Common and Differential Mode Filter Used in SEPIC Converter

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Abstract - Electromagnetic interference (EMI) represents one of the biggest problems facing the production of any electronic systems that must be minimised in order to respect electromagnetic compatibility standards. Compliance with standards is often achieved by adding a heavy and bulky filter to the system in order to optimise the EMC aspects. In this work, the origins of electromagnetic disturbances created by a SEPIC converter (Single Ended Primary Inductor converter) are presented in common and differential modes. These noises exceed the standard EMC limit CISPR22 Class B in the frequency range 150 kHz to 30 MHz. Then the design of an electromagnetic interference filter (EMI) for SEPIC converter was described, in order to reduce the emissions conducted. The simulation circuit is performed on LTspice Software.

Keywords – Common Filter, Differential Filter, Conducted disturbances, CISPR22, SEPIC Converter.

I. INTRODUCTION

The function of the DC/DC converters is to provide a variable DC voltage from a fixed DC voltage. There are two types of DC/DC converters. Those that are uninsulated, called choppers, and those that have a transformer providing galvanic insulation, called cut-out power supplies, in this work it is about SEPIC converter (Single Ended Primary Inductor converter).

However, static converters are sources of electromagnetic disturbances due to high frequency switching cells, decoupling capacitors and other elements such as parasitic inductances, The operation of these devices produces sudden variations in voltage and current. These variations are responsible for electromagnetic noise propagating inside the circuit and/or outside, either conducted by the cables in common and differential modes, or radiated by the propagation of the electromagnetic field in the air [1-6].

Both types of limits are imposed in the CISPR standards, namely near-peak, and mean, these limits are related to the types of detection used. There are different limits for Class A and Class B equipment. Class B limits are found to be more stringent than Class A limits [7-8].

Among the emission reduction solutions conducted in common and differential modes are passive EMI filters. The main work of the filter is based mainly on the levels of electromagnetic interference in common and differential modes and the EMC standard to which they are intended to qualify [9-11].

The tests were conducted in accordance with the European standard EN 55015 shown in Fig. 1 for the average and near-peak values [12] and by CISPR 22 in the United States "Limits and methods of measurement of radio waves characteristic of disturbance of electric lighting and equipment" [13-14].

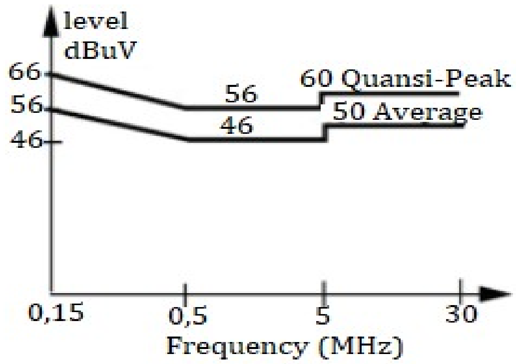


Fig. 1. Permissible interference limits for EN 55015 [13]

The objective of this work is to primarily determine the conducted emissions in common mode and differential mode for DC/DC SEPIC Converter with and without EMC Filter. The paper is structured as follows : Section II describes of the passive EMI filter and how to calculate the filter parameters in common and differential modes. The Section III presents the results of EMI Filters in common and differential modes in the frequency range between 100 kHz to 30 MHz. Finally, the conclusion of this work is given in section IV.

II. PASSIVE EMI FILTER

EMI filter are filters consisting of LC passive components in a low pass configuration. They are used to mitigate EM pollution. These filters are of type Γ or T, and consist in putting in series an inductance in the circuit and a capacity between two phases as illustrated in figure 2 [11-15].

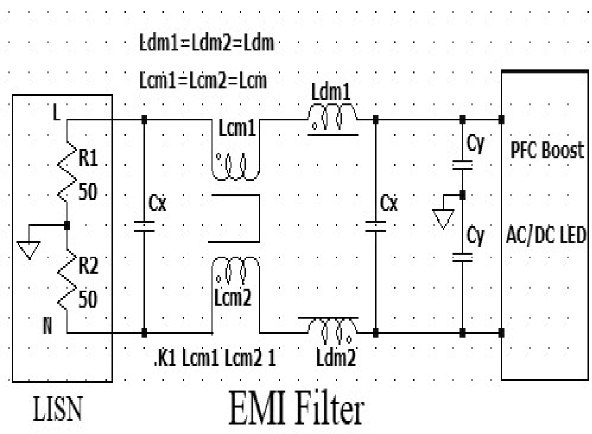


Fig. 2. Passive Electromagnetic interference (EMI) Filter.

