

Abstract

Wide-bandgap semiconductors like Gallium Nitride (GaN) are enabling higher efficiency and greater power density in power electronics. The objective of this work is to develop novel gate drive methods, identify applications and complementary technologies to facilitate the proliferation of Enhancement mode (E-mode) GaN power transistors.

The challenges of driving enhancement mode GaN devices are identified and gate drive study reviews the advantages and limitations of various gate drive methods. A 2-stage 2-phase circuit gate driver is proposed to reduce the gate ringing. Simulation is conducted to verify the design and the proposed design demonstrates reduction in gate ringing. A GaN gate driver IC was evaluated against the R-type and RC-type gate driver to demonstrate driving the GaN Gate Injection Transistor (GIT) at high slew rates ($\sim 150\text{V/ns}$) while having built-in active miller clamp and self-generated negative voltage rail for cross-conduction protection.

This research investigated the application of GaN GIT in Inductive Power Transfer (IPT) for Electric Vehicles (EV). IPT systems provide significant benefits over conventional plug-in chargers. However, in order for IPT to be adopted for EV charging, good efficiency needs to be achieved. A high frequency inverter using GaN GIT which have the benefit of low on-resistance and gate charge to reduce the switching and conduction loss. The switching characteristics of the GaN GIT are studied and the inverter is designed to ensure low switching losses, while keeping overshoot and slew rates under control. An efficiency centric mode of operation is proposed to improve the efficiency of the system, while ensuring sufficient power transfer. The system efficiency peaks at 95% at 100 kHz operation and 92% at 250 kHz operation for a coil gap of 80mm at 2kW output power. At a coil gap of 150mm, the system obtains above 90% efficiency at 1.3 kW. The inductive power transfer system is compared to a similar system using SiC power transistors and outperforms it by 1% at 2kW.

This work identified E-mode GaN devices in Point of Load (POL) converters as another potential application due to the increasing need for high efficiency and power density. An efficiency study on the buck converter for large step down applications from 48V to 1V is conducted and limitations to this topology is identified. In order to further reduce the solution size and reduce effects of parasitic inductance, a novel 3-dimensional mounting strategy is proposed to integrate the GaN device with the Si gate driver.