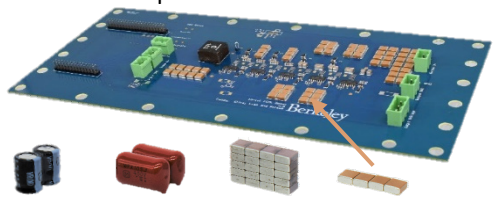
On the Size and Weight of Passive Components: Scaling Trends for High-Density Power Converter Designs

Berkeley Power and Energy Center

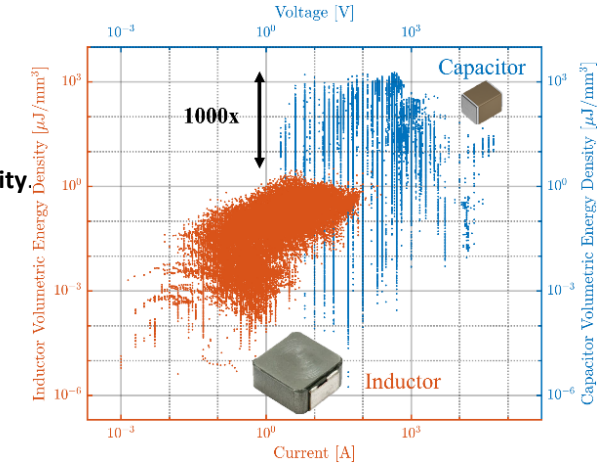
Motivation and Application

To build a high-density power converter, practicing engineers need to use passive components with the highest density.

- A component survey finds **Volumetric Energy Density**.
  - Visualized to assist component selection.
- But how to estimate **Gravimetric Energy Density**?
  - No component mass on most datasheet.

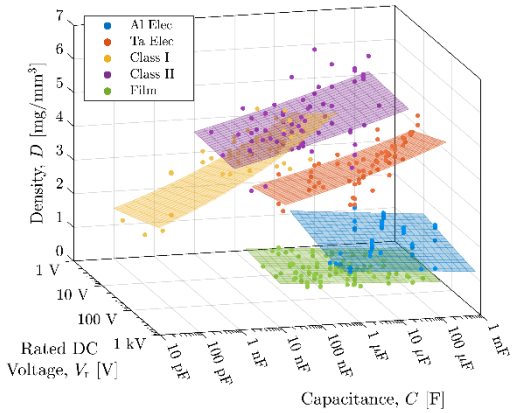


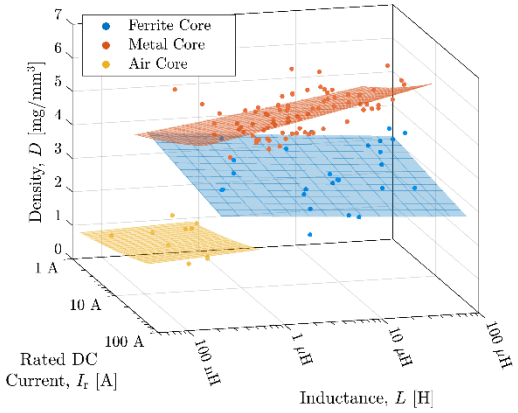
2 µF @ 450 V Aluminum Electrolytic | 2 µF @ 450V Polypropylene Metalized Film | 2 µF @ 450 V Class 1 Ceramic | 2 µF @ 450 V Class 2 Ceramic



Volumetric Energy Density determined by a component survey encompassing over **606,000 capacitors** and **88,000 inductors**

Power Fit Estimation for Specific Density (D)





