Analysis of Phase Timings for a Zero-Voltage Switching, Split-Phase Hybrid Dickson Converter

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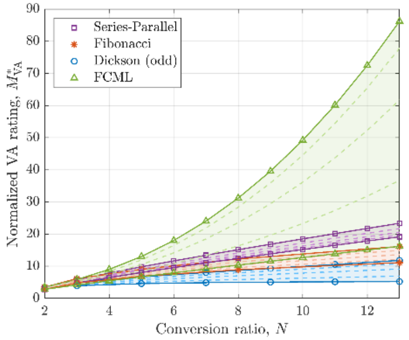
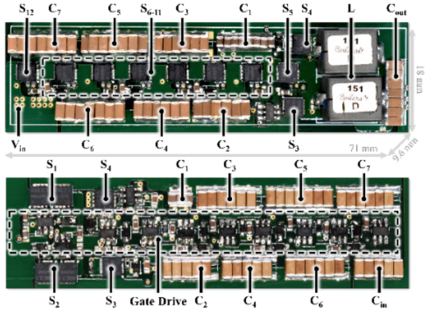
Motivation and Application

- Dickson-based converters are popular for hybrid switched capacitor (SC) solutions due to the reduced switch stress as compared to other topologies [1]
- Applications: high-conversion ratio systems
  - 48 V bus architectures for data centers and automotive powertrains
- Transistor switching losses can be significant share of overall losses, especially with trends towards faster switching frequencies
- Soft-switching techniques, such as zero-current and zero-voltage switching (ZCS and ZVS) can be used to reduce these losses



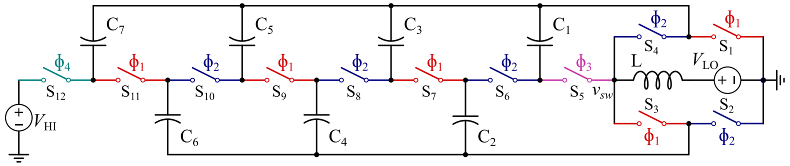
Switch Stress Metric (VA rating) for various hybrid SC converters over conversion ratios showing the Dickson converter having very low relative switch stress

Hardware

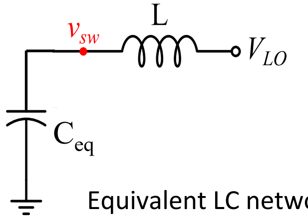


48 V-to-6 V prototype

- Per-phase analysis of an equivalent LC network to determine phase-timings
- Equivalent capacitance Ceq:
  - Main phases: A network of the flying capacitors C_1-C_7
  - ZVS sub-phases: A network of linearized transistor output capacitances [2]



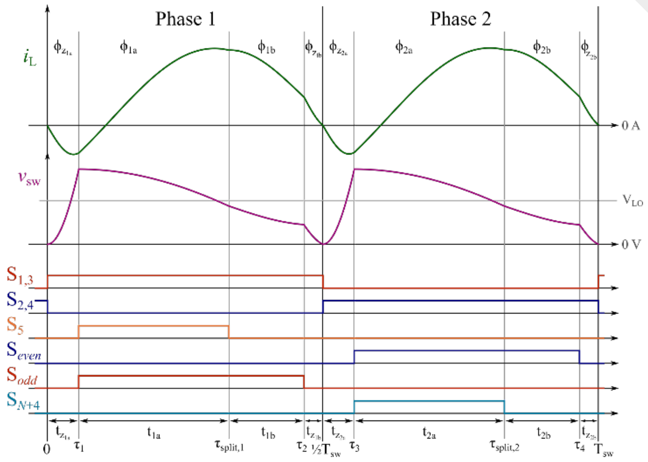
Schematic drawing of the 8-to-1 hybrid Dickson power stage



Equivalent LC network for per-phase analysis

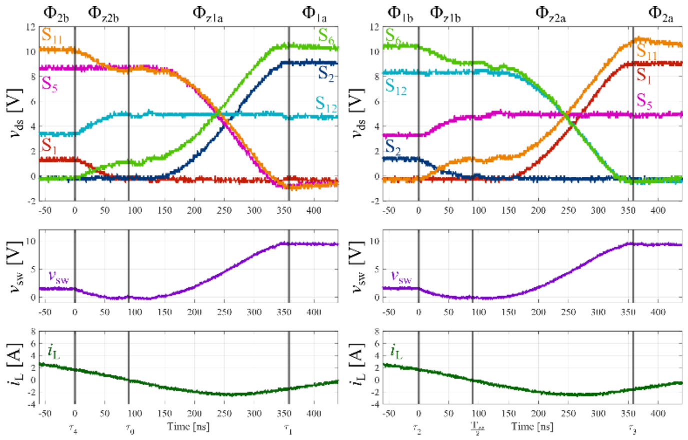
Challenges

- Phase-timings become non-trivial to determine
- ZVS timings are also non-trivial
  - Non-linear switch output capacitance
  - Multiple switches with different blocking voltages

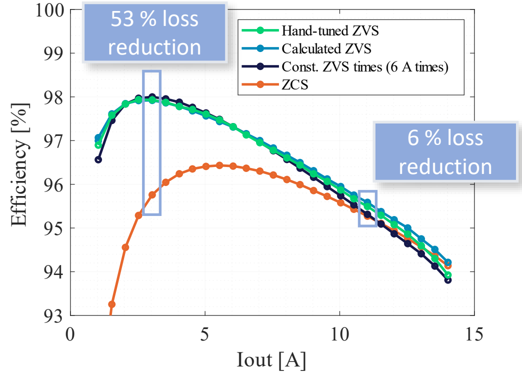


Exemplary phase-timings and waveforms of a resonant Dickson converter achieving ZVS on all switches

Experimental Verification



Measured drain-source voltages showing ZVS for all switches



An efficiency comparison of ZVS to ZCS, as well as calculated timings to fixed timings

References:

[1] N. M. Ellis, et. al., "A General Approach to Optimization and Control of Resonant Switched Capacitor Converters Using Peak Energy Storage and Switch Stress Including Ripple Considerations," *IEEE Transactions on Power Electronics, Early Access.*

[2] M. Kasper, R. M. Burkart, G. Deboy, and J. W. Kolar, "ZVS of Power MOSFETs Revisited," IEEE Transactions on Power Electronics, vol. 31, no. 12, pp. 8063–8067, Dec 2016.

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