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High Gain DC-DC Converter Collaborative
The Ohio State University Design

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Background and Objectives

A fundamental challenge for the battery storage in grid applications is that power systems favor high-voltage/low-current operations, while electrochemical cells are naturally low-voltage/high-current devices. Isolated high-voltage-gain dc-dc converters may be used to overcome this issue. But designing converters with simultaneously high efficiency and high voltage gain over a realistic range of operating conditions is a difficult task.

The effort presented in this poster is part of a family of projects focused on advancing the state-of-the-art in isolated converter design for battery storage applications. These projects share a common set of performance objectives but differ greatly in individual approach. Each unique solution represents a data point from within the space of design possibilities, and provides valuable insights on potential design synergies and areas for future exploration.

Table I – Converter Performance Specifications

Parameter	Value
Input Voltage Range	380 V – 420 V (400 V nominal)
Output Voltage Range	20 V – 33.6 V (24 V nominal)
Rated Power	±1 kW (bi-directional)
Efficiency	>95% for both charge and discharge
Battery Current Ripple	<2 A peak-to-peak

Proposed Circuit Topology

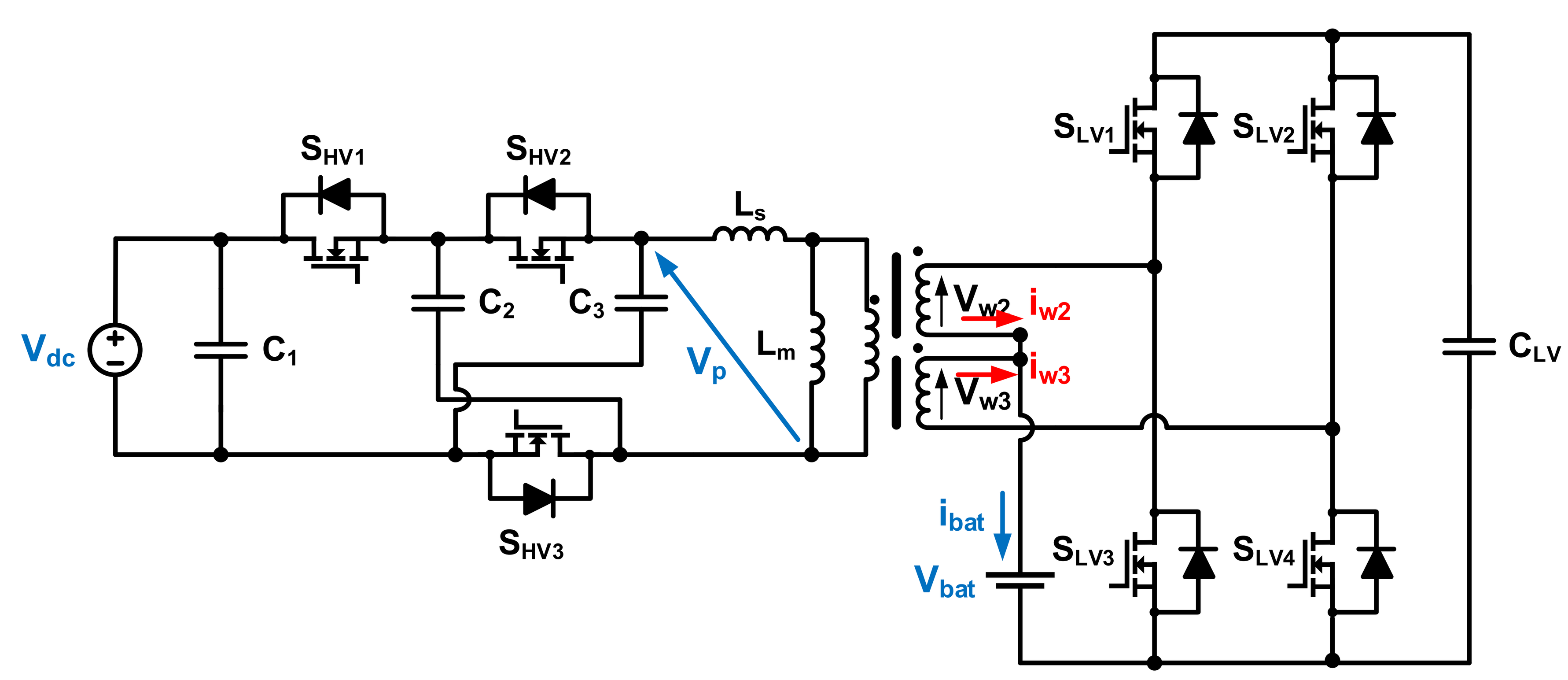

Figure 1 – Circuit diagram of the proposed isolated dc/dc circuit

High-voltage side quasi-switched-capacitor (QSC) circuit

- Reduced switching device voltage stress: $\frac{2}{3}V_{dc}$
    - Enhanced reliability of switching device operations
- Reduced voltage stress of transformer winding (primary side): $\pm\frac{1}{3}V_{dc}$
    - Increased circuitry's voltage conversion ratio
    - Reduced transformer winding turns and enhance the coupling between primary and secondary windings

Low-voltage side transformer-interleaved circuit

- Boosted voltage stress of transformer winding ($V_{W2}+V_{W3}$): $\pm 2V_{bat}$
    - Increased circuitry's voltage conversion ratio
    - Reduced transformer winding turns
- Reduced battery current ripples by interleaved operations (W2 and W3)

Circuit Simulation Results

Table 2 – Simulation Parameters

Parameter	Value
DC side voltage V_{dc}	400 V
Battery side voltage V_{bat}	24 V
Operation power P_{in}	1000 W
Switching frequency f_{sw}	300 kHz
Transformer turns ratio N	6 : 1 : 1
Resonant inductance L_s	6 μH
Transformer magnetizing inductance L_m	64 μH
LV side capacitance C_{LV}	33 μF
Switched capacitance C_2/C_3	5 μF

