TECHNICAL ARTICLE

NEW POWER SWITCH TECHNOLOGY AND THE CHANGING LANDSCAPE FOR ISOLATED GATE DRIVERS

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The emergence of new power switch technologies based on materials such as silicon carbide (SiC) and gallium nitride (GaN) offers a jump in performance over traditional systems based on MOSFET and IGBT technology. Higher switching frequencies will decrease component size, allowing reductions in cost, size, and weight; these are key advantages in markets such as automotive and energy. New power switches will also force changes on the components that control them, including the gate drivers. This article will look at some of the key differences in GaN and SiC switches vs. IGBT/MOSFET, and discuss how gate drivers will support these differences.

For many years the choice of power switch technology for power delivery systems has been quite straightforward. At the lower voltage levels (typically up to 600 V), MOSFETs were normally the de facto choice, with higher voltage levels more typically being the domain of the IGBT. The status quo is under threat with the emergence of new power switch technologies in the form of gallium nitride and silicon carbide.

These new switching technologies offer several significant advantages in terms of performance. Higher switching frequencies reduce system size and weight, which is important when considering target markets such as automotive and PV inverters used in energy applications such as solar panels. Increasing switch speeds from 20 kHz to 100 kHz offers a significant saving in transformer weight, allowing lighter motors for electronic vehicles, increasing range, and reducing the size of inverters used in solar applications, making them more acceptable for domestic applications. Additionally, higher operating temperatures (especially for GaN devices) and lower turn-on drive requirements simplify design work for system architects.

As with MOSFET/IGBT, the new technologies (at least initially) seem to service different application needs. Until recently, GaN offerings were typically in the 200 V range, although recent years have seen this rapidly expanding and several offerings in the 600 V range have emerged. This is still not encroaching on the main range for SiC, which is closer to the 1000 V range, potentially suggesting that GaN becomes the natural heir to MOSFET devices, leaving SiC to become a replacement for IGBT devices. However, just as SJ MOSFETs crossed the gap into higher voltage applications up to 900 V, it should come as no surprise that some GaN developments are starting to deliver devices capable of addressing applications above the 600 V level.

However, while the advantages make GaN and SiC power switches an attractive proposition to designers, the benefits do not come for free. First and foremost is cost, with device prices several times higher than their MOSFET/IGBT equivalents. IGBT and MOSFET production is a well developed and highly understood process, meaning it is highly cost optimized and well placed in terms of price competition vs. its newer rivals. Currently, SiC and GaN devices are still several times higher in price, while continually becoming more price competitive vs. their traditional rivals. Many experts and market reports have stated that the gap in pricing will have to close significantly before widespread adoption takes place. Even then, a wholesale switch should not be expected, even long-term estimates would predict traditional switch technology retaining the majority of the market for some time to come.

Outside of pure cost and financial considerations, technical considerations also come into play. Increased switching speeds and higher operating temperatures may be good operating points for GaN/SiC switches, but they still pose problems for the supporting cast of surrounding ICs required to complete the power conversion signal chain. A typical signal chain for an isolated system is shown in Figure 1. While increased switching speeds have consequences for both the processors that control the conversion and the current sense, which provide the feedback loop, the rest of this article will focus on the changes encountered by the gate drivers that provide the control signals for the power switches.

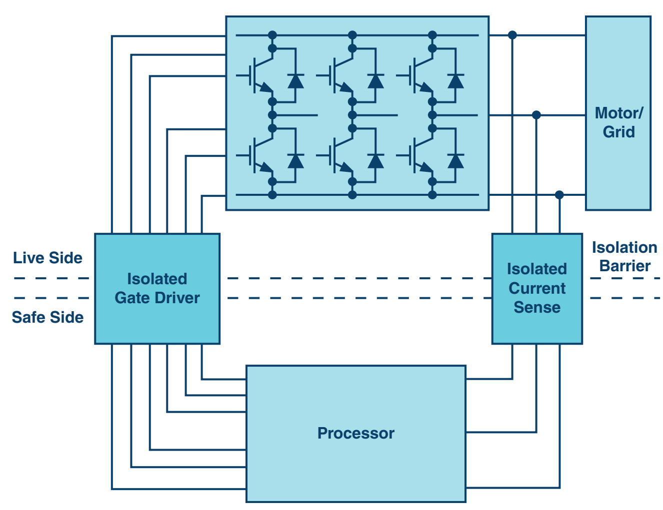

Figure 1. Typical power conversion signal chain.

