

# Power Electronics Meet Piezoelectrics: Unlocking a New Era of Scalability



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## Abstract

As suppliers, converters, and controllers of electrical energy, power electronics are the lifeblood of many exciting emerging technologies in transportation, energy systems, manufacturing, healthcare, information technology, and more. However, while integrated circuits have seen miniaturization and expanded performance characterized by Moore's Law, power electronics often remain the bulkiest, lossiest, and costliest components in the systems they serve. Miniaturization of power electronics is fundamentally bottlenecked by passive components, particularly magnetics (i.e., inductors and transformers), which have long been integral to power conversion but pose inherent size and performance challenges at small scales.

This talk explores how we can leverage an alternative passive component technology - piezoelectric components - to eliminate magnetics and unlock a new era of scalability for power electronics. Piezoelectrics offer numerous size, performance, and manufacturability advantages to power electronics, including energy densities three orders of magnitude greater than magnetics, but harnessing these advantages requires fundamental re-evaluation of both power electronic circuits and piezoelectric components themselves. To this end, I present the following recent advances: (1) The first set of dc-dc converter circuit topologies and control sequences capable of efficiently utilizing piezoelectrics as sole passive components; these converter implementations demonstrate the efficiency viability of piezoelectric-based power electronics and provide their highest experimental efficiencies to date (>99%). (2) A theoretical framework for evaluating piezoelectric materials and vibration modes for power electronics; this framework illuminates optimal piezoelectric component design requirements for power electronics and their associated scaling characteristics to small sizes. (3) The first experimental demonstration of dramatic miniaturization offered by piezoelectrics; this prototype piezoelectric component has an order of magnitude lower volume than a magnetic component of similar capability.

These are important steps in realizing the scalability advantages of piezoelectrics in power electronics, positioning them to revolutionize what is possible for computing, wireless communication, robotics, biomedical devices, renewable energy, and beyond.

## Bio

Jessica Boles is a Ph.D. candidate in the Power Electronics Research Group at the Massachusetts Institute of Technology (MIT), where she leads a research team focused on piezoelectric-based power electronics. She previously received her B.S. and M.S. degrees in electrical engineering from the University of Tennessee, Knoxville (UTK) in 2015 and 2017, respectively. Her research interests span power electronic circuits, components, and control, along with applications enabled by such.

Boles is a recipient of the NSF Graduate Research Fellowship, the MIT Collamore-Rogers Fellowship, and the UTK Bodenheimer Fellowship. Her work has been recognized with a Best Paper Award at the 2019 IEEE Workshop on Control and Modeling for Power Electronics and multiple prize presentation awards. She is also a recipient of the MIT EECS Department Head Special Recognition Award.

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