An EMI-Compliant and Automotive-Rated 48 V-to-PoL Dickson-Based Hybrid Switched Capacitor DC-DC Converter

Berkeley Power and Energy Center

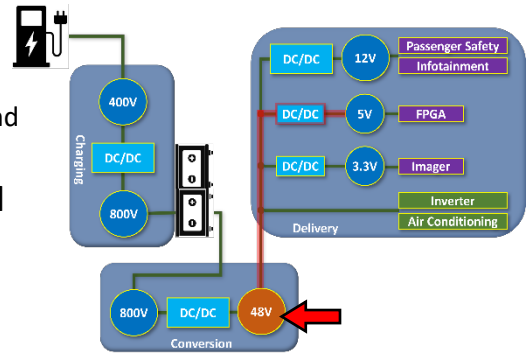
Motivation and Application

Data center power delivery and automotive powertrains tending towards a 48 V distribution rail

- Higher intermediate bus voltages minimize losses and reduce cabling weight

This work demonstrates the merit of hybrid SC topologies for use in 48 V automotive systems

- Regulating Dickson-based hybrid SC topology
- EMI mitigation techniques – filtering and spread-spectrum frequency modulation



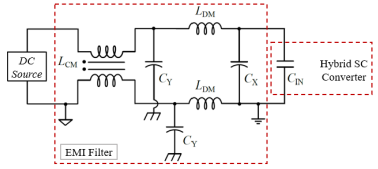
48 V automotive bus architecture

Hardware Implementation

Uses only automotive-qualified parts

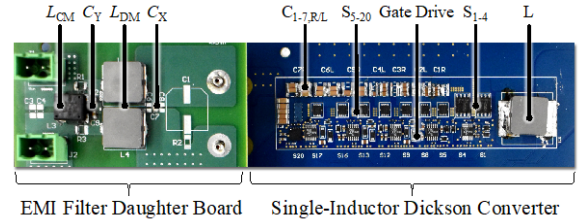
Switch selection based on required function, both Si and GaN

EMI input filter and spread spectrum frequency modulation (SSFM) to reduce EMI



Input EMI filter schematic

Switches and Key Parameters			
Switch	**S1-S4**	**S5-S18**	**S19-S20**
Tech	Si	Si	GaN
Function	Bridge switches	'String' switches	Input switches
$R_{DS(on)}$	1.4 mΩ	3.5 mΩ	2.5 mΩ
V_{DS}	40 V	40 V	80 V



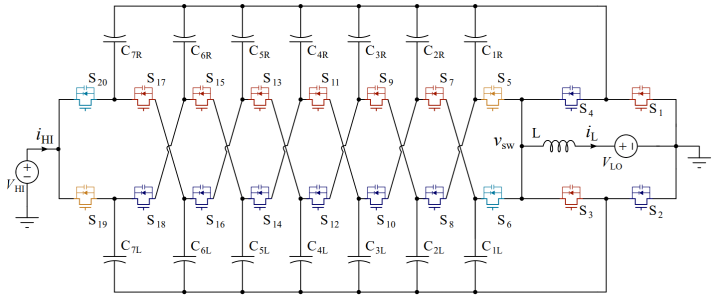
Topology and Challenges

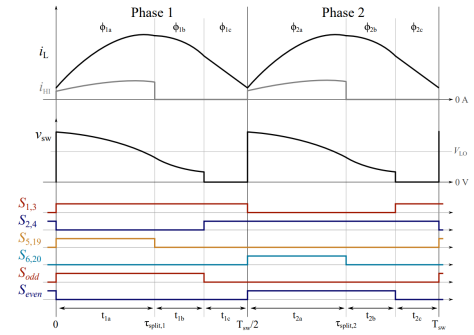
Hybrid switched-capacitor, 8-to-1 interleaved-input, single-inductor Dickson converter

- Differential input → continuous input current → reduced required input filter
- Inductor at output → filtering and EMI shielding at low side
- Inductor at output → voltage regulation

Challenges

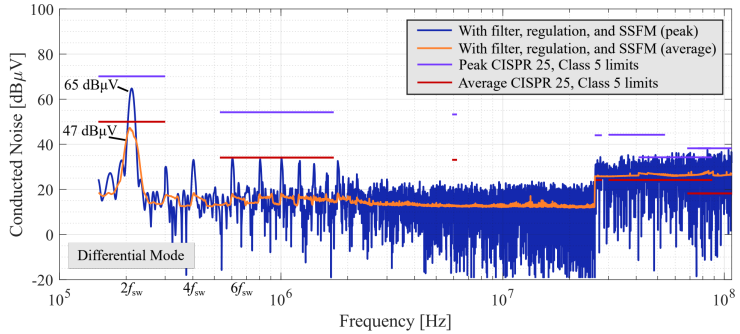
- Split-phase switching necessary for soft-charging of the flying capacitors
- Automotive component selection
- High efficiency, power density, and CISPR 25 Class 5 EMI compliance





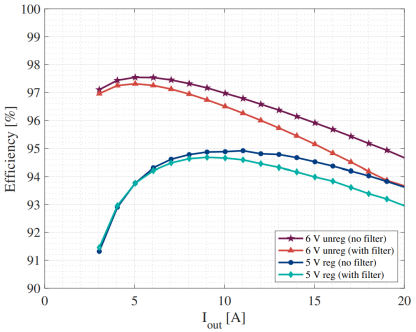
Experimental Results

Differential Mode (DM) EMI results



Peak and average DM emissions plots for above-resonant (~106 kHz) regulated 5 V operation with SSFM enabled

Converter Operating Parameters			
V_{IN}	**V_{OUT}**	**$P_{LO,max}$**	**f_{sw}**
48 V	6 V, 5 V	120 W	106 kHz



Measured efficiency of hardware prototype

References: [1] M. E. Blackwell, et al., "Direct 48 V to 6 V Automotive Hybrid Switched-Capacitor Converter with Reduced Conducted EMI," *2022 IEEE 23rd Workshop on Control and Modeling for Power Electronics (COMPEL).* [2] S. Krishnan, et al., "An EMI-Compliant and Automotive-Rated 48V to Point-of-Load Dickson-Based Hybrid Switched-Capacitor DC-DC Converter," *2023 IEEE Transportation Electrification Conference & Expo (ITEC)*

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