Gate Drivers for GaN/SiC

Gate drivers take logic level control signals, generated by the process controlling the system, and provide the drive signals required to drive the gate of the power switch. In an isolated system, they also provide isolation, separating high voltage signals on the live side of the system from both users, with sensitive low voltage circuitry on the safe side. Taking full advantage of the higher switching frequency capabilities of GaN/SiC technologies, gate drivers have to increase the frequency of their control signals. Current IGBT-based systems may switch in the tens of kHz range; emerging requirements suggest that switching frequencies in the hundreds of kHz, and possibly up to one to two MHz range may be required. This poses problems for system designers, as they try to eliminate inductances in the signal path from gate driver to power switch. Minimizing trace length to avoid trace inductance will be key and closing colocation of the gate driver to the power switch may become the norm. Most, if not all, recommended layout guidelines from GaN suppliers stress the importance of low impedance traces and planes. In addition, adopters will look to power switch and supporting IC providers to address issues caused by packaging and bond wires.

The higher operating temperature range offered by SiC/GaN switches will also be attractive to system designers, allowing more freedom to push performance without running into thermal issues. While the power switch will operate to much higher temperatures, the silicon-based components around them still face the same temperature limitations as always. Given the need to position the driver beside the switch, designers wishing to take advantage of the higher operating temperature of new switches are faced with the problem of not exceeding temperature limits of silicon-based parts.

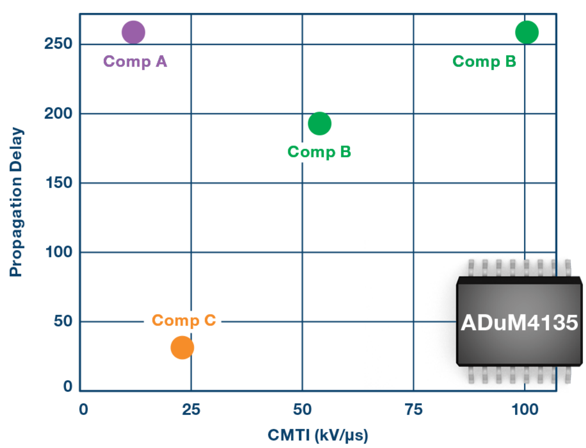

Figure 2. Propagation delay vs. CMTI performance for typical gate drivers.

The higher switching frequency also causes what could be the biggest problem for system designers: robustness against common-mode transients. High slew rate signals coupled across the isolation barrier found in isolated gate drivers can corrupt data transmission, resulting in unwanted signals on the outputs. In traditional IGBT-based systems, gate drivers with immunity levels of 20 kV/μs to 30 kV/μs were known to provide sufficient levels of immunity to common-mode events. However, GaN devices regularly exhibit slew rates in excess of these limits, and for robust system design gate drivers, supporting common-mode transient immunity levels of 100 kV/μs and above will be required. More recent offerings, such as the ADuM4135, featuring *i*Coupler® technology from Analog Devices, provide immunity against common-mode transients up to 100 kV/μs in direct response to this. Improving CMTI performance, however, can often come at the cost of additional delay. Increased delay means increasing dead time between high-side and low-side switching, decreasing performance. This is especially true in the area of isolated gate drivers, which traditionally have longer delay because of transferring signals across the isolation barrier. However, the ADuM4135 succeeds in offering 100 kV/μs CMTI while still delivering 50 ns of propagation delay.

The news isn't all bad for gate drivers tasked with driving new power switch technologies. Typical IGBTs have gate charges in the hundreds of nC range, and as a result, it's common to find gate drivers offering output drive capabilities in the 2 A to 6 A range. Currently, available GaN switches offer more than a 10× improvement in gate charge, typically in the 5 nC to 7 nC range, and as a result, drive requirements for gate drivers diminish significantly. Reducing drive requirements for gate drivers allows smaller faster gate drivers, reduces the need for external buffers to boost current output and, as a result, saves space and cost.

Conclusion

The emergence of GaN and SiC devices as new solutions in power conversion applications has been long predicted, eagerly awaited, and finally has arrived. While the technologies deliver attractive benefits, they are not free of cost. In order to deliver their best performance, new switch technology will change the requirements for the isolated gate drivers that are used, and will pose new problems for system designers. The benefits are significant and solutions to these problems are already emerging; also, viable GaN and SiC-based solutions are readily available.

About the Author

Maurice Moroney is the marketing manager for the isolated power conversion portfolio at Analog Devices, focused on isolated gate drivers and voltage/current sense, mainly in motor control, automotive, and energy applications. Previous roles included marketing/applications with focus on the consumer, industrial, and automotive industries. Maurice has a B.E. in electronic engineering (2000) and an M.B.A (2014) from the University of Limerick, Ireland.

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