Technical Article

How GaN FETs with Integrated Drivers and Self-protection Will Enable the Next Generation of Industrial Power Designs

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Physics has caught up with silicon devices. The traditional workhorses of power supplies – metal-oxide semiconductor field-effect transistors (MOSFETs) and insulated gate bipolar transistors (IGBTs) – can only boost power density if you sacrifice efficiency, form factor and heat dissipation.

Enter gallium nitride (GaN) semiconductors, which can process power electronics faster and deliver power more efficiently for a growing number of high-voltage applications. GaN's higher switching capabilities mean that it can convert higher levels of power more efficiently, with fewer components, as shown below in Figure 1. GaN semiconductors enable a new breed of power-supply and conversion systems in AC/DC power delivery applications, such as 5G telecom rectifiers and server computing. GaN is pushing the limits in new applications, and beginning to replace traditional silicon-based power solutions in automotive, industrial and renewable energy markets.

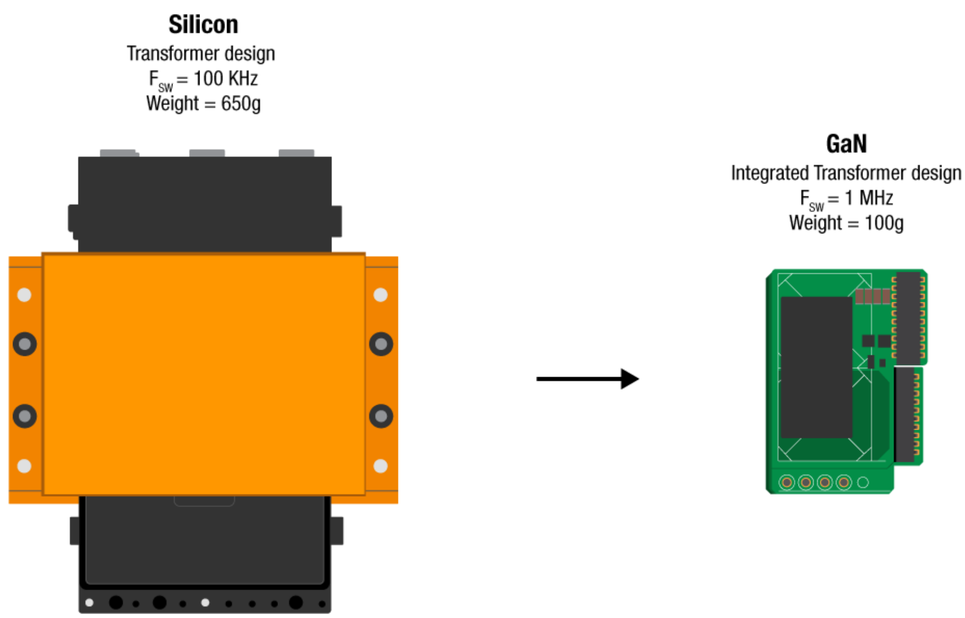

Figure 1. Comparing the power density of the magnetics of silicon designs vs. GaN designs

GaN FETs: new integration venues

Large-scale data centers, enterprise servers and telecom switching centers consume large amounts of power. In these power systems, FETs are typically packaged separately from their gate drivers because they use different process technologies, and end up creating additional parasitic inductance.

That, besides a larger form factor, can limit GaN switching performance at high slew rates. On the other hand, a TI GaN FET with an integrated gate driver, such as the LMG3425R030, can minimize parasitic inductance with a slew rate of 150 V/ns, while providing 66% lower losses and greater mitigation of electromagnetic interference compared to discrete GaN FETs. Figure 2 illustrates a TI GaN FET with an integrated gate driver.

