Extreme Density Power Electronics for Space and Solar Photovoltaic Applications

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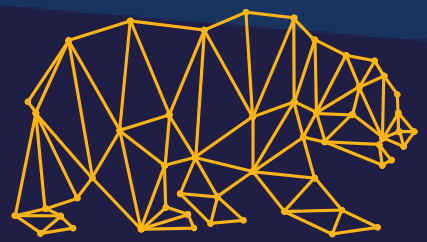

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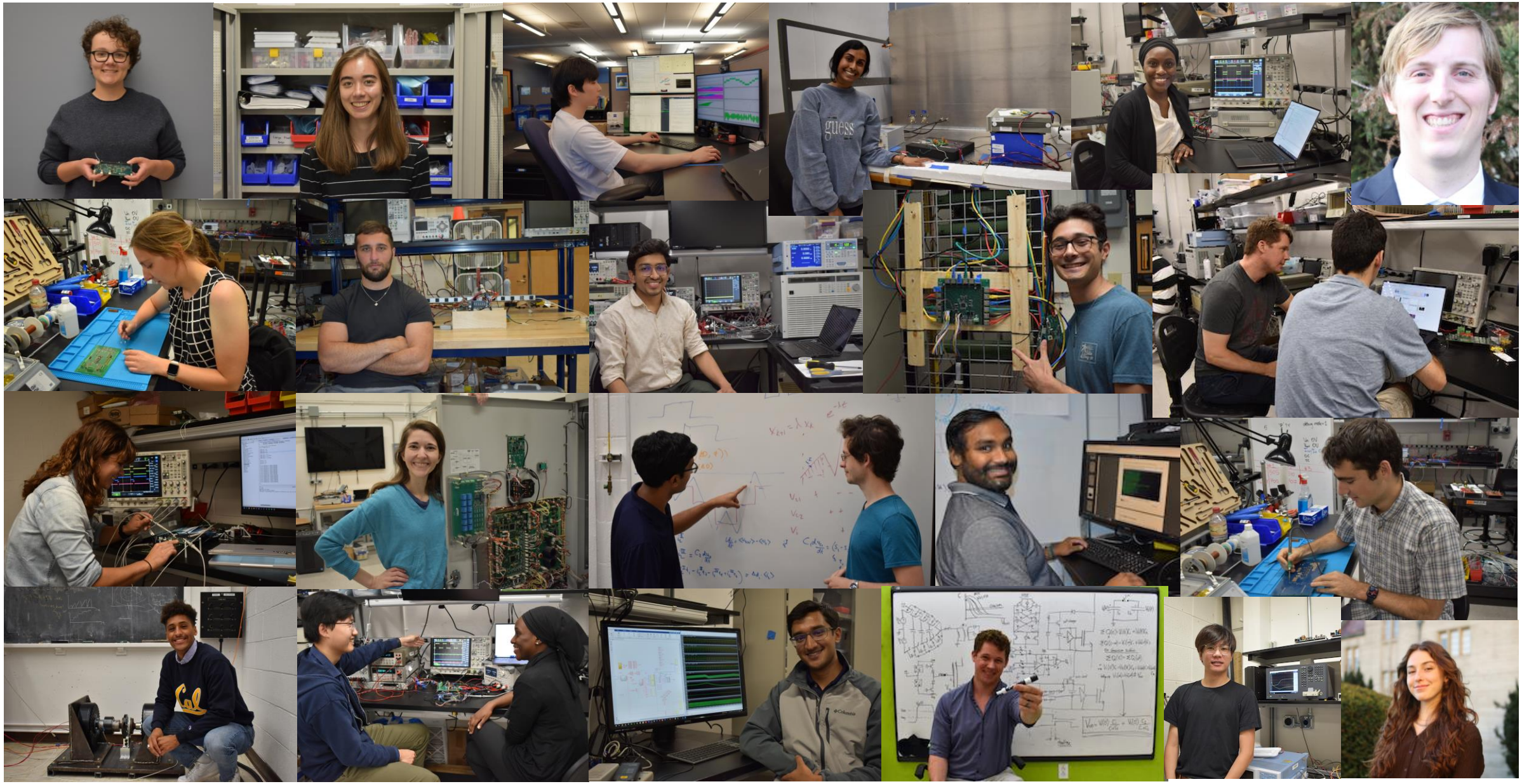

Breadth of Applications

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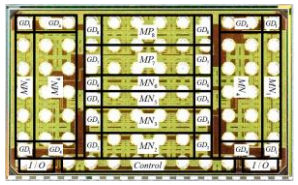
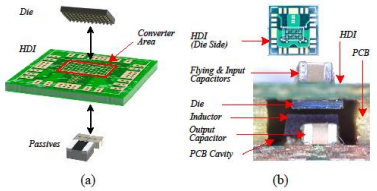
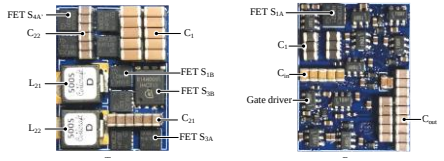
DC/DC

