

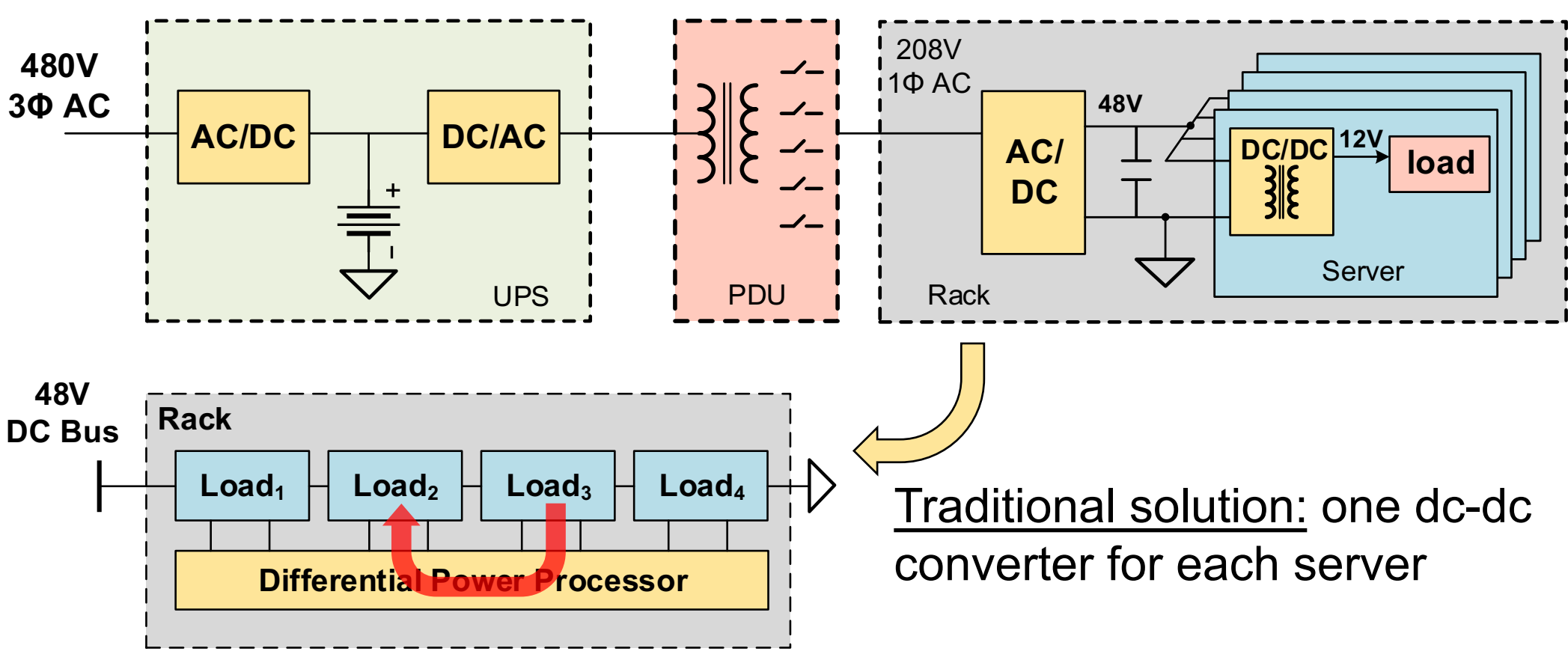
A 99.7% Efficient Series-Stacked Architecture for Rack-Level Power Delivery in HDD Storage Servers

