Application Note

System-Level Benefits of Using 650V Integrated GaN Power Stages in Residential Solar Inverters

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Abstract

This application note discusses the use of integrated 650V GaN power stages in residential solar string inverters. Using TIDA-011008 as a case study, this document reviews efficiency, thermal behavior, switching performance, power-density benefits, and system-level cost optimizations.

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1 Introduction

Residential solar inverters need to balance high efficiency, compact size, and competitive cost. Traditional IGBT-based designs often restrict switching frequency to reduce switching losses, which increases the size of magnetics, capacitors, and thermal-management hardware. Integrated GaN power stages enable efficient 100kHz operation, reducing passive component size while maintaining good conversion efficiency. This combination allows designers to improve power density and lower overall system BOM cost compared with traditional silicon-based implementations.

2 Why GaN for Solar Inverters?

2.1 TI GaN Module Description

GaN devices offer significantly lower switching losses compared to conventional silicon IGBTs. The integrated-driver architecture of the LMG3660 further reduces the number of components by eliminating external gate-driver. Additional benefits include reduced switching losses, lower EMI-filter noise, lower cooling requirements, and easier system implementation.

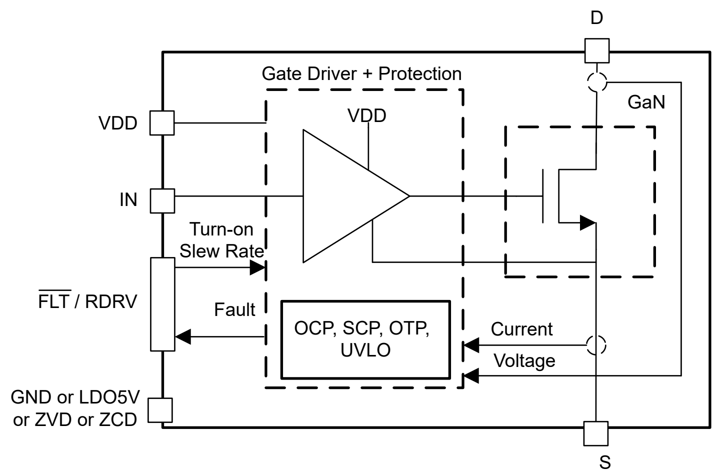

Figure 2-1. Block Diagram of LMG366x

Compared to non-integrated GaN transistors, the integrated driver design of the LMG366x significantly reduces the parasitic inductance in the gate driver loop. This integration allows the GaN power stage to switch with a clean waveform and a high slew rate, exceeding 40V/ns, while maintaining a low overshoot of only 12.5%.