The proposed EM filter design procedure can be summarized as follows : [9-11] , [16-17]

- ✓ The EMC standards that EMI is supposed to meet in this work, we have taken the standard CISPR 22 Class B (quasi-peak).
- ✓ Measure EM emissions including total disturbance, common mode (CM) and differential mode (DM) from the line impedance stabilizer network (LISN).
- ✓ Find Common Mode (CM) noise attenuation and Differential Mode (DM) noise attenuation within a known frequency interval, which can be simulated with the following two equations:

$$(V_{req-CM}) = (V_{CM-max}) - (V_{Lim}) + Mrg \quad (1)$$

$$(V_{req-D}\ ) = (V_{DM-max}) - (V_{Lim}) + Mrg \quad (2)$$

Where : (V_{req-CM}), (V_{req-DM}) are the line noise voltages in dBµV, (V_{Lim}) is the limit of the conducted emissions required by the standards EMC CISPR22 Class B.

Everything expresses in dBµV. A margin of 6 dB is added in order to account for possible inaccuracies in CE estimation, and also for the parasitics of the inductive and capacitive components [9].

- ✓ Determine the cut-off frequencies of the LC filter f_{c-CM} and f_{c-DM}, searching for the minimum values and using the following two equations :

$$(V_{req-CM})_{\text{dBV}} = 40\log_{10}\left({f_{CMmax}}/{f_{c-CM}}\right) \quad (3)$$

$$(V_{req-DM})_{\text{dBV}} = 40\log_{10}\left({f_{DMmax}}/{f_{c-DM}}\right) \quad (4)$$

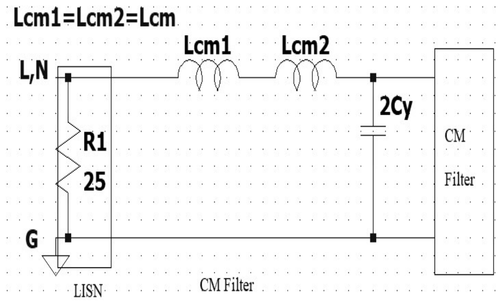
Where f_{c-CM} and f_{c-DM} refer to the cut-off frequencies of the two filters designed respectively for common mode (CM) and differential mode (DM) disturbances. $f_{CMmax}$and $f_{DMmax}$are the frequencies where the spectrum of disturbances conducted respectively in common mode (CM) and differential mode (DM) that has a maximum amplitude,.

- ✓ Find the values of the inductances $L_{CM}, C_{CM})$ and capacitors of the filters (L_{DM}, C_{DM}) respectively using the cutoff frequencies by using the following two equations:

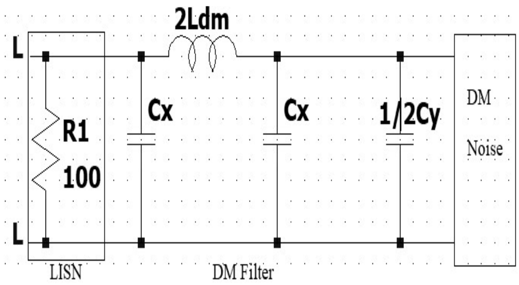
$$f_{c-CM} \frac{1}{(2\pi\sqrt{L_{CM}C_{CM}})} \quad (5)$$

$$f_{c-DM} = \frac{1}{(2\pi\sqrt{L_{DM}C_{DM}})} \quad (6)$$

The inductor $L_{CM}$and the capacitor $C_y = {}^1/_2\, C_{CM}$ are used to suppress the common-mode noise as shown in figure 3 (a), and the inductor L_{DM} and the capacitor $C_X = C_{DM}$ are used to suppress the differential mode noise as shown in figure 3 (b).



a)



b)

Fig. 3. Equivalent circuit of CM and DM filter : (a) CM Filter (b) DM filter.

