EMI filter inductor modelling method for power converters without actual device

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This paper proposes a modeling method for EMI filter inductors (CM inductors) in power converters to estimate common-mode (CM) attenuation without actual device. Conventionally, modeling is performed by equivalent electrical circuits from impedance measurements for actual inductors. This process limits optimization of the EMI filter design. In contrast, the proposed method relies only datasheet information which includes core loss and permeability with frequency dependence. Also, the inductance, parasitic capacitance, and resistance valued for winding part are estimated by math models. Evaluation results show that the modeled inductor well predicts the actual filter's attenuation characteristics, improving design efficiency and accelerating EMI filter development.

Keywords: Inductor; ESR; core loss; copper loss; CM inductor; EMI filter.

1. Introduction

The CM inductor design is a key part of power electronics systems for EMI filter design. However, the impedance characteristic data for EMI filter performance estimation is only provided for commercially CM inductors [1]. The manufacturer does not provide guidelines for impedance characteristics when users purchase cores and customise their own. Since parasitic elements by winding process such as ESR and capacitance significantly influence filter performance, the user customized CM inductor is difficult to estimate the EMI filter performance. It limits EMI filter design optimizations.

The contribution of this paper is CM inductor modelling method including the parasitic elements without actual device which enables EMI filter optimizations.

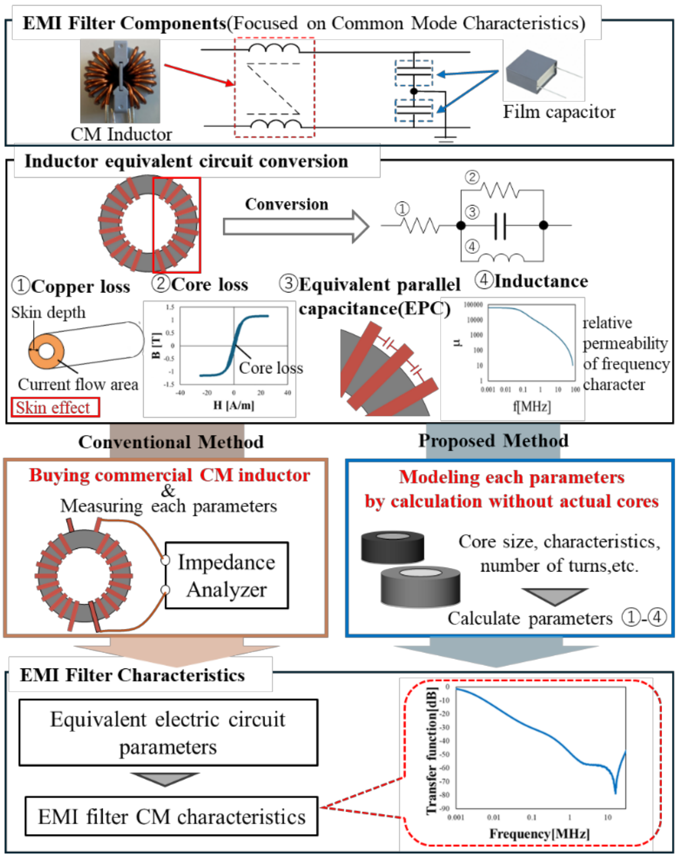


Figure 1: Overview of the EMI filter characteristic evaluation.

2. CM inductor modelling and discussion

CM inductor is modelled as follows: First, the resistive part 1 and 2 of the CM inductor model in Fig. 1 are expressed by the copper loss $R_{copper}(f)$ in winding and the core loss $R_{core}(f)$ in magnetic core. These resistive parts are calculated loss as

$$R_{copper}(f) = \rho \frac{l_1}{S_1(f)}\,[\Omega]\ (1),\quad R_{core}(f) = \frac{P}{V^2}\,[\Omega]\ (2).$$

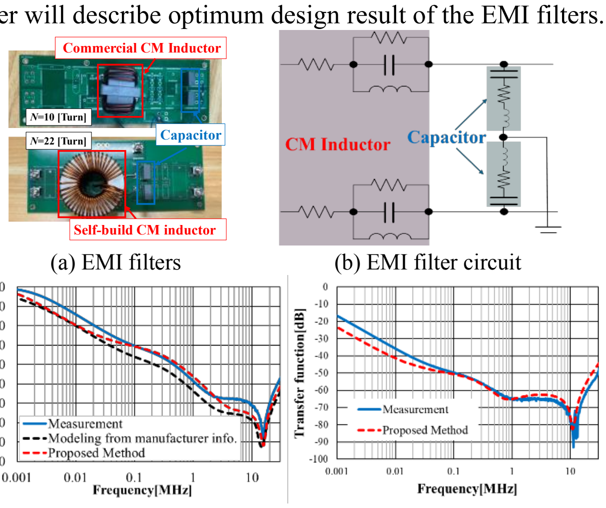
Where ρ is resistivity of winding material, l_1 is the total winding length in the CM inductor, S_1 is the equivalent cross-sectional area of the windings which reduced with frequency, P is the core loss data in the data sheet, V is excitation voltage for CM inductor.

Then, the capacitance part of the CM inductor is the parasitic capacitance between windings. This value is calculated by [2]. Finally, the inductance part of the CM inductor for frequency dependence with permeability $\mu_r(f)$ is expressed as

$$L(f) = \frac{\mu_0 \mu_r(f) S_2}{l_2} N^2\ (3).$$

Where μ_0 is the permeability of the vacuum, l_2 is the average magnetic path length, N is the turn number of windings, S_2 is the core sectional area of the magnetic core.

Figure 2 shows CM attenuation characteristics evaluation result for EMI filter with commercial CM inductor and self-build CM inductor from Nippon Chemi-Con Corp. The proposed method is well simulated the EMI filter's CM attenuation characteristics without accrual device. The final paper will describe optimum design result of the EMI filters.



(a) EMI filters (b) EMI filter circuit

(c) CM attenuation (Commercial CM inductor). (d) EMI filter circuit (Self-build CM inductor).

Figure 2: EMI filter circuits and CM attenuation characteristics.

References

[1] Nippon Chemi-Con Corp. "FW series core"
[2] Massarini, A. Kazimierczuck, M.K "Self capacitance of inductors", Power Electronics, IEEE Trans. on, 1997