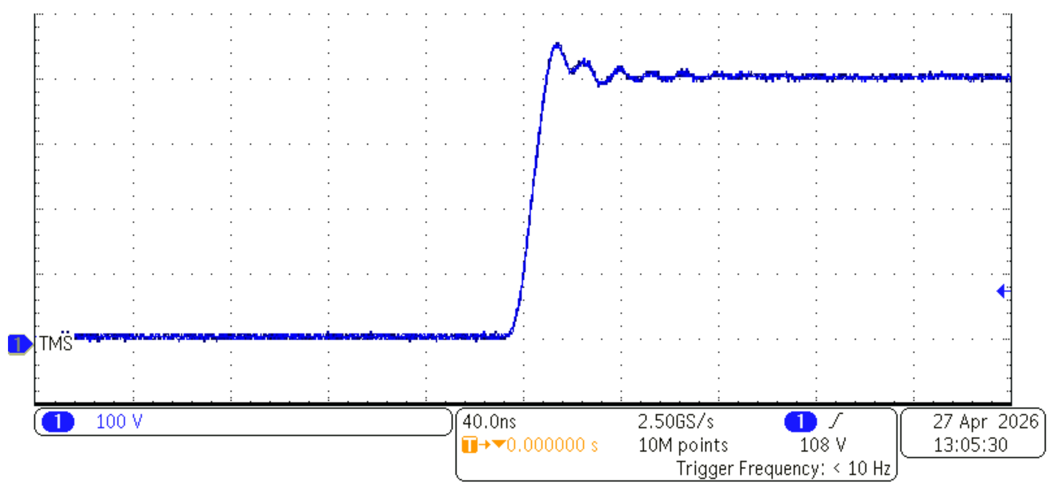

Figure 2-2. Switching Behavior of LMG366x, Rising Edge

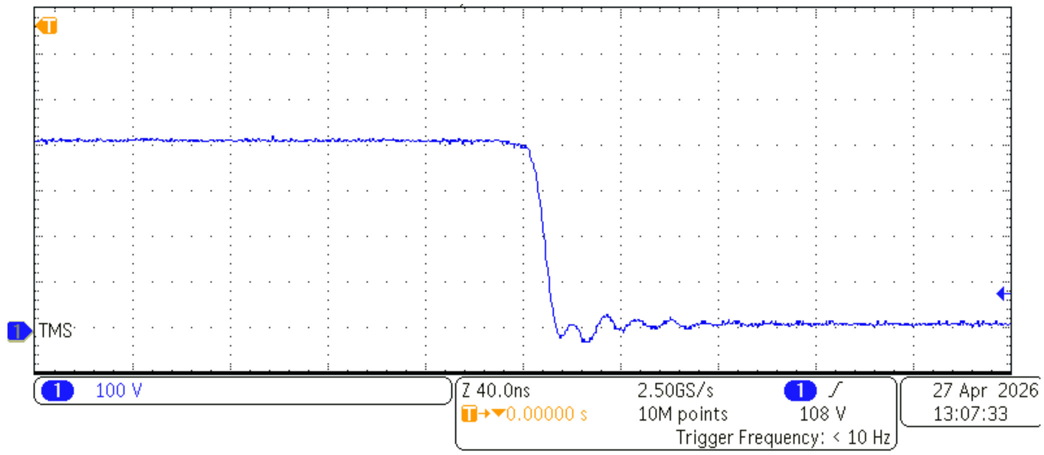

Figure 2-3. Switching Behavior of LMG366x, Falling Edge

2.2 GaN Versus IGBT Cost Comparison

Although GaN devices may have a higher component price than comparable IGBTs, a system-level analysis reveals a different conclusion. When the impact on all major subsystems is considered, the TIDA-011008 design demonstrates that a GaN-based implementation can achieve approximately 11% lower total bill of material (BOM) cost than an equivalent IGBT-based design.

As shown in Figure 2-4, the most significant cost reductions are associated with magnetic components and capacitors. These savings are primarily enabled by the higher switching frequency supported by the GaN power stage.

To maintain high MPPT efficiency, the input voltage ripple of the boost converter must be minimized, requiring sufficient input capacitance. Because capacitance requirements are inversely proportional to switching frequency, a 100kHz GaN-based boost converter requires only about one-third of the input capacitance needed by a comparable 33kHz IGBT-based design. This reduction directly lowers capacitor cost and volume.

The higher switching frequency also benefits the EMI filter design. Since for a given EMI filter, normally the conducted differential mode noise attenuation typically improves with increasing frequency, a GaN-based design can achieve the same filtering performance with smaller x-capacitors. Together, these factors contribute significantly to the overall reduction in capacitor cost.

Magnetic components represent another major source of cost savings. The increased switching frequency substantially reduces the required inductance value in both the boost stage and the DC/AC inverter stage, enabling smaller inductors with lower volume and weight, also lower price. In addition, the common-mode choke can be optimized because higher-frequency common-mode noise is easier to attenuate, further reducing magnetic-component cost.

As mentioned in the *TI GAN Module Description* section, with integrated gate driver, a separate gate driver is not needed, in most cases, only a PWM buffer or digital isolator is required.

Beyond the BOM savings shown in Figure 2-4, the compact design benefited from reduction of passive components can also reduce the cost of housing, and can also lower storage, transportation and installation. While these savings are not included in the BOM comparison, they provide additional opportunities for reducing the total system cost of the inverter.

Figure 2-5 highlights the major components that benefit from 100kHz GaN operation. Reduced capacitor, magnetic, gate-drivers collectively contribute to the overall BOM cost reduction.

