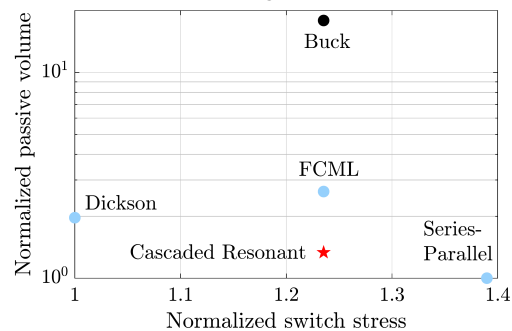


High Efficiency High Power Density Hybrid/Resonant Switched-Capacitor Converter



Theoretical Analysis



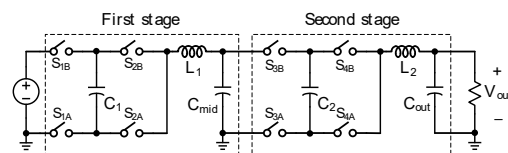
- Systematically analyze and calculate switch and passive utilization
- Compare and select the most suitable topology depending on application and power level
- Develop control technique to achieve soft-charging and soft-switching

Switch VA rating

$$\left(\sum_{switches} V_{ds} I_{ds} \right)$$

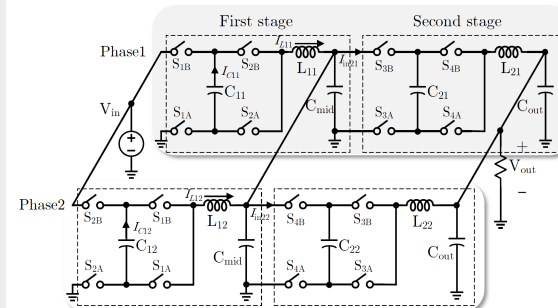
Total passives volume

$$\left(\frac{1}{2} \sum C V^2 + \frac{1}{2} \sum L I^2 \right)$$



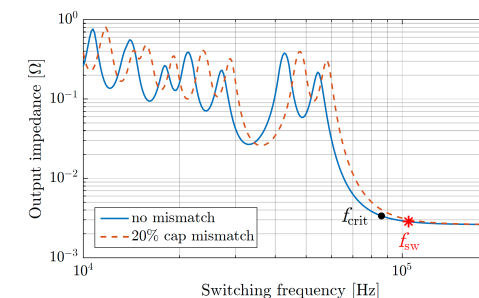
Cascaded Resonant Converter

Two-phase interleaved design



- Overcome the intermediate decoupling challenge of doubler topology

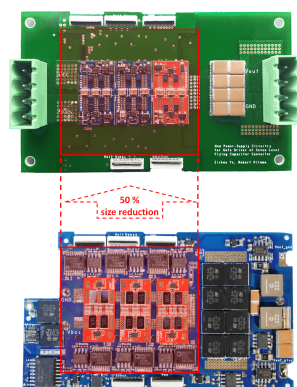
Zero voltage switching technique



- Operate the tank in the inductive region to achieve ZVS, while improving tolerance of component variations

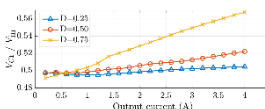
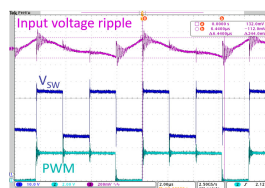
Practical Challenges and Solutions

Floating gate drive



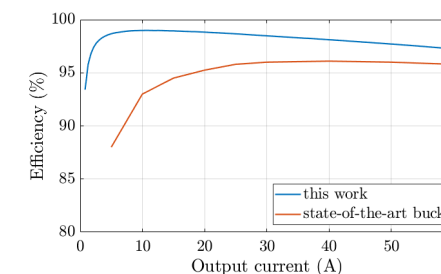
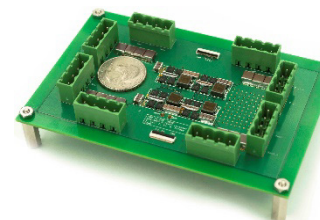
- Improved bootstrap and charge pump techniques to replace isolated dc/dc power supplies
- Achieving higher efficiency, lower cost and smaller footprint
- Working on system level circuit integration to further reduce size and cost

Capacitor voltage balancing

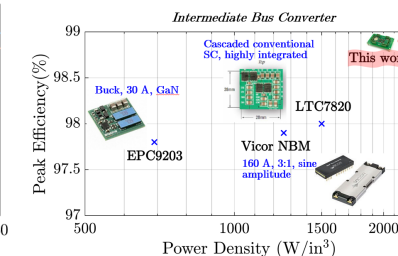


- Experimentally verified that source impedance and input capacitance can affect balancing drastically
- Even-level FCML converter has better natural balancing
- Gate drive voltage and signal mismatch can cause imbalance

Experimental Verification



Comparison with state-of-the-art



References:

- [1] Z. Ye, Y. Lei, W. Liu, P. S. Shenoy and R. C. N. Pilawa-Podgurski, "Design and implementation of a low-cost and compact floating gate drive power circuit for GaN-based flying capacitor multi-level converters," *APEC 2017*
- [2] Z. Ye, Y. Lei, Z. Liao and R. C. N. Pilawa-Podgurski, "Investigation of capacitor voltage balancing in practical implementations of flying capacitor multilevel converters", *COMPEL 2017*
- [3] Z. Ye, Y. Lei and R. C. N. Pilawa-Podgurski, "A resonant switched capacitor based 4-to-1 bus converter achieving 2180 W/in³ power density and 98.9% peak efficiency," *APEC 2018*

