Technical Article

Pushing the boundaries of solar energy systems with TOLL GaN

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Solar energy systems are gaining momentum, with the performance of photovoltaic inverters at the heart of technical innovations designed to harness the sun's energy as efficiently as possible.

One of these innovations involves the use of gallium nitride (GaN), which is rapidly replacing Silicon (Si) and Insulated Gate Bipolar Transistor (IGBT) systems. GaN contributes to better-performing solar energy systems in terms of higher efficiency, lower heat dissipation, smaller size, ease of installation and lower overall system costs.

GaN vs. SiC vs. IGBT

GaN enhances the performance of power-conversion systems through its properties of better resistance per die area (Rsp), lower input and output capacitances (Ciss and Coss), and zero reverse-recovery charge. These properties are paramount to lower conduction losses and lower switching losses with increase in the switching frequency, which consequently reduces size of passives, making systems light and compact.

Researchers are actively working on maximizing the potential of GaN through improvements in manufacturing, Rsp and packaging. For example, as shown in Table 1, the transistor outlines leadless (TOLL) surface-mount package offers better thermal performance and lower parasitics compared to surface-mount packages such as the double decawatt package (D2PAK) or transistor outline (TO)-247 package.

Table 1. Thermal Resistance values of GaN devices in TO-247, D2PAK, TOLL packages

Package	Package Size	RDSon	$R_{\theta JC}$
TO-247	21.0 mm × 15.8 mm	50 mΩ	0.95
D2PAK	9.15 mm × 10.16 mm	50 mΩ	1.05
TOLL	9.8 mm × 11.6 mm	70 mΩ	0.73

Introduction to TOLL packaging

As a leadless package, the TOLL package's parasitic inductance is very low, which results in faster switching (reducing switching losses), higher slew rates, and lower electromagnetic interference. The dimensions of a TOLL package are 9.9mm by 11.68mm by 2.3mm, which is significantly smaller than the TO-247 at 15.94mm by 20.95mm by 5.02mm, and would result in 70% higher area on a printed circuit board. An optimized GaN process enables GaN field-effect transistors (FETs) with very low drain-to-source on-resistance (RDS (on)), suitable for high-power applications. The compact size of the TOLL package enables faster heat dissipation, improving thermal efficiency.

Integrating the GaN FET with the driver further improves efficiency and cost, and helps reduce the gate inductance loop and enabling the ability to embed overcurrent and overtemperature protections in the power stage. The advantages of the TOLL package are better harnessed with integration, contributing to even lower parasitics and reduced system costs. Devices such as TI's LMG3650 combine the advantages of integration and thermally efficient packaging and can be used in high-voltage power-conversion systems where thermal performance is a primary consideration, especially if active cooling is a challenge.

TOLL in energy infrastructure applications

Solar microinverters, string inverters and energy storage systems each have power-conversion stages that are sensitive to efficiency, size and cost, given their demand in both commercial and residential setups.

In solar energy applications, the inverter output is often tied to the AC grid and FETs need to be rated to withstand voltages up-to 650V. In addition, these inverters should be as compact as possible so that they have the flexibility to be implemented in either residential or commercial systems. High voltage GaN FETs are rated to withstand an absolute maximum voltage of 800V and allow increasing of switching frequency to reduce the size of passives, thus catering to both system requirements of high voltage and size. Being thermally efficient, the TOLL package is suitable for solar energy applications where the ambient temperature of the systems is higher than room temperature and effective dissipation of heat is critical.

The integrated power stage in the LMG3650 comes with protection features such as overtemperature protection, overcurrent protection and undervoltage lockout, which helps eliminate the need for external protection circuitry, reducing both design complexity and size. It has advanced features such as zero voltage detection and zero crossing detection to optimize dead time and reduce losses, along with a 5V low dropout regulator output for current-source capability to drive any auxiliary circuitry. These features contribute to optimizing the performance as well as cost of energy conversion systems.

The 600W gan-based single-phase cycloconverter reference design has a cycloconverter topology and uses the LMG3650 on the high-voltage side and the LMG2100 on the low-voltage side. This reference design underscores the potential of integrated GaN devices with a power density of 640W/L, a peak efficiency of 96.1%, and operation at switching frequencies up to 600kHz.

