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Tutorial Title

Understanding of Observed Switching Waveform for High-Speed SiC Devices: From Application Perspectives with Analytical Insights

Instructor Team

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Abstract

SiC power devices promise the revolution of next-generation power electronics and have been adopted in many applications, such as electric vehicles, photovoltaics, and energy storage systems. High-speed switching is one of the key features, enabling SiC-based power electronics to be highly efficient and ultra-dense. Therefore, high-fidelity switching data based on switching testing become an essential step for high-precision device datasheets by SiC device manufacturers, product design optimization by SiC converter OEMs, and SiC-based R&D activities by researchers and graduate students.

It is observed, including presenters' experiences, the measured SiC switching waveforms are extremely non-ideal and highly sensitive to the test circuit design, measurement system, and even the operator. With the given SiC part under the same operating condition, switching waveform discrepancies under two different setups is quite normal but confusing. Usually, "noise" and "parasitics" are two common terms to be blamed for the explanation of the observed waveforms with limited insights into what's truly happened during the switching test. In reality, the dynamics (overshoot, undershoot, high-frequency ringing, low-frequency oscillation, spurious spike) in a switching waveform is typically a combining effect because of circuit parasitics, load high-frequency characteristics, measurement setup, probing, etc. Without holistic considerations, misleading and confusion are highly possible.

With this, the proposed tutorial focuses on the understanding of observed switching waveform for high-speed SiC devices. Three impact factors will be targeted: parasitics, load, and measurement. We will first overview parasitics in the switching loop considering the physical implementation in the actual circuit (e.g., device lead, PCB traces, interconnection, etc.), then holistically discuss its impact on the switching waveform based on the equivalent circuit with the detailed device model. Second, we will perform a comparative analysis with two loads: 1) an optimally designed inductor with minimized capacitive parasitics and 2) an actual induction motor with the power cable. Starting from the load modeling considering the high-frequency characteristics, its impact on switching behavior will be quantified based on the circuit simulation. Third, we will focus on the measurement, including grounding loop effects due to probing and the probe location-induced measurement error.

As a basic format, for each part, we will present illustrations of the representative SiC switching waveforms in industry products and laboratory engineering prototypes by leveraging the presenters' extensive work from both industry and R&D laboratories. Then we will attempt to understand the observed waveforms through device modeling and circuit analysis. Finally, we will demonstrate the theoretical analysis using simulation to visualize the non-ideal waveform and enhance the understanding. In the meantime, the interactive instructor-audience approaches will be introduced during the simulation demonstration.

Instructor Biography

Xu She

Dr. Xu She received the Ph.D. degree in electrical engineering from North Carolina State University, Raleigh, NC, in 2013. From 2013 to 2022, he held engineering design and leadership roles at General Electric and Carrier Corporation. Since 2022, he has been the Director of Electrical Engineering at Lunar Energy, US. He is a recognized industry leader in power electronics by utilizing SiC power devices and has made foundational contributions to several groundbreaking technologies and products. He has more than 75 papers, 40 patent families, and 3 book chapters to his R&D credit. He was the recipient of several prestigious awards, including the 2017 IEEE IAS Andrew W. Smith Outstanding Young Member Achievement Award, the 2018 GE Whitney Technical Achievement Award, the 2021 IEEE Region 1 Industry Technological Innovation Award, and 2022 IEEE IES Rudolf Chope R&D Award.

He is a Distinguished Lecturer of the IEEE Power Electronics Society and has delivered a tutorial titled "Application of Silicon-Carbide Power Devices and Converters: Opportunities, Challenges, and Opportunities" at ECCE 2018.

Zheyu Zhang

Dr. Zheyu Zhang is the Warren H. Owen – Duke Energy Assistant Professor of Engineering at Clemson University. Dr. Zhang delivered 10+ well-received webinars and tutorials, including two IEEE webinars, seven IEEE tutorials (including two presented at past ECCE conferences), and one AIAA/IEEE short course. Among them, "Wide Bandgap Device Characterization" at IEEE APEC 2016 with 156 attendees is rated as the top one over 21 professional education seminars; "Design Issues for High Power and High-Performance SiC Converters" at IEEE APEC 2019 with approximately 200 attendees; and one PELS Webinar in 2019 with 222 attendees.

Dr. Zhang has published over 100 papers, filed over 10 patent applications, and authored one book and one book chapter. His research interests include wide bandgap-based power electronics for electrified transportation and grid applications. Dr. Zhang is currently an Associate Editor for IEEE Transactions on Power Electronics and IEEE Transactions on Industry Applications. He was the recipient of three prize paper awards from the IEEE Industry Applications Society and IEEE Power Electronics Society. He was the recipient of the 2021 IEEE IAS Andrew W. Smith Outstanding Young Member Achievement Award and the 2022 NASA Early Career Faculty Award. He is a senior member of IEEE.