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Low-cost SOI-based level-shift gate driver for high-voltage and >1MHz switching in GaN applications

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1. Problem Statement and Challenges

The increasing demand for high-efficiency power conversion systems has led to the development of Gallium Nitride (GaN) transistors, known for their high switching speeds and superior performance in high-frequency applications. However, driving GaN devices in high-voltage and high-frequency regimes presents significant challenges for the level shift gate drivers, particularly related to the gate driver loss, thermal management, and reliable operation. This paper explores the use of a low-cost SOI-based level-shift gate driver for driving Infineon's GIT GaN transistors, specifically in applications requiring high voltage and switching frequencies greater than 1 MHz.

2. Design of SOI-Based Level-Shift Gate Driver

2.1 Level-shift gate-driver working principle

See the Fig. 1, the Level Shift Gate Driver block diagram in a half-bridge topology includes several key blocks.

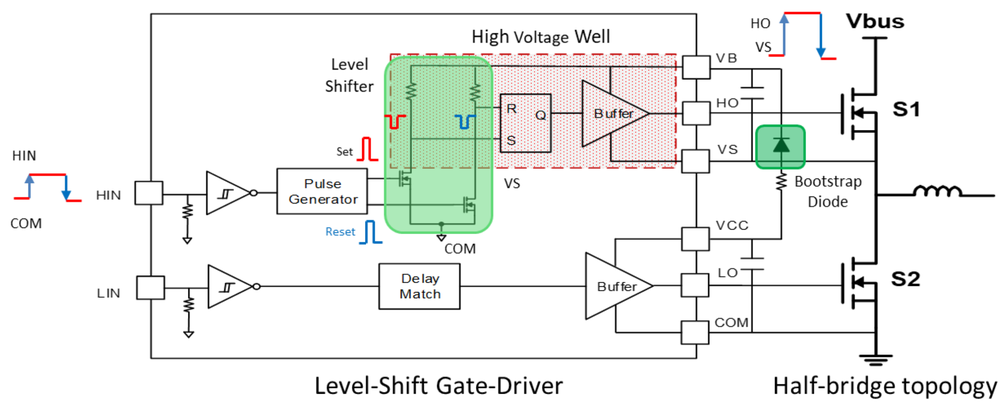


Fig. 1. Level-Shift Gate-Driver block diagram

2.2 The power loss of the Level-shift gate-driver

Fig.2 shows the typical power loss of SOI based level-shift gate-driver:

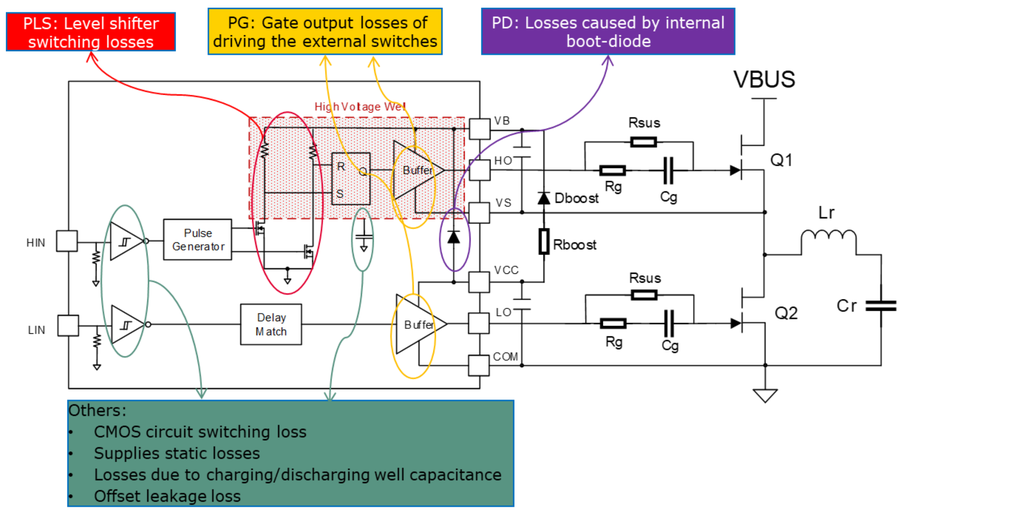


Fig. 2. Typical SOI based Level-Shift Gate-Driver losses

2.3 Novel level shifter design

Fig.3 shows the block diagram of the level shifter design. Differential voltage sensing is employed to enhance common-mode noise immunity. These design features collectively ensure reliable signal transmission, minimize propagation delay, and significantly reduce level shifter losses.

