CM Noise Reduction of Isolated Converter by Balancing Technique

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Abstract— Common mode (CM) Electromagnetic interference (EMI) noise in an isolated converter is mainly due to parasitic capacitance occurring within the SMPS (Switch-mode Power Supply). It flows through transformer coupling capacitance and the parasitic capacitance of MOSFETs and diodes. Several techniques have been proposed in the literature to mitigate the common mode noise flowing through transformer windings. Transformer shielding is one of the most effective methods to reduce EMI noise between the primary and secondary windings, however. However, further improvement should be possible by developing more precise models. In this paper, we develop an EMI noise model for an isolated converter that allows detailed performance analysis. It incorporates the parasitic elements of the converter components and also the coupling capacitance of the transformer. Using this model we propose a new balancing technique to mitigate the CM noise of the isolated converter with modified transformer. The proposed method is applied to an isolated converter and experimental results are provided to verify the novel balancing technique.

I. INTRODUCTION

Electromagnetic interference (EMI) is defined as an electromagnetic disturbance that limits the performance of electronic and electrical equipment [1]. Therefore, EMI safety standards have been established to guarantee the performance of equipment without degradation.

EMI standards are necessary to meet according to EMC regulatory bodies and EMI filters are designed to mitigate EMI noise to meet these standards. However, there is a practical limit to the line filtering y-capacitance in EMI filter which limits the filtering performance. Conducted EMI noise is categorized into common mode interference (CM) and differential mode interference (DM) noise. The generation and coupling mechanisms are different for each type of interference. The common mode interference is typically caused by parasitic couplings (such as inductive and capacitive) occurring within the SMPS and flows through the ground wire and returns back via the phase and neutral lines. On the other hand, the differential mode interference is mainly due to transistor switching action and flows through the neutral line returning back via the phase line.

II. CM NOISE MODEL OF A CONVERTER

Consider a fly-back converter as for example that shown in Fig 1. At the front end of the converter a Line Impedance Stabilization Network (LISN) is normally used to stabilize the impedance to allow measurement of the conducted EMI noise of the converter. In noise measurement, the input and output capacitor acts as a short circuit. The points, Q (across
MOSFET) and D (across Diode), in the circuit diagram of Figure 1 indicate the node where \( \frac{dv}{dt} \) can introduce switching noise due to the MOSFET and diode.

Cq and Cd represent the parasitic capacitance across the MOSFET and Diode respectively. Cp-s is the inter-winding capacitance between the primary and secondary winding of the transformer. Therefore, the switching action of the MOSFET introduces CM noise at node Q, which can propagate through Cq and Cp-s. Cq and Cp-s act as a parallel capacitance which results in enhancing the overall cm noise. On the other hand, CM noise produced by the Diode can propagate through Cd to ground. Both CM noise from the MOSFET and Diode can propagate to ground.

Fig. 1. Off-line fly-back converter showing LISN

A. Balancing Technique

A new balancing technique for noise reduction is proposed to improve the converter performance. In this scheme, the compensating winding Np-a and compensating capacitor Cq’ are added into the circuit to generate complimentary voltage at node Q’. The voltage at Q’ is 180° out of phase with the voltage at Q thus producing a current in the opposite direction to cancel out the noise current of Cq. The other advantage of Npa winding is to nullify the effect of noise across Ns by balancing the inter-winding capacitances. Similarly, other compensating winding Nsa and compensating capacitor Cd’ are added to neutralize noise current of Cd.

Fig. 2. Off-line fly-back converter with balancing technique

B. Transformer Winding Construction

The design of the transformer winding for a conventional converter is shown in figure 3. Np and Ns stand for the total number of primary and secondary windings respectively. Cps represents the inter-winding capacitance between primary and secondary coils. On the other hand, the proposed transformer construction is shown in figure 4, which includes Npa and Nsa compensating windings. Npa and Nsa characterize the total number of primary auxiliary and secondary auxiliary windings respectively. Cpa and Csa are the inter-winding capacitances between primary and auxiliary windings and secondary and auxiliary windings respectively.

Fig. 3. Conventional Transformer winding construction

Fig. 4. Proposed Transformer winding construction
C. Voltage noise distribution across transformer windings

During MOSFET turn ON

The voltage noise distribution across primary winding, Np, and primary auxiliary winding, Npa, are shown in fig 5a. The voltage at nodes Q and Q’ are 0V and 2Vin respectively. While the voltage at point A is constant at Vin (input voltage of converter). In fig 5b, the voltage noise distribution across secondary winding Ns is shown and it is clear from the figure that the voltage noise distribution across secondary winding is constant and equal to Vin.

During MOSFET turn OFF

The voltage noise distribution across primary winding Np and primary auxiliary winding Npa are shown in fig 7a. The voltage at point Q is \{Vin + (V_0*N)\} and the voltage at point Q’ is \{Vin - (V_0*N)\}. While the voltage at point A is constant at Vin (input voltage of converter). In fig 7b, the voltage noise distribution across secondary winding Ns is shown and it is clear from this figure that the voltage noise distribution across the secondary winding is constant and equal to Vin.

In fig 6a, the voltage at point D is \{Vo + (Vin/N)\} and the voltage at point D’ is \{Vo – (Vin/N)\}. While the voltage at point B is constant at Vo (output voltage of converter). In fig 6b, the voltage noise distribution across primary winding Np is shown and it is evident that the voltage noise distribution across the primary winding is constant and equal to Vo.

In fig 8a, the voltage at point D is 0 and the voltage at point D’ is 2Vo. While the voltage at point B is constant at Vo (output voltage of converter). In fig 8b, the voltage noise distribution across primary winding Np is shown and it is evident that the voltage noise distribution across the primary winding is constant and equal to Vo.
From the above discussion, it is clear that the voltage noise distribution across primary and secondary windings are constant throughout the switching period of the converter. Therefore, the cm noise across both windings should be reduced due to the compensating windings.

### III. EXPERIMENTAL RESULTS AND DISCUSSION

To validate the proposed novel balancing technique, a flyback converter of 132 kHz switching frequency was built and tested. The input and output specifications of this converter are shown in table 1 below

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Input Voltage</td>
<td>230V</td>
</tr>
<tr>
<td>2. Input frequency</td>
<td>50Hz</td>
</tr>
<tr>
<td>3. Output Voltage</td>
<td>12V</td>
</tr>
<tr>
<td>4. Output Current</td>
<td>1A</td>
</tr>
<tr>
<td>5. Output power</td>
<td>12W</td>
</tr>
</tbody>
</table>

Table 1 Specification of test converter.

The results of the Flyback converter using the conventional transformer winding and the corresponding conducted EMI noise measurement are shown in Fig. 9. The results of the new modified balanced transformer winding structure applied to the flyback converter are shown in Fig. 10. The results show that the conducted EMI noise for balanced transformer winding is improved by almost 10 dB.

The proposed technique used the extra windings in a transformer which not only reduce the EMI filter size but also improve the performance of power supply. This would provide the benefits of improved EMI reduction in practical designs compatible with EMI specifications.

### CONCLUSION

In this paper, a new balancing technique is proposed to reduce the overall cm noise of an isolated converter. This technique mitigates the cm noise not only through parasitic capacitance of MOSFET/Diode but also through inter-winding capacitance by balancing the transformer winding. It is confirmed experimentally that the proposed method works efficiently to overcome the problem of EMI noise in isolated converters and reduces the noise by nearly 10 dB for the case of a flyback converter when compared to conventional technique. We intend to further refine the technique and investigate its application in a range of converter topologies.
REFERENCES


