Contribution ID: **487** Type: **Invited Oral**

M3Or4N-04: [Invited] LTspice modeling for GaN-GIT HEMT including cryogenic temperature

Wednesday 12 July 2023 17:25 (20 minutes)

Highly efficient electrically driven avionics have led to a renewed interest in cryogenic propulsion systems with the goal of reducing carbon emission footprint. Although cryogenic converters promise better efficiency and improved power density, a successful design is incumbent upon the appropriate switching device selection and simulation-based analyses performed prior to initial prototyping. In this work, a datasheet-driven compact model for a gallium nitride (GaN) Gate Injection Transistor (GIT) has been proposed and implemented in LTspice, a versatile, high-performance, and free circuit simulator. GaN-GIT is a very promising High Electron Mobility Transistor (HEMT) structure that allows a normally off (E-mode) fail-safe operation and is deemed to be an excellent candidate for cryogenic applications like aircraft due to the absence of "carrier freeze-out" effects. The structure demonstrates "conductivity modulation"at gate voltages higher than the gate built-in voltage without compromising the normal field-effect transistor (FET) like operation in ON and OFF states. Further, the structure allows for lower gate leakage due to the AlGaN/GaN barrier prohibiting the back flow of electrons to the p-GaN layer.
Apart from accurately modeling the channel current in both the first and third quadrants, the model includes the dc gate leakage current inherent to GaN technology. In addition, none of the available GaN-GIT models considers the "conductivity modulation"due to hole injection. In this work, a secondary path for channel current has been defined as the gate voltage surpasses the built-in potential. In order to capture the dynamic behavior accurately, a phenomenological modeling approach has been undertaken to model the interelectrode capacitances. The vendors'provided model uses conventional JFET-based capacitance modeling, which fails to incorporate the transition in capacitance at corresponding field-plate pinch-off voltages. Model parameter extraction is completely datasheet-driven, so the designer requires no restricted device processing parameters. In addition, LTspice being a free simulator, designers can easily automate the extraction procedure in a co-simulation approach using Python, MATLAB, etc. Finally, the temperature scaling in available models is limited to room temperature and higher, which, if extrapolated for lower temperatures, will inadvertently result in incorrect predictions. All three important parameters of a GaN-GIT e.g., threshold voltage, transconductance, and on-state resistance, present strong sensitivity to temperature. The on-resistance reduces due to an increase in electron mobility. The increase in the threshold voltage can be attributed to the hole injection from the metal gate to the p-GaN layer and their accumulation near the interface. The transconductance increases with the channel mobility and carrier velocity increase.
A commercial GaN GIT (31A/600V) has been characterized for this work with a parametric curve tracer. For cryogenic measurements, a thermal chamber connected to a liquid nitrogen dewar was deployed.
This paper aims to implement a datasheet-driven GaN-GIT HEMT model in LTspice with accurate static and dynamic behavior to provide a means for designers to select the best devices for an appropriate wide temperature range. Additional complex converter topologies, such as a Cascaded H-Bridge (CHB) multilevel inverter, will be simulated to demonstrate the model's convergence robustness. This work has been supported by the NASA ULI: Development of the CHEETA Design Concept.

Primary author: JEWEL, Maksudul Hossain

Co-authors: Dr WEI, Yuqi (University of Arkansas); HASAN, Abu Shahir Md Khalid (University of Arkansas); Prof. MANTOOTH, H. Alan (University of Arkansas)

Presenter: Prof. MANTOOTH, H. Alan (University of Arkansas)

Session Classification: M3Or4N: Transportation Symposia IV: Cable, Power Distribution