Designing with TOLL devices

Selecting the right GaN devices for your design is imperative to improve system performance by lowering switching and conduction losses. Using a lower RDS (on) device might not be a one-stop solution to increase efficiency because it requires a larger GaN die, which increases the output capacitance and in turn switching losses and costs.

In hard-switching topologies, a low RDS (on) with a higher Coss would lead to higher switching losses than conduction losses, while in case of soft-switching topologies, a low RDS (on) would enhance efficiency and exhibit very low switching and conduction losses.

Another point of concern for designers is multisource capability. TI's integrated TOLL GaN devices are package compatible with the discrete TOLL GaN devices and enable multi-sourcing options for our customers. As shown in Figure 1, you can deploy TI TOLL devices on the same board as discrete devices by keeping the schematics and layout the same, making only minor changes to components.

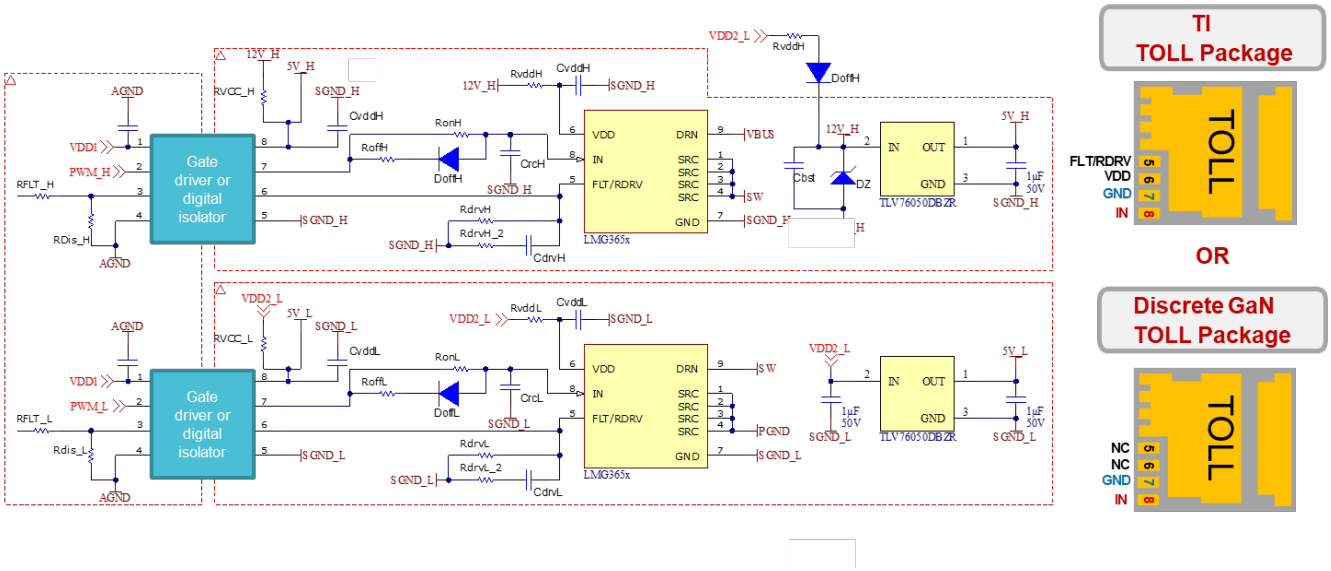

Figure 1. A schematic for TI and discrete TOLL GaN packages

Conclusion

With ever-increasing power demands, adopting GaN devices can result in improvements to the performance, cost and size of power-conversion systems. GaN devices in the TOLL package are a good fit for solar energy applications that demand efficiency, compactness and thermal performance in an industry standard package. The rapid evolution of GaN technology is expected to revolutionize power systems, leveraging its inherent advantages to enable the development of highly efficient, robust, and reliable solutions.

Additional resources

- LMG3650 - 650V TOLL-packaged GaN FET with integrated driver and protection, available in 3 RDSon options – 25 mΩ, 35 mΩ, 70 mΩ
- Check out the LMG3650R035 Evaluation Module EVM User's Guide
- Know more about our GaN Technology

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