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Motivation

Power Delivery Architecture in Data Center

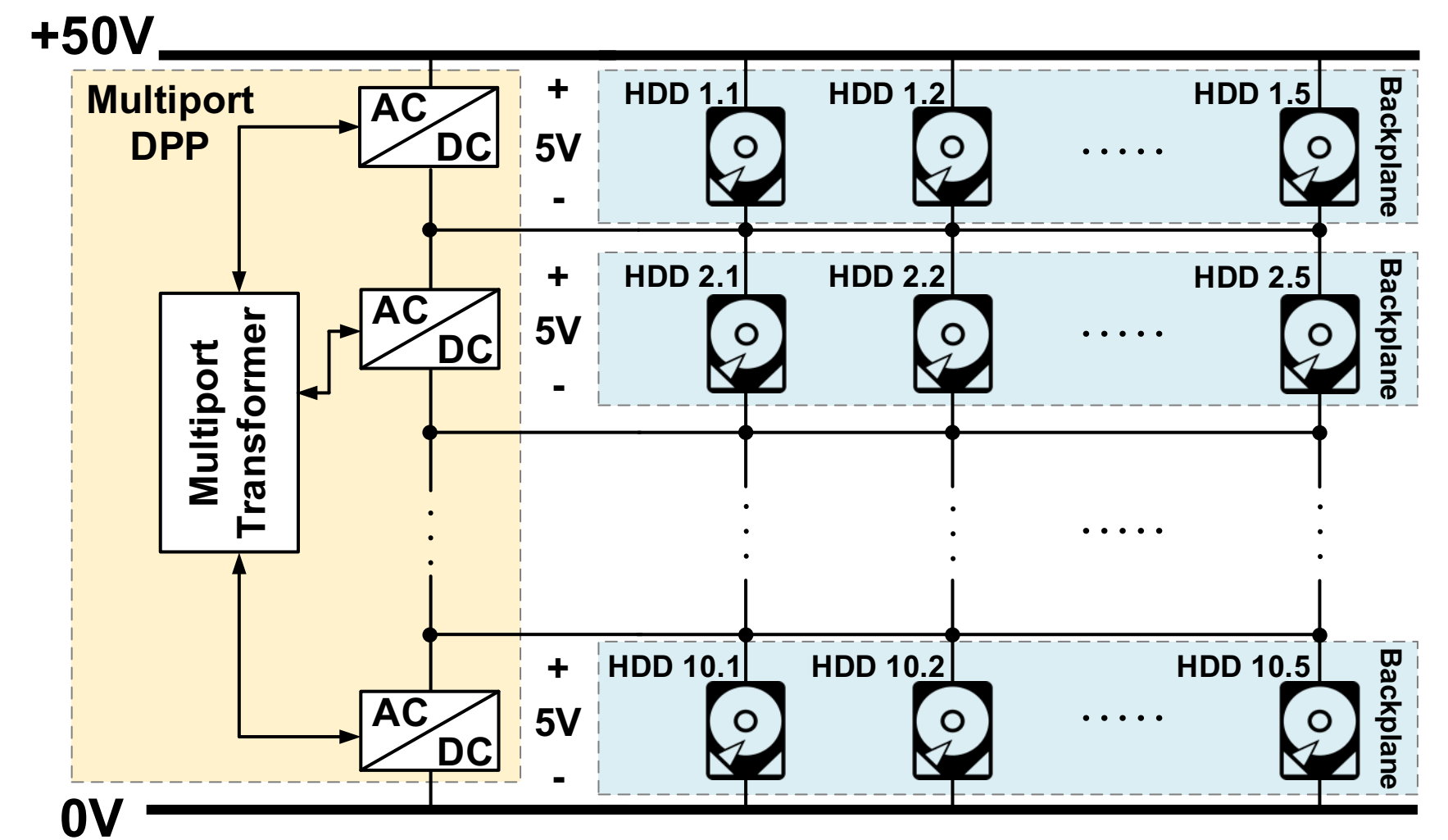


- A 50V to 5V solution with 10 series-stacked voltage domains:
- Series-stacked architecture which can step down voltage by nature and support a large number of loads
 - Differential power processing (DPP) for extreme efficiency
 - Multi-port ac-coupled (MAC) converter

The authors would like to thank the DOE ARPA-E CIRCUIT program for supporting this work.

HDD Storage Server

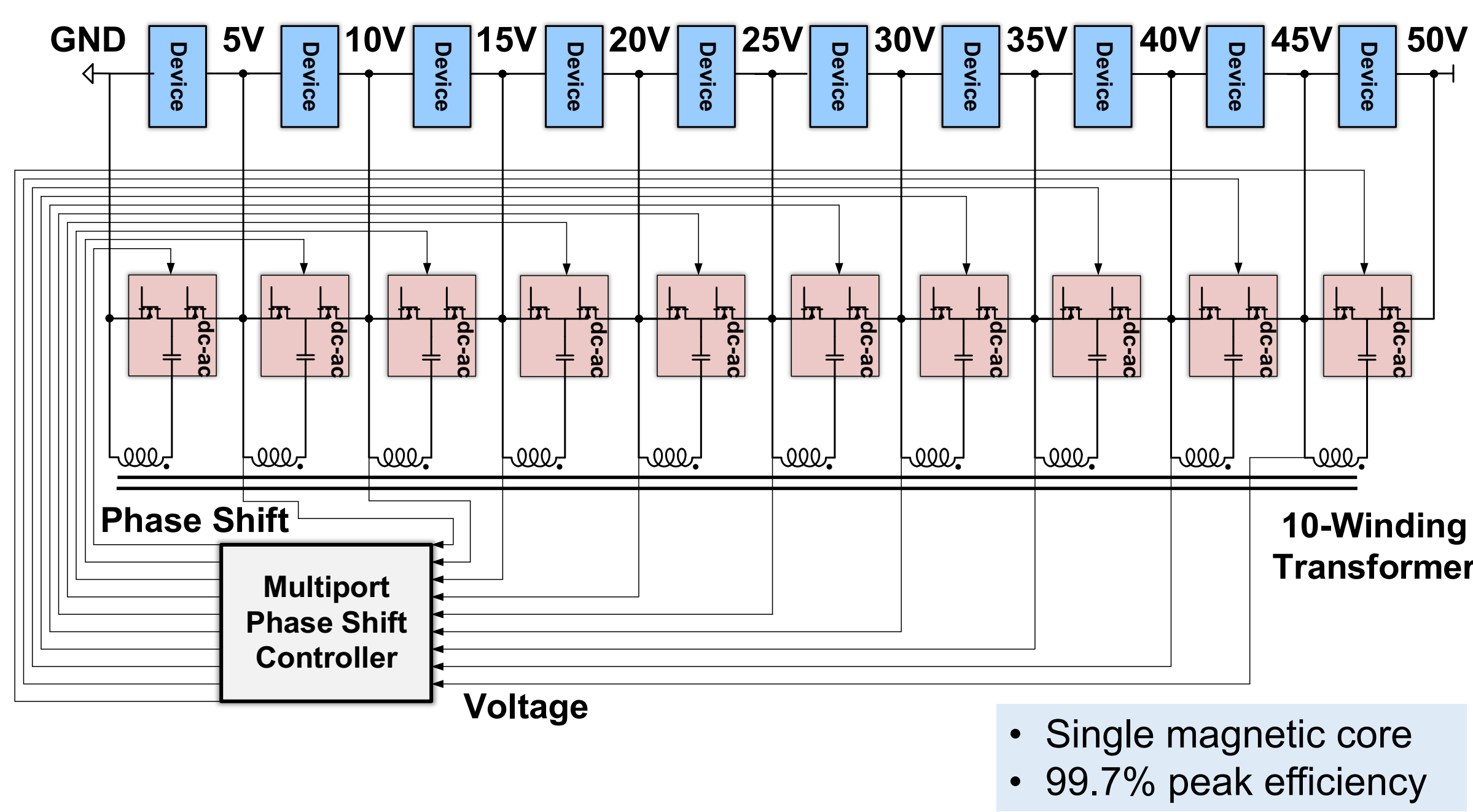
Overall DPP Architecture for HDD Storage Server