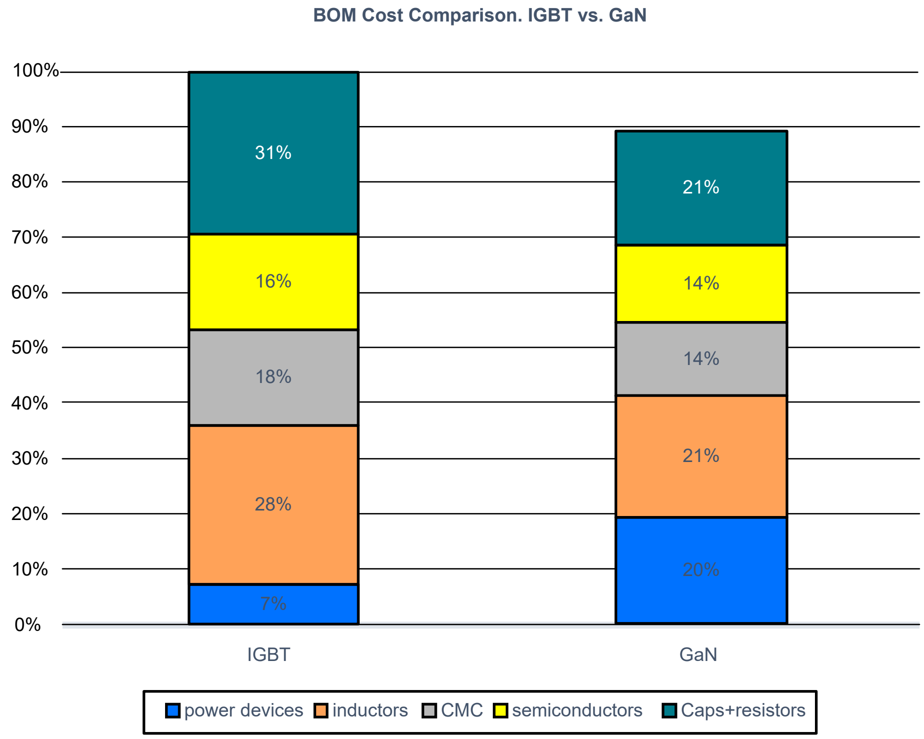

Figure 2-4. Cost Comparison Between IGBT and GaN-Based Designs

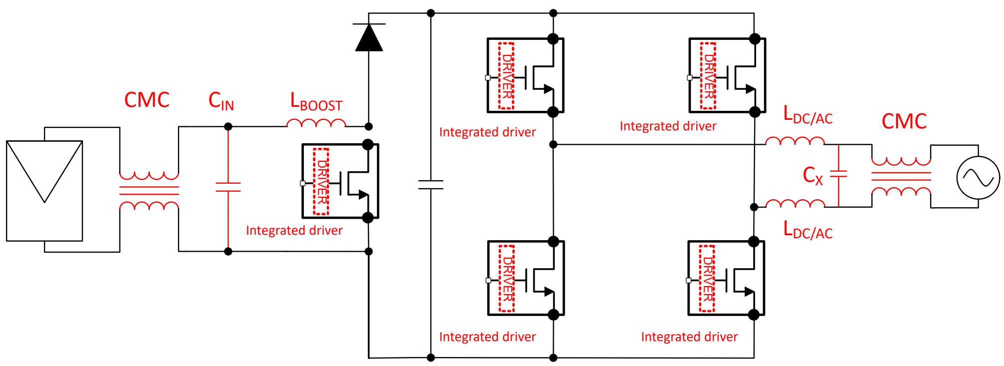

Figure 2-5. System Block Diagram

3 Measured Performance of a 3.6kW GaN String Inverter

3.1 DC/DC Boost Performance

The TIDA-011008 boost stage operates over a wide PV input range and output is a regulated 400V DC-link voltage. Measured efficiency above 99% across a broad operating range. At approximately 500W output power with 200V and 250V input voltages, the converter enters a quasi-ZVS operating region, reducing switching losses and improving light-load efficiency. Figure 3-1 shows that for >200V input voltage, 400V output voltage, a hard-switching non-synchronized boost stage has a >98.5% efficiency in most cases, which eases the design of heatsink.

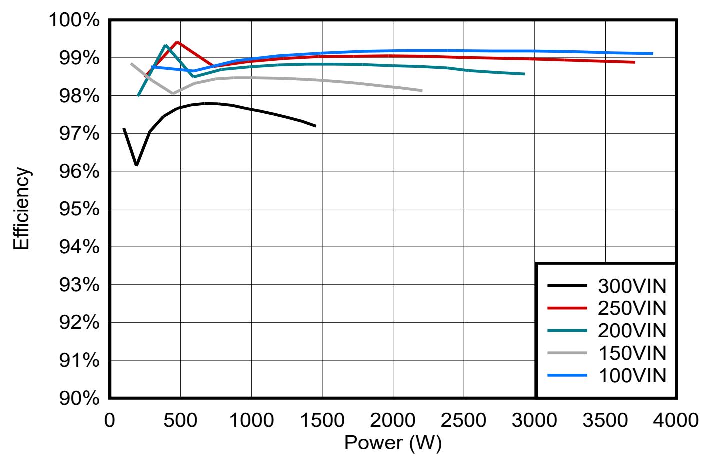

Figure 3-1. DC/DC Boost Efficiency Versus Output Power

3.2 DC/AC Inverter Performance

The inverter stage connects with 230VAC grid and delivers up to 3.6kW using a bipolar full-bridge architecture operating at 100kHz switching frequency. Measured results show a full-load efficiency of approximately 98.0% and a CEC weighted efficiency of approximately 98.2%.

