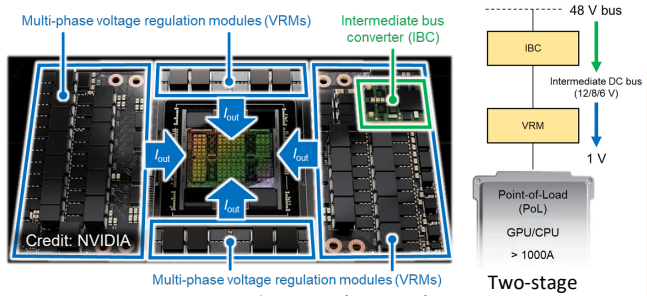
A 1200-A/48-V-to-1-V Switching Bus Converter: Toward Single-Stage Vertical Power Delivery for Next-Generation Ultra-High-Power Microprocessors

Berkeley Power and Energy Center

Background and Motivation

Existing two-stage lateral power delivery (LPD) architecture

- Large power distribution network (PDN) and high PDN losses
- Occupies a large area on the top side of the baseboard

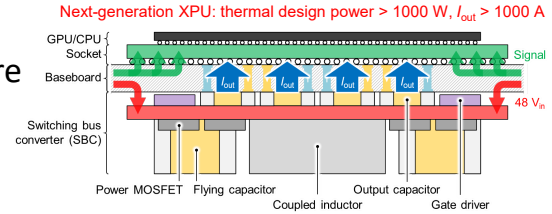


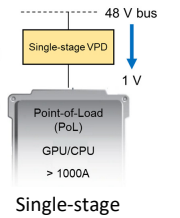
Existing two-stage LPD architecture (top view)

Two-stage conversion

Proposed single-stage vertical power delivery (VPD) architecture

- Much lower PDN losses
- Saves the topside area for high-speed communication and memories





Proposed single-stage VPD architecture (side view)

Single-stage conversion

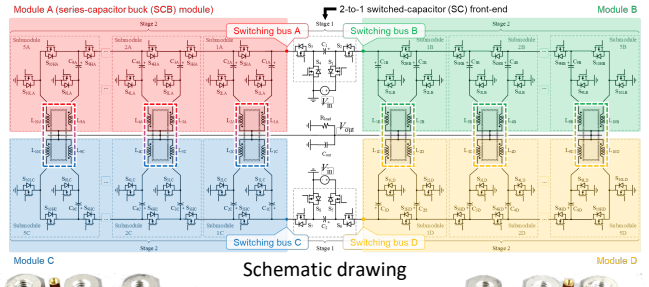
Proposed Switching Bus Converter (SBC)

Hybrid switched-capacitor topology

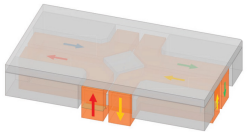
- Two 2-to-1 switched-capacitor (SC) front-ends
- Four series-capacitor buck (SCB) modules
- Two switching buses

Hardware prototype

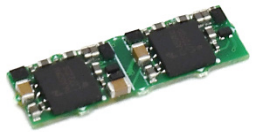
- Good modularity
- Custom four-phase coupled inductor
- Efficient and compact gate drive circuitry



