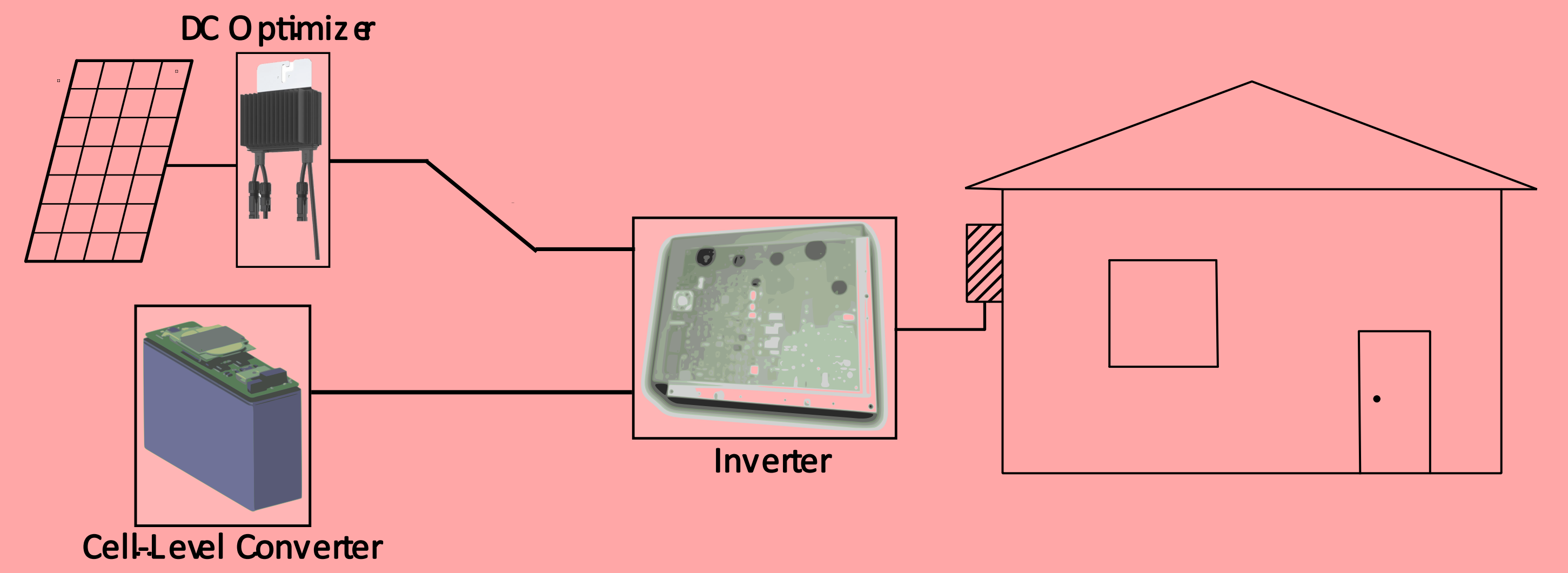


High Conversion Cell-Level Battery Power Converter

DOE Phase II SBIR • Chris Recio (PI), James Sorber, Aidan Barefoot

Objective

To develop a power converter with an extreme conversion ratio to interface a single lithium battery to a high voltage DC bus that can be used to generate 120/240 V split-phase service.



Impact

The main focus is commercialization of a system that is reliable, low-cost, and easily expandable to serve the tribal communities (21% of Navajo Nation homes and 35% of Hopi Indian Tribe homes do not have electric service per the U.S. Department of the Interior – Tribal Energy Development).

Our goal is to have a fielded 2 kW, 120/240 V split phase system which provides improved capabilities over the current single-phase system.