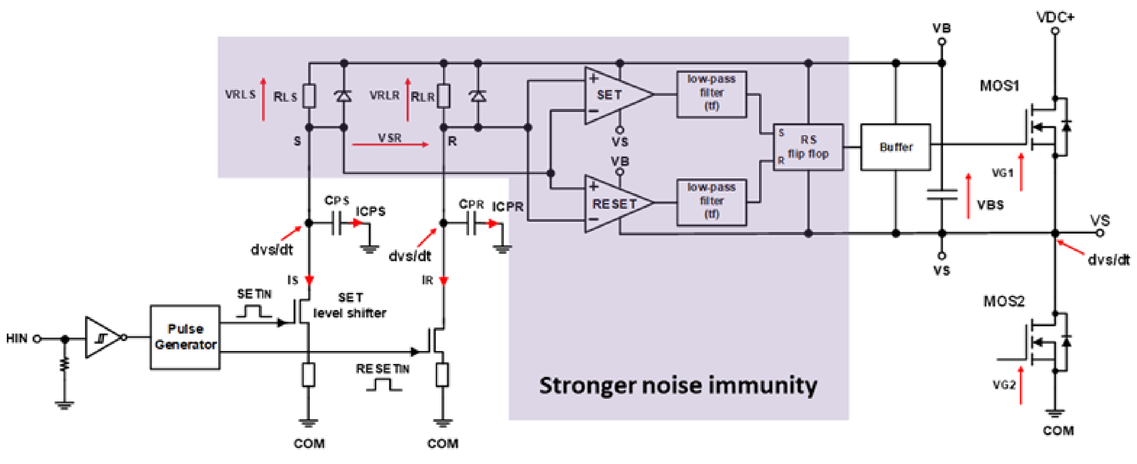


Fig. 3. Novel level shifter design

3. Thermal Testing and Performance Evaluation:

Provide detailed information about the thermal tests performed on the gate driver (SOI gate driver – 2ED2101S06F [3]).
Fig. 4 show the test board configuration and schematic.

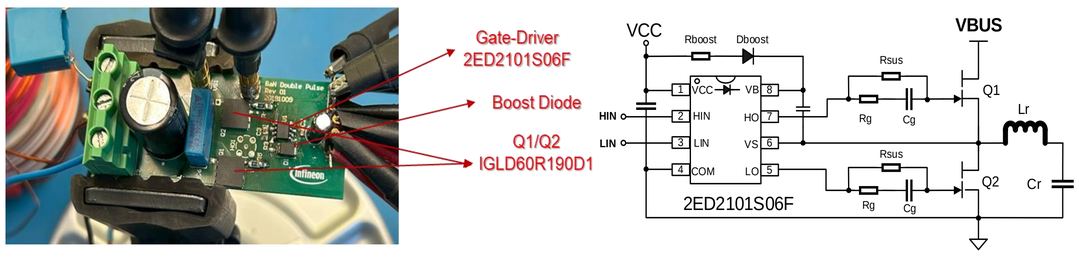
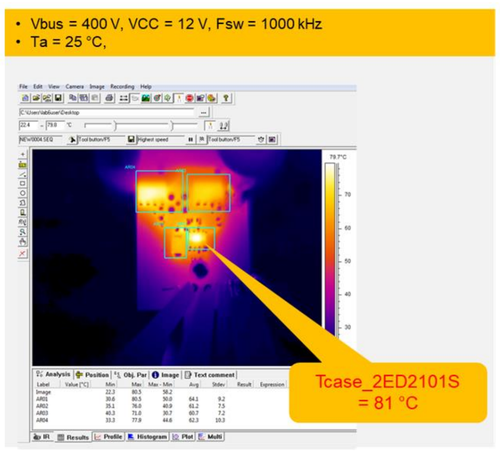


Fig.4 Test board and schematic

Fig.5 shows the thermal test results. The thermal image shows the maximum case temperature of SOI gate driver (2ED2101S06F) is 81°C at Vbus = 400 V, VCC = 12 V, Fsw = 1 MHz and Ta = 25 °C, which is similar as the maximum case temperature of GaN switch (Q1) 78°C. SOI-based gate driver (2ED2101S06F) ensures efficient operation without excessive heating, which would not limit the switching performance of the GaN devices.



Fsw (kHz)	Tcase_GD (Max) °C	Tcase_BD (Max) °C
800	72	70
900	76	73
1000	81	76
1100	83	80
1200	86	82

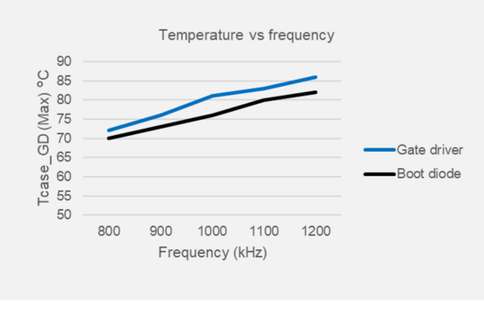


Fig.5 Thermal test results

4. Conclusion:

This paper presents a low-cost, Silicon-on-Insulator (SOI)-based level-shift gate driver for high-voltage, high-frequency GaN switching applications. The proposed gate driver demonstrates significant improvements in both thermal management and gate driver loss mitigation, crucial for the efficient operation of GaN power electronics. Through extensive testing, including thermal evaluations, it has been shown that the SOI-based gate driver effectively manages heat generation, ensuring that the GaN devices can operate at switching frequencies exceeding 1 MHz without performance degradation.
The novel level-shift gate driver addresses key challenges in high-voltage, high-frequency power conversion systems by utilizing the benefits of SOI technology. The results from testing validate the practicality and effectiveness of the SOI-based gate driver in real-world applications. This work can help to pave the way for cost-effective, high-performance gate drivers in next-generation power electronic systems.

5. References

[1] Weidong Chu, "1.2 kV SOI level-shift gate driver with Miller clamp and short circuit clamp to drive SiC MOSFETs", PCIM Asia 2023, Shanghai China, August 2023
[2] Weidong Chu, Bruce Wu, Elisabeth Preuss, "Infineon's 650V SOI HVIC for high frequency and cost-efficient applications", Industry Session presentation number 3072 APEC 2021
[3] 2ED2101S06F (650 V high-side and low-side gate driver IC with integrated bootstrap diode) datasheet, Infineon Technologies, Germany