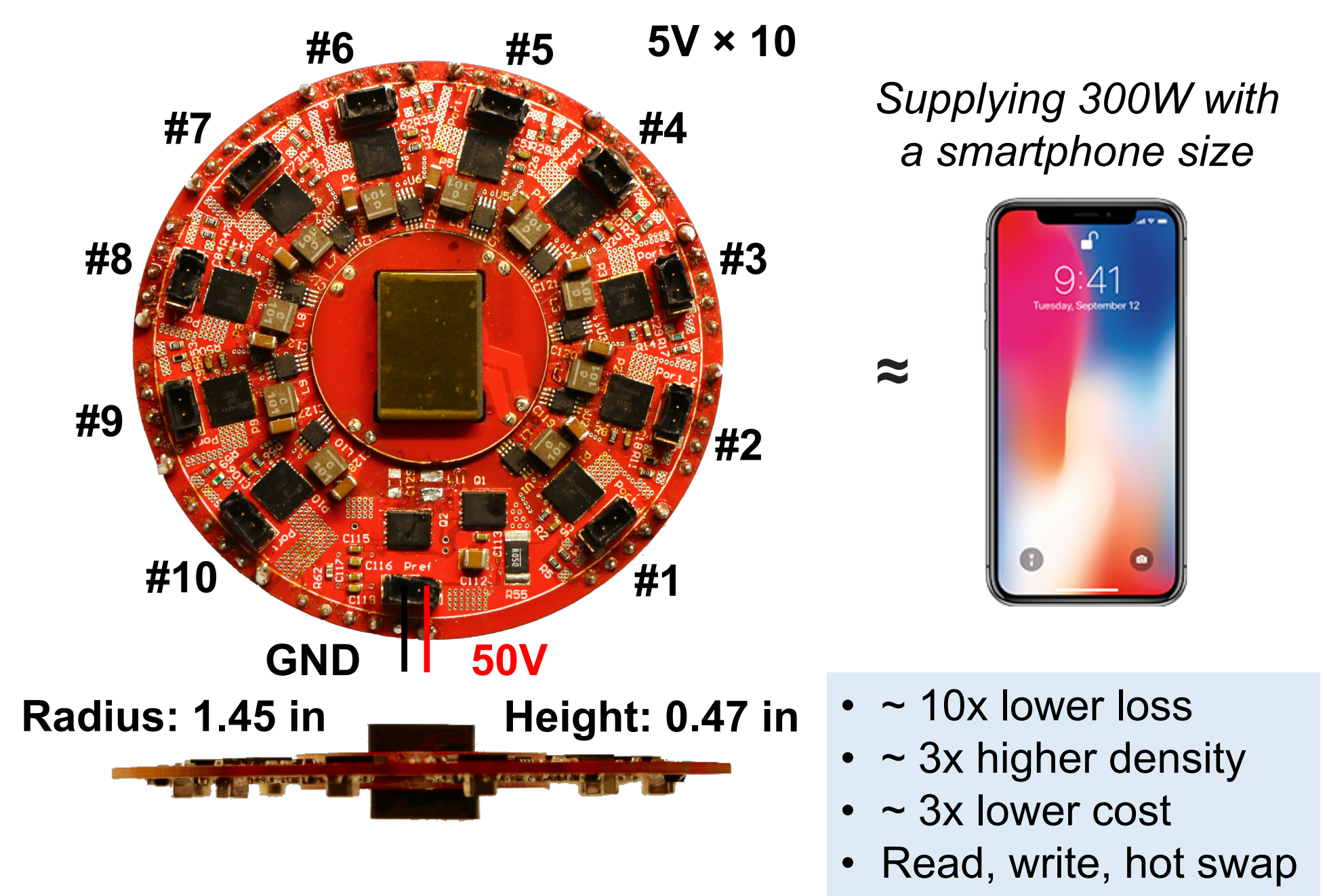
- 50x2.5-inch HDDs are grouped into 10 series voltage domains
- Each domain supplies 25W peak power (5 HDDs)
- Support "hot-swap" of an entire domain (30W differential power)