$$D = k \cdot V_r^{\alpha} \cdot C^{\beta} \quad \left[\frac{mg}{mm^3}\right]$$

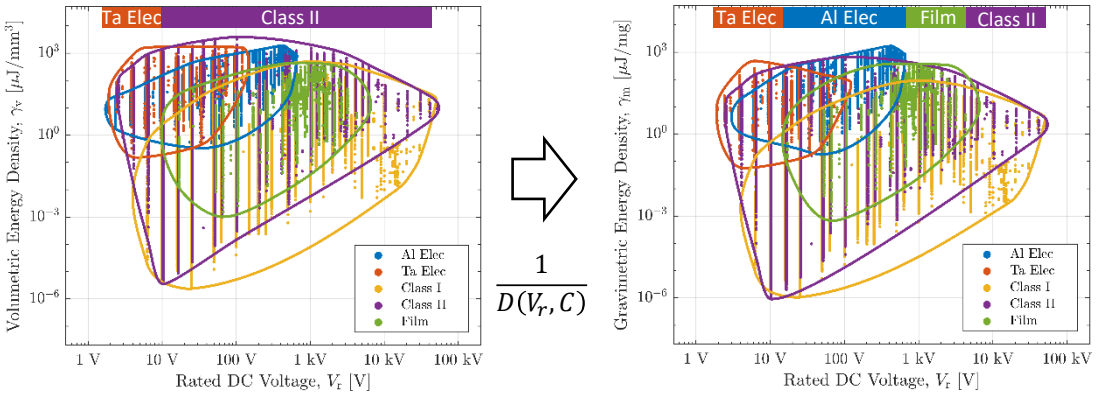
$$D = k \cdot I_r^{\alpha} \cdot L^{\beta} \quad \left[\frac{mg}{mm^3}\right]$$

Mass data was obtained through manual measurements of over **6,000 components**

Capacitor Volumetric vs. Gravimetric Energy Density

$$\rho_V = \frac{\frac{1}{2} C V_r^2}{Vol} = \left[\frac{J}{mm^3}\right] \qquad D(V_r, C) = \frac{Mass}{Vol} \qquad \rho_M = \frac{\frac{1}{2} C V_r^2}{Mass} = \left[\frac{J}{mg}\right]$$

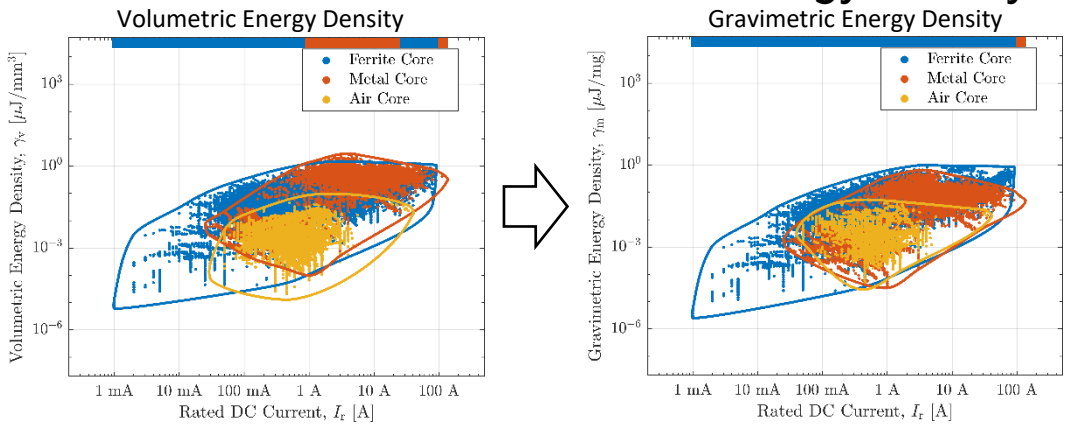
Volumetric Energy Density | Gravimetric Energy Density



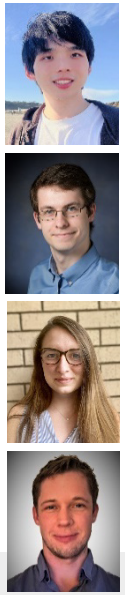
$$\frac{1}{D(V_r, C)}$$

Use **Specific Density (D)** to Derive **Gravimetric Energy Density** from **Volumetric Energy Density**

Inductor Volumetric vs. Gravimetric Energy Density



References: J. Zou, N. C. Brooks, S. Coday, N. M. Ellis and R. C. N. Pilawa-Podgurski, "On the Size and Weight of Passive Components: Scaling Trends for High-Density Power Converter Designs," 2022 IEEE 23rd Workshop on Control and Modeling for Power Electronics (COMPEL), Tel Aviv, Israel, 2022, pp. 1-7, doi: 10.1109/COMPEL53829.2022.9829957.



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