

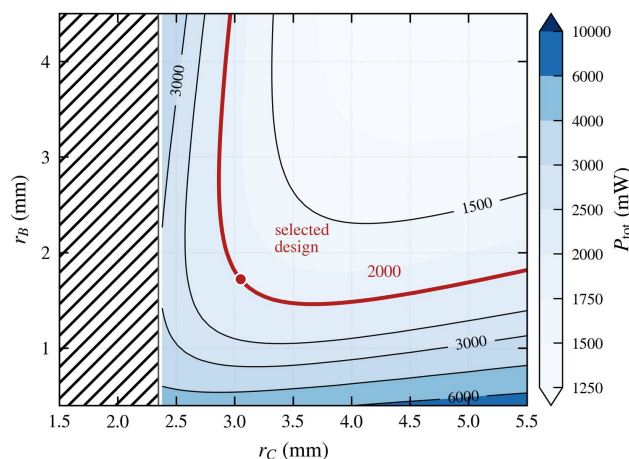
Design and Experimental Validation of a PCB Integrated Inductor for Space Oriented Four Switch Buck Boost Converters

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Abstract

This paper presents the complete design flow of a PCB integrated inductor for a 200 W (210 W maximum), 21–37 V input four-switch buck-boost (FSBB) converter switching at 450 kHz. A timing optimization minimizing the RMS cell current under a fixed-dead-time zero-voltage-switching constraint yields the worst-case four-phase inductor current, which is then the sole excitation of the magnetic design. The air gap is opened on one face only—a single-sided variant of the compensating fringing-field concept—and its optimal placement is fixed, in normalized coordinates, by a parametric 2-D finite-element (FE) map that keeps R_{AC}/R_{DC} below 1.20 while remaining compatible with a three-piece self-locating core. An analytical sizing procedure, combining the Dowell model for copper losses and MagNet-Hub for core losses, then selects the design of minimum board footprint under a 2.0 W loss budget. The core height is not a design variable: it follows from the normalized gap placement itself, which sets the distance between the gap and the first copper layer. The result is a three-turn design wound as four parallel sets on a twelve-layer board, occupying $11.3 \times 11.3 \times 6.5$ mm and weighing 2.9 g of ferrite—one quarter of the litz-wire component it replaces. A tolerance analysis shows the air gap dominates the inductance spread ($\pm 17\%$ RSS under standard $\pm 50\ \mu\text{m}$ machining tolerances) and identifies a moderate switching-frequency adjustment as the system-level lever that absorbs it. A 3-D FE analysis of the part as drawn—assembly clearances included—yields $0.957\ \mu\text{H}$ and an AC-to-DC winding-resistance ratio of 1.62 at 450 kHz, below the value assumed in sizing; the recomposed FE loss budget, 1.92 W at the worst case, holds the 2 W target. A hardware prototype is manufactured and characterized under representative operating conditions.



Total losses over the design space of the three-turn inductor, with the 2 W budget.

Keywords: PCB integrated inductor, four-switch buck-boost converter, space power electronics, finite-element optimization, high-frequency losses, ZVS timing optimization, fringing-field compensation.

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