



Tutorial Title

State-of-the-Art and Future Research Directions for 48V to 0.7V / 2,000A Power Conversion for Future CPU, GPU, FPGA Applications

Instructor Team

Team Chair: Yan-Fei Liu, Queen's University

Co-Speakers: Don Tan, Northrop Grumman Space Technology (NGST)

Abstract

This tutorial will discuss the challenges and solutions in 48V to 0.7V (2,000A) power converters used in data center / server, as well as AI. Machine learning systems. Two power architectures will be discussed and compared. The first architecture is a two-stage where the 48V is converted to 12V (or another intermediate level) and then the 12V is converted to 0.7V. The second architecture is a “single stage” where the 48V is converted “directly” to 0.7V. With “direct” conversion architecture, no intermediate voltage bus is accessible (visible). After a brief introduction to the background information and the power requirement of an OAM (OCP Accelerator Module), which is used widely in data center, server and others, the tutorial will provide a new understanding to the technologies to reduce the power loss and to increase the power density. The tutorial will at first review the latest technologies of the two-stage architecture and evaluate the advantages and limitations. Then, the tutorial will review the state-of-art technologies of the “single stage” architecture and evaluate the advantages and disadvantages. Based on the above analysis and review, the tutorial will propose and discuss the research directions for 48V to 0.7V (down to 0.3V), 2,000A (or higher), applications that will achieve extremely high efficiency, extremely small size, and current sharing, expandable, fast dynamic response, etc.

Instructor Team Biographies

Dr. Liu (Fellow of IEEE, 2013, Fellow of CAE, 2018) received his bachelor's and master's degree from the Department of Electrical Engineering from Zhejiang University, China, in 1984 and 1987, and PhD degree from the Department of Electrical and Computer Engineering, Queen's University, Kingston, ON, Canada, in 1994.

He was a Technical Advisor with the Advanced Power System Division, Nortel Networks, in Ottawa, Canada from 1994 to 1999. Since 1999, he has been at Queen's University, where he is currently a Professor with the Department of Electrical and Computer Engineering. His current research interests are listed as following: (1) Best utilization of GaN and SiC devices to explore the full advantage of these devices to design high power density and high-efficiency power converters; (2) Extremely high efficiency (>99%) and extremely high power density (>2500W / inch³) DC-DC Bus converter for data center application; (3) High power density LLC resonant converter for different power levels (from 65W to 4000W) for different applications (such as PD adapter, data center power, EV on-board DC-DC converter); (4) Digital Control technologies for accurate current sharing of multi-phase interleaved LLC



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resonant converter to achieve high efficiency and high power density simultaneously; (5) Digital control technology for fast dynamic response of DC-DC converters; (6) High efficiency, high power density AC to DC power converter for USB C Power Delivery (PD) application using GaN switches; (7) On-board EV DC-DC converter with high efficiency and high power density using GaN switches; (8) High power, high efficiency, and high power density single-phase AC-DC rectifier suitable for On-Board Chargers using GaN and SiC switches.

He has authored 297 technical papers in the IEEE Transactions and conferences and holds 70 U.S. patents. He has written a book titled “High Frequency MOSFET Gate Drivers: Technologies and Applications”, published by IET. He is also a Principal Contributor for two IEEE standards. He received “Modeling and Control Achievement Award” from IEEE Power Electronics Society in 2017. He received Premier’s Research Excellence Award in 2000 in Ontario, Canada. He also received the Award of Excellence in Technology in Nortel in 1997.

Currently, Dr. Liu serves as the chair of the IEEE Medal in Power Engineering Committee. He serves as an Editor of IEEE Journal of Emerging and Selected Topics of Power Electronics (IEEE JESTPE) since 2013. He was the Vice President of Technical Operations of IEEE Power Electronics Society (PELS, from 2017 to 2020). He was the general chair of ECCE 2019 to be held in Baltimore, USA in 2019). His other major service to IEEE is listed below: a Guest Editor-in-Chief for the special issue of Power Supply on Chip of IEEE Transactions on Power Electronics from 2011 to 2013; a Guest Editor for special issues of JESTPE: Miniaturization of Power Electronics Systems in 2014 and Green Power Supplies in 2016; as Co-General Chair of ECCE 2015 held in Montreal, Canada, September 2015; chair of PELS Technical Committee (TC1) on Control and Modeling Core Technologies from 2013 to 2016; chair of PELS Technical Committee (TC2) on Power Conversion Systems and Components from 2009 to 2012.

Dr. Tan is with NGSS, where he served up to executive level as Distinguished Engineer, Fellow, Chief Engineer-Power Conversion, program manager, department manager, and center director (acting). Don earned his PhD from Caltech and is an IEEE fellow. Well-recognized as a visionary leader in ultra-efficient power conversion and electronic energy systems, he has pioneered breakthrough innovations with high impact industry firsts and record performances that “significantly enhance our national security.” Recently-deployed James Webb Space Telescope (JWST), winner of Time magazine’s Invention of the Year Award in 2022 and the Robert J. Collier Trophy in 2023 (The trophy recognizes the greatest achievement in aerospace and astronautics in America), represents human’s most power telescope for a historical mission. His suite of the world-class electronics performed flawlessly for JWST on orbit with record-breaking performances.

Dr. Tan has received 60+ awards/recognitions and delivered 70+ keynotes/invited presentations across the globe. He is, among others, Chair, IEEE Fellow Committee, IEEE Board of Directors and immediate past Steering Committee Chair, IEEE PELS/PES eGrid. He was Director, IEEE Board of Directors, PELS Long Range Planning Committee Chair, Nomination Committee Chair, PELS President, Editor-in-Chief (Founding) for IEEE Journal of Emerging and Selected Topics in Power Electronics, General Conference Chair for APEC, Vice President-Operations, Guest Editor-in-Chief for IEEE Transactions on Power Electronics and IEEE Transactions on Industry Applications, Fellow Committee, Vice President-Meetings, IEEE Chair for IEEE/Google Little Box Challenge (awarded \$1M cash prize), and IEEE/DoD Working Group Chair



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