Enhancing Reliability and Compatibility with Upgraded E-mode GaNFET

GaNPower International unveils an advanced version of the E-Mode GaNFET (GP65R45T4), featuring a boosted gate turn-on voltage of 4V and an expanded gate driving range of +/-20V. This device incorporates cutting-edge All-GaN-IC technology, enabling a seamless transition from traditional silicon and SiC MOSFETs while ensuring pin-to-pin replacement compatibility.

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Evolution and Reliability of Cascode and E-Mode GaNFETs

Cascode GaN, with a structure depicted in Figure 1 (a), combines a low-voltage normally-off silicon MOSFET and a high-voltage normally-on GaN HEMT in a cascode configuration. The combination effectively results in an enhancement-mode behavior and this technology has been commercially available since the early 2010s. The presence of the silicon MOSFET, with a common gate threshold voltage of 4V, simplifies the gate drive requirements compared to native GaN solutions, as those Cascode GaNs can typically be driven with standard silicon gate drivers. In addition, the hybrid nature of using a silicon MOSFET can enhance reliability. Silicon's known characteristics and behavior can be leveraged to protect the more sensitive gate of GaN HEMT, reducing the risk of failure due to high voltage spikes or improper gate voltage.

However, the extra silicon MOSFET between gate and source of GaN HEMT will considerably increase the effective input capacitance of Cascode GaN device, which largely sacrifice fast-switching characteristics, one of the most outstanding advantages compared to SiC MOSFETs. What's worse, the series connection of silicon MOSFET and D-mode GaN for co-packaging will lead to additional parasitic inductance that cause more ringing and overshoots in the switching waveforms, affecting overall performance and raising concerns on electromagnetic interference (EMI).

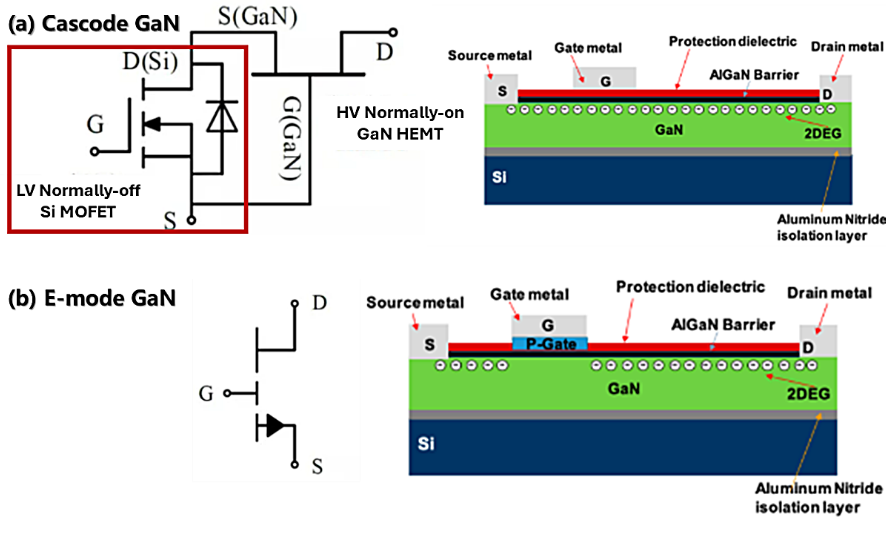
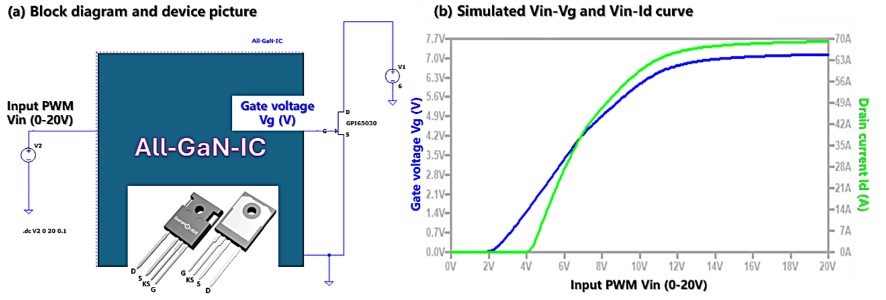