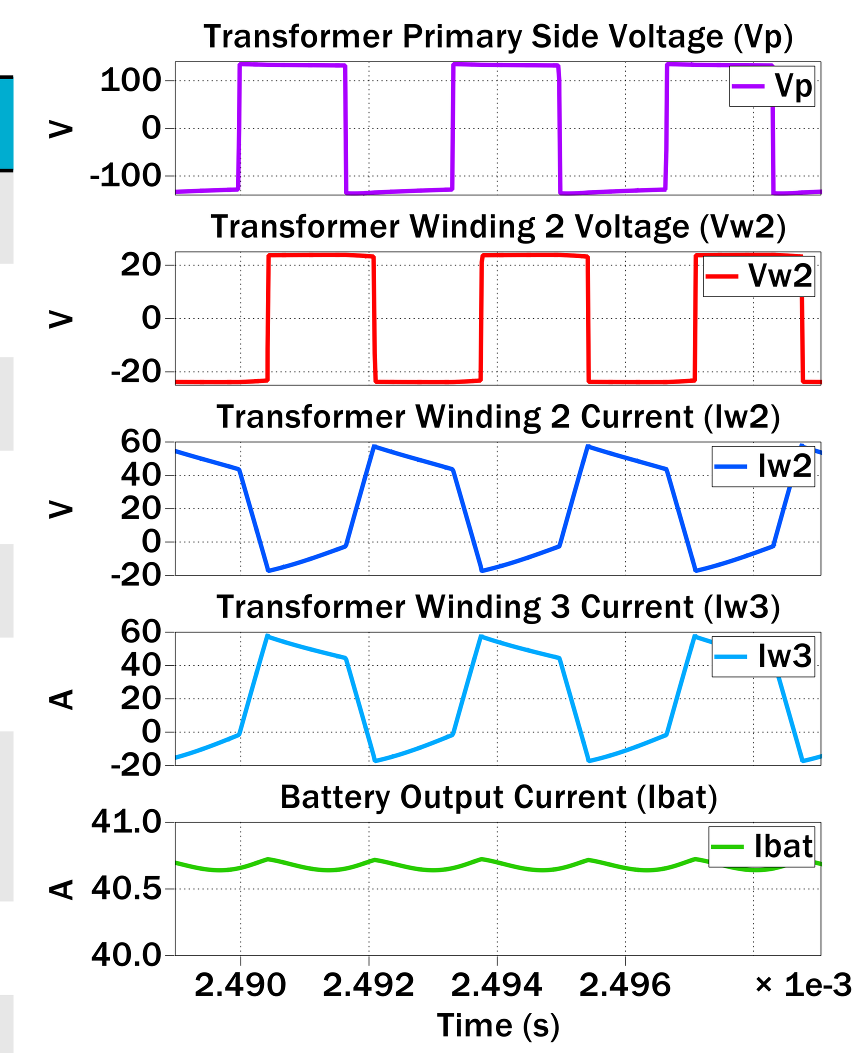

Figure 2 – Circuit simulation waveforms

Prototype and Experimental Results

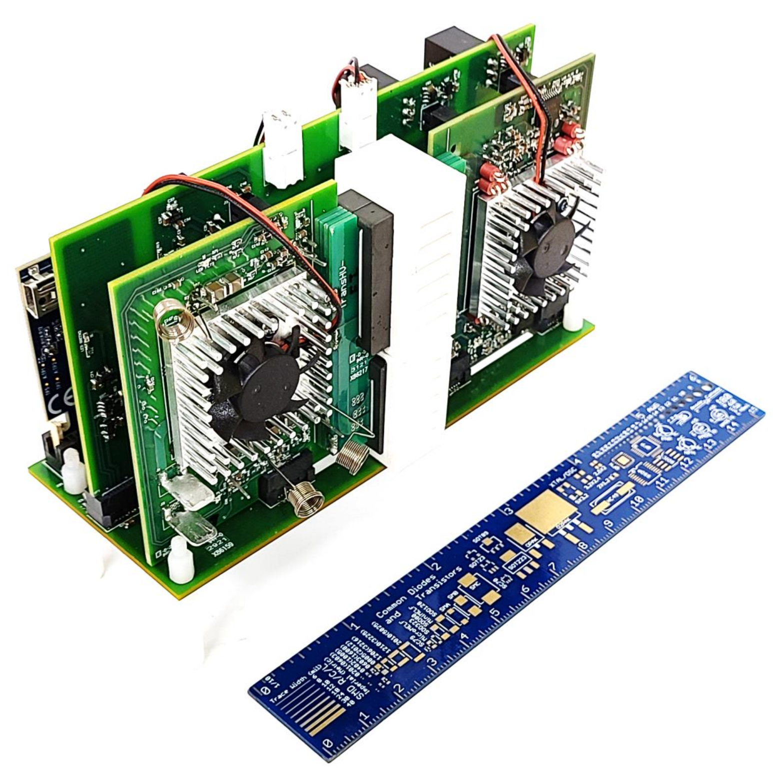

Figure 3 – Prototype of proposed circuit

Prototype specifications

- Volume: 13.0 cm × 7.4 cm × 5.3 cm
- Power density: 1.96 W/cm^3
- Expected efficiency: 98.1% at 1-kW charging

Preliminary results

- Verified QSC device voltage stress: $\frac{2}{3}V_{dc}$ (267 V)
- Device waveforms show clean switching
- Tests on low-voltage side circuit in progress