Multiport Ac-Coupled (MAC) Differential Power Processing

10-Port MAC DPP Converter Circuit Topology

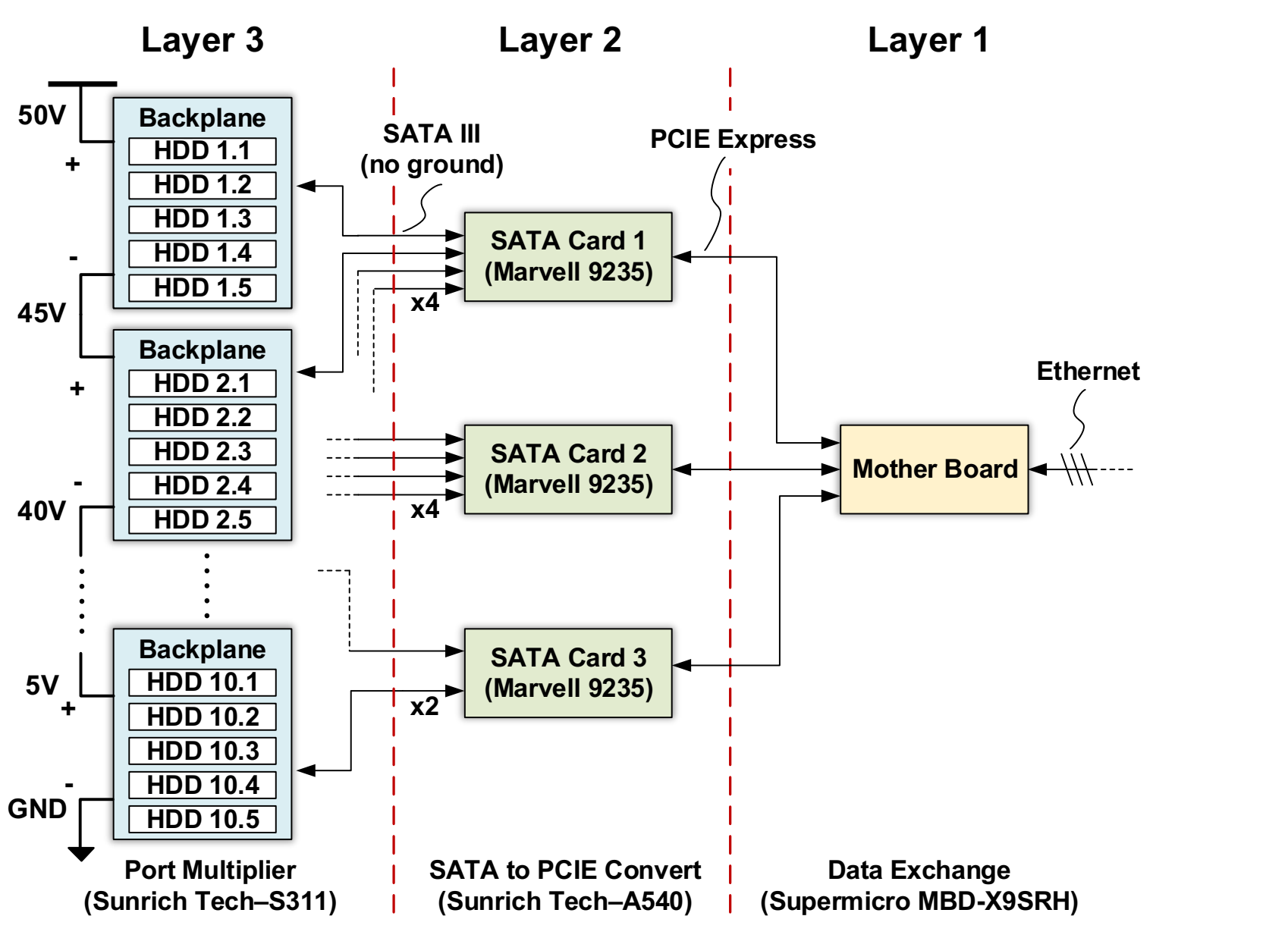


MAC DPP Prototype (100 W/in³ Power Density)