Improve lifestyle for Native Americans by expanding electric service

Motivation

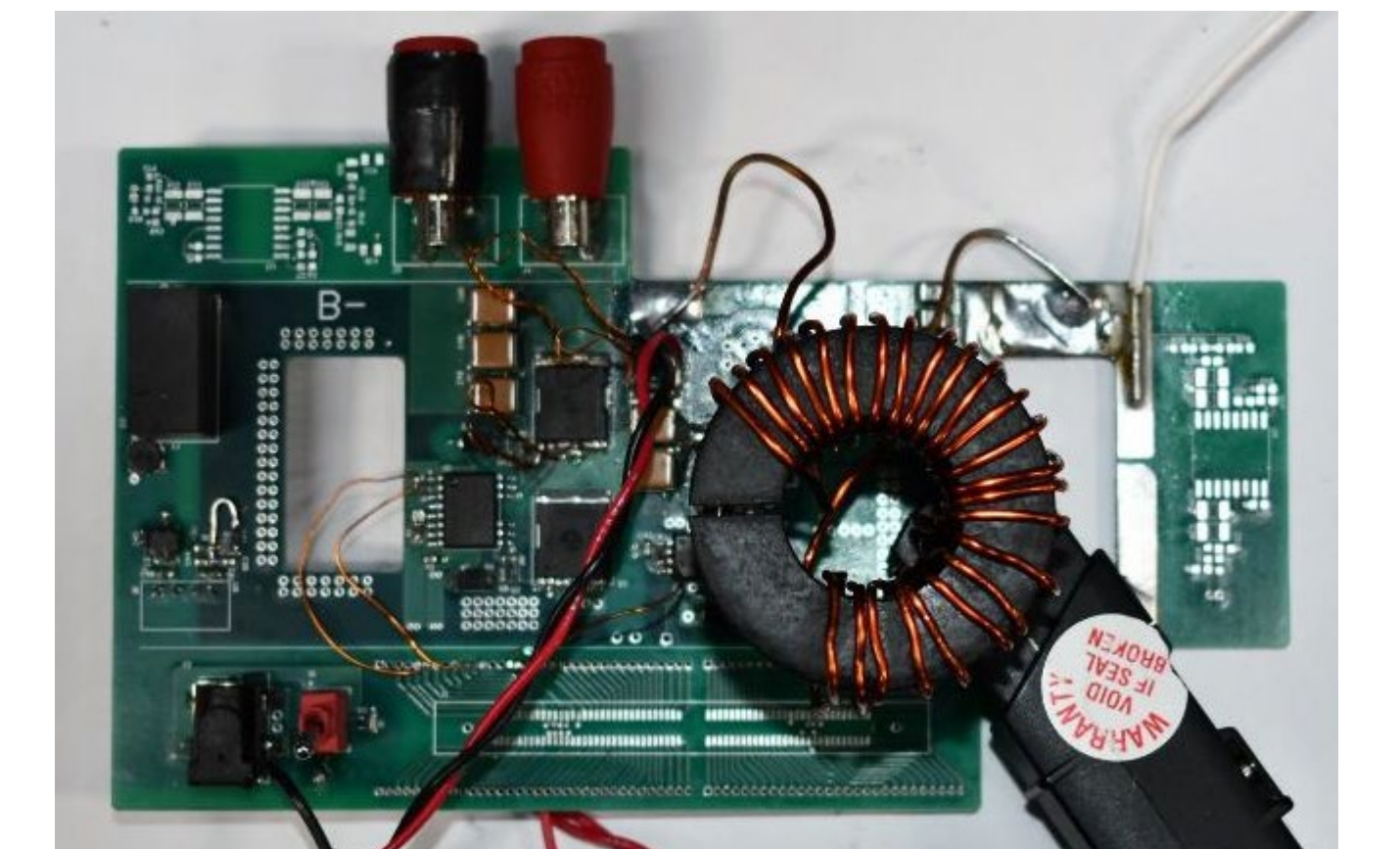
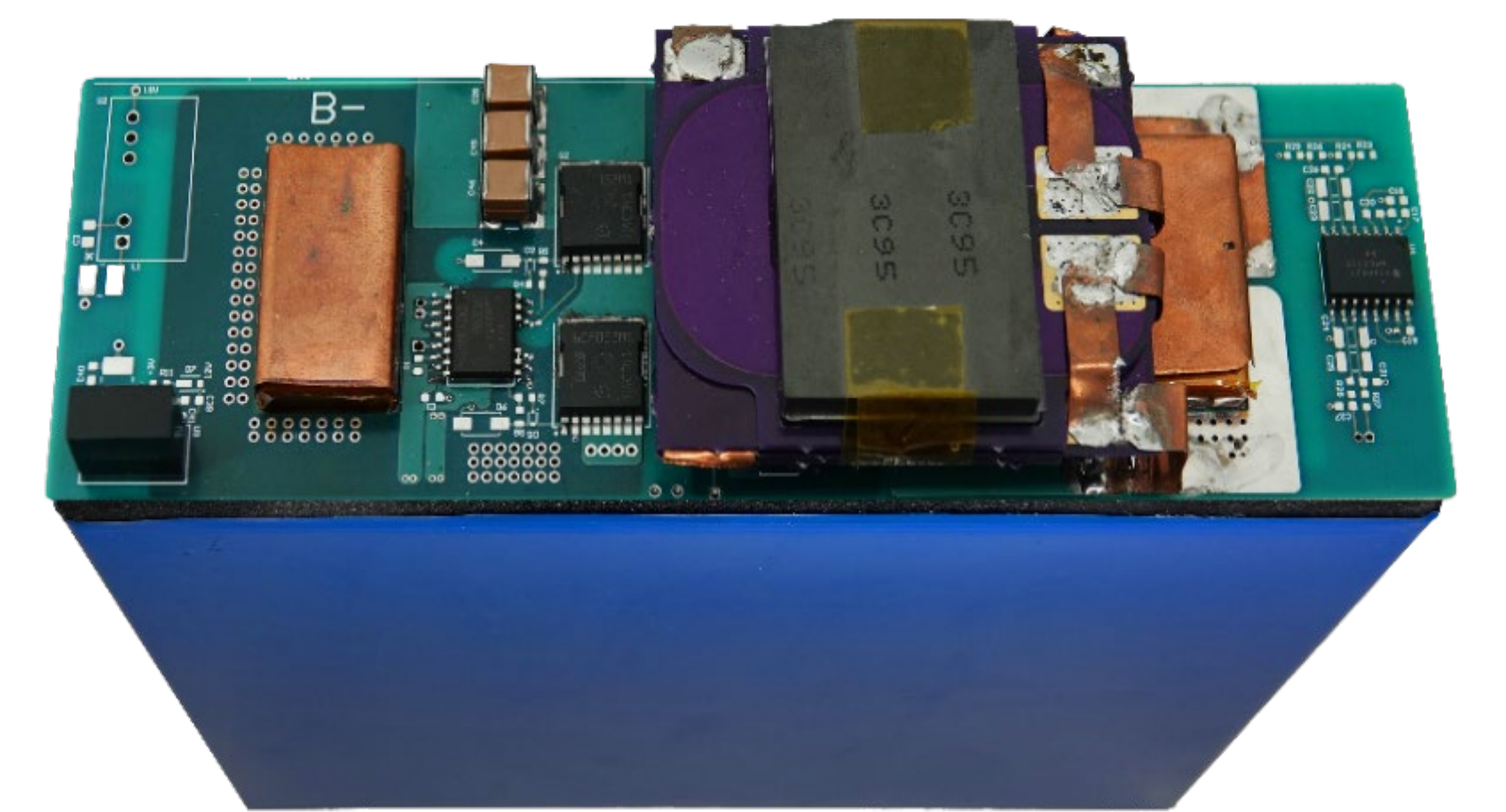
To find a novel alternative for *off-grid residential power* and *backup power* targeted for tribal communities.