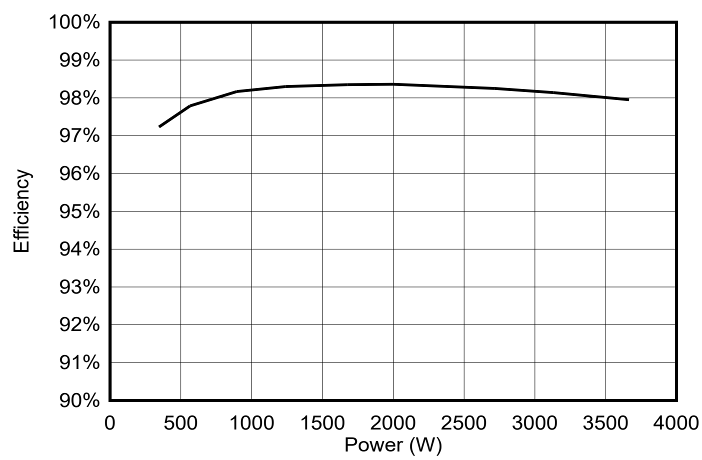

Figure 3-2. DC/AC Inverter Efficiency versus Output Power

In addition to high efficiency, the inverter demonstrates excellent output current quality. As shown in Figure 3-3 and Figure 3-4, CH1 is output current, CH2 is output grid voltage, CH3 is DC link voltage, tested with a grid emulator. Testing at approximately 80% load at 400VIN, 230VAC, shows an output current THD of only 1.23%. Measurements under very light-load conditions at 200VIN, 35VAC, also indicate good harmonic performance and clean sinusoidal current waveforms. These results demonstrate the effectiveness of the GaN-based power stage and control architecture in maintaining low distortion across a wide operating range.

In Figure 3-5, CH1 is output current, CH2 is DC link voltage, CH3 is output grid voltage, real-grid test shows good reactive power operation, the grid voltage THD is about 4.2%, and output current THD is only 3.5% at 45%

load. This indicates that the inverter can maintain excellent current quality even when operating on a distorted utility grid, making it well suited for residential grid-connected solar applications.

