Application Brief

Inductors

An inductor is a passive electric component capable of storing energy in its magnetic field. One of the basic electric components used in a wide range of applications, such as signal processing and analog circuits, it is characterized by its inductance.

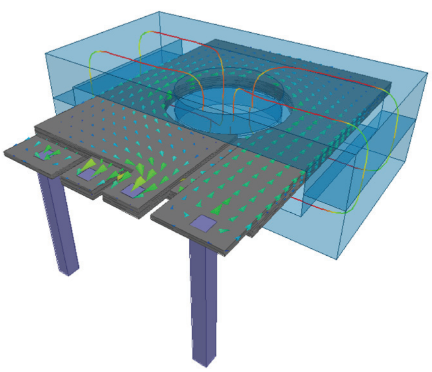

Figure 1. Simple planar inductor modeled with ANSYS Maxwell

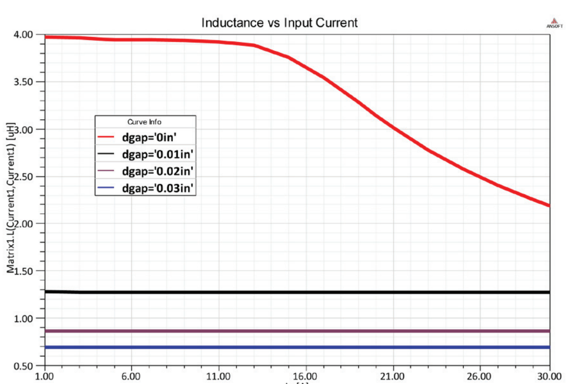

Figure 2. Output from parametric simulation, showing inductance of planar inductor versus input current for different air gap dimensions

Products

ANSYS® Maxwell® 15.0, ANSYS Optimetrics™, ANSYS Simplorer® 10, ANSYS DesignXplorer™, ANSYS Workbench™

Keywords and Definitions

Inductors, impedance matrix, inductance, power converter

Inductance is the property that determines a component's capacity to store magnetic energy and directly affects system dynamics through its impedance, which determines how quickly changes in power flow can occur. The impedance of an inductor, or group of coupled inductors, can be calculated into a matrix, called the impedance matrix. The value of this matrix depends on the geometry, nonlinear magnetic materials and source frequency, which can make analytical solutions very difficult. The impedance matrix is used directly as the modeling tool when performing circuit simulations to predict the effect the inductor has on the rest of the power system.

ANSYS Maxwell is capable of automatically calculating the impedance matrix for complex geometries by directly solving for the magnetic fields produced from current in the coil(s) of the inductor(s). Key issues in the design of such magnetic components that benefit from accuracy of a full numerical field solution include:

- Nonlinear saturation of the magnetic core from over excitation in the coils
- Optimizing core gap size to tradeoff inductance for linearity
- Optimizing coil location to minimize loss due to proximity to the gap
- Selecting an operating frequency

Parametric Analysis

The design of an inductor depends on many variables: material properties, geometries of coil(s) and core, frequency of operation and input current, all of which can be included in design sweeps to study how the impedance matrix, and therefore the inductance, is affected by changes in these properties. Using Maxwell's parametric capabilities, a series of simulations studies how inductance is affected when the air gap of the planar inductor, shown in Figure 1, is varied from 0 in to 0.03 in and the current is varied from 1 A to 30 A. The results for this parametric analysis are shown in Figure 2, in which the effects of higher currents introduce saturation in the

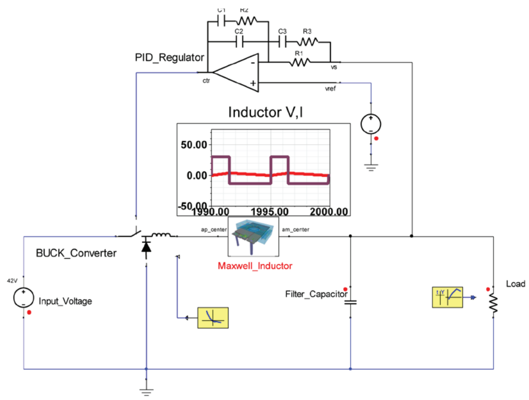

Figure 3. Simplorer schematic of a buck converter with cosimulation inductor model from ANSYS Maxwell

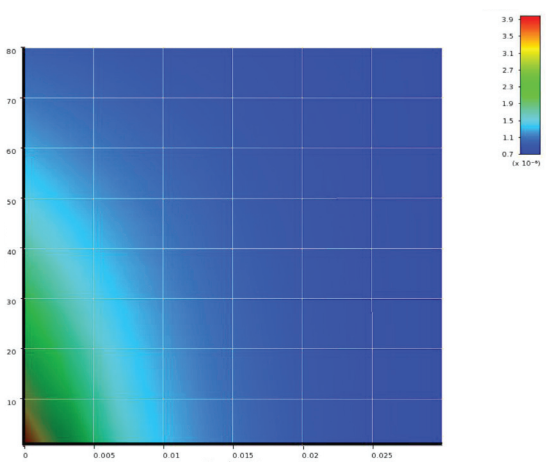

Figure 4. Response chart, output from sensitivity analysis performed with ANSYS DesignXplorer

nonlinear material, therefore reducing the inductance. Results also demonstrate that for bigger air gaps, the saturation doesn't occur within the input current range; rather, the overall inductance is reduced due to reduction of magnetic material in the core.

System Integration

The performance of the inductor when connected to other electrical components can be studied using ANSYS Simplorer, which is a multidomain, multisignal system simulator. A similar FEA design is linked with Simplorer in a way that all the excitations used in Maxwell can be driven from signals created or generated inside a Simplorer schematic. With the capabilities of linkage between a field and a system simulator, it is possible to consider the nonlinearities in the system from the inductor. Figure 3 shows a simple example of an electric circuit in which the usual inductance was replaced by the field-dependent model created with Maxwell.

Design Exploration

Optimization and sensitivity analyses are often project requirements. ANSYS DesignXplorer uses response surfaces to efficiently explore the solution space considering all predefined variables; this occurs within the ANSYS Workbench environment. The design analysis considers the air gap dimension and input current. Establishing upper and lower limits to these variables, DesignXplorer creates a design of experiments (DoE) to efficiently sample a response surface with a minimum number of simulations, as shown in figure 4. From this response surface, it is possible to graphically visualize sensitivity of output inductance to input variables.

Beacuse ANSYS capabilities make a broad array of studies and analyses possible, the suite offers many ways to help engineers to design, analyze and optimize inductors, from single-component performance to systems-level integration.

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