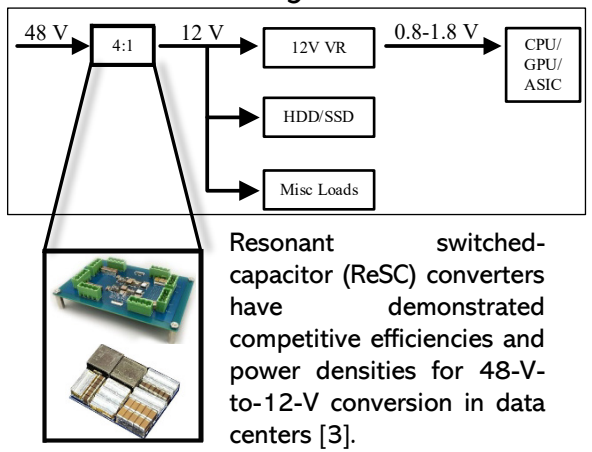
Autotuning of Resonant Switched-Capacitor Converters for Soft Switching Operation

Berkeley Power and Energy Center

Motivation and Application

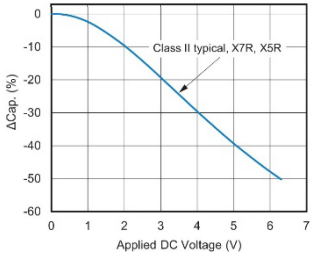
Data Center Two-Stage Power Architecture



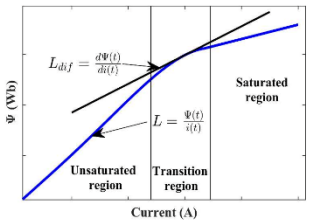
Resonant switched-capacitor (ReSC) converters have demonstrated competitive efficiencies and power densities for 48-V-to-12-V conversion in data centers [3].

Due to finite terminal filtering capacitances, the efficiency of ReSC converters is often maximized when they are precisely soft switched [4]. However, circuit non idealities render ZCS and ZVS timing challenging to estimate creating the need for active control techniques.

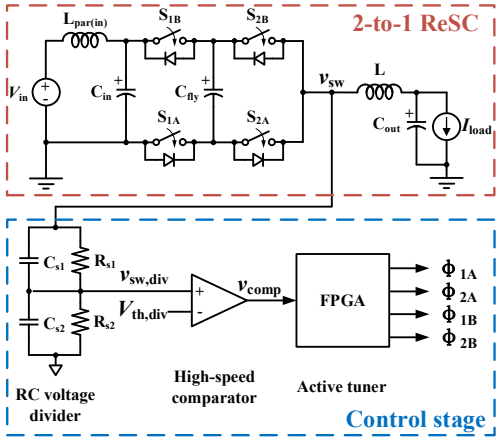
Class II MLCC DC Bias Derating

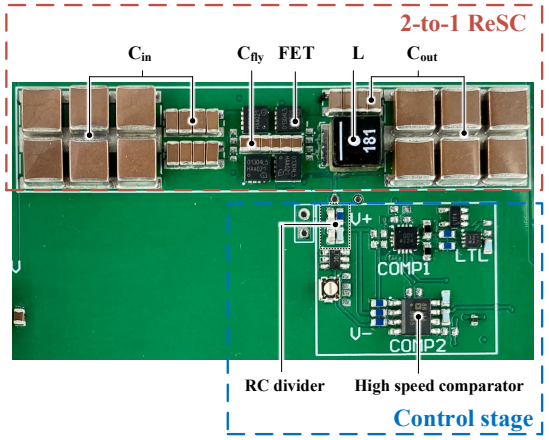


Inductor Soft Saturation



Hardware

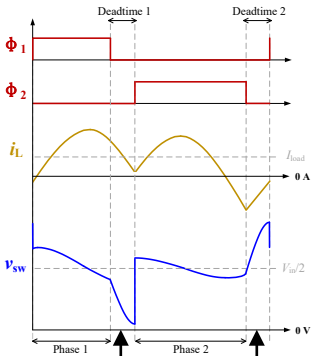




The presented 2-to-1 converter is the foundational ReSC topology. The control technique is verified on a 48-V-to-24-V hardware prototype and can be extended to higher conversion ratio topologies.