Latest gen system can be improved:

- 96.5% Inverter efficiency (CEC), 96% battery charging, 60 W no load consumption
- Light usage → high loss over majority of operation
- Lead acid batteries are expensive and need to be replaced often
- Voice of the customer (Navajo Tribal Utility Authority): biggest problem is the reliability of the inverter

Benefits of proposed system include:

- Inherently modular system without the need for a BMS
- Agnostic to cell chemistry/capacity
 - Flexible system allows mix/match so that user can add cells of a different type for future expansion
- Improved system reliability and resilience
 - System continues to operate at a reduced capacity in the event of a cell failure and is easily serviceable
- Low cost, highly efficient (>98%)



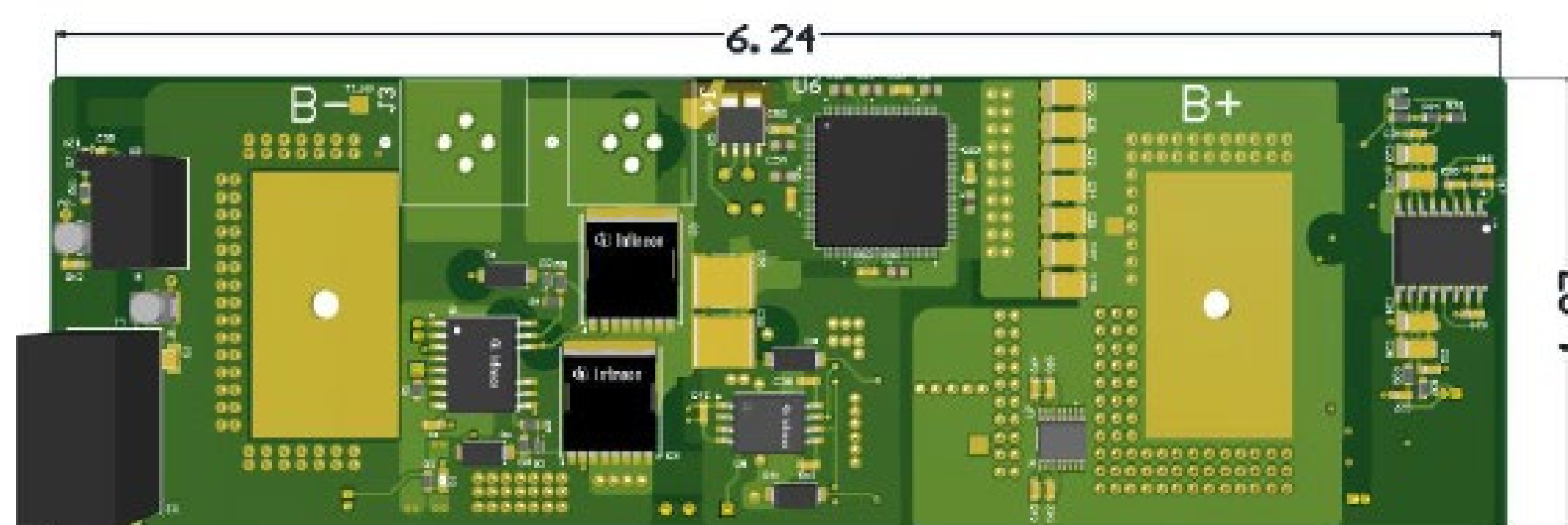
Milestones and Accomplishments

Milestone 1: Demonstration of Hardware Prototype

Results: Successfully demonstrated 30x, 57x, and 117x conversion ratios operating in battery charge mode.