III. SEPIC CONVERTER STUDY

The DC/DC SEPIC converter simulated by using LTspice software as shown in Figure 4. It's constitued by : voltage = 200 V, Load R = 40 Ω, the switching frequency of the converter MOSFET is F = 100 kHz, with the duty cycle is equal to 50%.

The disturbances are measured by the line impedance stabilizer network at the terminals of the resistor of value R = 50 Ω.

Figure 5 shows the electromagnetic disturbances generated by SEPIC Converter where it can be seen that both common and differential modes exceed the CISPR22 Class B standard limit in the frequency range 150 kHz to 30 MHz, with peaks up to 120 dBµv at frequency F = 200 kHz.

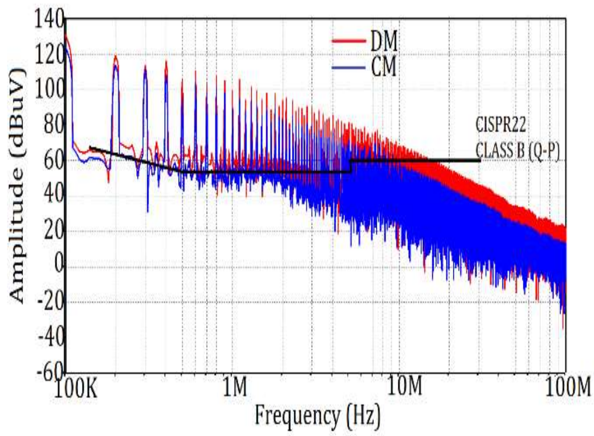


Fig. 5. Common and differential mode voltage

IV. PASSIVE FILTER STUDY

To calculate the values of the filter elements, the previously proposed steps are followed. From the spectra of the conducted disturbances represented in figure 5.

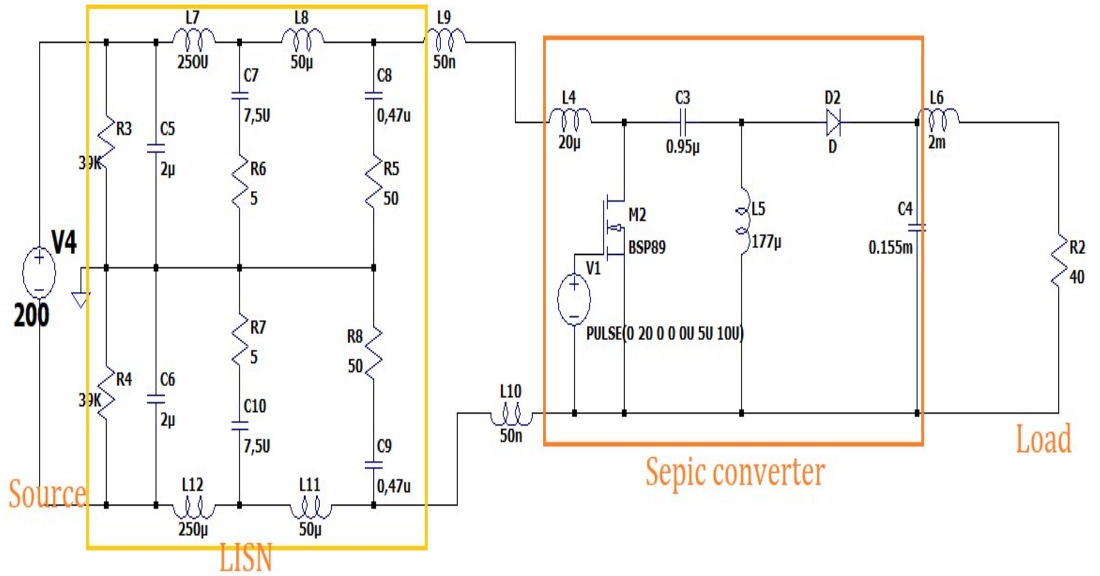


Fig. 4. SEPIC converter with LISN under LTspice software.

