Common Mode Reduction by the Method of Interleaved Converters

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Abstract—The isolated DC/DC converter is becoming increasingly important in high-speed switching devices. The electrical isolation provides certain safety aspects. There is a need for the reduction of the electromagnetic interference (EMI) produced by these converters. Earlier studies have shown the reduction of differential mode (DM) noise by interleaving. Next to DM reduction, it is possible to cancel common mode (CM) noise, which exists due to parasitic capacitance, for instance at the switching node. In this study, certain limitations of in the cancellation technique are demonstrated and discussed.

Keywords—Common mode (CM), differential mode (DM), electromagnetic interference (EMI), forward converter, interleaved converters.

I. INTRODUCTION

With the transition from traditional power electronics to higher-speed switching power electronics, new challenges are introduced. These challenges arise from different aspects, one of which is the increase of switch mode power supplies (SMPS) in many applications, such as multilevel converters and electric aviation [1-3]. As a result, numerous topologies are proposed in order to increase power density while also increasing efficiency, reliability, and power rating with further research into modular power systems [4, 5].

Electromagnetic interference (EMI) can cause significant problems in a system that contains a few electronic components. These issues can be addressed in the early stages of design, beginning with topology selection. Within a design, there is a need for an inherent reduction of differential mode (DM) and common mode (CM) noise. If this is considered when designing a converter, the EMI filter’s volume and weight can be reduced as it has to attenuate less noise. By using interleaving, the DM noise spectrum is shifted to higher frequencies, which can be mitigated with smaller components [6, 7]. Besides the reduction in DM noise caused by interleaving, the CM could be reduced if certain boundary conditions are considered.

II. INTERLEAVING TOPOLOGY AND THEORETICAL BACKGROUND

As demonstrated in [7], one of the benefits of interleaving is the reduction of DM noise. Interleaving can be done if a converter is connecting multiple converters in parallel with a common clock, as shown in Fig. 1. The considered topology in this investigation is the forward converter. The parasitic capacitances from the transformer are not considered in order to identify the behavior of the switching operation on the CM capacitance at the switching node.

Besides the reduction of DM noise, the interleaving could also be used for the reduction of CM noise. This can only happen if two switches are operating at the same time, but inverted. This applies an opposing \( \frac{dv}{dt} \) across the CM capacitance as shown in Fig. 2 and based on (1) and the condition in (2):

\[
I_{CM1} + I_{CM2} = C_{CM1} \frac{dV_1}{dt} + C_{CM2} \frac{dV_2}{dt} = 0 \tag{1}
\]

\[
\frac{dV_1}{dt} = - \frac{dV_2}{dt} \tag{2}
\]

It should be noted that \( V_1 \) and \( V_2 \) represent the rate of change of the drain-source voltage caused by the switching signal. To make this equation valid, all of the parasitic capacitances must be equal, \( C_{CM1} = C_{CM2} = \ldots = C \).

III. INVESTIGATION OF THE CONDUCTED EMI WITH DIFFERENT OPERATING CONDITIONS

The CM cancellation can vary due to various parameters, and its effectiveness should be considered before relying on it. The first parameter to consider is the number of interleaved modules, with a focus on 2, 3, and 4 converters. There may also be a difference due to the difference in rise and fall times of the MOSFETs used in the converter. It is also dependent on the difference between the parasitic capacitance of the MOSFETs.

IV. RESULTS

A simulation has been done to observe a CM reduction due to the interleaving. Fig. 3(a) depicts the EMI noise for shifting pulse signals in the case of two, three, and four converters. The addition of more converters can also reduce CM noise and shift the noise to higher frequency ranges. This would result in a reduction of the CM EMI filter size at the converter's output port. The CM noise of the 2-legged interleaved converter is shown with different duty cycles in Fig. 3(b). The duty cycle in blue is 50% and in orange 75%. With the 50% duty cycle, there is significant reduction. In Fig. 3(c), it can be seen that the rise and fall times of the gate source signal have a deviation, while the peak of the switching frequency noise and its harmonics are nearly the same. On the other hand, the power in the subharmonic region is lower when the switching times are equal. The last results related to the deviation of the parasitic capacitance, where a significant reduction can be observed if the parasitic value is equal between the legs, as shown in Fig. 3(d).

V. CONCLUSION

In this paper, it has been found that interleaving can reduce CM noise. But only if the switching moment occurs simultaneously. Although the theory shows that it should be approaching zero, this does not happen in practice. Based on this, further parameters should be considered to determine the beneficial behavior of interleaving on the CM noise.

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REFERENCES