Milestone 2: Next revision design

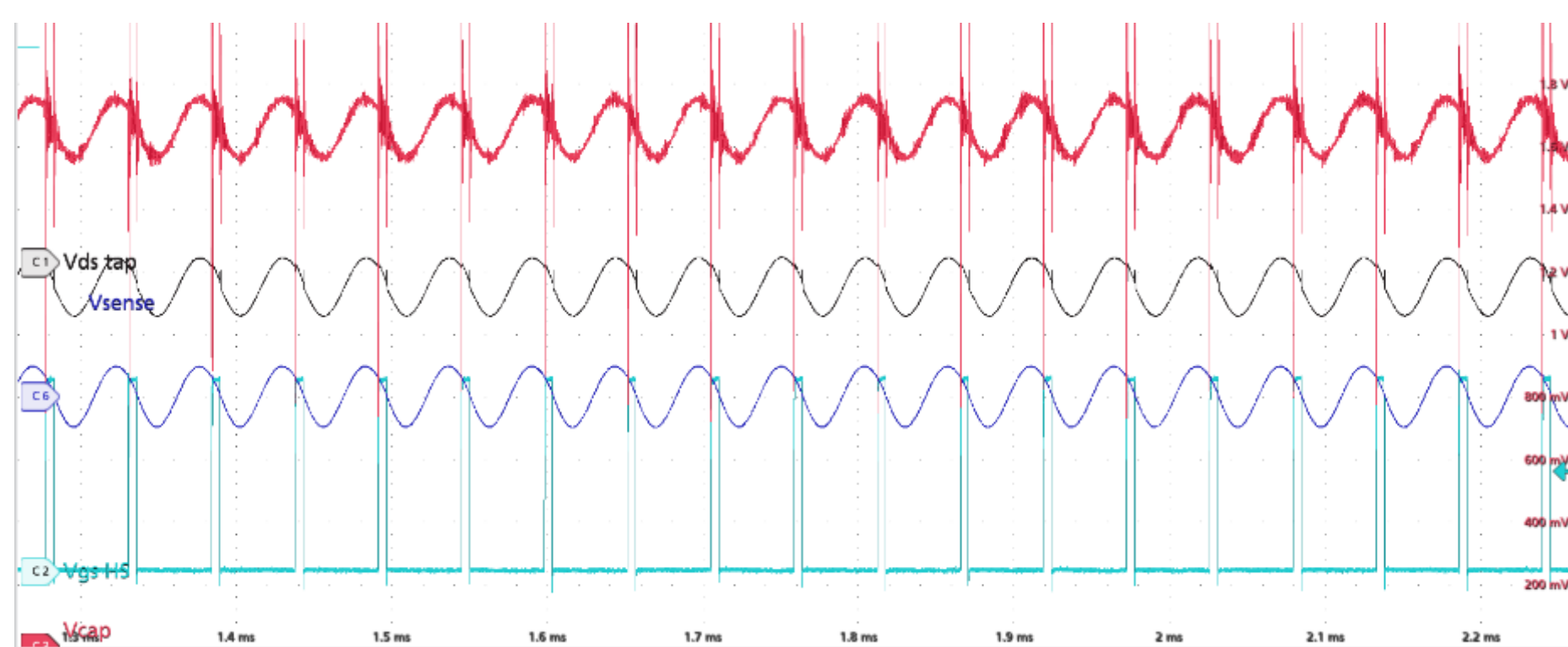
Results: PCB dimensions are 6.24" x 1.97", within battery face dimensions.



