CASE STUDY

IIT Kanpur Develops ASM-HEMT Model for GaN Transistors Using Parametric and Device Characterization

Gallium nitride-based RF and power devices have gained tremendous momentum in recent years for next-generation communication like 5G and power electronic applications. Remarkable device properties such as high breakdown voltage, charge density, mobility, and saturation velocity increasingly enable improved performance for both RF and power circuits. To extract the best circuit-level performance from these devices in a time and cost-effective manner, advanced simulations and modeling capabilities are necessary. Indeed, GaN device modeling is a very active research area. Several compact modeling solutions have been proposed over the years with a variety of modeling methodologies.

As power modules shrink, switching frequencies increase, and new wide band gap (WBG) technologies enable ever faster edge switch rates, there is a growing need for accurate device models from the power electronics (PE) design community. PE design engineers are under strong schedule pressure to address the growing needs of power conversion and motor drivers, among other things. High surges in voltage and current, along with the ringing that follows can cause circuit malfunction, and in some cases, circuit explosion. High switching frequencies and associated harmonics can lead to undesirable electromagnetic interference.

Company:

- Indian Institute of Technology Kanpur

Key Issues:

- Create an accurate and simple compact SPICE model
- Introduce an industry-grade model for power electronics and RF applications

Solution:

- Keysight parametric and device characterization solutions

Results:

- Developed industry-first ASM-HEMT model for GaN transistors
- Model adopted by Keysight PathWave Device Modeling software and multiple other EDA vendors
- Developed use case for 5G and power electronics applications

KEYSIGHT TECHNOLOGIES

These are big problems that need to be simulated and resolved. On the one hand, designers may improve reliability by using larger power modules, but this leads to increased cost and size. On the other hand, smaller nimbler devices must be simulated to predict voltage and current surge issues. Modern power converters are now increasingly digitally controlled, with arrays of discrete power devices placed side-by-side.

PE designers must be able to accurately capture the transient over-voltage of a device, but modeling this is no easy task. Many PE designers simply give up, relying instead on their decades of experience making circuits work on the lab bench. As a result, designs become iterative, with managers planning small changes between hardware releases. R&D budgets often swell due to longer than expected design cycles. Even worse, the design team may lose its competitive edge.

Identifying a Critical Need

Professor Yogesh Chauhan with the Indian Institute of Technology (IIT) in Kanpur, found himself confronting the need for an accurate compact SPICE model for GaN devices. It was the same need identified by the industry compact model standardization committee or Compact Model Coalition (CMC). That model needed to be accurate to produce trustworthy simulations, and simple so that simulation time could be kept to a minimum and parameter extraction would be easy. The challenge was how exactly to create this model. For professor Chauhan, accuracy and speed were critical to help him achieve his objective.

To solve this challenge, professor Chauhan and his team used Keysight Technologies' tools with its range of highly accurate, precision solutions for parametric and device characterization (Figure 1). These solutions include the B1500 IV/CV parametric analyzer, B1505 high power IV/CV analyzer, and PNA-X with load-pull system, as well as Keysight's PathWave Device Modeling (formerly IC-CAP) and ADS software.

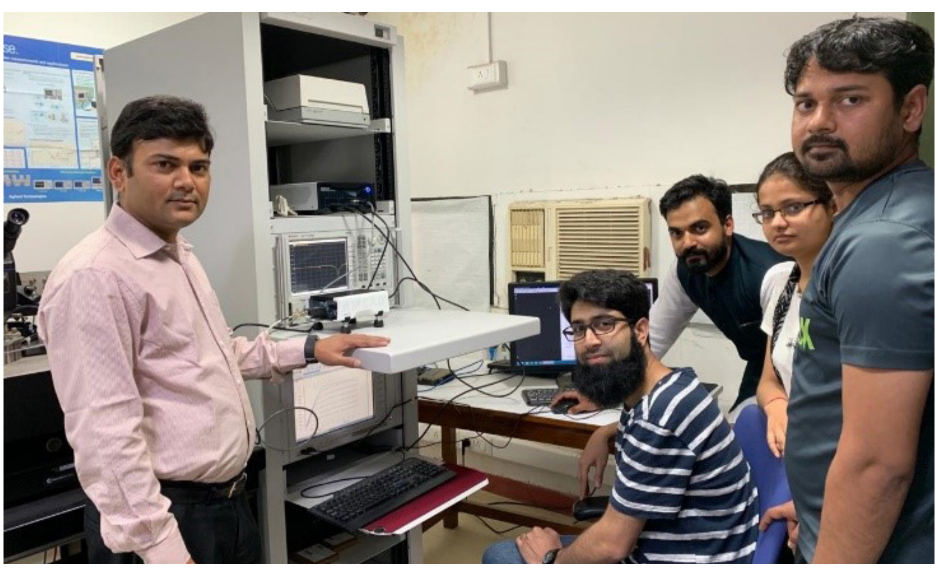

Figure 1. Professor Chauhan and team

Keysight's B1500, part of the Precision Current-Voltage Analyzer Series, ensures accurate and efficient current-voltage measurements that provide clear insight into IV characteristics across a wide range of applications. Powerful characterization software and integrated source and measurements units (SMUs) make it much quicker and simpler to obtain accurate IV characterization. Keysight's EasyEXPERT group+ software works with the B1500 to support all characterization tasks such as measurement setup and execution, data analysis, and data management and protection using the graphical intuitive user interface and mouse/keyboard operation.

Keysight's B1505 Power Device Analyzer is an all-in-one solution for power device evaluation. With its ability to characterize high power devices from the sub-picoamp level up to 10 kV and 1500 A, the analyzer can easily evaluate novel new devices such as IGBT and materials such as GaN and SiC.

From Model to Standard

After years of innovative thinking and hard work, along with use of Keysight solutions, Professor Chauhan's team in collaboration with Dr. S. Khandelwal created the industry's first Advanced Spice Model for High Electron Mobility Transistors (ASM-HEMT). The model not only offers the right amount of compactness, but also a high degree of accuracy and minimal simulation time.

The ASM-HEMT model has a surface potential-based core that considers 2 energy sub-bands at the interface of an AlGaN/GaN High Electron Mobility Transistor. To capture the effects exhibited by real-world devices, several models were developed on top of this core including:

- Nonlinear access region resistances
- Mobility degradation models
- Self-heating models
- Noise models
- Field plate models
- Models for conductance effects (CLM, DIBL, etc.)
- Models for trapping phenomena
- Models for gate leakage, including Fowler-Nordheim and Poole-Frenkel effects

This model was submitted to the Silicon Integration Initiative's Compact Model Coalition (Si2-CMC) body for evaluation. CMC's model standardization process is a rigorous multistep process.

Following almost six years of research and development, the Advanced SPICE Model for GaN (ASM HEMT) passed all steps of the CMC standardization process and was selected as an industry-standard model. This classification is a big win for Professor Chauhan and his team. With excellent convergence, simulation time on the order of microseconds, and accuracy requirements of approximately 1% RMS error after fitting, the ASM HEMT model now provides a much-needed use case for the growing range of communication and power electronics applications.