SAND2020-12367R

2020 U.S. DRIVE Highlight

Co-Optimization of Boost Converter Reliability and Volumetric Power Density

Optimized designs were achieved using a genetic algorithm to evaluate multi-objective trade space, including Mean-Time-Between-Failure (MTBF) and volumetric power density

Sandia National Laboratories

There is an increasing demand to improve the performance of electric drive systems through innovation in semiconductor devices, passive component materials, and thermal management technologies between power electronics and electric motors. However, such tightly integrated systems require comprehensive analysis to identify the factors driving reductions in cost, volume, and weight while simultaneously increasing efficiency and reliability.

A team at Sandia National Laboratories has utilized multi-objective optimization to analyze the reliability and power density of a boost converter, which is a step-up DC-DC converter that may be used in an electric drive system. The simplicity and ubiquity of the circuit also make it a very useful test case by which to evaluate the accuracy of the optimization approach. A genetic algorithm, which is a population-based evolutionary search technique, was employed to investigate different design trade-offs between various component materials and cooling techniques.

Fig. 1 depicts pareto-optimal solution sets that evaluate MTBF and power density for a 5 kW boost converter utilizing different magnetic component types. The figure illustrates the trade-offs due to the varying magnetic properties and loss characteristics in different inductor core materials. Moreover, similar approaches have been taken for cooling mechanisms, semiconductor devices, and capacitor materials.

Figure 2 Picture of hardware prototype with the High Flux core design, P3.

Fig. 2 shows a hardware prototype that was constructed to demonstrate and verify the design operating points. Fig. 3 illustrates good agreement between the experimental results and the simulated behavior of the converter.

This work provides a foundational platform that can be used to optimize additional power converters, such as an inverter for the EV traction drive system as well as trade-offs in thermal management due to the use of different device substrate materials.

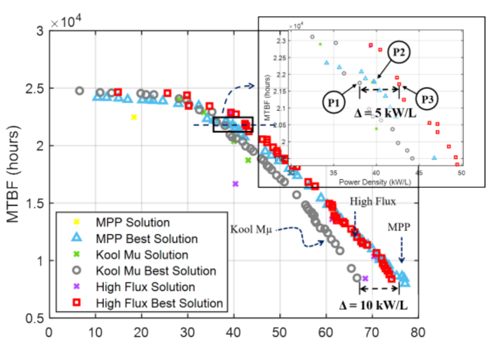

Figure 1. Pareto solution evaluating Kool Mμ, High Flux, and MPP and the prototypes with different inductors denoted as P1, P2, and P3

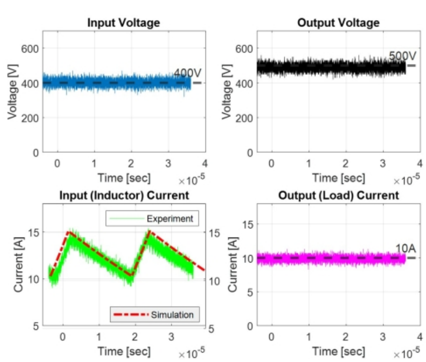

Figure 3 Measured waveforms of the 5 kW boost converter operation with input of 400 V and output of 500 V for design – P3, High Flux

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