Milestone 3: Electrical characterization and full evaluation

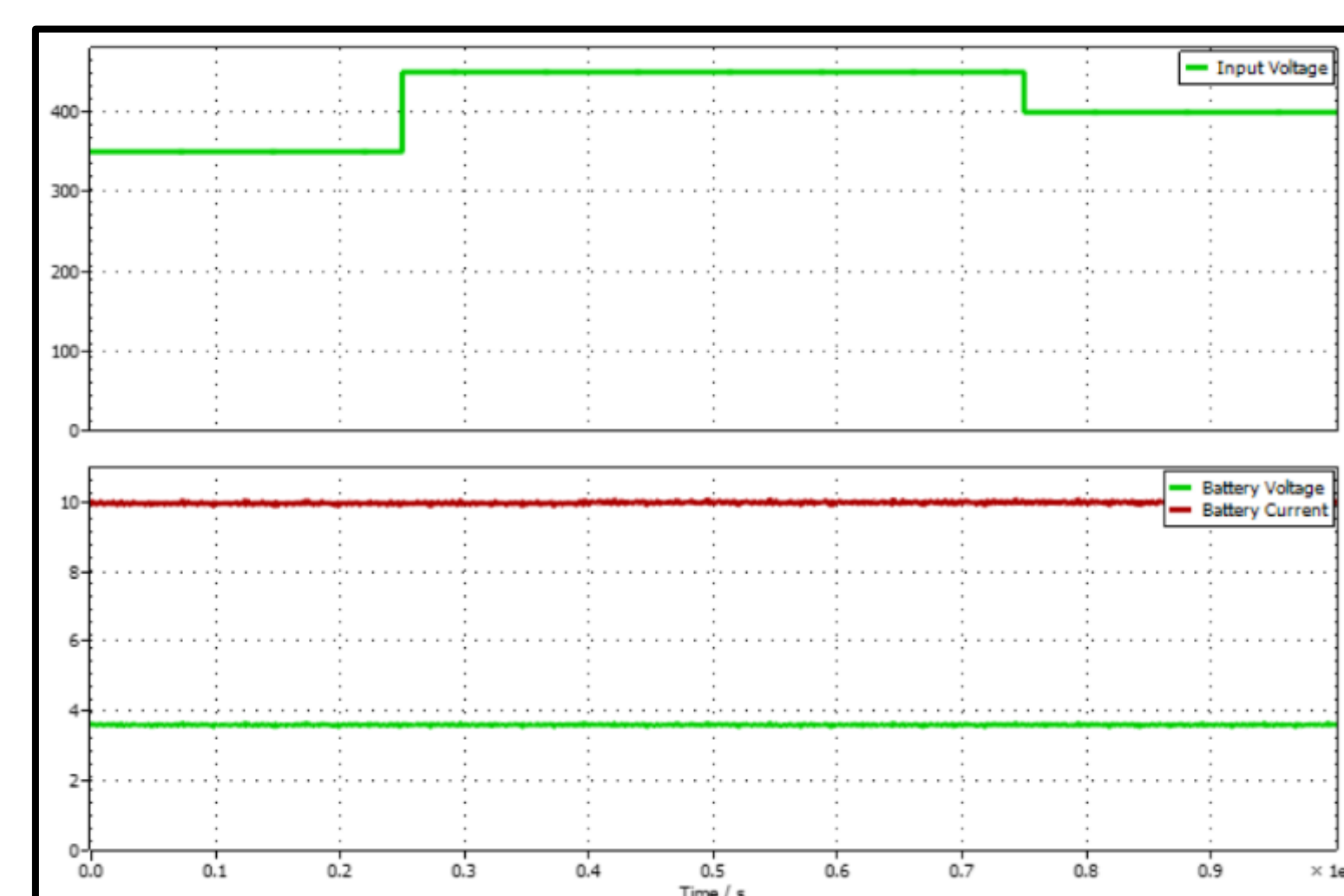
Milestone 4: Implement Control Scheme

Results: Developed a resonant tank voltage sense circuit to be used with the PLL for zero voltage, zero current switching.

