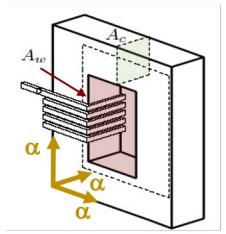
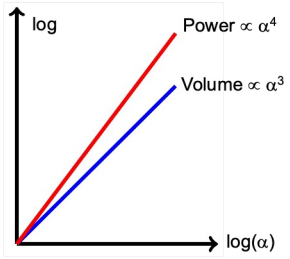
Piezoelectric Passive Components for High-Performance Miniaturized Power Conversion

Berkeley Power and Energy Center

Piezoelectrics as Passive Components

Magnetics present fundamental size and performance challenges at small scales

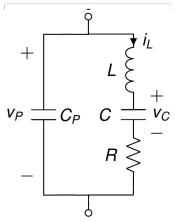


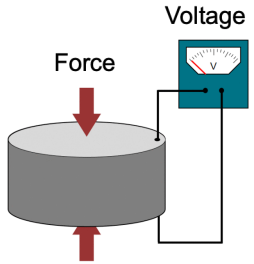


Piezoelectrics are promising alternative passives for miniaturized power conversion

Piezoelectrics store energy in mechanical compliance and inertia

Circuit Model



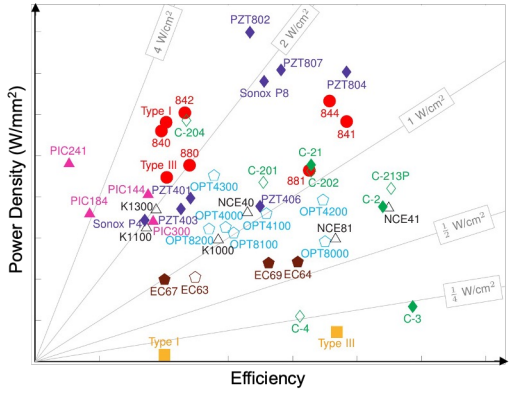


- ✓ High power density
- ✓ High efficiency
- ✓ Isolation
- ✓ Planar form factor
- ✓ Batch fabrication
- ✓ Integration potential

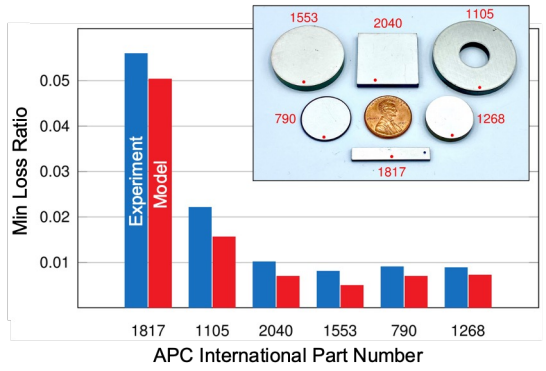
Materials and Vibration Modes

We evaluate the efficiency and power density capabilities of numerous piezoelectric materials and vibration modes

Power Density vs. Efficiency for Hard PZT Materials



Experimental vs. Modeled Minimum Loss Ratio

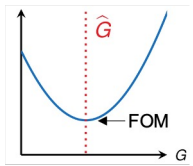


Structures and Design Optimization

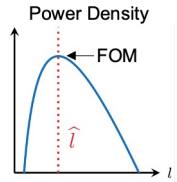
We develop design guidelines for achieving maximum efficiency and power density in a variety of piezoelectric component structures

Geometry optimization

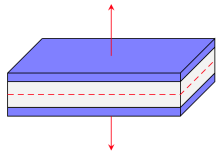
Loss Ratio



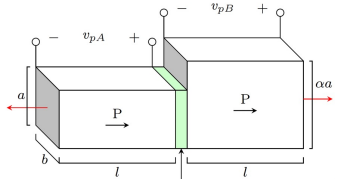
Power Density



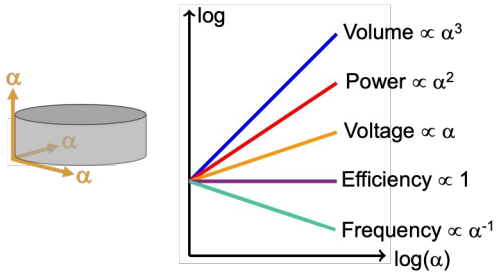
Mass-augmented piezoelectric resonator



Piezoelectric transformer

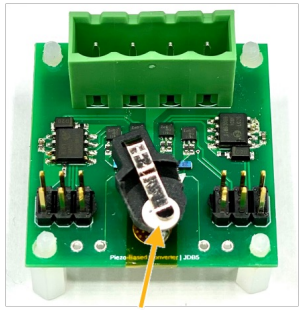


Fundamental scaling laws show that power density *rises* as volume decreases

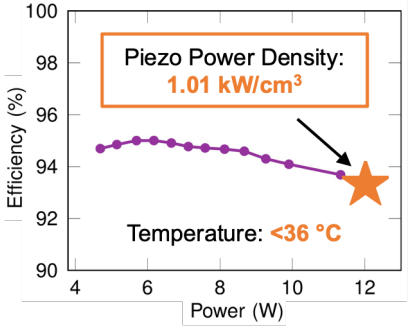


Experimental Demonstration

We experimentally demonstrate the drastic miniaturization capabilities of piezoelectrics compared to magnetics

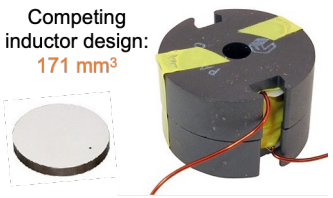


Piezo



Competing inductor design: 171 mm³

This piezo design: 12 mm³



J. D. Boles et al., "Evaluating Piezoelectric Materials and Vibration Modes for Power Conversion," *IEEE TPEL*, 2022.
J. D. Boles et al., "A piezoelectric-resonator-based dc-dc converter demonstrating 1 kW/cm³ resonator power density," *IEEE TPEL*, 2023.
J. D. Boles et al., "Piezoelectric-based power conversion: recent progress, opportunities, and challenges,," *IEEE CICC*, 2022.

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