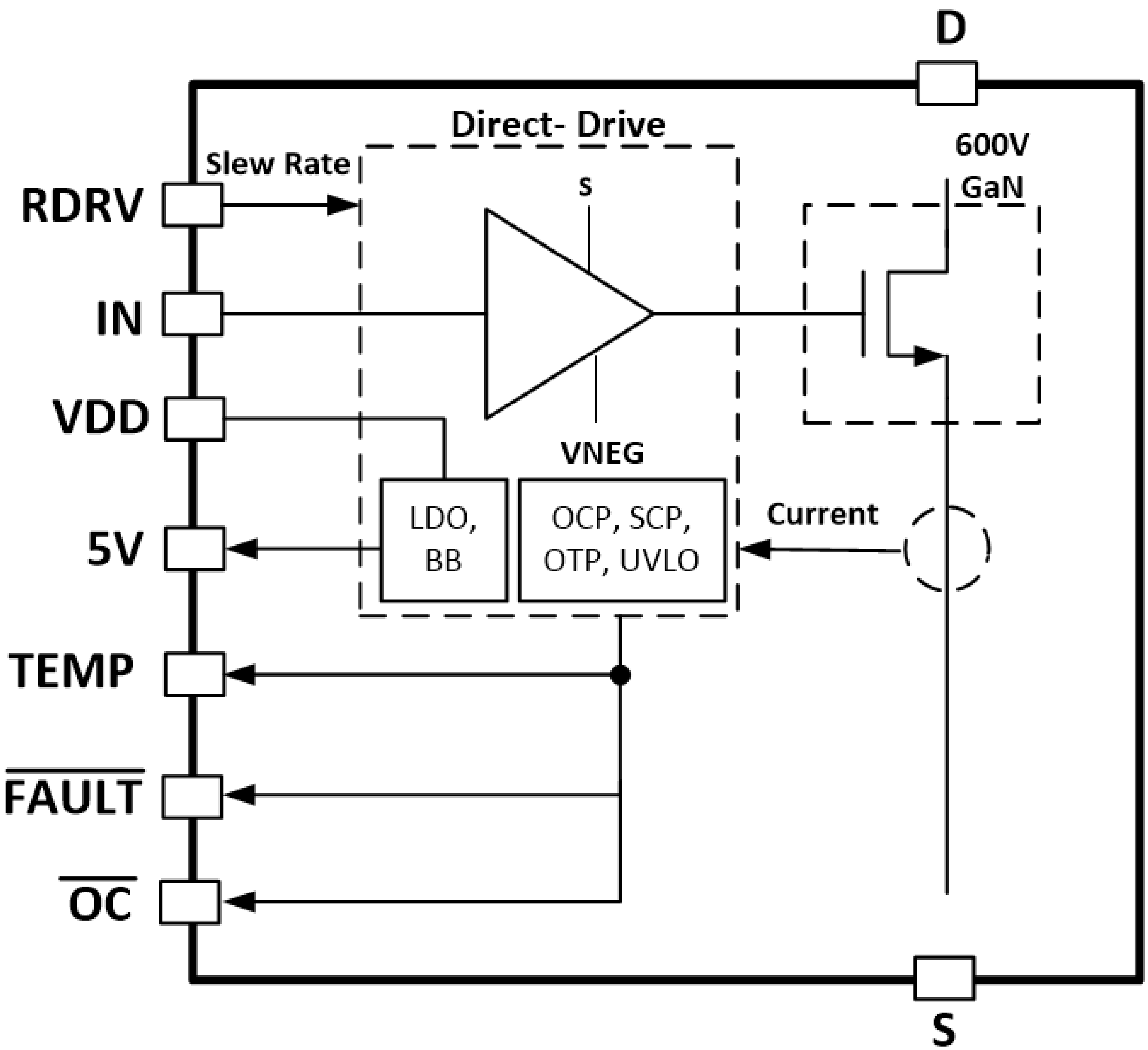

Figure 2. The integration of a 600-V GaN FET with a gate driver and short-circuit protection

In data centers and server farms, TI's new GaN FETs enable simpler topologies, such as totem-pole power factor correction, which in turn lower conversion losses, simplify thermal design and lead to smaller heat sinks. These devices enable twice as much power density compared to silicon MOSFETs in the same-size 1U rack server while achieving 99% efficiency. This power-density and efficiency savings become especially important when considering long-term impacts. For example, let's say that a server farm is increasing their AC/DC efficiency 3% each month by installing GaN devices. If that server farm that converts 30 kW of power daily, they would save more than 27 kW a month, which is roughly $2,000 monthly and $24,000 annually.

When a GaN FET is integrated with current-limiting and overtemperature detection, it can protect against shoot-through and thermal runaway events. Additionally, system interface signals enable self-monitoring capability.

Reliability is a crucial factor in power electronics. Therefore, compared with traditional cascade and stand-alone GaN FETs, a highly integrated GaN device can more effectively boost reliability and optimize the performance of high-voltage power supplies by integrating functional and protection features.

With an external driver, parasitic inductance can cause switching losses as well as ringing and reliability issues at high GaN frequencies. Common source inductance increases turnon losses significantly. Likewise, designing a robust overcurrent protection circuit at a high slew rate is difficult and costly. But GaN naturally lacks a body diode, which leads to less ringing on switch nodes and eliminates any reverse-recovery losses.

GaN devices with protection features

GaN devices have very different constructions than silicon devices. Although they can switch faster and harder, there are unique challenges from performance and reliability standpoints. There are also issues such as design simplicity and bill-of-materials cost when using discrete GaN devices.

A new family of industrial, 600-V GaN devices integrates a GaN FET, driver and protection features at 30- and 50-mΩ power stages to provide a single-chip solution for applications ranging from sub-100 W to 10 kW. LMG3422R030, LMG3425R030, LMG3422R050, and LMG3425R050 GaN devices are targeted at high-power-density and high-efficiency applications.

Unlike silicon MOSFETs, GaN conducts in the third quadrant in a “diode-like” manner and minimizes dead time by reducing the voltage drop. TI’s ideal diode mode in the LMG3425R030 and LMG3425R050 further minimizes losses in power delivery applications. Read the application note, “Maximizing the Performance of GaN with Ideal Diode Mode,” to learn more.

These GaN devices have gone through 40 million hours of device reliability testing, including accelerated and in-application hard-switch testing. The reliability tests occurred under highly accelerated switching conditions at maximum power, voltage and temperature environments.

Conclusion

Designers of switching power supplies are continually trying to raise power density while increasing efficiency. While silicon MOSFETs and IGBTs offer low power density and efficiency, silicon carbide (SiC) devices facilitate higher power density and efficiency at a greater cost.

GaN devices enable solutions with twice the power density of what is possible with best-in-class superjunction FETs. Likewise, they facilitate qualification to standards like 80 Plus Titanium that demand very high efficiency for power supplies in server and telecom applications.

While GaN is a game-changing technology for power electronics, it also demands thorough process and materials engineering. That calls for growing high-quality GaN crystal, optimizing the dielectric films and achieving very clean interfaces in the fabrication process. Masterful testing and packaging are also a must.