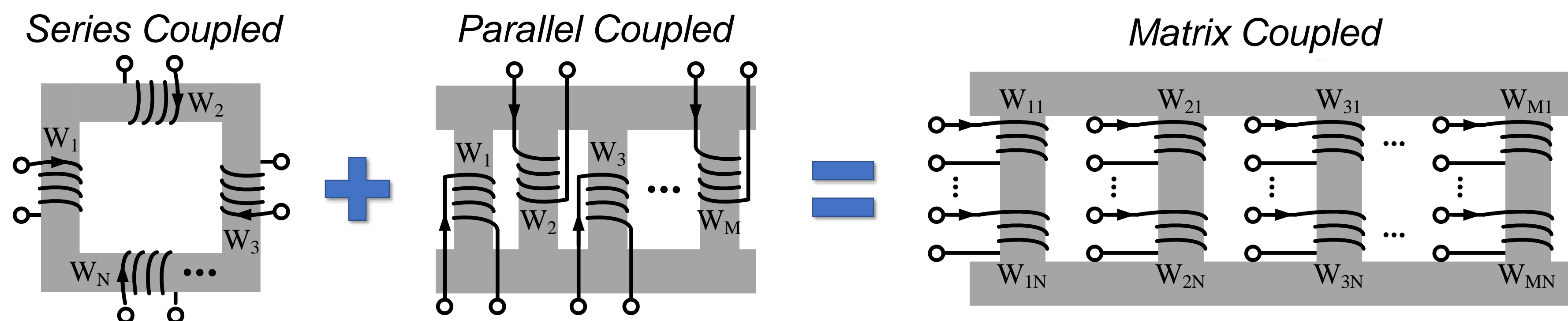


Introduction

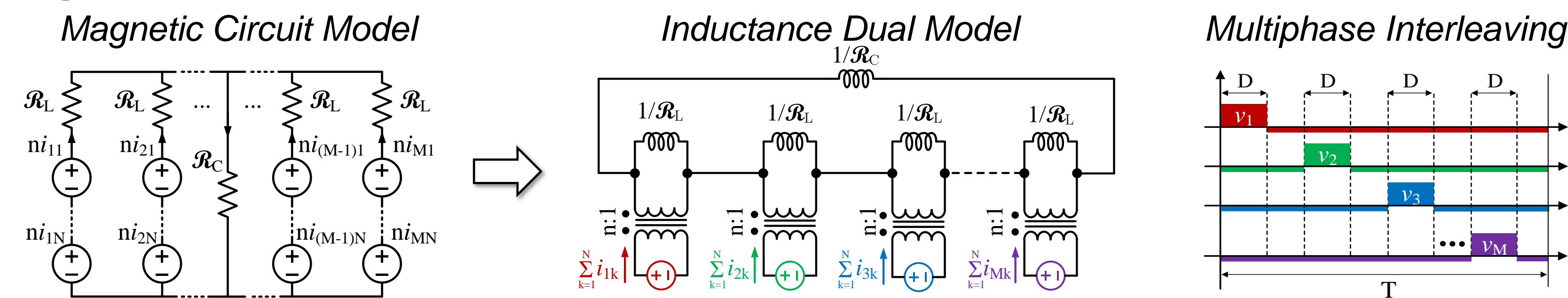


Coupled Magnetics Structures:

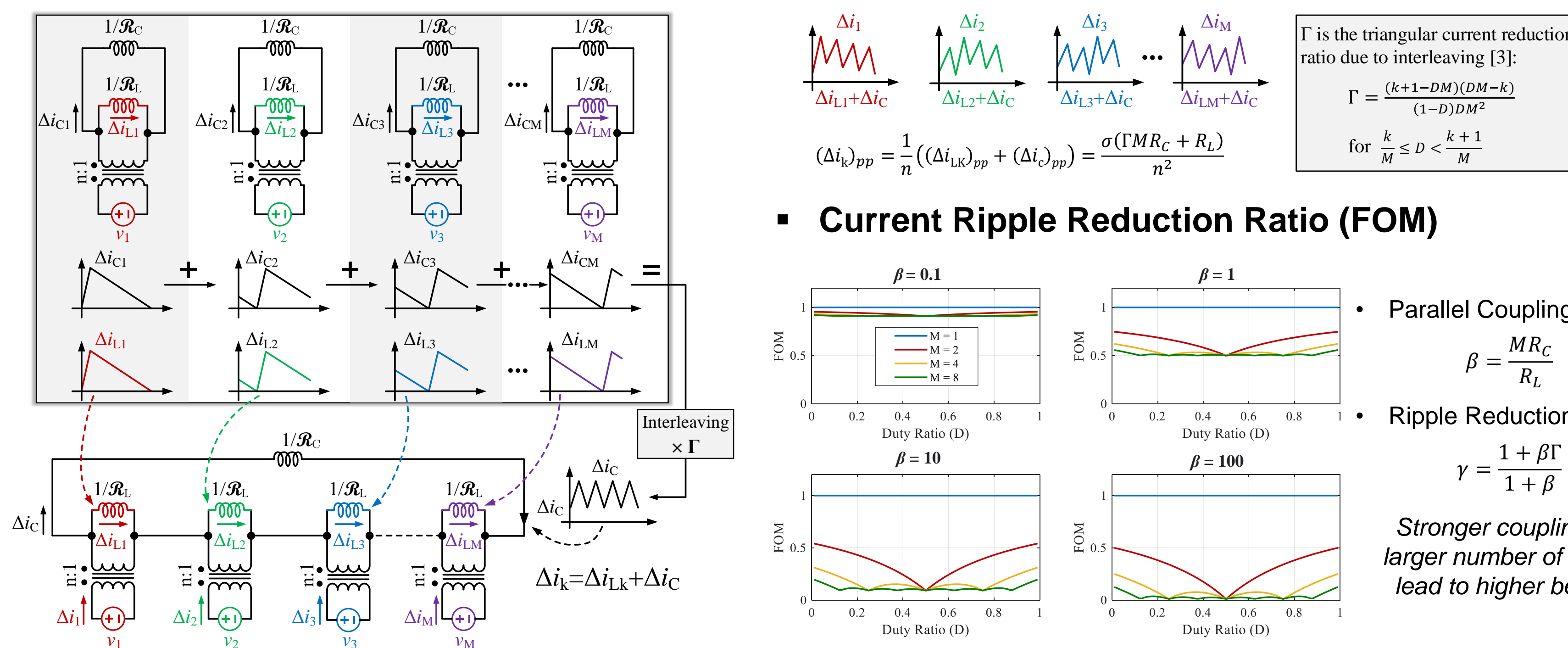
- Series coupled:** windings of similar voltages can be coupled in series
- Parallel coupled:** windings of similar currents can be coupled in parallel
- Matrix coupled:** combining series and parallel couplings to miniaturize size and dc energy storage; achieving high efficiency and power density with ultra-fast transient response [1].