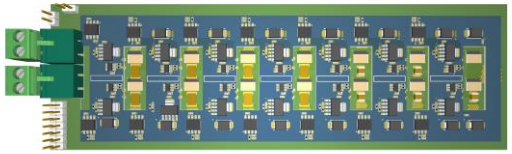
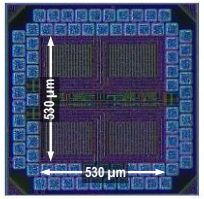
1V

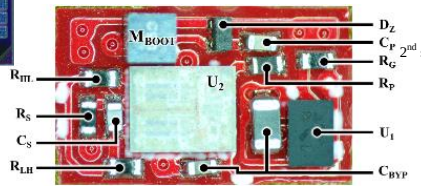
1500V

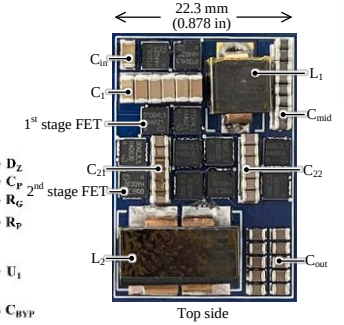
AC/DC &
DC/AC

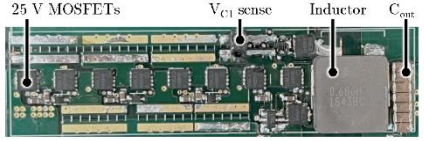



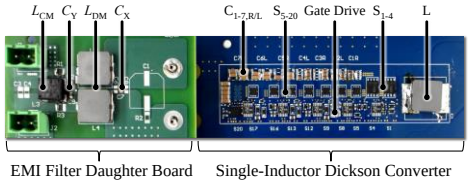


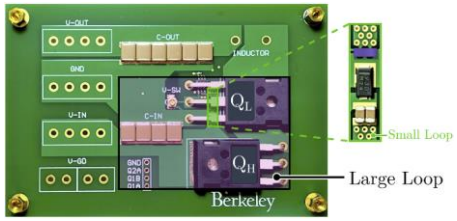




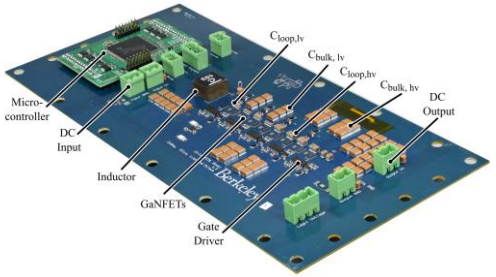


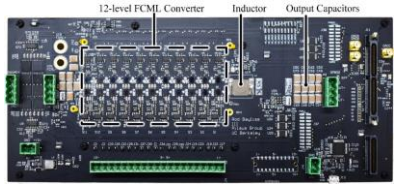


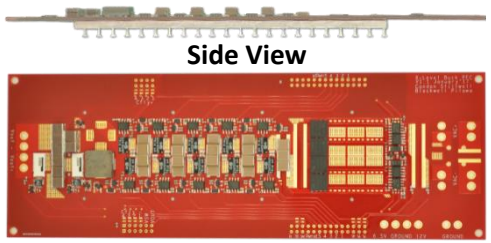


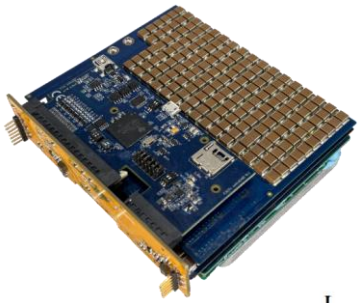
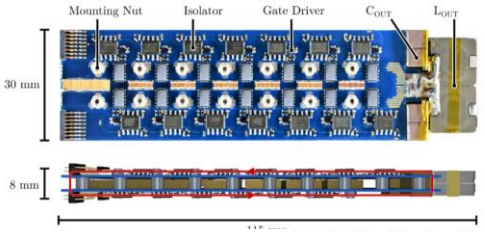