Figure 1: Figure 1. Schematic comparison between (1) Cascode GaN and (2) E-mode P-gate GaN HEMT



FFigure 2: (a) Block diagram and (b) simulated verification of a gate regulator circuit monolithically integrated with a main E-mode p-gate GaNFETs

E-mode GaNFETs, as shown in Figure 1 (b), use a p-type GaN gate structure to provide a positive threshold voltage, making the device normally-off inherently in a single chip solution. This is crucial for power applications where fail-safe operation is necessary. Without any extra components, E-mode GaNFET typically exhibit very low gate charge and capacitances. which results in faster switching speeds and reduced switching losses. They are highly efficient in applications requiring high-frequency operation.

Nevertheless, p-type GaN gate provides a typical lower gate threshold voltage of 1.4V, which would cause accidental device turn-on and system failure due to noise or gate voltage fluctuations. Furthermore, the typical driving range is -10V to 7V that is not compatible with the driving voltages for most of other power devices which requires 12-18V, making it difficult for people switching to GaN HEMTs from other power switches. Last but not least, as p-type GaN gate is not quite mature and more vulnerable, there are concerns about its long-term reliability and threshold voltage stability.

All-GaN-IC Solution: A Leap in Gate Threshold Voltage and Driving Range

GaNPower International has innovated an All-GaN-IC method that boosts the gate threshold voltage from 1.4V to an impressive 3.5-4.0V, with an extended driving range up to ±20V. A proprietary GaN based gate regulating circuit has been monolithically integrated with the power GaNFETs in single chip. This innovation, depicted in Figure 2 (a), aligns the new E-Mode GaN with the pin-outs, threshold voltage, driving range of silicon and SiC MOSFETs, earning it the nickname 'pin-to-pin' (p2p) for its exceptional compatibility. The P2P technology perfectly combine the advantages of Cascode GaN and E-mode GaN, aims to achieve a more reliable gate driving without largely compromising the fast-switching benefits of GaN power switches.

According to the LTSpice simulated results as shown in Figure 2 (b), the gate threshold voltage of our P2P GaN switch has been increased to around 4V and its gate voltage has also been properly clamped below 7V by All-GaN-IC with 0-20V PWM input. Room temperature experimental static Id-Vg measurement results, presented in Figure 3, also verify the enhancement of gate threshold voltage (3.6V) for our P2P GaN, compared to normal E-mode GaN without the GaN based gate regulating circuit.

Demonstrating Superior Switching Performance

A double pulse testing platform with a customized air-core 128µH load inductor, a freewheeling SiC diode, and a reliable voltage clamp circuit for accurate dynamic Rdson measurement has been built for the burst-mode switching evaluation of our P2P GaN.

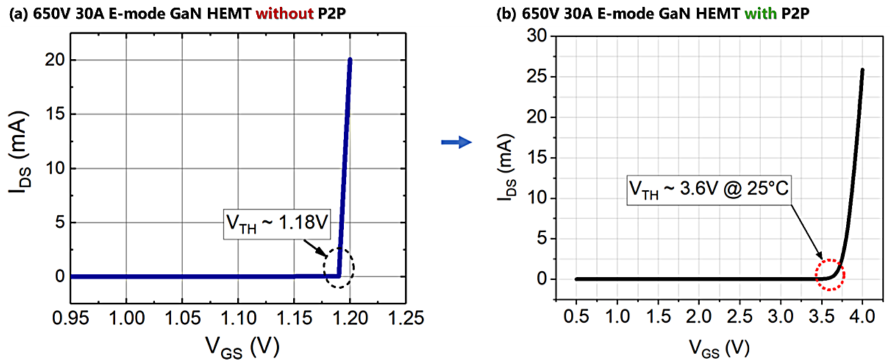


Figure 3: Comparison of Ids-Vgs measurement between 650V 30A E-mode GaN HEMT (a) without and (b) with a monolithically integrated gate regulator circuit (i.e., P2P technology)

