Numerical Computation and Design Verification of Integrated Magnetics Used in Linear Level Control Converters

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***Abstract*—A novel structure of a 1.08 kW planar Linear Level Control (LLC) transformer with magnetic integration is discussed in this paper. The developed planar LLC transformer has a number of advantages and is suitable for use in the LLC resonant converter. Both 2-Dimensional (2-D) Finite Element Method (FEM) and 2-Dimensional (3-D) FEM were utilized as the verification tools of the transformer design, and the simulation results are consistent with the measurements.**

***Index Terms*—LLC resonant converter, finite element methods, magnetic integration, planar transformer.**

I. Introduction

LLC resonant converters have attracted great interest in past decades due to the pressure from power industry. However, it is only in recent years that such converter have been more widely introduced onto the market due to the difficulties of the controlling circuit design [1]. To achieve the Zero Voltage Switching (ZVS) or the Zero Current Switching ZCS), a resonant tank is required in the front end of the converter [2]. The resonant tank in the LLC converter is composed of the resonant inductor L_s, the magnetizing inductor L_p and the resonant capacitor C_s. In order to further reduce the converter volume, the resonant tank must be integrated into the transformer. However, this poses difficulties for transformer designers; especially for the introduced structure of integrated magnetics (see 0) [3]. This paper outlines transformer design verification by using 1.08 kW integrated magnetics as the example. The verification was achieved with the use of FEM in both 2-D and 3-D; in which 2-D FEM has the advantage of fast verification processes, and 3-D FEM is employed if a more accurate result is required.

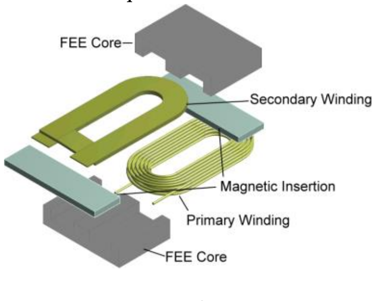

Fig. 1The explorer view of the proposed structure

II. Verification and Measurement

A. Flux Distribution

Flux density simulation results for the introduced transformer are shown in Fig. 1. The results fulfill the design requirements and show that both the main core and magnetic insertion of the transformer are working under its saturation region in either a light-load or heavy-load situation (B_{sat}=430 mT at 25℃).

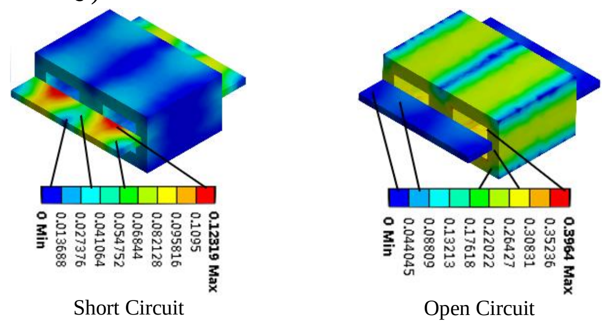

Fig. 2The 3D simulation of flux distribution

B. Impedance Analysis

The measurements were obtained by using an HAMEG HM8118 LCR meter (20Hz to 200 kHz). The comparison results are shown in Table I, and indicate that both simulation and measurement results are consistent with the design requirements. In terms of simulation accuracy in relation to measurements across operating frequencies (40 kHz to 70 kHz), the winding resistances R_s have a small variation of 11.3~19.6 % between the simulation result and measurements. The difference between simulations and measurements can be attributed to the wire used to short-circuit the secondary side, in which the secondary wire resistance differences amplify in a step-down transformer when coupled to the primary side. On the other hand, the accuracy of core resistance R_p in simulations is very much depending on the correctness of the magnetic characteristic information; this pose another difficulty as the transformer operates in a non-linear behavior.

TABLE I
The Impedance Comparison between Measurement and Simulation at 90 kHz

	L_p (μH)	R_p (kΩ)	L_s (μH)	R_s (Ω)
Requirement	175	N/A	33	N/A
Measurement	173.25	38.7	32.797	0.968
Simulation (3-D)	175.83	39.703	33.04	0.778

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