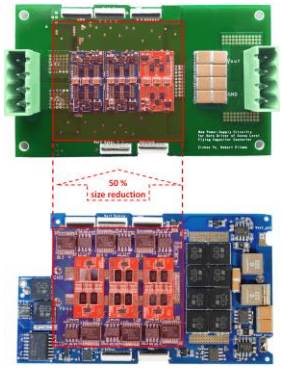


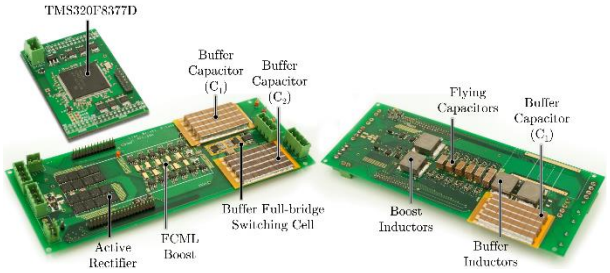


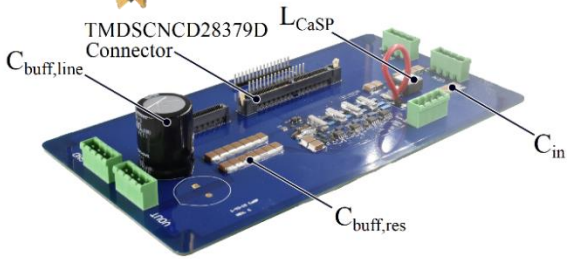


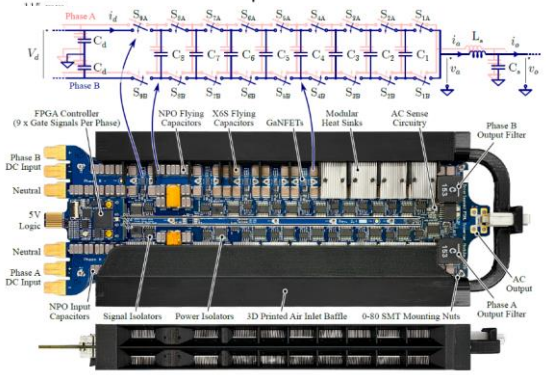




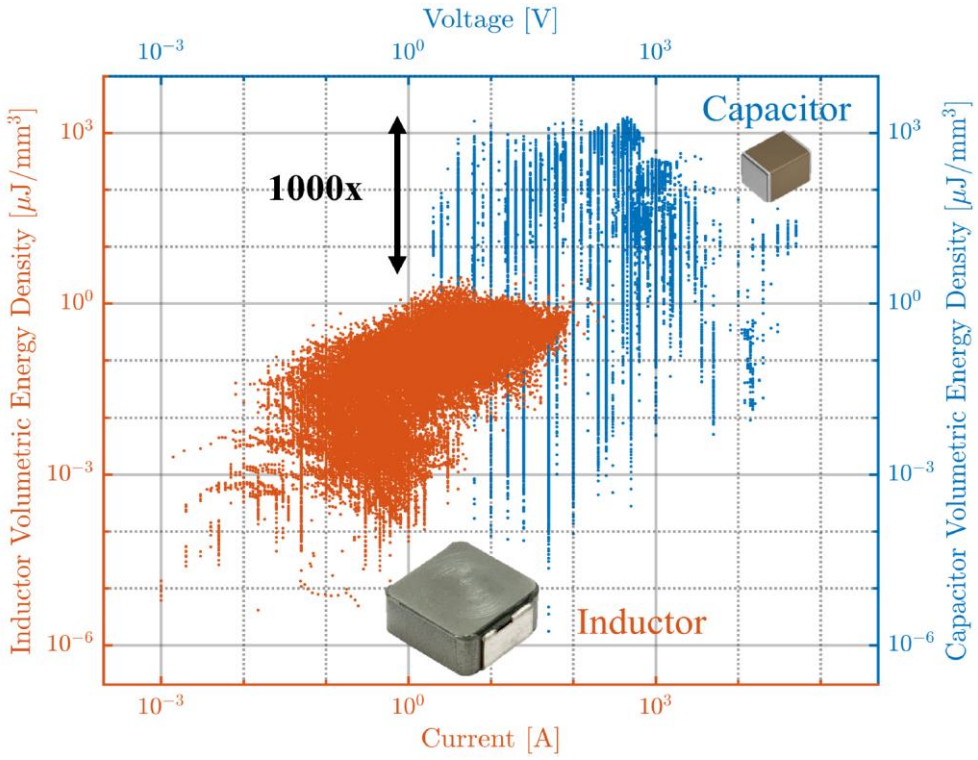




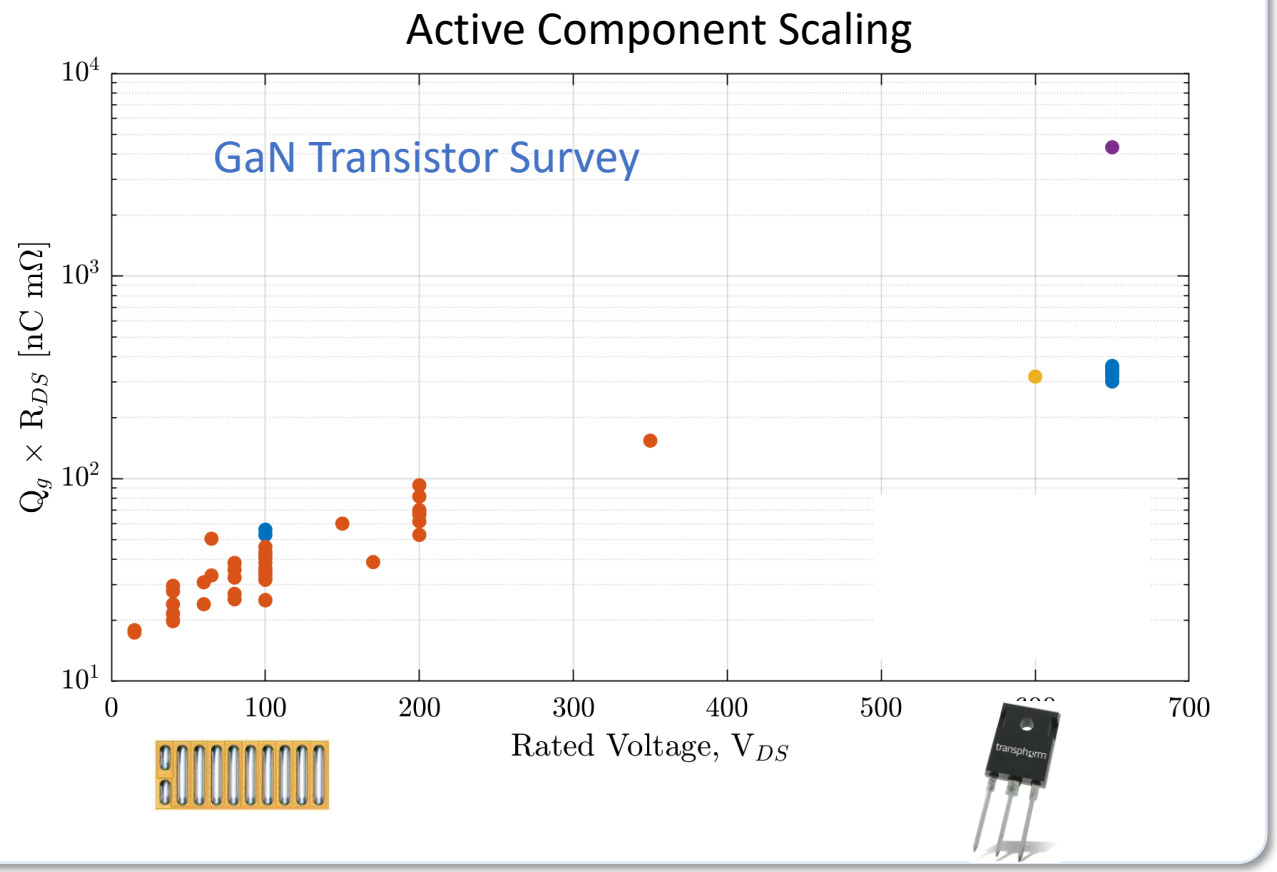


Extreme Density Power Converters

- Our group specializes in high-density, high-efficiency power converters
  - Exploit superior power density of capacitors compared to inductors
  - Leverage advantageous scaling of low-voltage semiconductors (GaN and Si)

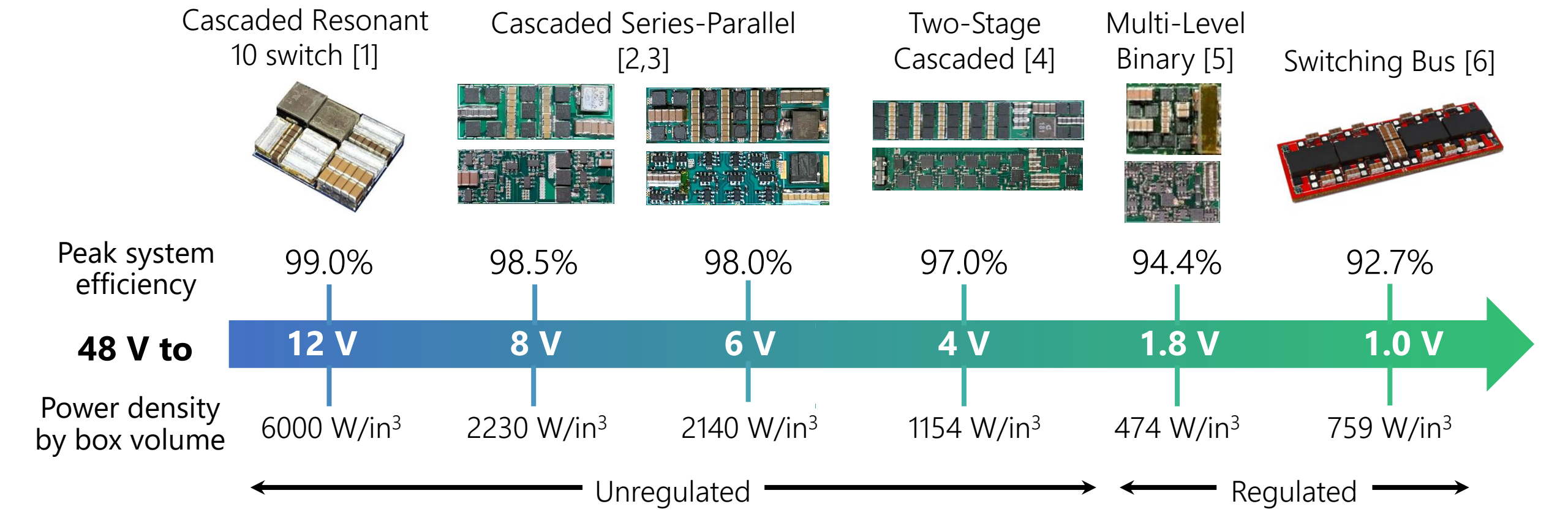


Multi-layer ceramic capacitors can store over 1000x more energy than inductors per unit volume [1]



[1] J. Zou et al., "On the size and weight of passive components: scaling trends for high density power converter designs", COMPEL 2022

Low Voltage DC-DC Solutions



[1] T. Ge, Z. Ye and R. C. N. Pilawa-Podgurski, "Geometrical State-Plane Analysis of Resonant Switched-Capacitor Converters: Demonstration on the Cascaded Multiresonant Converter," in *IEEE Transactions on Power Electronics*, vol. 38, no. 9, pp. 11125-11140, Sept. 2023.

