark days of obsolescence notices, Micropower Group now has a product that is better and that likely has a long production life ahead, with close support from the cascode manufacturer and its local distributor. The company now sees SiC cascodes as the future in its designs and has already started a new 13-kW charger project using parallel cascade devices. The tantalizing possibility of even higher efficiency, with a hugely reduced size of the magnets and other passive components, is there for the taking in new designs, with consequent cost, size, and energy savings for customers. For Micropower Group, the future is lithium-ion battery charging, higher battery voltages of 400 V and more for electric vehicle applications, and wireless charging at >1 kW, all supported by SiC cascode technology.

About the Author

Christopher Rocneanu (croceneau@unitedsic.com) received his post-graduate degree in electrical engineering and business from the University of Kiel, Germany, in 2011 following his graduate studies at the University of California, Santa Barbara, in 2009. He began his career as a field applications engineer at MEV Elektronik Service GmbH, where he developed an interest in silicon carbide (SiC) devices. He then moved to ROHM Semiconductor, where he did business development for the SiC device product line, before joining UnitedSiC.