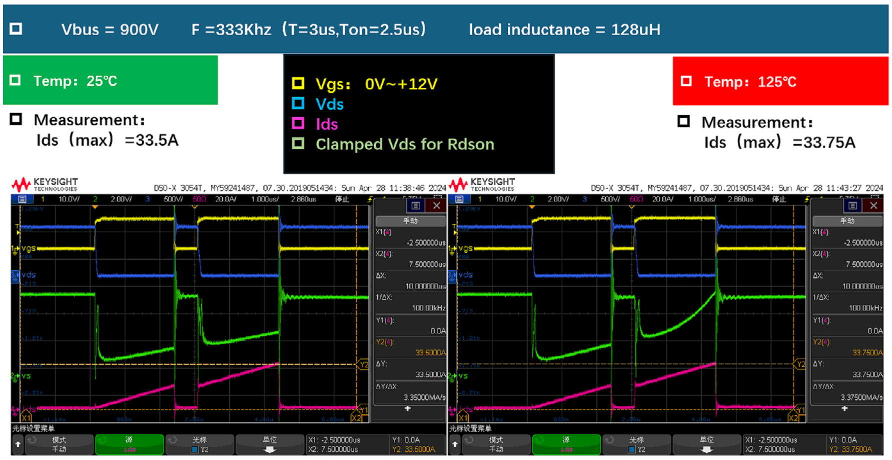


Figure 4: The results of double pulse testing (DPT) at 33A drain current and 900V bus voltage, demonstrating good switching performance at both (a) 25°C and (b) 125°C

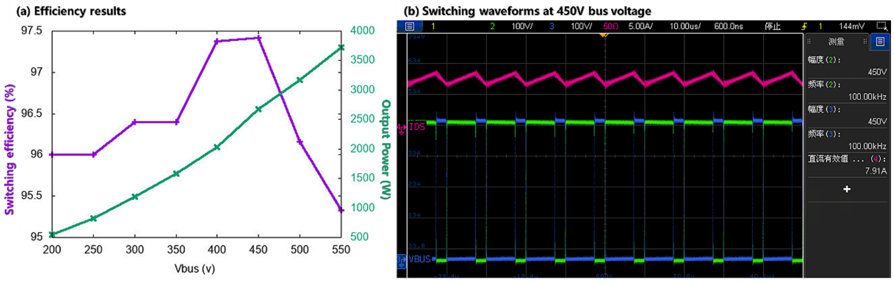


Figure 5: (a) Switching efficiency and (b) switching waveforms of an air-cooled half-bridge Buck converter, where two GaNPower P2P GaN HEMTs (GP65R45T4) were under continuous hard-switched tests

With 12V PWM input and 900V bus voltage, all the switching waveforms (Vgs, Vds and Ids), as shown in Figure 4, are quite clean without considerable ringing or overshoots. In addition, the dynamic Rdson is also within a reasonable range up to 33A (its current ratings) drain current under room temperature, which can be observed from the clamped Vds waveforms. Another double pulse tests conducted at similar loading conditions under 125°C show comparable switching waveforms demonstrated good thermal stability of the GaN based gate regulating circuit.

A 100KHz half-bridge Buck testing platform with a high saturation toroidal power inductor and a constant 40ohm high power resistor load was built for the continuous hard-switched evaluation of our P2P GaN. Two GP65R45T4 devices with suitable heat sinks were installed on the main test board and proper fan cooling was used during the tests.

According to the efficiency reports shown in Figure 5 (a), with 12V PWM input and 200-550V bus voltage, the P2P GaN based Buck converter achieved a peak efficiency of 97.42% and a maximum power output of 3.7kW. Figure 5 (b) demonstrated good continuous switching waveforms without substantial ringing and overshooting at the peak efficiency with 450V bus voltage.

More rigorous reliability testing on a large scale of GP65R45T4 samples are in progress to make sure our P2P GaNs are reliable and optimized in practical industry applications.

In conclusion, the integration of E-Mode GaNFETs with a GaN-based gate regulating circuit (P2P technology) significantly enhances the reliability and compatibility of gate driving for GaN switches, while preserving the fast-switching properties and mitigating ringing caused by co-packaging related parasitic components. This positions GaNPower's P2P technology as a critical innovation in the field of power electronics.

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