[2] R. A. Abramson, Z. Ye and R. C. N. Pilawa-Podgurski, "A High Performance 48-to-8 V Multi-Resonant Switched-Capacitor Converter for Data Center Applications," *2020 22nd European Conference on Power Electronics and Applications (EPE'20 ECCE Europe)*, 2020.

[3] R. Abramson, Z. Ye, R.C.N. Pilawa-Podgurski, "A High Performance 48-to-6 V Multi-Resonant Cascaded Series-Parallel Switched-Capacitor Converter", *IEEE Applied Power Electronics Conference and Exposition (APEC)*, 2021.

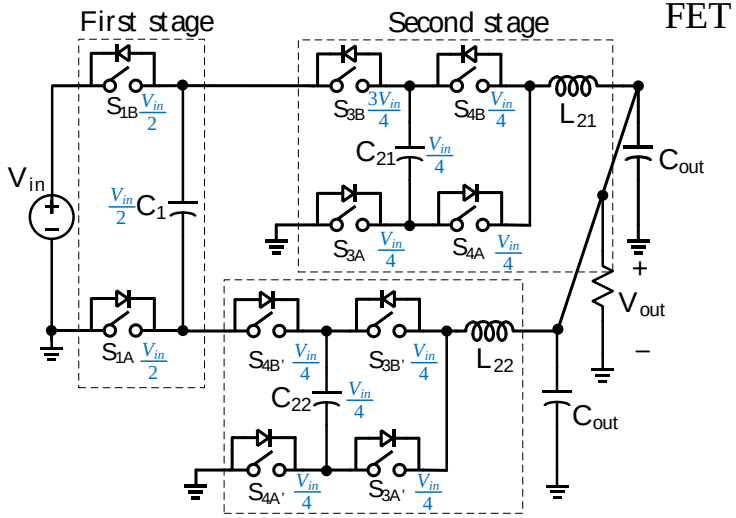
[4] W.C. Liu, Z. Ye, R.C.N. Pilawa-Podgurski, "A 97% Peak Efficiency and 308 A/in^3 Current Density 48-to-4 V Two-Stage Resonant Switched-Capacitor Converter for Data Center Applications" *IEEE Applied Power Electronics Conference and Exposition (APEC)*, 2020.

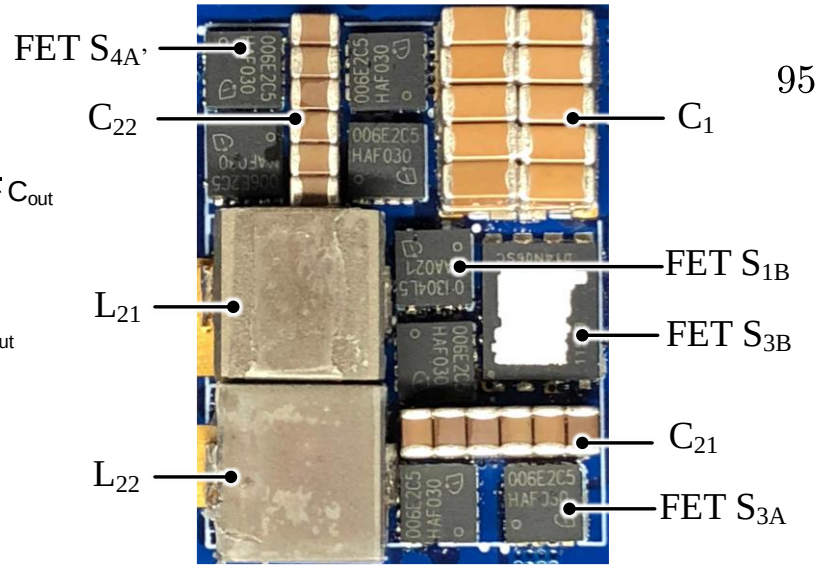
[5] T. Ge, R. Abramson, Z. Ye and R. C. N. Pilawa-Podgurski, "Core Size Scaling Law of Two-Phase Coupled Inductors – Demonstration in a 48-to-1.8 V Hybrid Switched-Capacitor MLB-PoL Converter," *2022 IEEE Applied Power Electronics Conference and Exposition (APEC)*, Houston, TX, USA, 2022.

[6] Y. Zhu, J. Zou, R.C.N. Pilawa-Podgurski, "A 1500-A/ 48-V-to-1-V Switching Bus Converter for Next-Generation Ultra-High-Power Microprocessors", *IEEE Applied Power Electronics Conference and Exposition (APEC)*, 2024.

