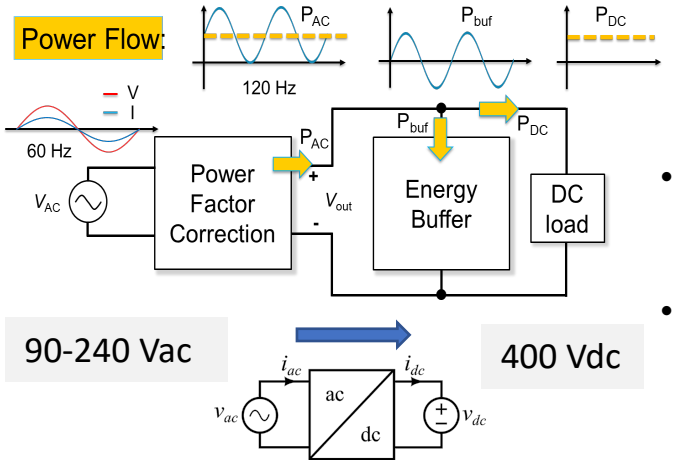
A Bidirectional Liquid-Cooled GaN-based AC/DC Flying Capacitor Multi-Level (FCML) Converter with Integrated Startup and Additively Manufactured Cold-Plate for Electric Vehicle Charging

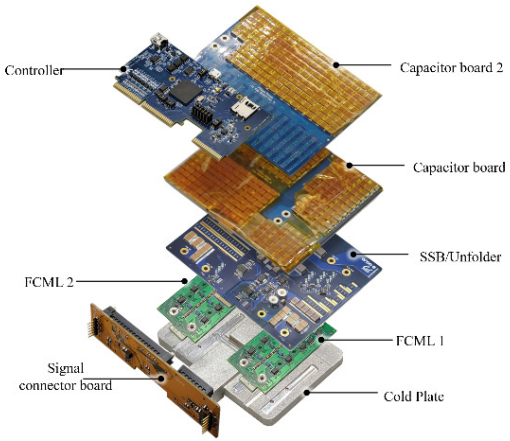
Berkeley Power and Energy Center

Motivation and Application

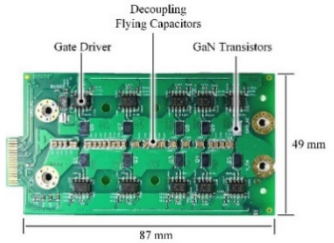


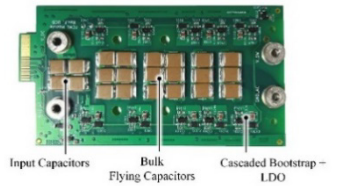
- 90-240 Vac to 400 Vdc is a critical conversion stage for applications such as data center power delivery, electric vehicle charging, etc.
- Ac-dc power factor correction
  - Reduce boost inductor size
- Twice-line frequency power ripple buffering
  - Reduce buffer capacitor size

Hardware Implementation



Modular stack-up of full system





Flying capacitor multi-level"(FCML) converter as the power factor correction stage

- Use of flying capacitors as energy storage greatly decreases volume of passive components and reduce filtering needs

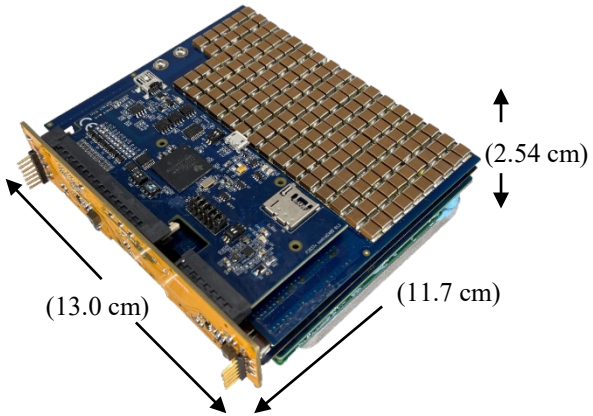
Series-stacked Buffer as energy buffer stage

- Use of active circuitry decreases capacitance requirement for twice-line frequency buffering and further promoted volume reduction

Design Objectives

High Power Density

Reduce system volume via new circuit topologies and control

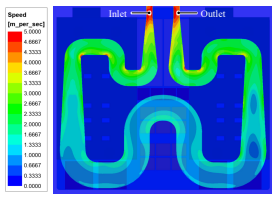


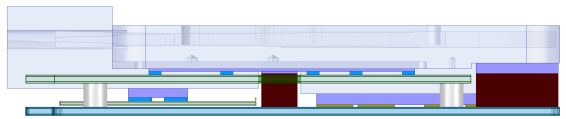
Reduced Weight

Custom 3D-printed cold-plate (collaboration with Miljkovic Group at UIUC)

3D printed cold-plate

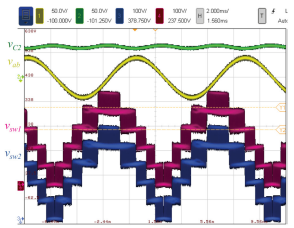
Printed Fluid Channels



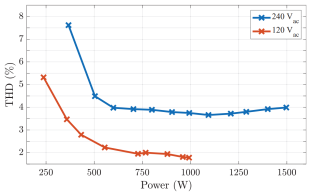


Experimental Verification

Parameter	Notes
Peak tested power	6.1 kW
Peak efficiency (1.1 kW)	99.1%
Efficiency @ 6.1 kW	97.8%
PFC up to 1.5 kW	> 99.6%
Box-volume power density **with** cold plate:	7.6 kW/L



400 V_{dc} to 240 V_{ac} system waveforms at 6.1 kW



THD up to 1.5 kW

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References:
[1] D. Chou et al., "An Interleaved 6-Level GaN Bidirectional Converter with an Active Energy Buffer for Level II Electric Vehicle Charging," 2021 IEEE Applied Power Electronics Conference and Exposition (APEC), Phoenix, AZ, USA, 2021
[2] Z. Liao, D. Chou, K. Fernandez, Y. -L. Syu and R. C. N. Pilawa-Podgurski, "Architecture and Control of An Interleaved 6-Level Bidirectional Converter With an Active Energy Buffer for Level-II Electric Vehicle Charging," 2020 IEEE Energy Conversion Congress and Exposition (ECCE),
[3] K. Fernandez et al., "A Bidirectional Liquid-Cooled GaN-based AC/DC Flying Capacitor Multi-Level Converter with Integrated Startup and Additively Manufactured Cold-Plate for Electric Vehicle Charging," 2022 IEEE Applied Power Electronics Conference and Exposition (APEC), Houston, TX, USA, 2022