Princeton Power Electronics Research Lab

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PowerLab Overview

We are a team of electrical engineers re-imaging the power and energy systems of the future from theory to applications, inspiration to ideas, and from creation to innovation with a diversity of thinking and a convergence of mission. We aim at making fundamental breakthroughs in power electronics to enable important and emerging applications. Currently, our group focuses on next generation power electronics solutions for the following four important research areas:

- Smarter power electronics at the grid edge
- Smaller power electronics for robotics and EVs
- Ultra-Efficient power electronics for information and data systems
- Design methods and software tools for power electronics and system architectures

Fundamentals

We build electronic circuits and systems to manage electrical energy and control power flow. We study device physics, circuit topology, electromagnetics, control theory, and system architecture to push the state-of-the-art of power electronics. Specifically, we specialize in the following three research topics with leading expertise:

- High Frequency Power Electronics
- Wide-Band-Gap Semiconductor Devices
- Power Electronics Architectures

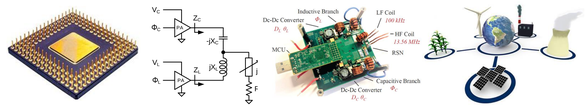

Fig. 1: Devices, Circuits, Systems, and Architectures.

Applications

The future world needs smarter and more efficient power electronics. Renewable energy resources contribute about 10% of US total electricity generation. Data centers consume more than 90-B kWh of electricity a year in the US. Advanced power electronics is the enabling technology to modernize the grid, upgrade the transportation systems, and transform medical devices, robotics, and telecom and data communication systems.

Fig. 2: Power Electronics Application Areas.

Methodologies

Advanced modeling and control methods are needed to push the performance boundary of power electronics and to enable sophisticated power electronics system functions. Princeton PowerLab is dedicated to develop "full-stack" design methods and software tools to accelerate the design process of power electronics.

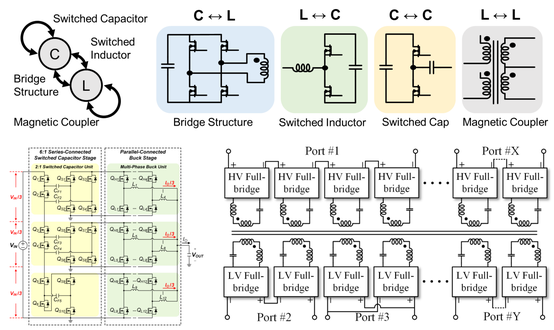

Fig. 6: LEGO Power Building Blocks.

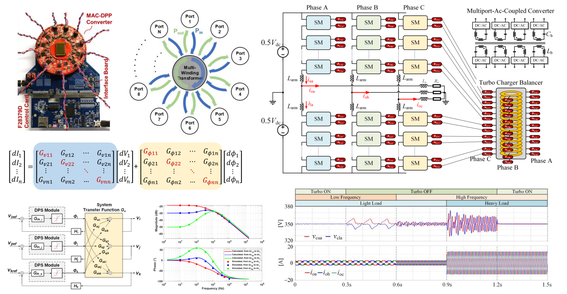

Fig. 7: Control of Sophisticated Power Flow.

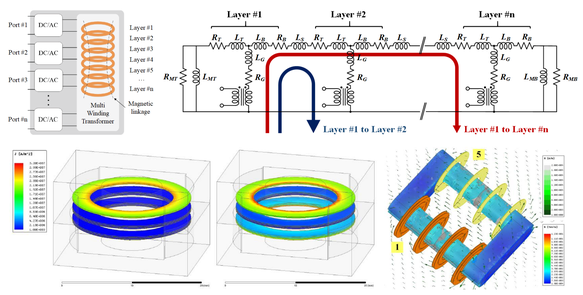

Fig. 8: Advanced Magnetics Modeling Methods.

Renewable Energy & Grid

An electric grid with a large percentage of renewable integration may become highly unstable if not coordinated correctly. Princeton PowerLab is developing smarter power electronics which can support more than 50% of renewable energy on the grid and can autonomously cluster into microgrids to defend against natural hazards.

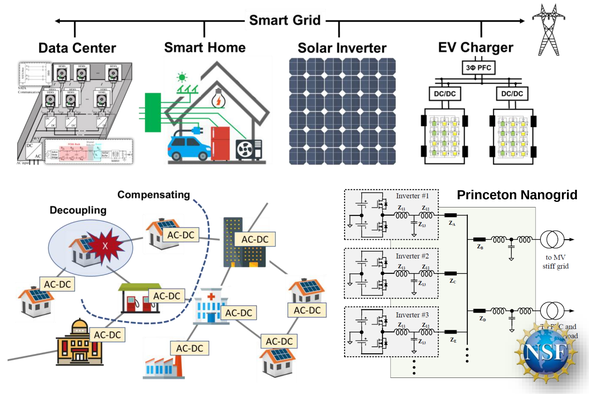

Fig. 3: Granular Power Electronics at the Grid Edge.

Information & Data Systems

US data centers currently consume more than 90 billion kWh of electricity a year and produce as much carbon emission as the entire airline industry. The transmit of every bit of information consumes energy. High performance power electronics are needed for future data centers, artificial intelligence (AI) hardware, and 5G communication. We are developing "full-stack" power electronics solutions to power future telecom & data systems.

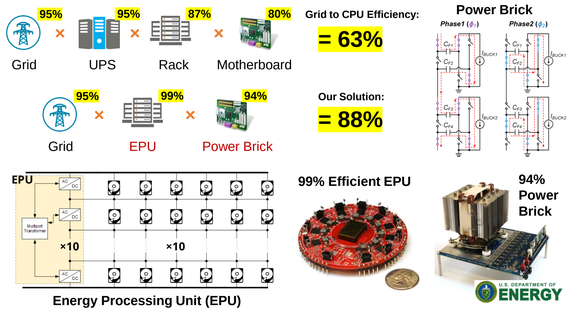

Fig. 4: Power Electronics for Information Systems.

Robotics & Electric Vehicle

High performance miniaturized power electronics are needed for future robotics and electric vehicles. We develop novel power delivery concepts and drive mechanisms with modular architecture, wireless power transfer, flexible electronics, and multifunctional materials. We explore exciting multi-disciplinary research opportunities for extreme performance power electronics.

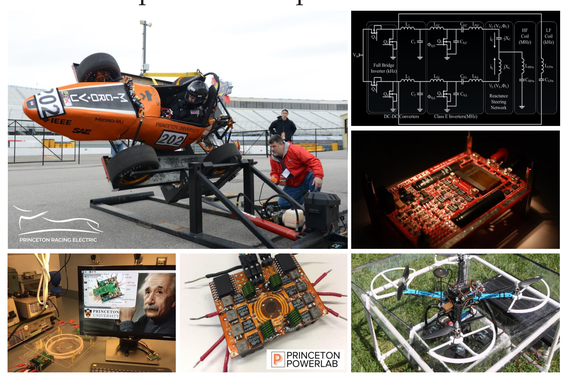

Fig. 5: Power Electronics for Robotics & Vehicles.

Team Awards

- IEEE PELS Prize Paper Awards (2017 & 2018)
- First Place, Princeton Innovation Forum
- APEC Outstanding Presentation Award

Selected Past, Ongoing and Future Research Projects

1. Ultra efficient data center power delivery (DOE ARPA-E); 2. Ultra compact CPU/GPU/TPU power Supply (Google/Intel); 3. Granular power electronics at the grid edge (NSF); 4. Andlinger distributed energy and power testbed (Campus-as-Lab); 5. Wireless charging platform for drones (for undergrad).

Contact Information

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