

Conducted Differential-Mode Emission from Buck Converter

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Abstract – Conducted electromagnetic emissions are projected using a frequency domain approach in this analysis for the DC/DC buck converter. Modeling the source of noise and the noise direction take parasite elements of PCB tracks and control components into account and provides reliable electromagnetic compatibility (EMC) noise requirements. This approach would strengthen the traditional paradigm by introducing electromagnetic interference (EMI). The differential-mode model (DM) takes into account the parasite oscillation emitted during diode switch-offs and the MOSFET. An analogous circuit simulates the switching oscillations. The full converter DM model is eventually applied in the frequency domain using the SPICE simulator and is faced with experimental measurements based on the Laplace Transform. The simulation results are compared to the measurements to assess the robustness of the modeling process.

Keywords – DC/DC Converter, Differential-Mode, Frequency Domain, Fast Fourier Transformer.

I. INTRODUCTION

The recent advancement of electronic energy today has contributed to a large rise in the number of static converters. On the other hand, the advancement of semiconductive component technologies in terms of volume reduction and high-frequency switching gradually produces electromagnetic interference (EMI). For power circuit conception, the study of electromagnetic compatibility has become a compulsory prerequisite [1-3]. It has to be modeled to predict a static transformer's electromagnetic emission intensity. The goal is to determine the EMC effect of the converter during the design stage [4-6].

Previous research has recommended the time and frequency-domain approach to two fundamental methods of EMI prediction.

The solution time-domain uses circuit simulation tools, and a fast Fourier transformation (FFT) then achieves the noise spectrum [7-9]. The time-domain simulation incorporates all phenomena linked to executed interference and enables determining the key causes and routes of propagation. However, the time

of such a simulation is very long and there are issues of integration because the circuits are complex [10].

The solution to frequency-domain is preferred because the simulation time is shorter and there is no convergence problem. It is modeled by volume or current equivalent generators on pollution sources and through localized impedances on propagation routes.

This paper constructs simpler models for each mode to measure the emission of a statically transformed device obtains the simulation effects directly into the spectrum and is experimentally tested.

II. BUCK CONVERTER MODELING

Figure 1 presents the converter scheme, it is supplied with $V_{dc} = 42V$ over a Line Impedance Stabilized Network (LISN). MOSFET, the diode, and the disassembling condenser are the main components of the converter. The PCB trace parasites and electronic power components are included.

The differential-mode noise can be predicted using three subcircuits together as shown in figure 2. The first is the low-frequency or conventional DM subcircuit [11-13]. It contains a current source I_{MOSFET} and a decoupling capacitor.



Fig. 4. Modeling of interconnections of printed circuit boards.

E) Modeling of capacitance

As shown in figure 1, the parasitic capacitances (C_{L1_gnd} , C_{L2_gnd} and C_{mid_gnd}) form the CM noise propagation paths.

Where, C_{L1_gnd} and C_{L2_gnd} are the capacitors between ground-plane and conductors, C_{mid_gnd} is the capacitance formed between the heat sink and MOSFET. Using analytical calculation we obtain :

$$C_{L1_gnd} = C_{L2_gnd} = \frac{24,2\varepsilon}{\log\left[\left(\frac{h}{r}\right) + \sqrt{\left(\frac{h}{r^2}\right) - 1}\right]} = 32 \text{ pF} \quad (5)$$

Where: r is the radius of cable, h is the distance between ground-plane and conductor.

And:

$$C_{mid_gnd} = \frac{\varepsilon_0 A}{d} = 30,50 \text{ pF} \quad (6)$$

Where : ε_0 is the permittivity of the insulator, A is the area of the MOSFET tab, and d is an insulator thickness [21].

The capacitance C_p is calculated by using:

$$C_p = C_{L1_gnd} + C_{L2_gnd} + C_{mid_gnd} = 94,50 \text{ pF} \quad (7)$$

In this section, a simple representation in LTspice simulator has been given, which will allow us to calculate rapidly the differential-mode emission.

Using the functions of transfer instead of the high-frequency subcircuits in figure 2, the novel simulation model of differential-mode emission becomes as illustrated in figure 5.

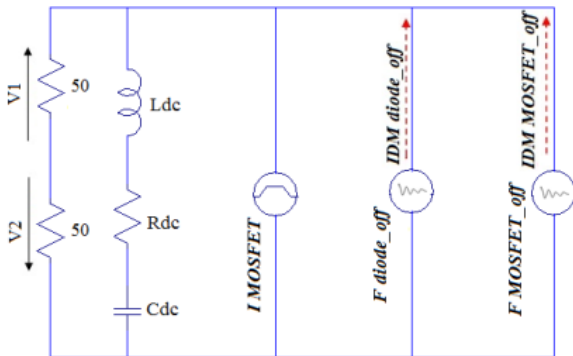


Fig. 5. Novel simulation model of differential-mode emission.