Current Ripple Reduction Mechanism

Magnetic Models



Current Ripple Analysis by Superposition

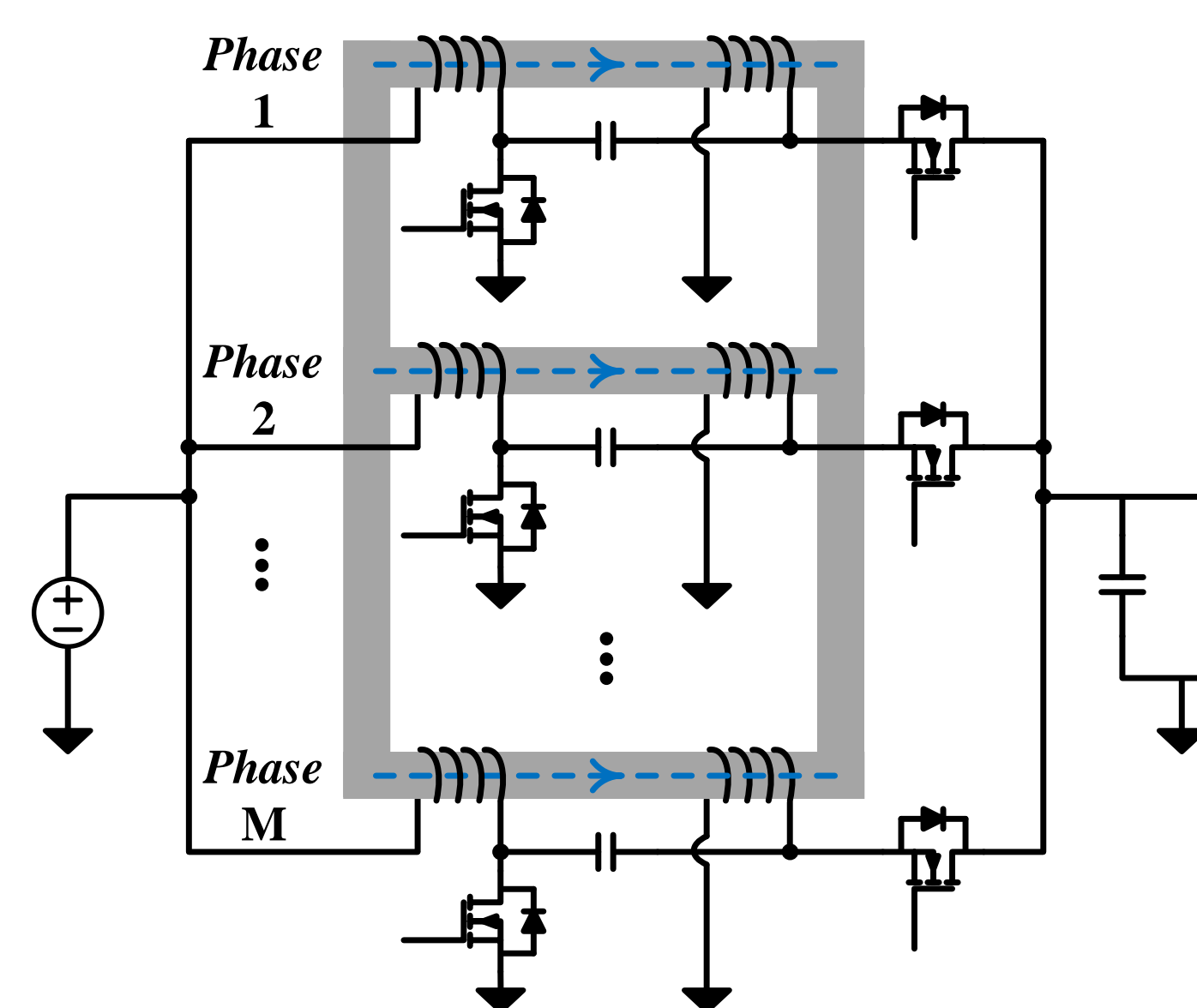


Key Contributions

- Presenting an all-in-one matrix-coupled magnetic structure, achieving miniaturized magnetic size, high efficiency, high power density, and fast transient response.
- Revealing the current ripple reduction mechanism of the matrix-coupled magnetics with interleaving operation.
- Building a four-phase matrix-coupled SEPIC converter to validate the all-in-one magnetics concept

