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Tutorial Title

GaN FETs and GaN Integrated Circuits for DCDC and Motor Drives Applications

Instructor Team

Marco Palma, M.Sc.Eng., M.B.A. Director, Motor Drives Systems and Applications Efficient Power Conversion Corporation (EPC)

Michael de Rooij, Ph.D. Vice President, Applications Engineering Efficient Power Conversion Corporation (EPC)

Abstract

Gallium nitride (GaN) power semiconductors have seen increased adoption in many power-electronic applications. Recently GaN devices have made inroads into compact and efficient DCDC converters and BLDC motor drives with surprising benefits that include ultra-low audible emissions, small size, high DC to mechanical efficiency, reduced component count, and improved precision control when compared to MOSFET-based inverters.

The goal of this tutorial is to provide engineers with the tools and understanding needed to fully utilize the potential of GaN FETs and emerging GaN integrated circuits and be able to implement them in advanced DCDC converters and in BLDC motor drive applications. The seminar comprises four main sections; 1) An introduction to the important distinguishing characteristics of GaN FETs, 2) The fundamentals of designing with GaN FETs and ICs, 3) GaN-based DCDC and motor drive application examples demonstrating the techniques presented in section II, and 4) an update to the state-of-the-art GaN integration.

Section I opens with a brief progression of GaN FETs characteristics over the last decade and how those characteristics have yielded performance improvements over MOSFETs. Methods to quantify those benefits for quick comparison based on device characteristics and target application operating modes will also be given. This includes an introduction to the next generation of GaN FETs (the 6th) and integrated circuits and how these new devices are reshaping the design of power electronic converters. This section will also show a comparison between EPC GaN devices and other GaN devices in the market. The results of the latest reliability tests on GaN FETs will also be covered, showing the exceptional reliability GaN devices offer.

Section II goes into detail on how to design converters and inverters using GaN devices starting at the schematic with a focus on gate drivers and bootstrap supplies techniques. Various third-party GaN FET compatible gate drivers will be presented, including new techniques for high-voltage devices. It will cover how to quantify reverse recovery's damaging impact on MOSFET-based converters and how GaN devices offer a significant performance advantage.

The next part in section II covers layout techniques and guidelines for PCB design to maximize electrical performance, reliability, and manufacturability that largely impact QFN and Chip Scale Package (CSP) devices. Examples of what can go wrong, from the PCB design through assembly, and procedures to follow to prevent them will be given. The ability to add additional cooling is paramount to high power density solutions, and this section will conclude with details on a simple yet very effective approach to adding heatsink solutions for GaN devices. The GaN power bench tools that properly dimension the converter devices and simulate the thermal behavior will be presented live.

Section III explores application examples that have significantly benefitted from GaN FETs and ICs. DCDC converters will be covered, including multi-phase converters for high current loads and multi-level converters for minimizing the thickness of converter solutions. Multi-level converters will cover 100 V and 200 V GaN devices and include advanced techniques to address low voltage drop bootstrap multi-level shifting gate drivers. The expansion of GaN FET-based applications to motor drives and how GaN integration can significantly increase power density, reduce weight, and improve overall performance. The difference between 20 kHz and 100 kHz operation will be demonstrated, as well as the effect of dead time. These parameters affect audible emissions, mechanical efficiency, torque ripple, and DC filter requirements that will be supported by specific measurements that will be presented.

Section IV concludes with a look at the progression of GaN integration and what lies ahead for the future. A look into the latest releases reveals half bridges complete with level shifting gate drivers and synchronous bootstrap power supply minimizing external component count, reducing board area, and increasing operating frequency capability for many applications.

The tutorial closes by opening the floor to questions and discussion.

Instructor Biography

Marco Palma joined EPC in 2019, where he is the Director of motor drives systems and applications. He has over 20 years of experience in motor control power electronics ranging from switches to gate drivers, controllers, and algorithms. He authored and co-authored more than 50 articles and held several industrial tutorials at major conferences. He has been granted 11 US patents on motor drive systems, as well as integrated circuits for power converters. For International Rectifier, Marco worked on the smallest 13 kW fully integrated and programmable motor drive power module in 2002, the first industrial sensor-less FOC controller IC in 2004, and the smallest 100 W, fully integrated fan drive module in 2009. For Infineon technologies, he worked on the smallest programmable 100 W fully integrated motor control power module in 2018. Marco earned his Master of Science degree in Electronics from Politecnico di Torino and his Master of Business Administration from SDA Bocconi Management School, Milano.

Dr. Michael A. de Rooij received the B. Eng., M. Eng. and, D. Eng. degrees from The University of Johannesburg fka Rand Afrikaans University, South Africa, in 1992, 1994 and 1998 respectively, with major in power electronics. He is currently Vice President of Applications Engineering at Efficient Power Conversion Corporation (EPC). Dr. de Rooij has authored and co-authored over 50 papers at various conferences and journals and has been granted over 58 US and international patents. He is the author and co-author of 7 books. His experience covers highly resonant loosely coupled wireless power, high-density DC to DC converters, RF power amplifiers, utility applications of power electronics, uninterruptible power supplies, integration of power electronic converters, power electronic packaging, induction heating, photovoltaic converters, Magnetic Resonance Imaging (MRI) Systems. Dr. de Rooij is a senior member of the IEEE.