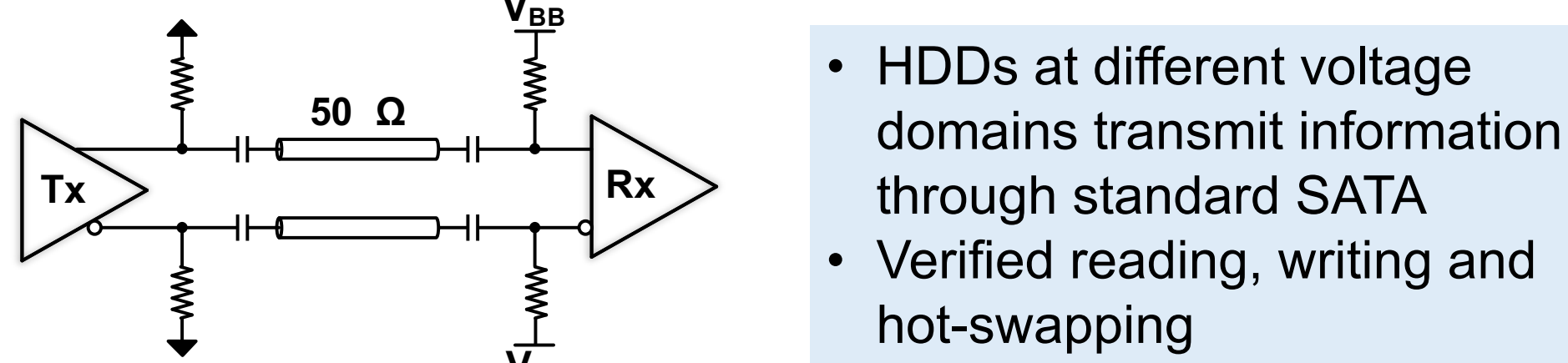


Communication Infrastructure

A Three Layer Solution with SATA Extension Boards

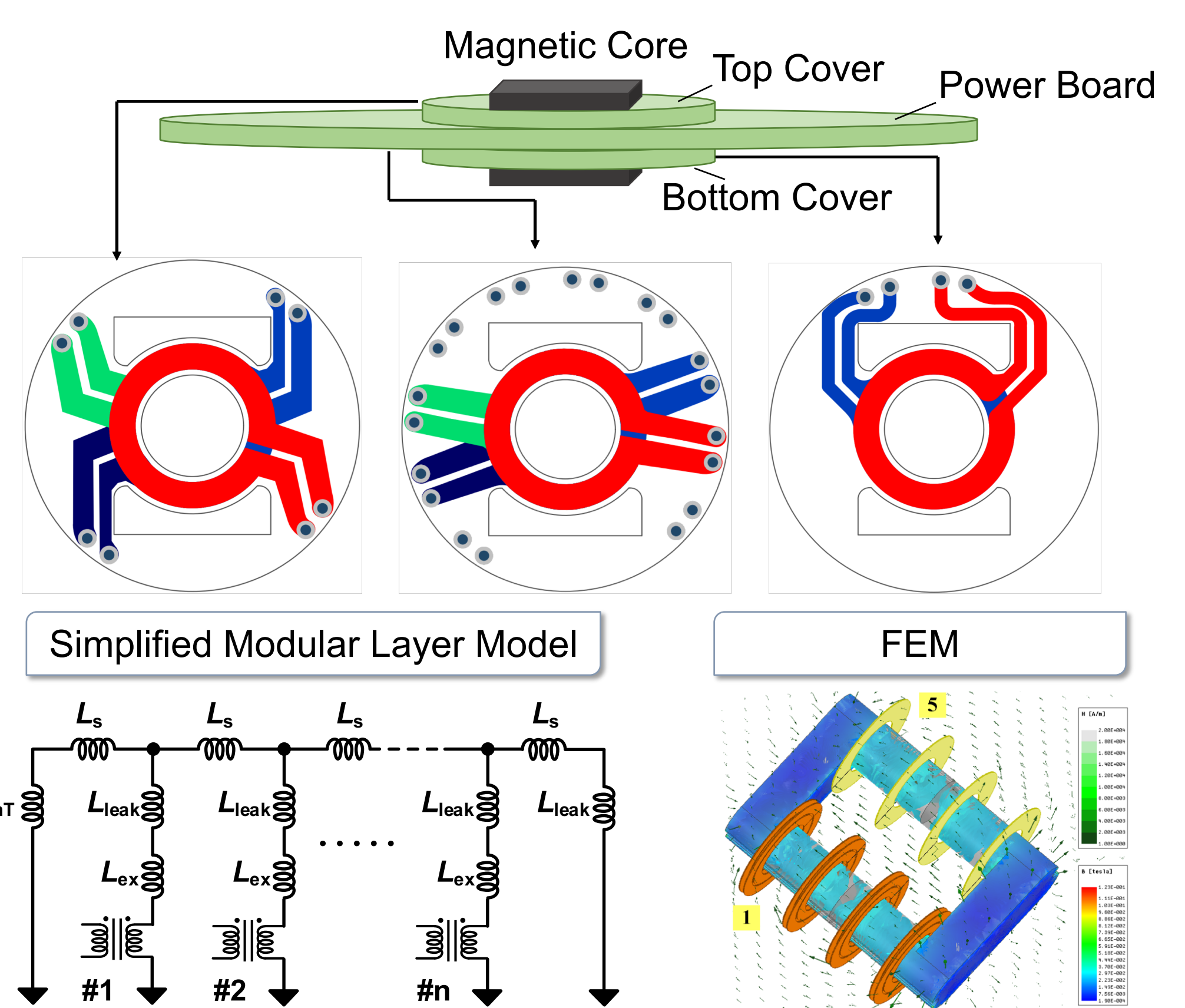


High Speed Differential SATA Signal