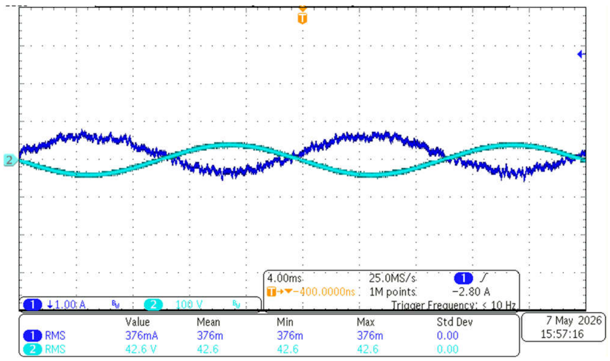

Figure 3-3. Grid Emulator, Output Current Waveform, Light Load

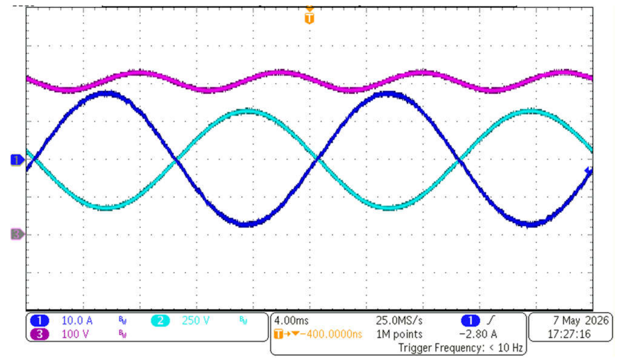

Figure 3-4. Grid Emulator, Output Current Waveform, Heavy Load

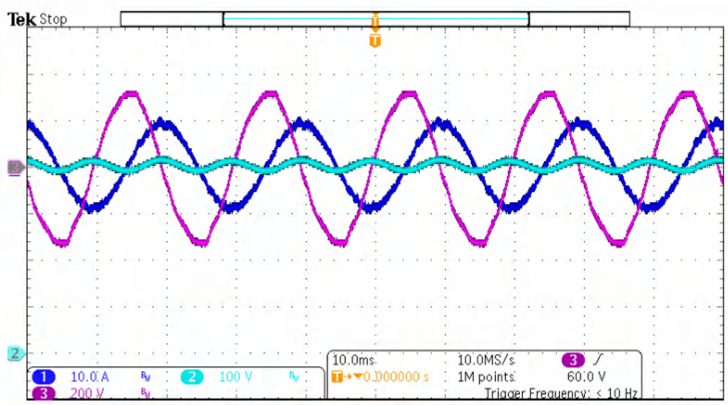

Figure 3-5. Real Grid Output Current Waveform

3.3 Thermal Performance

From Figure 3-6, thermal measurements indicate that the DC/AC inverter stage exhibits a GaN device temperature rise of approximately 50°C under high-power operating conditions. The tests were performed with the heatsink preheated to approximately 40°C and an ambient temperature of approximately 30°C, representing a realistic elevated-temperature operating environment.

GaN device temperature was measured using an ISOTMP35 temperature sensor placed near the pins of the LMG366x power stage. Despite operating at a 100kHz switching frequency, the measured temperature rise remained well controlled, highlighting the low-loss characteristics of the integrated GaN design and reducing the need for aggressive thermal-management measures.

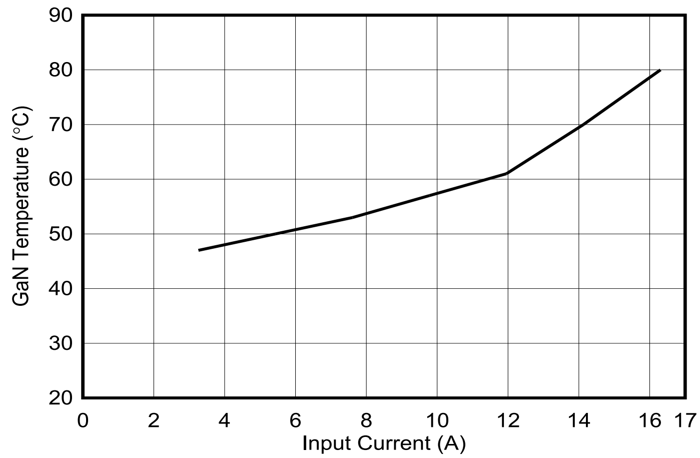

Figure 3-6. Temperature Data of GaN

3.4 System Efficiency and Power Density

End-to-end efficiency reaches approximately 97.5% with CEC efficiency up to 97.3% with boost stage not switching. Operating at 100kHz switching frequency significantly reduces the size of the boost inductor, output filter inductors, and other passive components compared with conventional lower-frequency implementations. The resulting reduction in magnetic volume enables higher power density and contributes to a compact system design. As demonstrated by TIDA-011008, the inverter can be implemented on a 205mm × 205mm board platform while maintaining high efficiency and thermal performance.

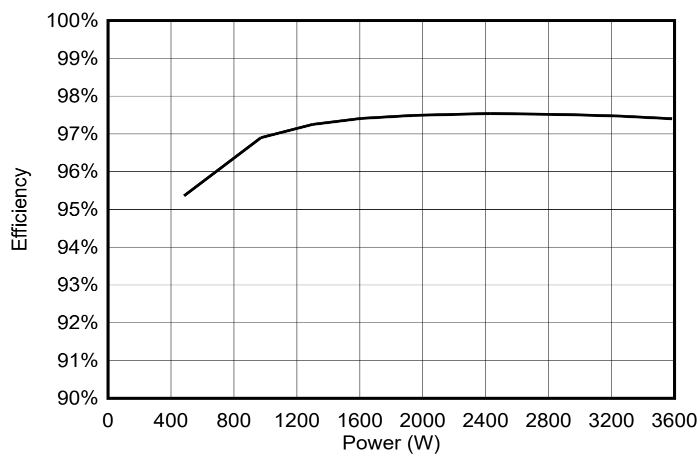

Figure 3-7. System Efficiency

4 Summary

GaN technology enables more than just higher efficiency. The TIDA-011008 results demonstrate that integrated GaN power stages can simultaneously improve efficiency, power density, thermal behavior, and overall system cost. The measured data shows that a properly optimized GaN design can outperform traditional IGBT architectures while also reducing overall BOM cost.

5 References

1. Texas Instruments, *3.6kW, GaN-Based Single-Phase String Inverter Reference Design*, design guide.

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