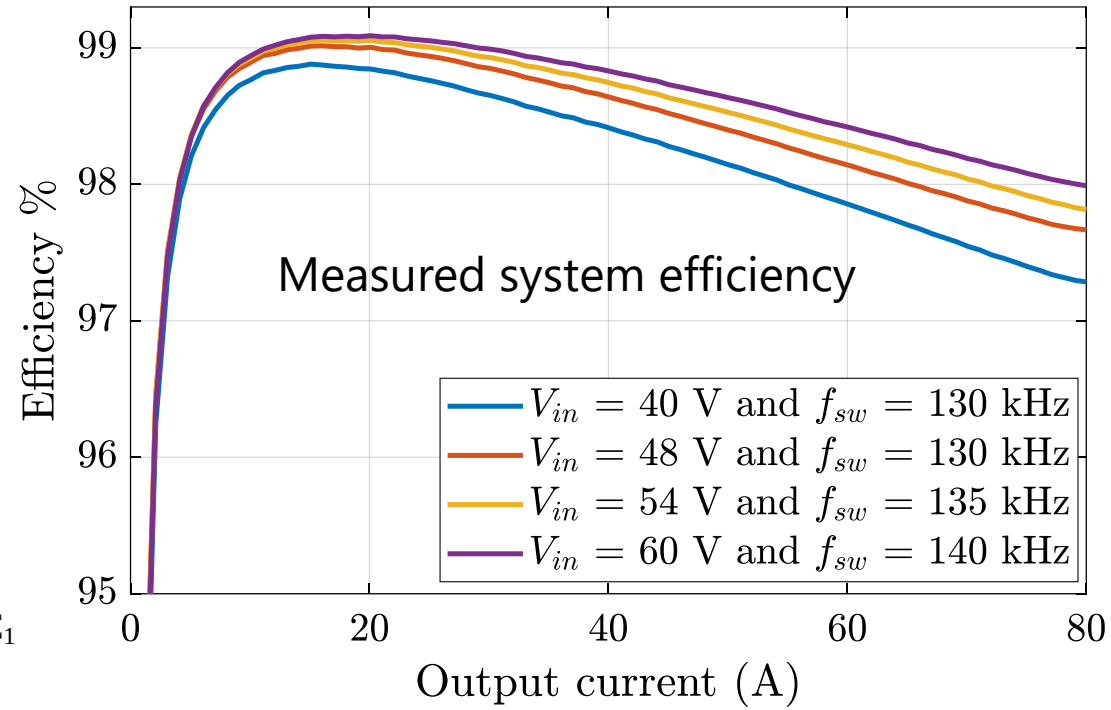
Performance of 48-to-12 V Cascaded ReSC

- 4-to-1 fixed ratio (unregulated)
- Maximum I_{out} = 80 A
- 6000 W/in^3 (366 kW/L) power density
- 9720 W/in^3 (593 kW/L) peak power density
- 99.0% peak and 97.7% full-load system efficiency