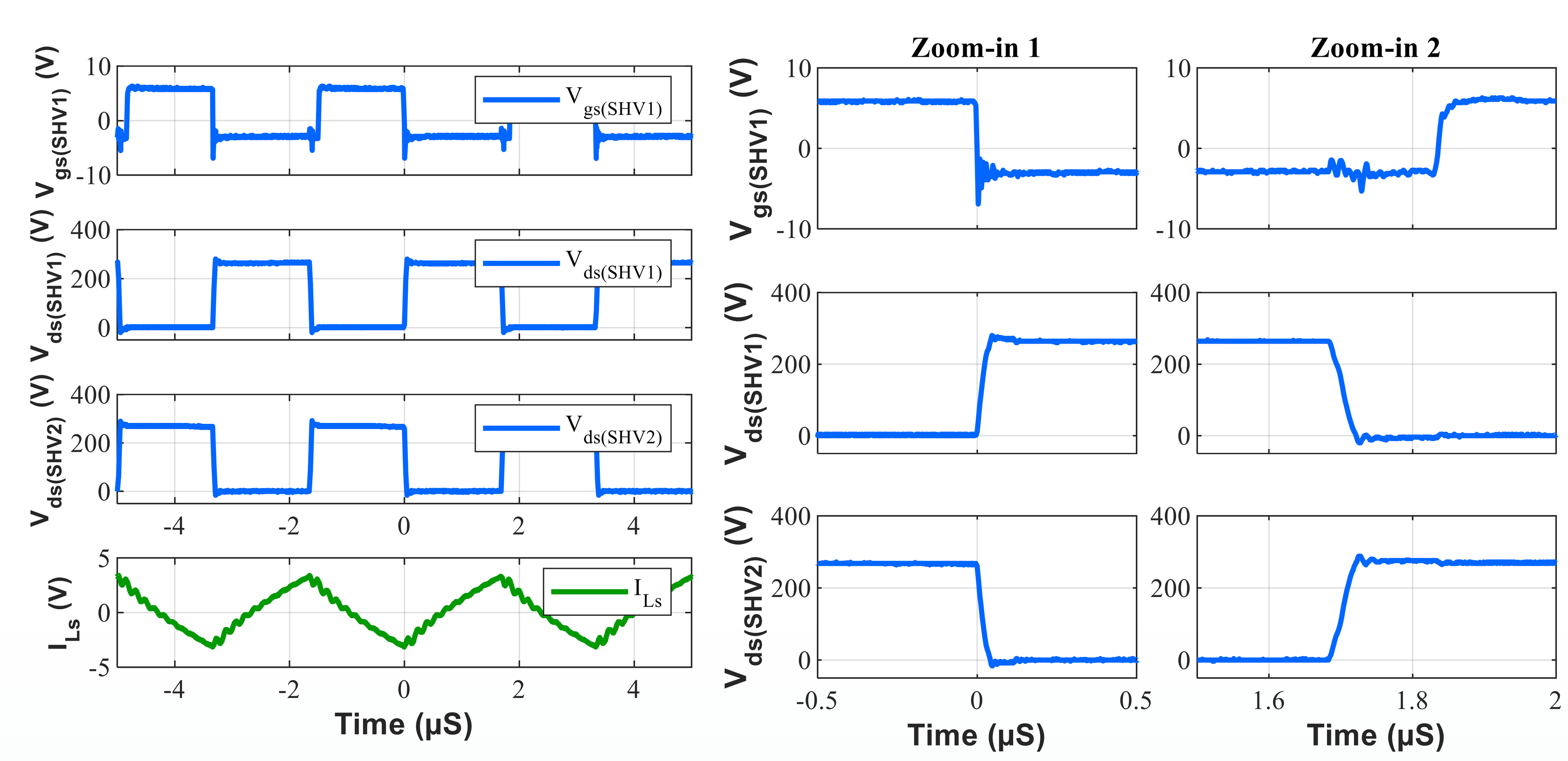

Figure 4 – QSC circuit test waveform at light load condition

Conclusions

A QSC transformer-interleaved circuit was proposed to fulfill the targeted voltage gain and current ripple requirements. A 1-kW, 300-kHz, 400-V/24-V circuit prototype has been designed and built based on proposed circuitry. Preliminary test results have verified the circuit analysis for the QSC circuit. Additional experiments are in progress to verify the operation of the whole converter.

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