Multi-Winding Transformer

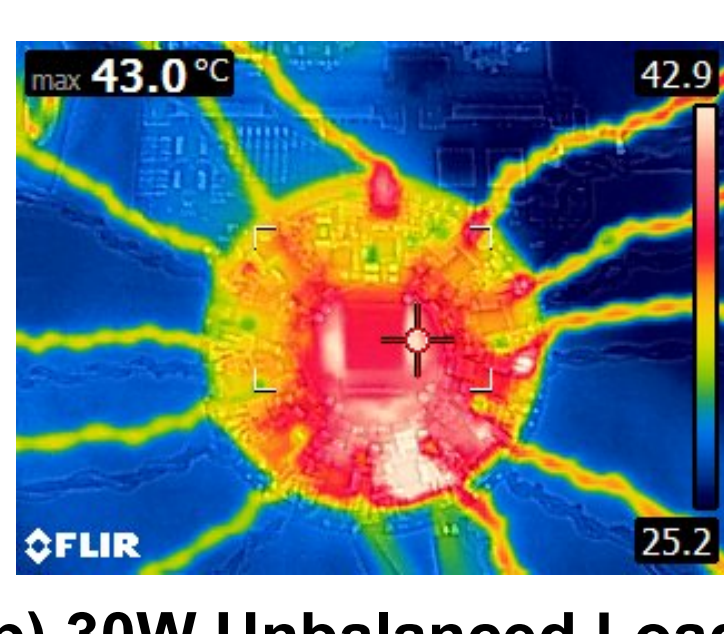
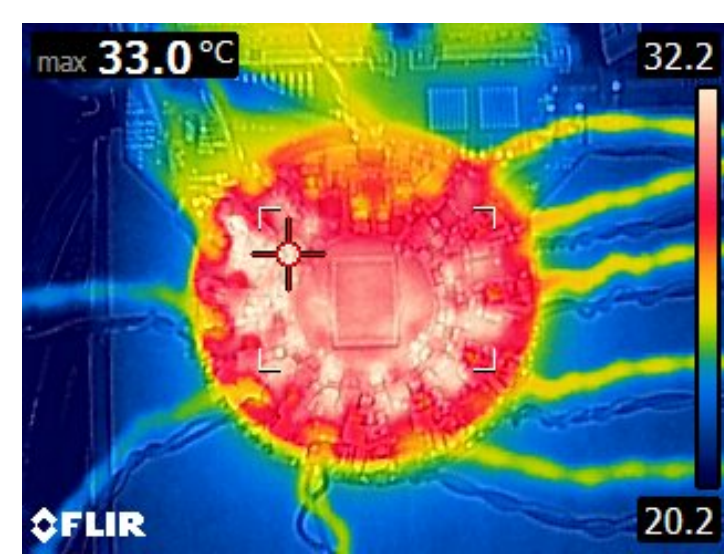
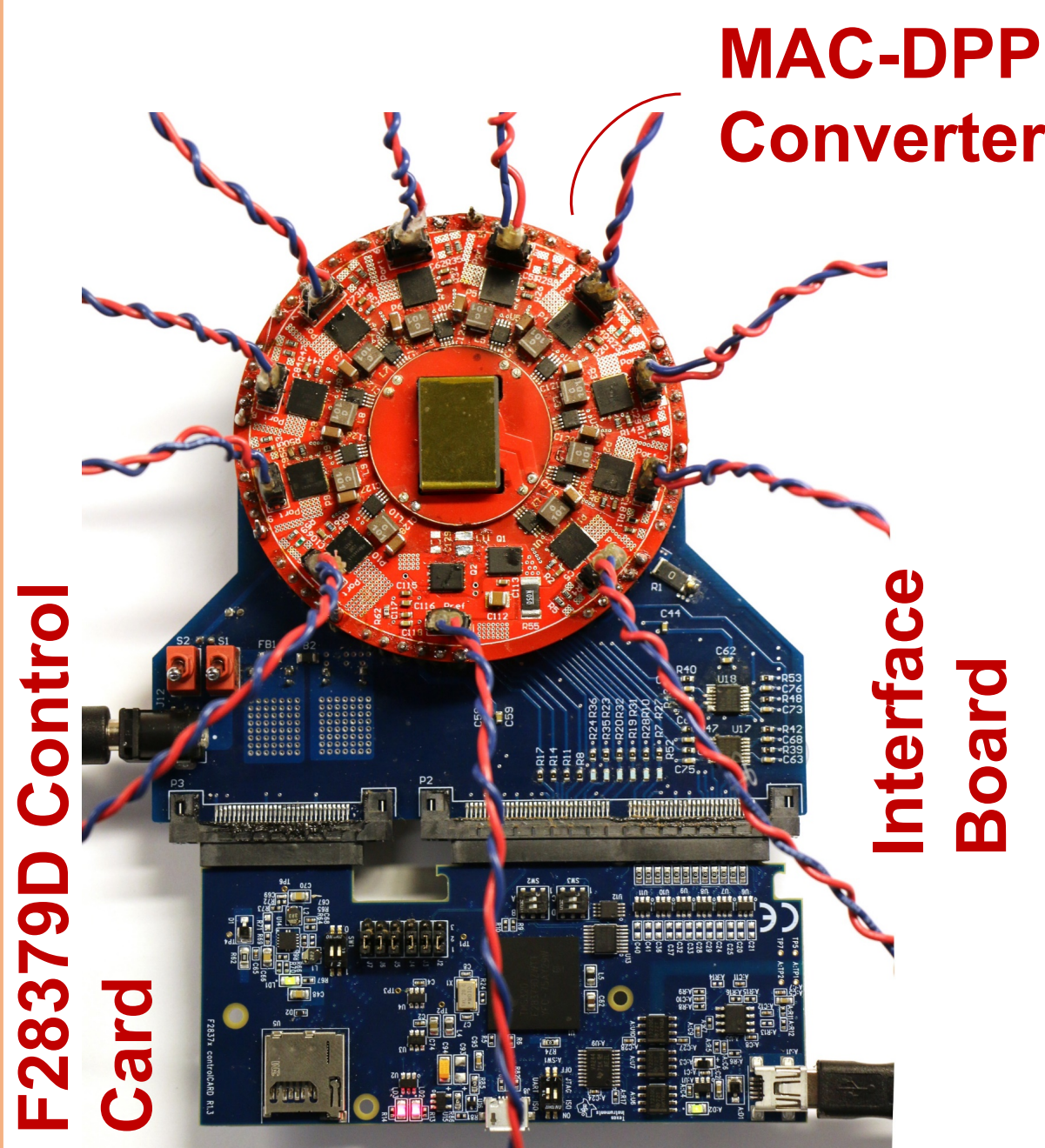
Planar PCB Structure



