Modelling and Simulation of Electronic Power Devices with regard to Frequency Dependent Parasitics

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Abstract

Electric or hybrid driven vehicles are not only supplied by high voltage energy storage, but also need some power electronics for DC/DC conversion. These devices have to be very efficient, by the means of power losses as well as weight, available space and power density. The challenge is to handle thermal problems and in especially electric parasitics caused by geometry of bus bars, transformers etc. and their interactions, which lead to an additional loading of semiconductors and passive elements.

1. INTRODUCTION

With motor vehicles getting more and more electrified and hybridized, electronic power devices for automotive applications get more and more attention. Because energy storage and consumption in vehicles have to be very efficient, every part of the car is designed and optimized with regard to available space, high efficiency and lowest possible weight. Combining these three factors turns out to be a big challenge.

Energy consumption is growing and the available space for electronic power devices is held very small, so the power density increases and thermal management becomes more difficult. As dimensions of bus bars, semiconductors or inductive components are shrinking, parasitic influence becomes more and more significant.

Possible effects are: ringing, voltage and current spikes and distribution of losses not only on semiconductors but also in conductors. In consequence, robust and thus expensive elements are needed, although not fully exploited.

If anybody could reduce or even eliminate these effects, efficiency and thermal management could be improved and some elements could be dimensioned smaller.

For getting information about function and influence of parasitics of electronic power devices, simulation is a very important tool since it saves much time and gives the possibility to extract internal dimensions of electrical circuits which cannot be measured in reality.
2. MODELLING AND SIMULATION

2.1 Modelling

In this work, a dc-dc-converter for hybrid electric vehicles is dealt with.

In a first step, the basic functionality is simulated with Ideal elements in Simplorer.

![Figure 1 – DCDC Converter with current doubler rectifier](image)

The next step is to model magnetic and inductive elements such as transformer and chokes. This could be achieved with Maxwell 2D or 3D and PExprt.

By integrating these models in Simplorer, the influence of winding capacitances and leakage inductance resulting from geometry is being modelled.

![Figure 2 – Transformer Model (PExprt)](image)

For accuracy in semiconductor drives, the switches are imported as SPICE Models.

2.2 Parasitic Extraction

In circuits with high currents there are large planes or even bus bars, which, compared to semiconductors, have an inductance and resistance that cannot be neglected since the switching frequency is about 100 kHz. Because these values are dependent on geometry and frequency, a 3D simulation tool is necessary.
Figure 3 – Q3D Model of Current doubler rectifier in a dc-dc-converter for HEV

The tool Q3D is a 3D simulation and extraction tool, where one can compute inductance, resistance and capacitances of a given geometry such as bus bars or even whole PCBs.

Once computed in Q3D, the frequency dependencies of parasitics can be integrated as block in the Simplorer Model in the upcoming Simplorer 8.

Figure 4 – Simulated frequency dependencies of the geometry in Fig. 3
2.3 Simulation of the entire system

The full model including PExprt and Q3D Imports is shown in Fig. 5.

Figure 5 – Full Simulation Model including frequency dependencies from Q3D (see Fig. 4)

The latest simulation tests did provide a high accordance with measurement:

Measured Data
Simulated Data

Fig. 6 – LV Side Voltage (blue) and Current (brown) waveforms

In further steps, the geometry and design can be modified and optimized in Q3D, so that parasitic effects are minimized, without having time-expensive hardware designs.