The expression of differential-mode emission is written as follows :

$$V_{DM} = \frac{(V_1 - V_2)}{2} \quad (8)$$

With: V_1 and V_2 are the voltages across the resistors (50Ω) of LISN.

III. EXPERIMENTAL VALIDATION

The experimental and simulation results of the differential-mode emission are shown in figure 6.

High correspondence between the simulation system spectrum and the measurement can be found across the entire frequency range (150 kHz - 30 MHz).

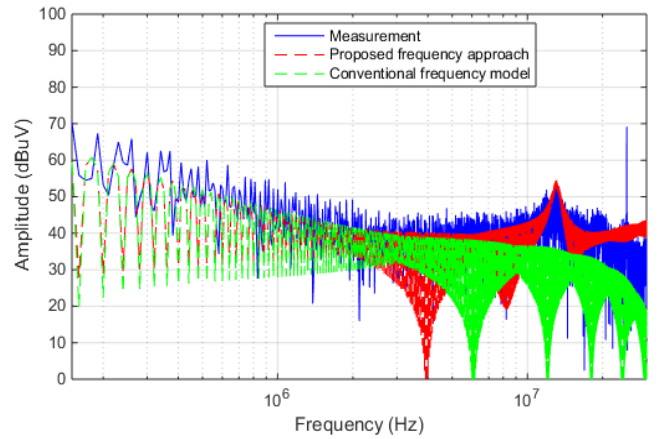


Fig. 6. Experimental and simulation results of differential mode emission.

In this section, we have changed the parameters of the converter to measure the robustness of the previously defined modeling process. A simulation analysis will be done to decide how each parameter differs in differential-mode concerning the amounts of the performed emission.

The routing of the converter with more long distances than the first was selected to study the effects of parasite inductances and trace resistances on the levels of conducted EMI. Figure 7 indicates the second routing used.



Fig. 7. Second routing used.

The experimental and simulation results of the differential-mode emission for both routings are shown in figure 8.

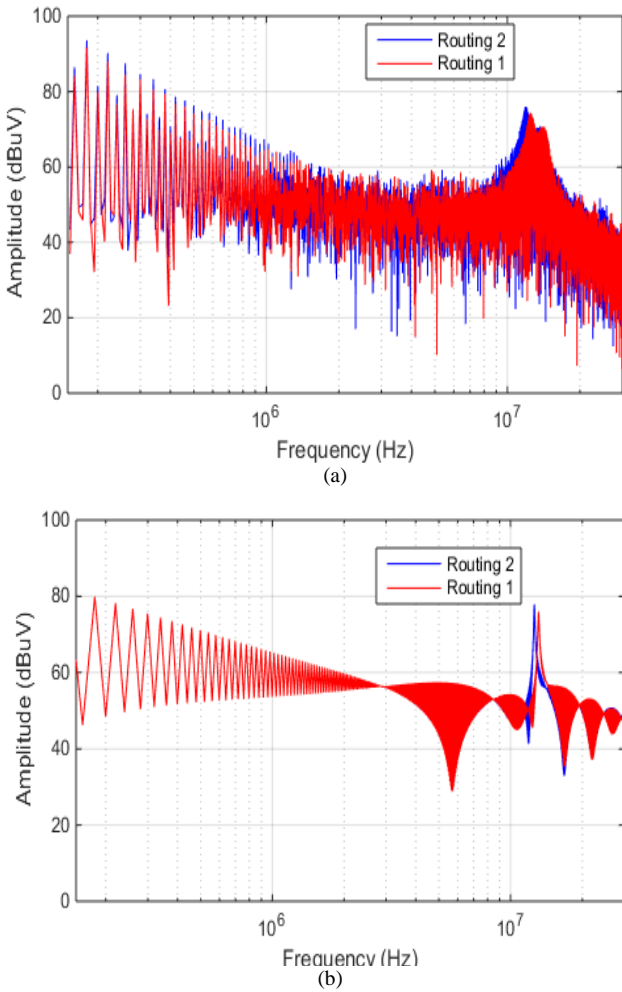


Fig. 8. Experimental (a) and simulation (b) results of differential-mode Emission for both routing

The experimental and simulation at 20 kHz, 60 kHz, and 100 kHz have been done to observe the effect of the operating frequency on the frequencies of the EMI carried out.

The experimental and simulation results of the differential-mode emission are shown in figure 9.