Applicable Topologies

Matrix-Coupled SEPIC Converter



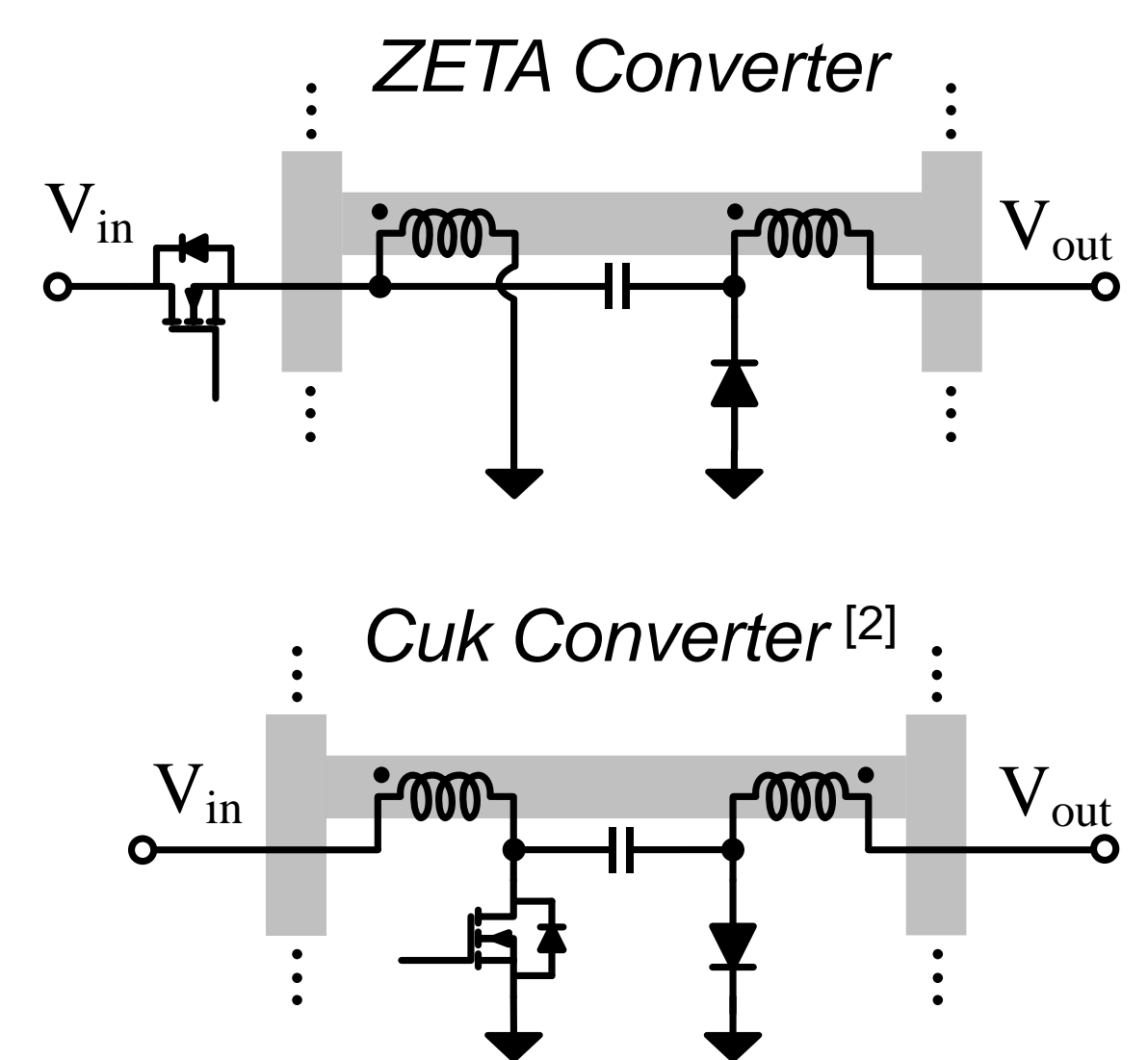
Series Coupling:

Two Inductors of each phase have identical voltage waveforms