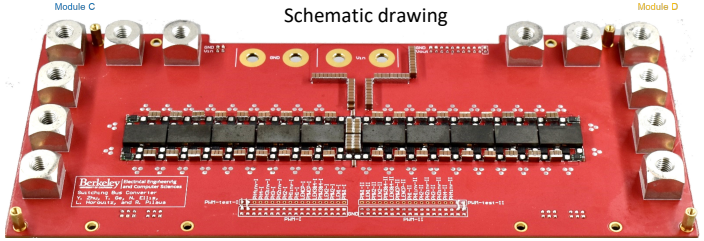
Schematic drawing



Four-phase coupled inductor



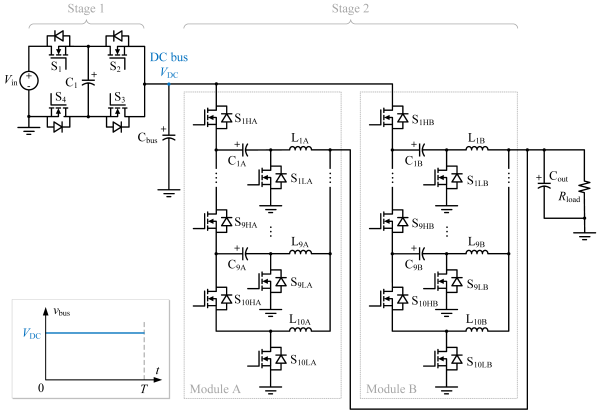
Gate drive daughterboard



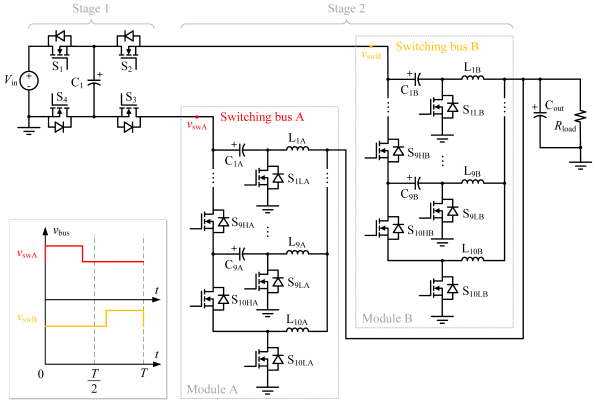
Photograph of the hardware prototype

Advantages of Switching-Bus-Based Architecture

- Does not require a large decoupling capacitor to maintain a stiff DC bus voltage
- One redundant switch can be removed on each switching bus while two stages are merged
- Ensures complete soft-charging operation



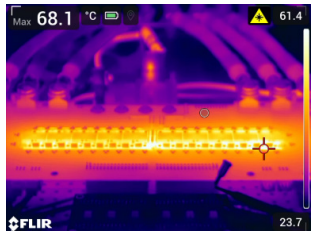
DC-bus-based architecture



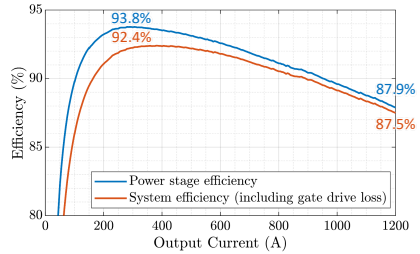
Switching-bus-based architecture

Experimental Results and Performance Comparison

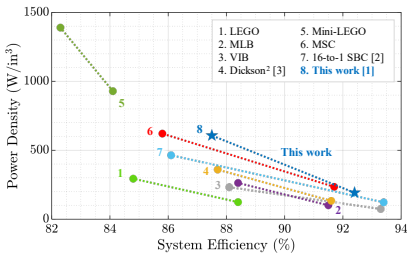
- 92.4% peak system efficiency and 607 W/in^3 power density (including gate drive loss and volume)



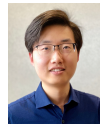
Thermal image at equilibrium with 220 CFM air cooling (I_{out}=1200 A)



Measured 48-V-to-1-V efficiency



Performance comparison between this work and the state-of-the-art 48-V-to-1-V hybrid SC works



References:

[1] Y. Zhu , et al., "A 48-V-to-1-V Switching Bus Converter for Ultra-High-Current Applications," COMPEL 2023. **[Best Paper Award]**

[2] Y. Zhu , et al., "A 500-A/48-to-1-V Switching Bus Converter: A Hybrid Switched-Capacitor Voltage Regulator with 94.7% Peak Efficiency and 464-W/in3 Power Density," APEC 2023.

[3] Y. Zhu , et al., "A Dickson-Squared Hybrid Switched-Capacitor Converter for Direct 48 V to Point-of-Load Conversion," APEC 2022.

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