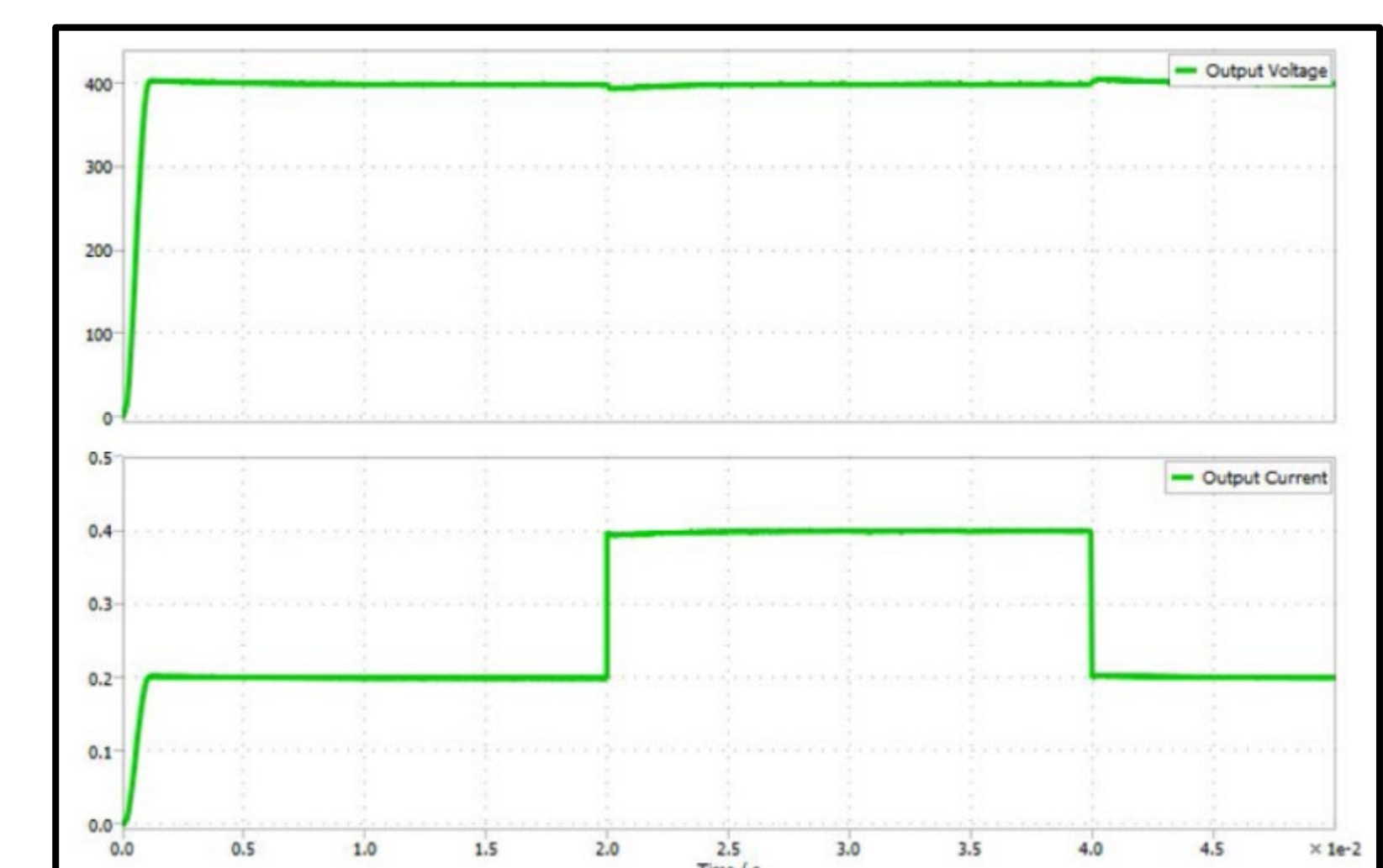


Milestone 5: Magnetics Evaluation

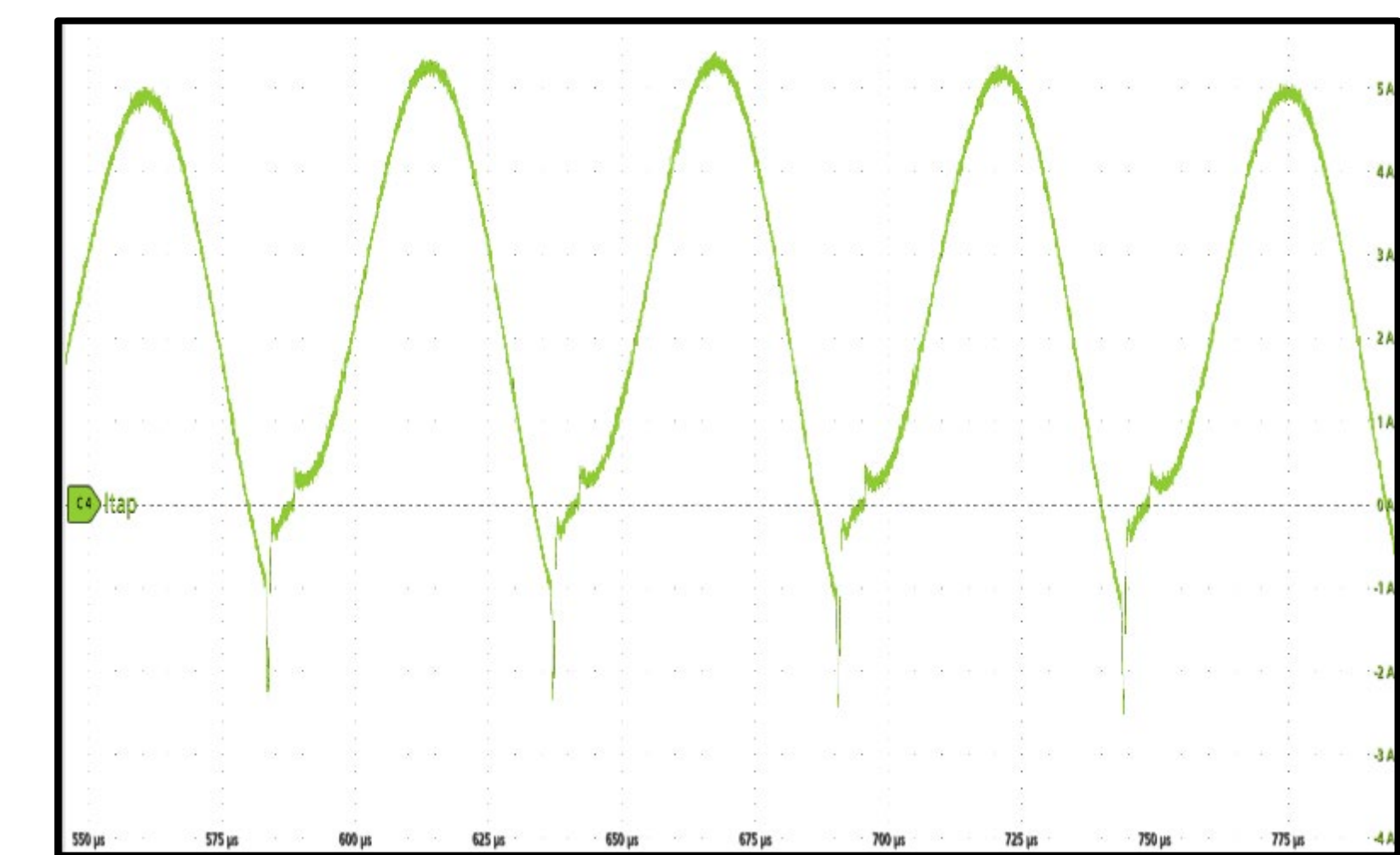
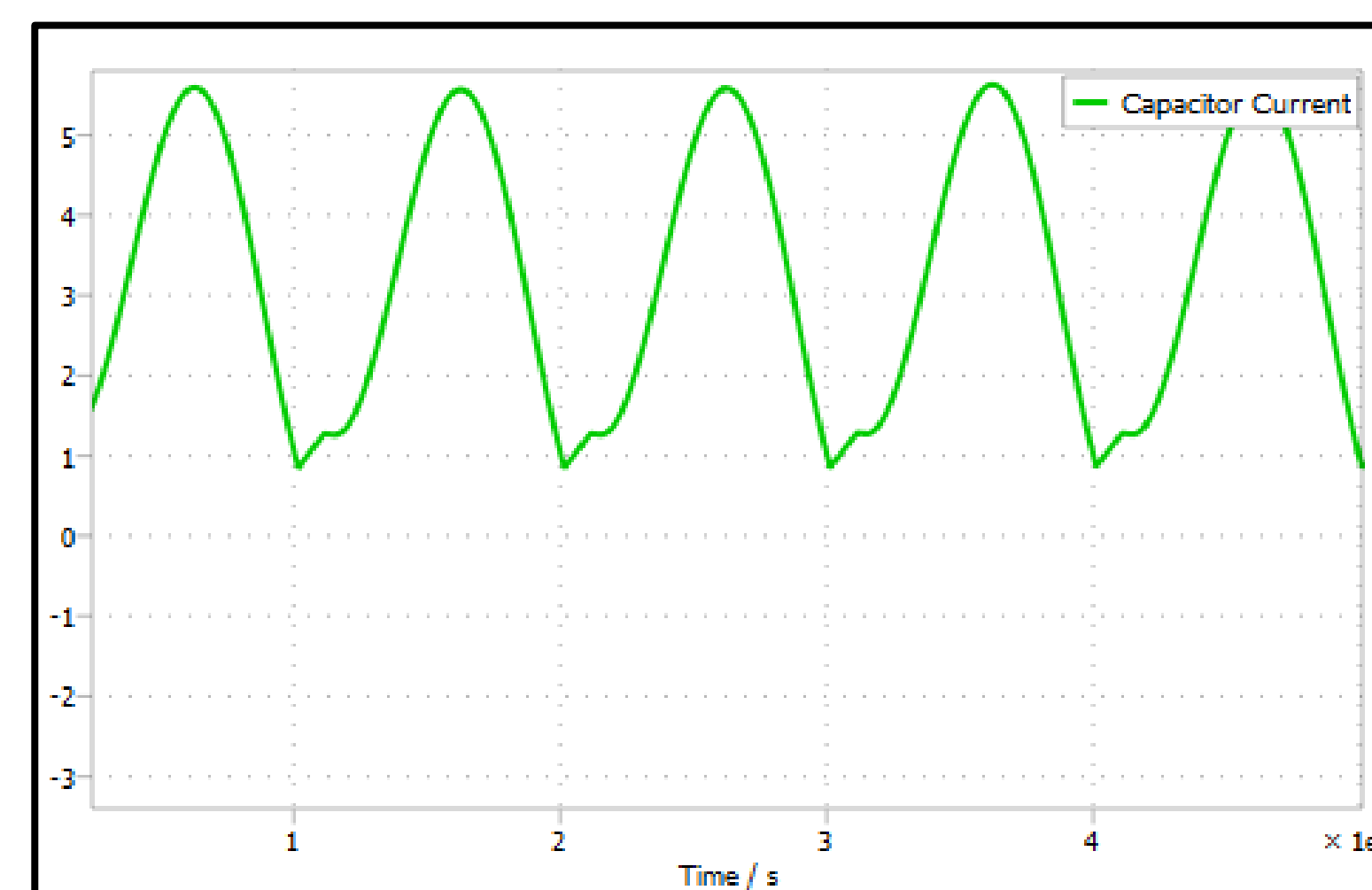
Results: Assembled 3 sets of magnetics with different turns ratios (2:1, 4:1, and 9:1) to evaluate converter at different conversion ratios.