and are coupled in series

Parallel Coupling:

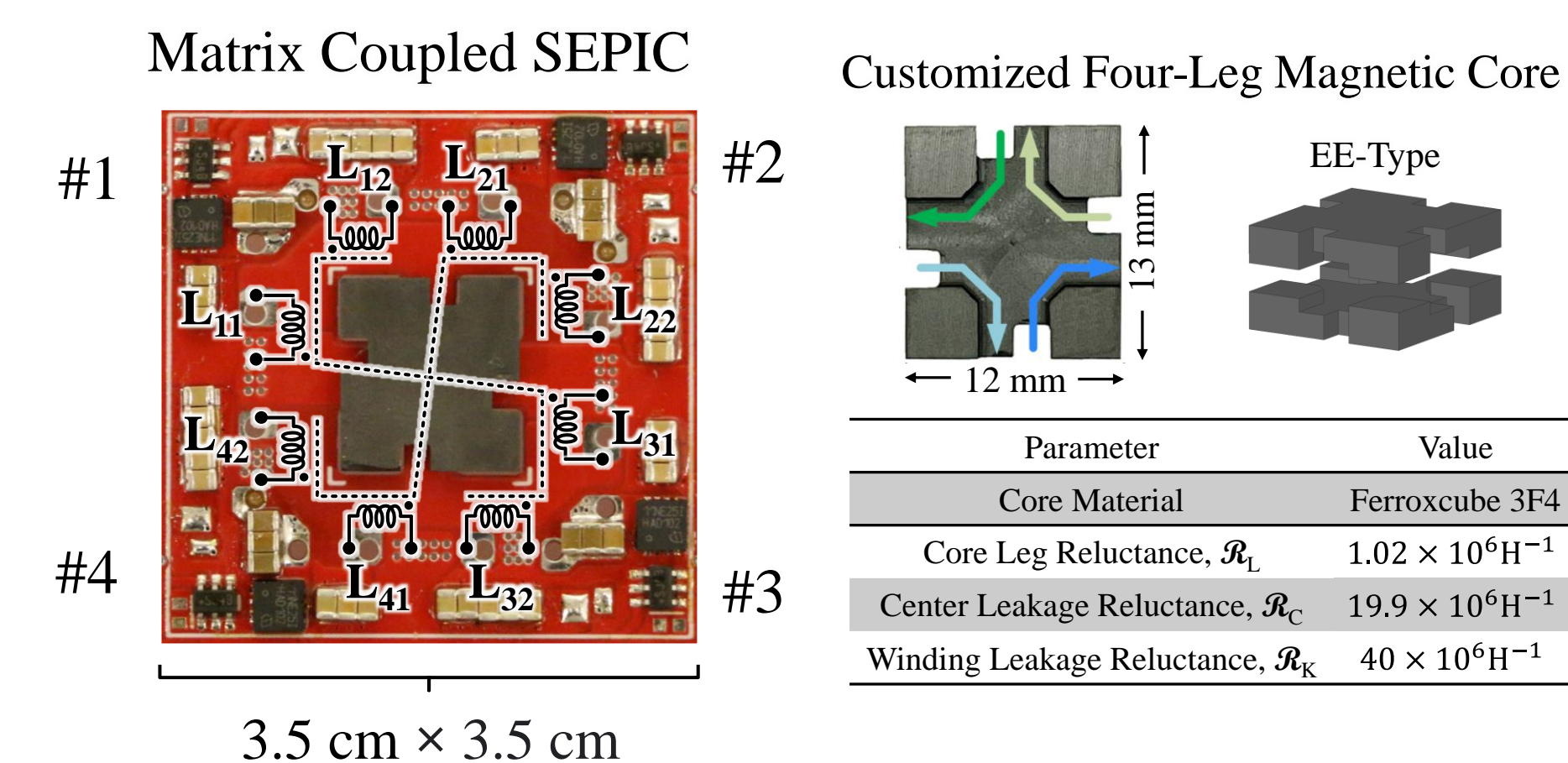
Inductors of multiple phases are coupled in parallel with interleaving operation

