Effect of a Simulation Model Considering Dynamic Characteristics of Power Inductors on DC-DC Converter Performance

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In in-vehicle electrical equipment design, Model-Based Design (MBD) is highly effective for front-loading to deal with complex multi-domain physical phenomena and reduce development time. Additionally, it is important to consider the actual dynamic behavior of electronic devices in MBD. VHDL-AMS is a suitable modeling language for multi-physics simulation. The authors have been working on MBD using VHDL-AMS for in-vehicle electrical equipment design to promote the use of MBD. This study presents a dynamic power inductor simulation model incorporating temperature and current dependencies for electro-thermal simulation using VHDL-AMS and evaluates the effect of this model on the performance of a DC-DC converter.

The characteristics of actual power inductors depend on various parameters, such as frequency, temperature and current. In particular, high currents and temperature rise cause a reduction in the inductance of power inductors. Furthermore, the characteristics of power inductors vary due to their dependence on the properties of the magnetic material and structure of inductors. Therefore, accurate DC-DC converter circuit design requires a dynamic power inductor simulation model that reflects those dependencies.

The dynamic characteristics of a ferrite power inductor have been measured using a large-signal measurement system that can apply a DC bias and heat DUT in a micro-chamber with hot air. The measured characteristics have been expressed using a nonlinear equivalent circuit in which behavioral voltage sources are defined as a function of current and temperature. Furthermore, a dynamic inductor model for VHDL-AMS has been developed by converting the nonlinear equivalent circuit into VHDL-AMS description.

Circuit simulation of a boost DC-DC converter including the developed dynamic inductor model for VHDL-AMS has been performed, and the inductor current and output voltage waveforms have been calculated. Figure 1 shows a comparison of the simulation results for the ideal inductor model and the developed dynamic inductor model. As the inductor current is high and approaches its rated value, the inductor current peak value in the developed dynamic inductor model becomes larger than in the ideal model. This peak value further increases when considering temperature rise. The simulation results show that the developed dynamic inductor model is effective in improving the accuracy of circuit simulations because the temperature and current dependencies of the power inductor are correctly reflected in the circuit characteristics.

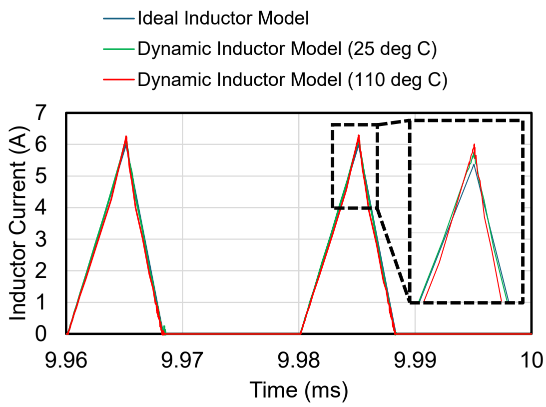

Fig.1 Calculated Inductor Current Waveform of Boost DC-DC Converter

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