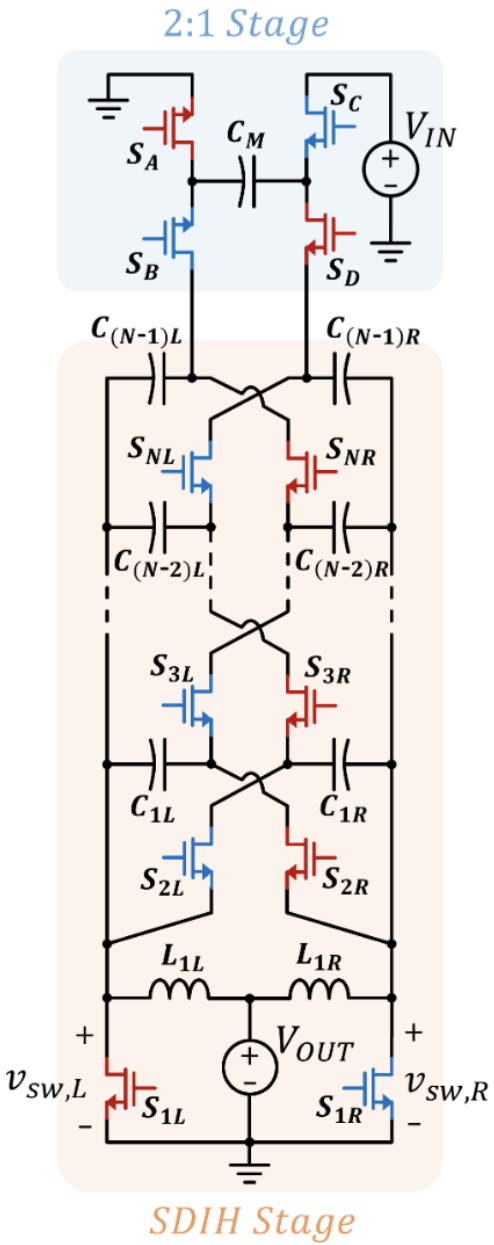


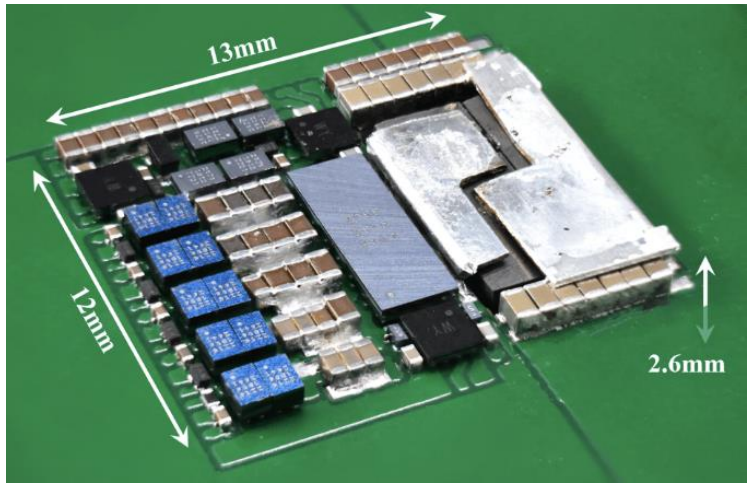
Dimensions: 0.681 × 0.905 × 0.26 in (17.3 × 23 × 6.6 mm)

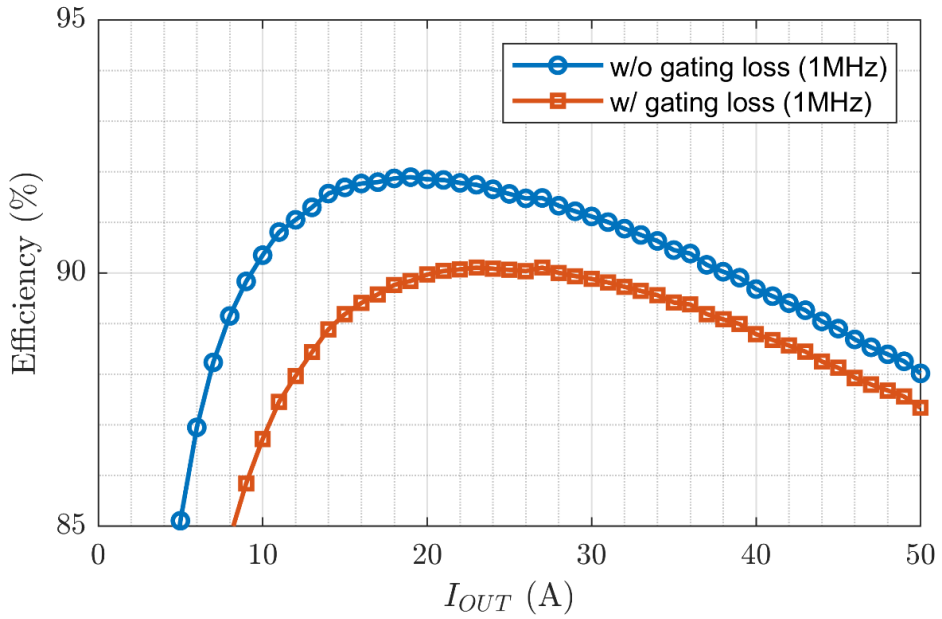


T. Ge, et. al., "T. Ge, Z. Ye, R.C.N. Pilawa-Podgurski, “Geometrical State-Plane Analysis of Resonant Switched-Capacitor Converters: Demonstration on the Cascaded Multiresonant Converter”, IEEE Transactions on Power Electronics, 2023