Other Alternatives

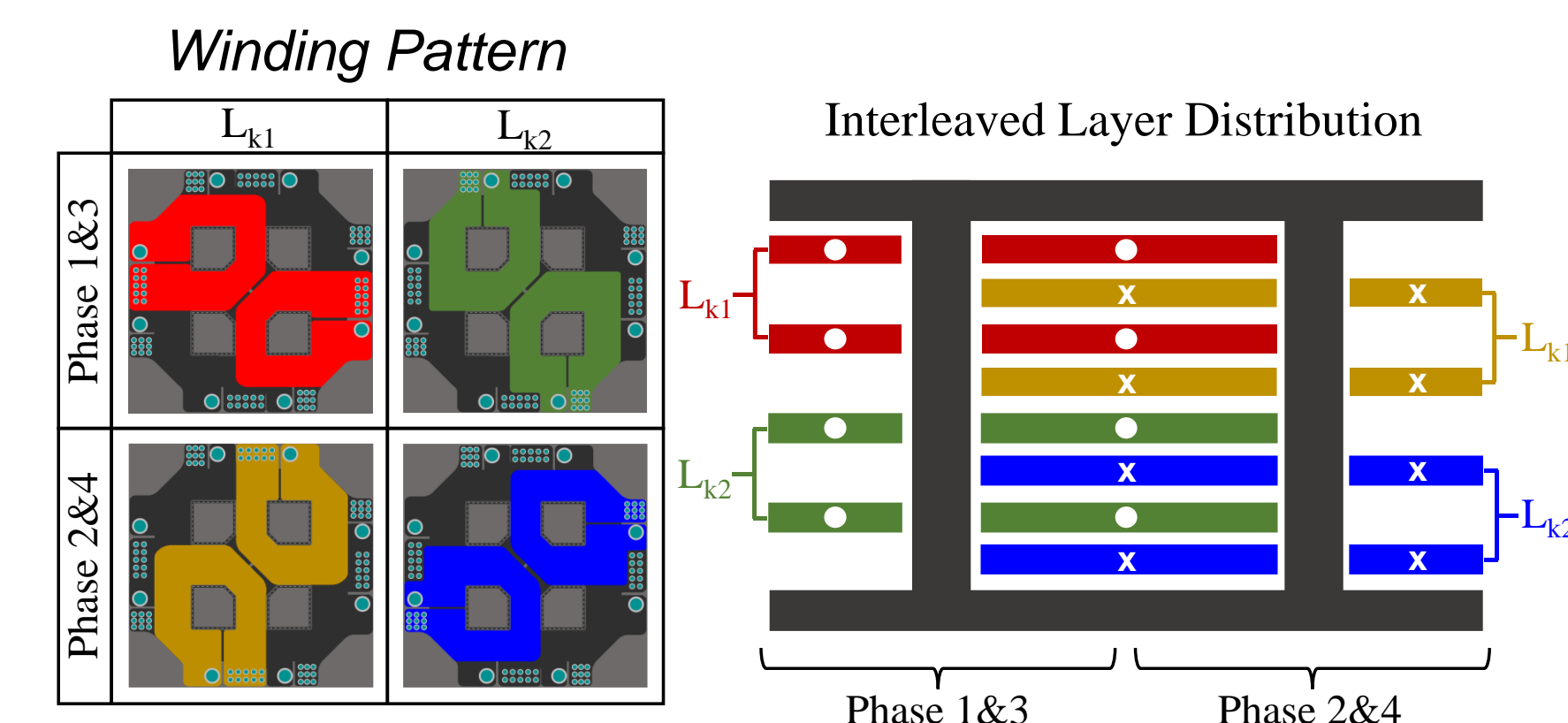


Hardware Prototype and Experimental Results

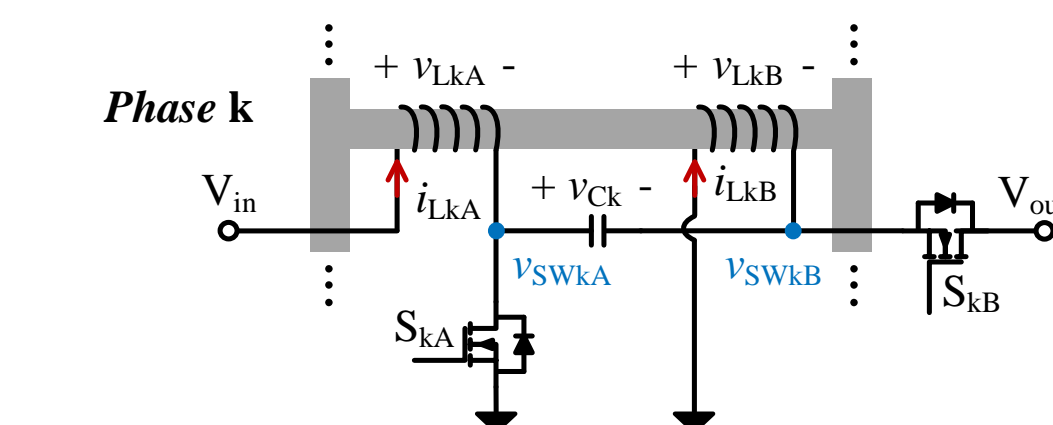