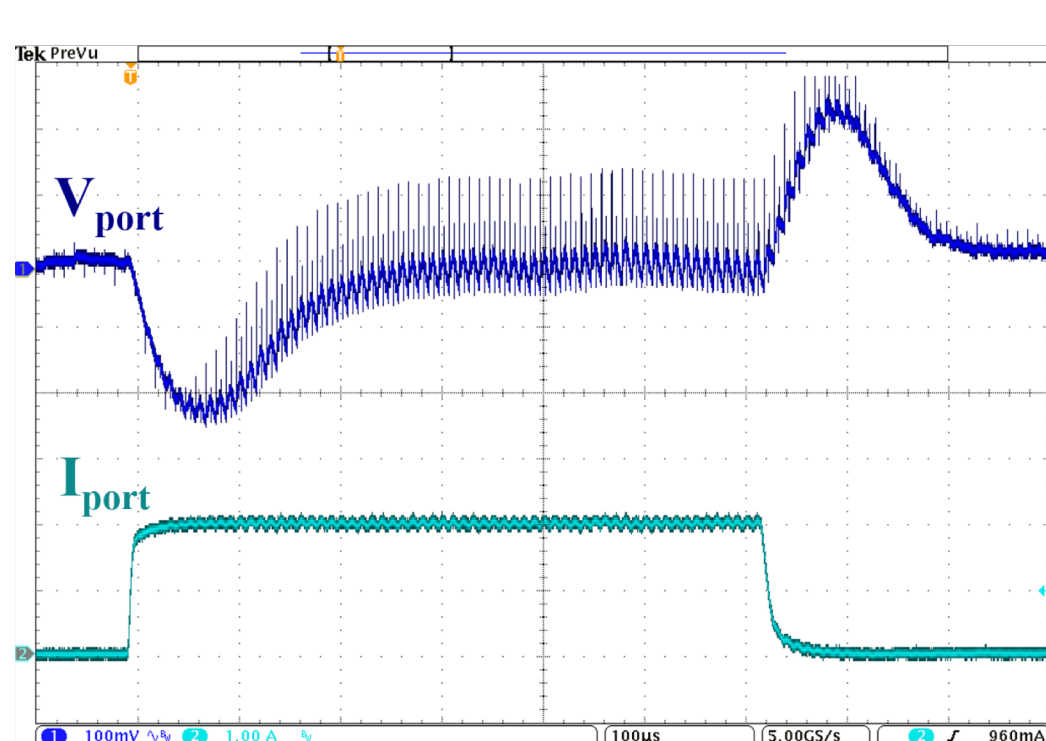
Experiment Results

Prototype Overview

Thermal Images

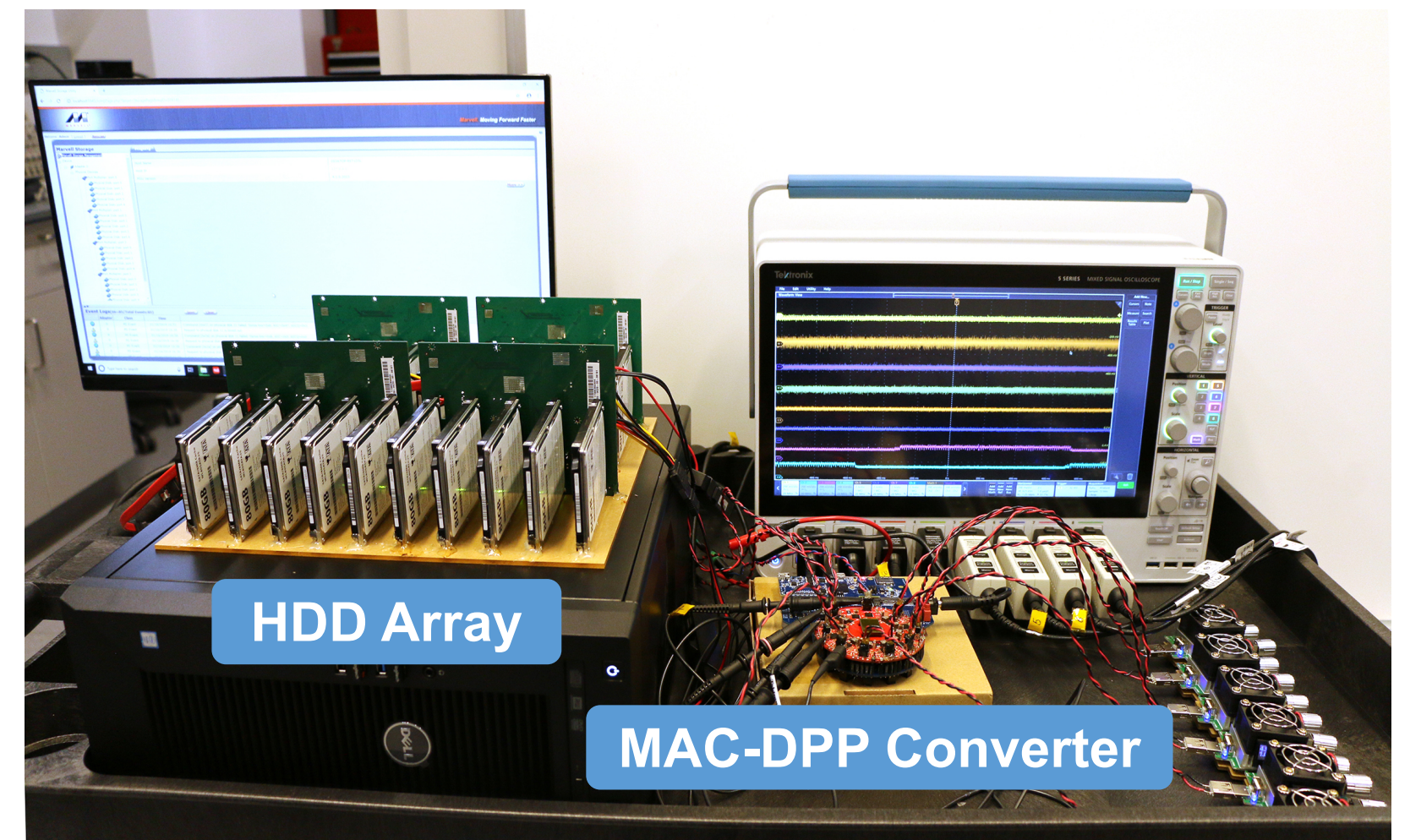


Transient Response (2A Step Load at One Port)

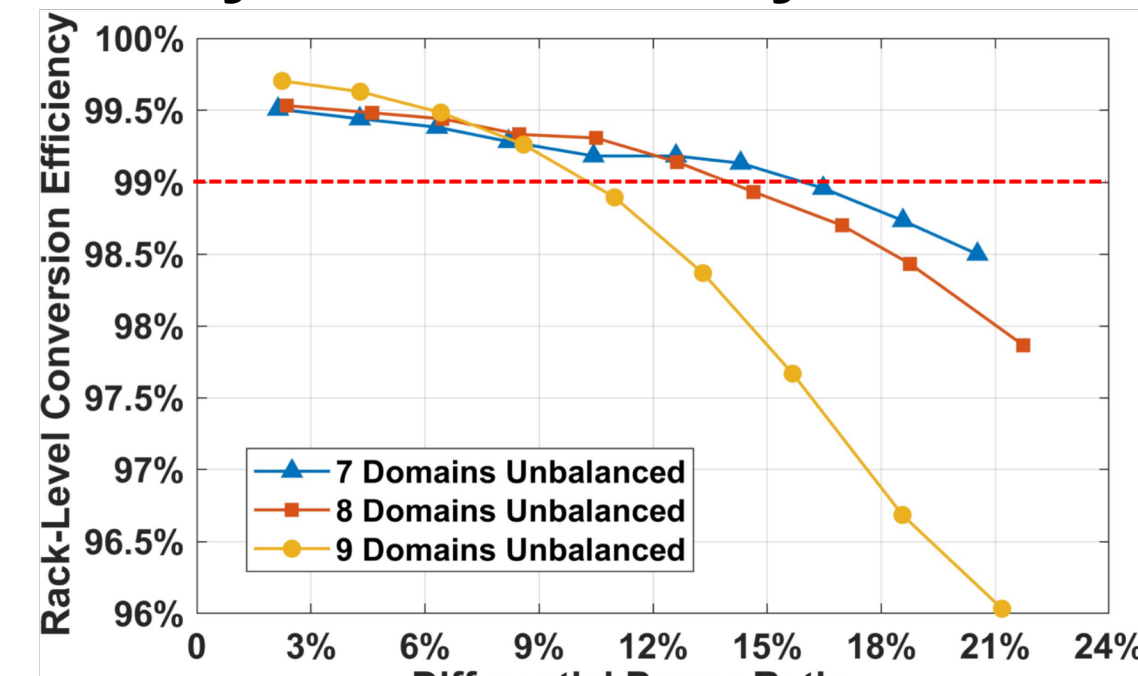


- 700 uF output capacitance.
- Transient overshoot : <230 mV.
- Settling time : <200 us.
- Meet the hot-swap requirement of typical HDDs (5% of VDD)

HDD Storage System Testbench



System Efficiency



$$\eta = \frac{\text{Power Consumed by HDD}}{\text{System Power}}$$

- Peak efficiency: 99.7%
- Efficiency: >99% for differential power ratio <10%.

MAC-DPP Demo Video



References

- P. Wang and M. Chen, "Towards Power FPGA: Architecture, Modeling and Control of Multiport Power Converters," 2018 IEEE 19th Workshop on Control and Modeling for Power Electronics (COMPEL), Padua, 2018, pp. 1-8.
- E. Candan, P. S. Shenoy and R. C. N. Pilawa-Podgurski, "A Series-Stacked Power Delivery Architecture with Isolated Differential Power Conversion for Data Centers," IEEE Transactions on Power Electronics, vol. 31, no. 5, pp. 3690-3703, May 2016.