Battery Charge Mode
• Invariant to stepped source



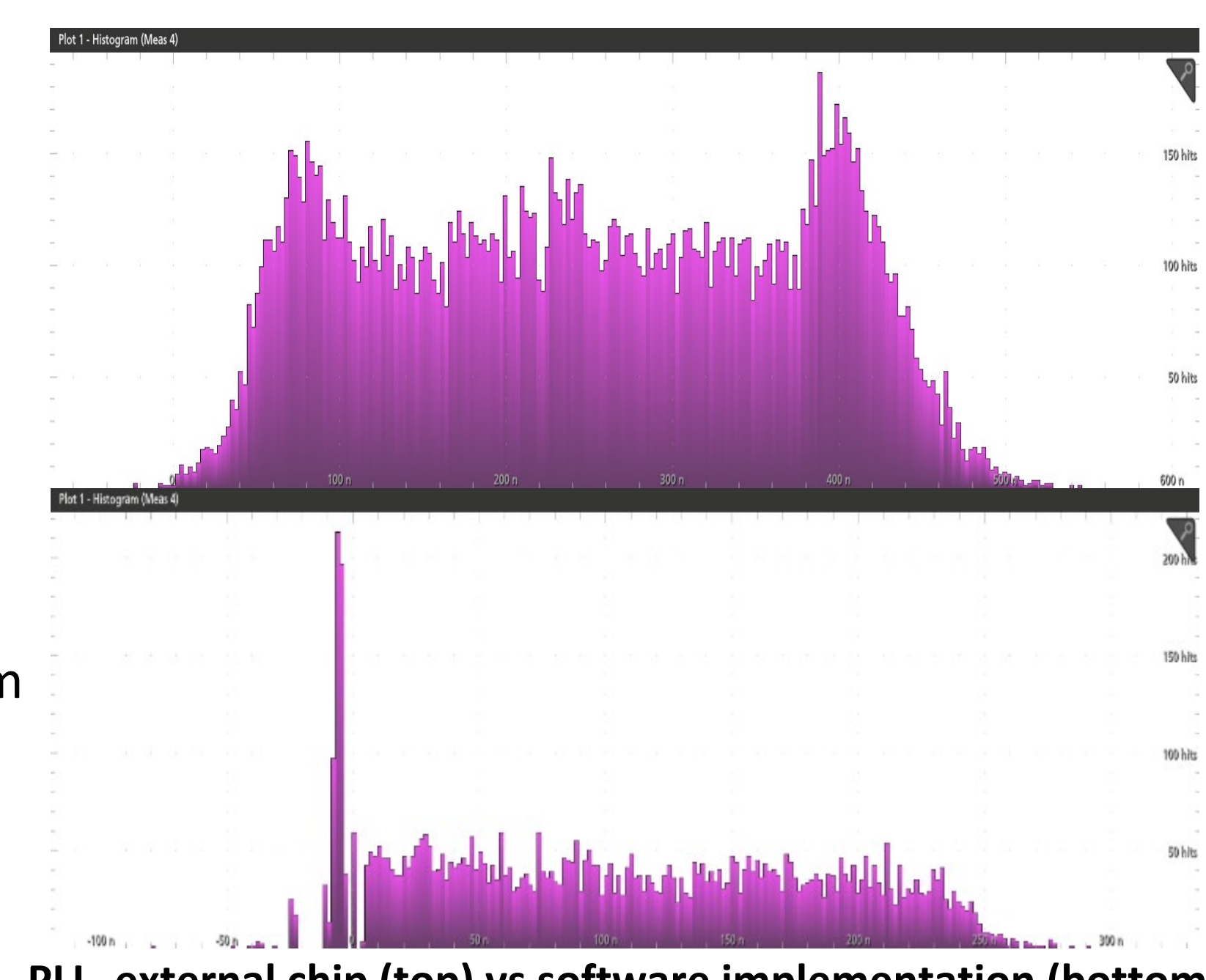
Battery Backup Mode
• Load step 80 W → 160 W → 80 W
• 1.5% change in output voltage, 2 ms recovery



Switching of resonant circuit: simulated (left), measured (right)

Remaining Work

- Test battery backup mode with 100x conversion ratio
- Next gen board development
 - Optimization of resonant tank, switching dynamics, phase-locked loop (PLL)
- Evaluate control stability and dynamics
- System testing
 - Characterize baseline with locally installed system
 - Optimize performance of our system across various load profiles
- Commercialization strategy
 - Tribal, DoD, data centers, marine/RV



PLL, external chip (top) vs software implementation (bottom)



Acknowledgement: This material is based upon work supported by the U.S. Department of Energy, Office of Electricity (OE), Energy Storage Division.

Contact: crecio@mainstream-engr.com