Hardware Prototype



PCB Planar Magnetics

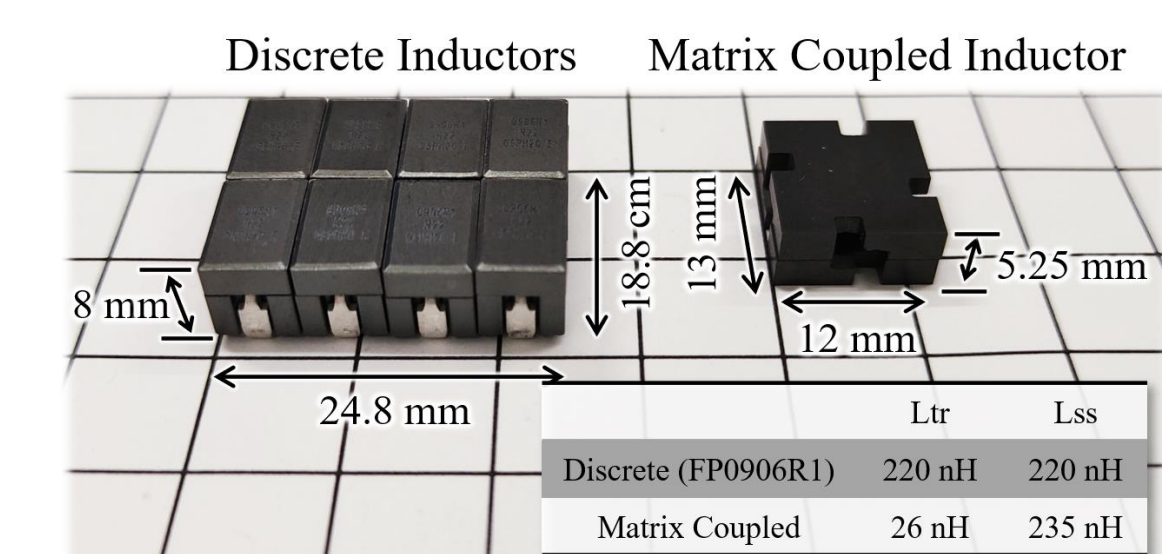
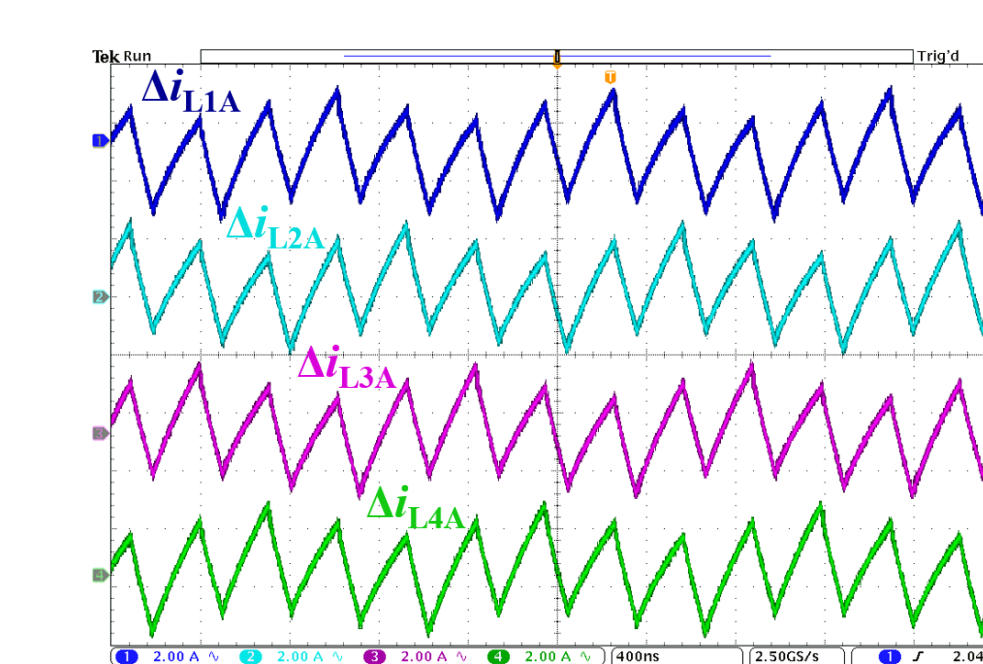
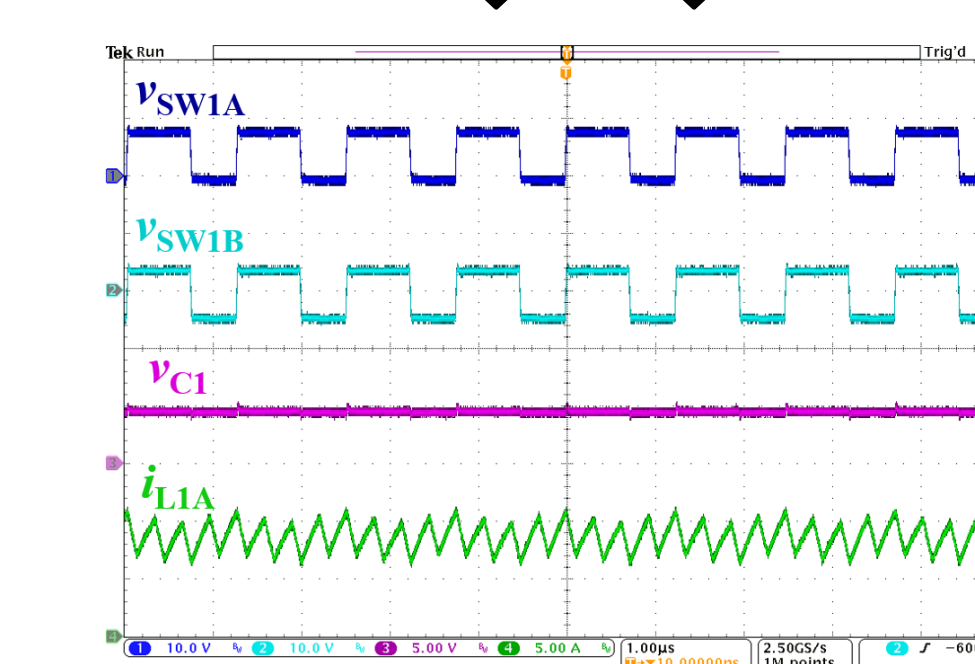