48V to 1V – Rad Hard GaN Solution





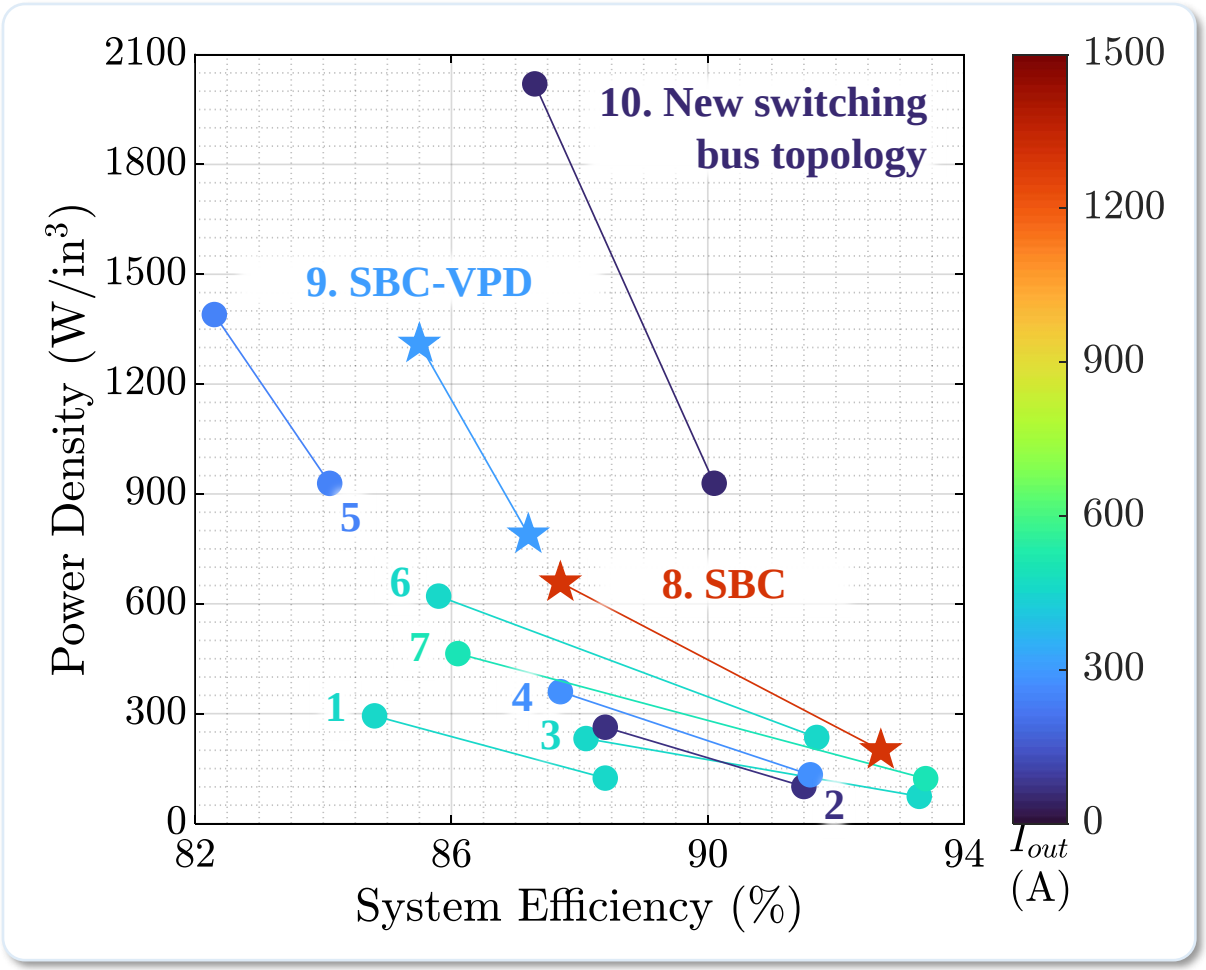


V_{IN}:	48V
V_{OUT}:	1V
I_{OUT}:	$0 - 50$A
f_{SW}:	1MHz
$Density$:	$2{,}020W/inch^3$

50W output power, 1.58 grams [31.6 kW/kg]

Performance Comparison

- Performance comparison with the state-of-the-art 48-V-to-1-V hybrid SC works
  - Loss and volume of the gate drive circuitry are included in efficiency and power density calculations

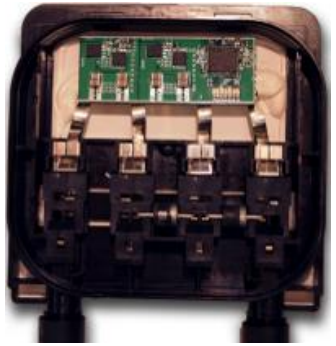


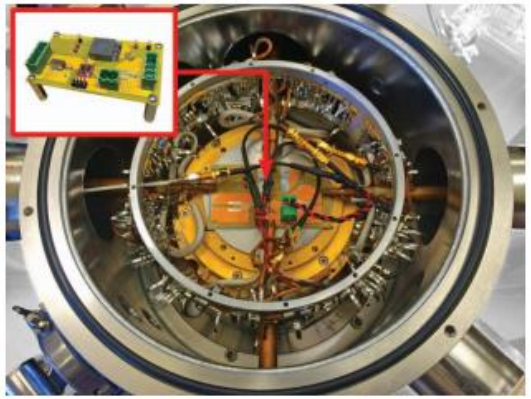
1. LEGO
2. MLB
3. VIB
4. Dickson[2]
5. Mini-LEGO
6. MSC
7. 16-to-1 Switching Bus Converter
8. **SBC (APEC 2024) (UCB Design)**
9. **Next generation (SBC-VPD)** (UCB Design - Unpublished)
10. **New switching bus topology** (UCB Design - APEC 2024)

N.M. Ellis, Y. Zhu and R. C. N. Pilawa-Podgurski, "A Gallium Nitride-Based 48V-to-1V Point-of-Load (PoL) Converter for Aerospace Telecommunications and Computing Applications," APEC 2024

Applications and Environments

- Experience in Solar PV DC-DC and DC-AC Power Converter
- Space rated power electronics, industry and NASA JPL collaborations
- Flight qualified hardware prototypes – ARPA-E
- Extreme environment – cryocooled power converters





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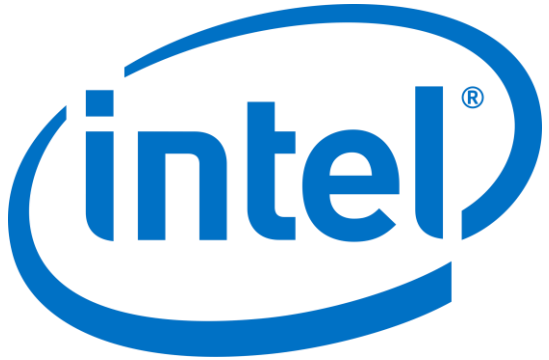

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