Experimental and simulation results with the resistance of 10 Ω were done in the previous segment. To explain the effect of the door resistor on the EMI levels carried out, tests and calculations are made while the converter operates at resistances of 20 Ohm and 37 Ω.

There can be a very strong correspondence between the spectra obtained by the simulation approach and the measuring of the whole frequency spectrum (150 kHz - 30 MHz).

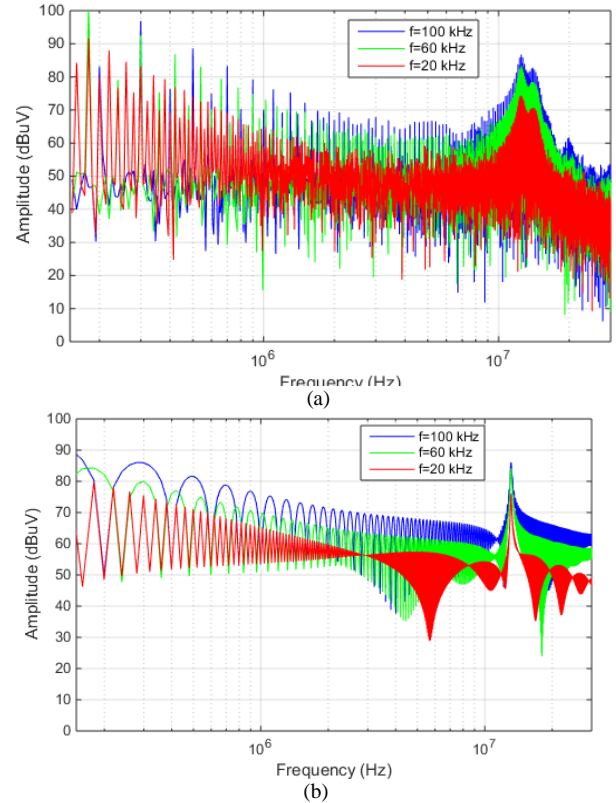


Fig. 9. Experimental (a) and simulation (b) results of differential-mode emission at different switching frequencies

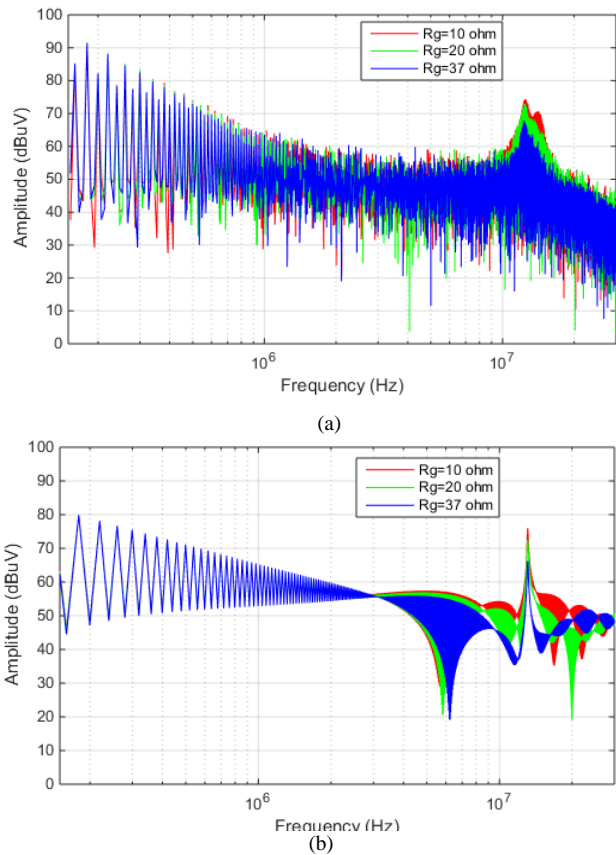


Fig. 10. Experimental (a) and simulation (b) results of differential-mode emission at different gate resistances

IV. CONCLUSION

This article introduces an Electromagnetic Interference (EMI) prediction in DC/DC Buck Converter for Frequency Domain Process. Taking into consideration parasite components of PCB tracks and electronic power components, the simulation of the noise source and noise path makes the exact EMC noise levels. The parasitic oscillation produced by diode switching and MOSFET switching is applied to the traditional model in the agreed approach. DM is applied in the frequency domain using the Laplace transition as a SPICE simulator.

Comparisons of simulation results with experimental results demonstrate the utility of the proposed system in a DC/DC buck converter for the carried out EMI prediction. Different parameters such as PCB routing, frequency switches, and door resistance can be forecast by this tool.

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