Theory and Control

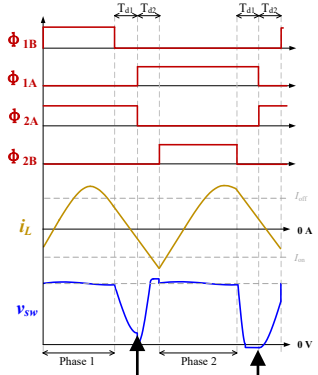
Non-Ideal ZCS



Positive turn-off inductor current → switch node voltage below $\frac{V_{in}}{2}$

Negative turn-off inductor current → switch node voltage above $\frac{V_{in}}{2}$

Non-Ideal ZVS

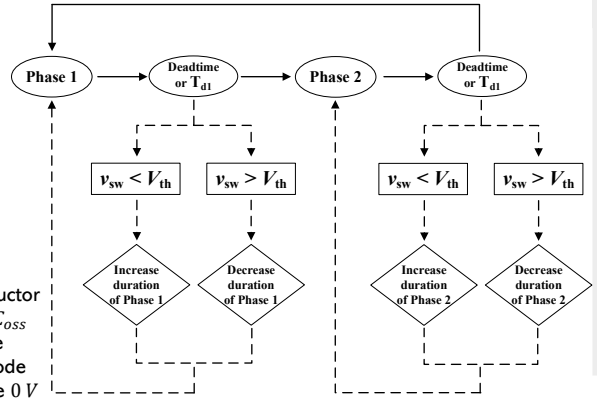


Insufficient inductor current for C_{oss} discharge → switch node voltage above $0\ V$

Excessive inductor current for C_{oss} discharge → switch node voltage above $0\ V$

By sensing the switch node voltage, non-ideal soft switching conditions can be detected. Complete ZCS or ZVS can then be achieved by implementing the proposed control scheme.

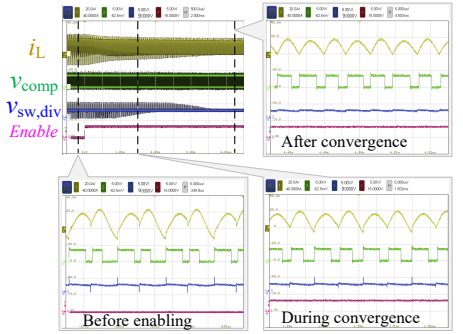
Control Flowchart



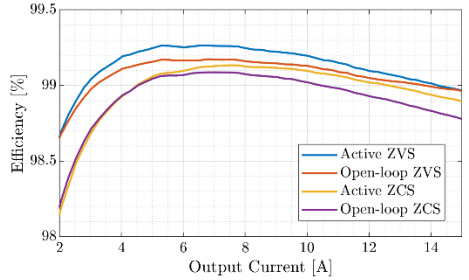
Experimental Verification

- Convergence to complete soft switching can be achieved from a wide range of initial switching frequencies.
- Active ZVS and ZCS control allow for higher peak efficiencies than the conventional open-loop techniques.

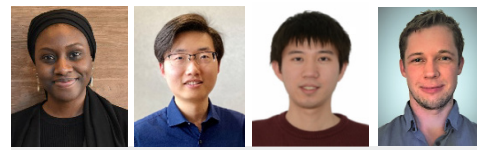
Convergence to Soft Switching



Efficiency



References:
[1] H. Sambo, Y. Zhu, T. Ge, N. Ellis, and R. Pilawa-Podgurski, "Autotuning of Resonant Switched-Capacitor Converters for Zero Current Switching and Terminal Capacitance Reduction," APEC 2023.
[2] H. Sambo, Y. Zhu, and R. Pilawa-Podgurski, "Autotuning of Resonant Switched-Capacitor Converters for Zero Voltage Switching," COMPEL 2023.
[3] T. Ge, Z. Ye, and R. Pilawa-Podgurski, "Geometrical State-Plane Analysis of Resonant Switched-Capacitor Converters: Demonstration on the Cascaded Multiresonant Converter," TPEL 2023.
[4] Y. Zhu, Z. Ye, T. Ge and R. Pilawa-Podgurski, "Multi-Resonant Compensation Control for Terminal Capacitance Reduction in Resonant Switched-Capacitor Converters," COMPEL 2021.



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