Experimental Results

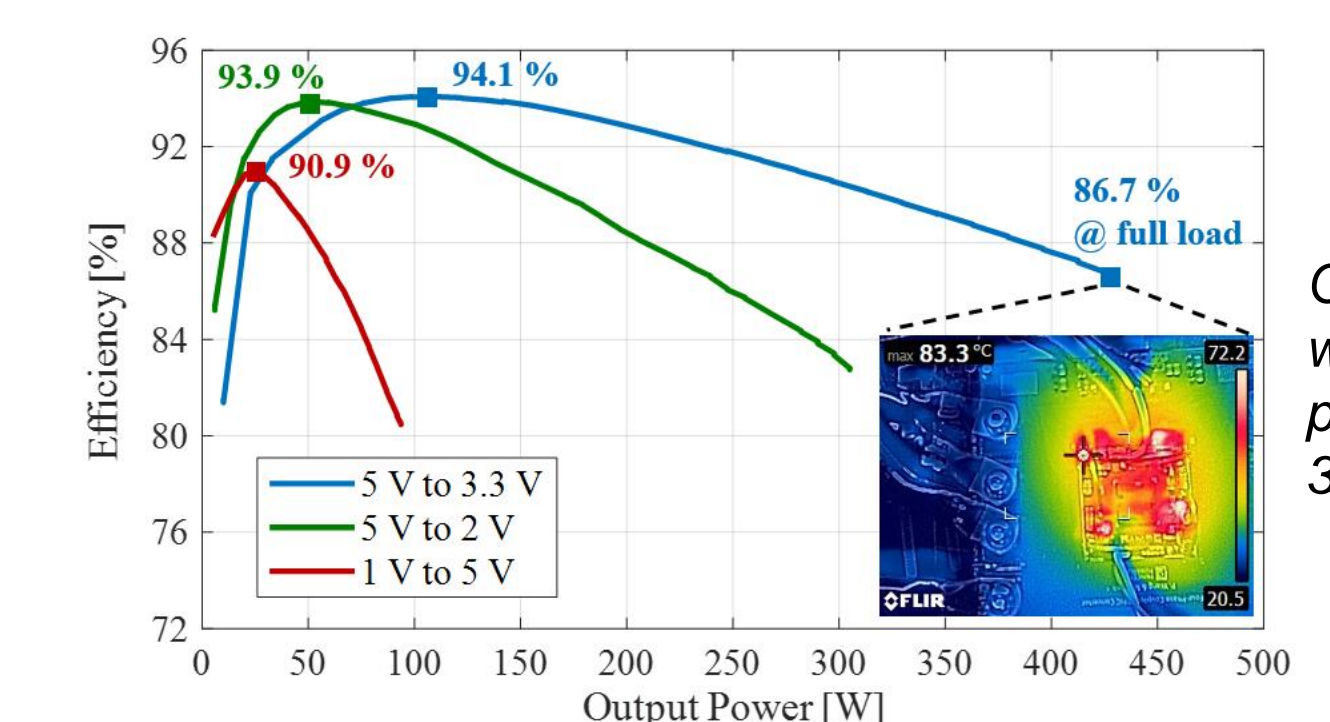


Testing Condition:

- $f_{sw} = 806 \text{ kHz}$
- Voltage conversion: 5 V \rightarrow 3.3 V
- Output Current: 50 A



Over 4x size reduction compared to discrete L



Over 1000W/in³ when delivering power from 5 V to 3.3 V

References

- [1] C. R. Sullivan, B. A. Reese, A. L. F. Stein and P. A. Kyaw, "On Size and Magnetics: Why Small Efficient Power Inductors are Rare," International Symposium on 3D Power Electronics Integration and Manufacturing (3D-PEIM), Raleigh, NC, 2016.
- [2] S. Cuk, "A New Zero-Ripple Switching DC-to-DC Converter and Integrated Magnetics," TPEL, 1983.
- [3] M. Chen and C. R. Sullivan, "Unified Models for Coupled Inductors Applied to Multiphase PWM Converters," TPEL, 2021.