We can identify the maximum level of these spectra in the frequency interval 150 kHz to 30 MHz. We have chosen the CISPR standards 22 Class B (quasi-peak), in the first time we have indicated :

$(V_{CM-max})_{dBuV}$ =114 dBµV

$(V_{DM-max})_{dBuV}$= 120 dBµV

For the same frequency is equal to 150 kHz, according to the two equation (1) and (2) we obtain:

$(V_{req}\quad)_{dBuV}$ = 54 dBµV

$(V_{req-D}\ )_{dBuV}$ = 60 dBµV

The cut-off frequencies are calculated by equations (3) and (4), we obtain :

f_{c-CM} = 8,91 kHz and f_{c-DM} = 6.31 kHz

The last step is to determine the filter values (L_{CM}, C_{CM}) and (L_{DM}, C_{DM}). We took the values of inductance which should be in the range from 200 µH to 400 µH.

So, in this paper, we took 200 µH. The following table shows the EMC filters applied in this work.

Table 1. Parameters of the filters in common and differential modes.

Type	L_{CM} (µH)	L_{DM} (µH)	C_{CM} (µF)	C_{DM} (µF)	C_x (µF)	C_y (µF)
Filter	200	200	1.6	3.18	3.18	0.8

Figure 6 presents the spectra of the electromagnetic disturbances in common mode with and without filter. We notice a very important reduction of the conducted emissions in the range of frequency 150 kHz to 30MHz, even the peaks.

Figure 7 shows the frequency spectra in differential mode with and without filter, where there is a reduction in conducted emissions compared to CISPR 22 Class B (quasi-peak).

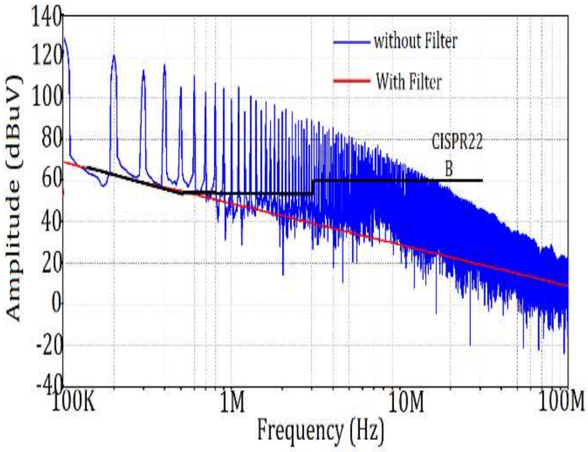


Fig. 6. Comparison of common mode emission with and without filter.

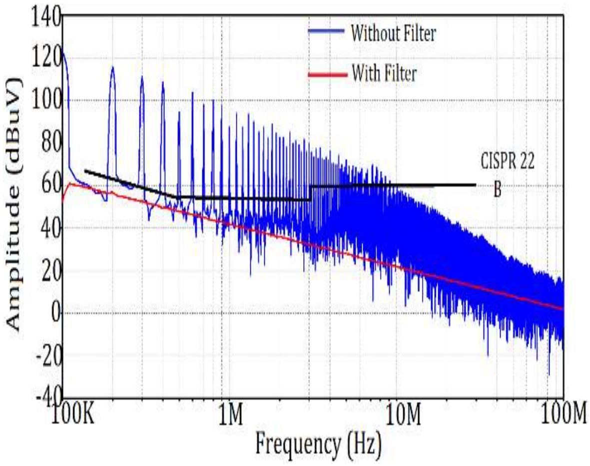


Fig. 7. Comparison of differential mode emission with and without filter.

V. CONCLUSION

This paper presented an approach to design the passive EMI filters step by step in common and differential modes in order to reduce the conducted emissions generated by the SEPIC converter. By respecting the limits of CISPR 22 class B Standards, in the frequency range of 150 kHz to 30 MHz. In the first, the conducted emissions was measured, where we noticed that is very important noise in two modes. Then, the procedures for selecting passive filters are determined. The future work consists in the realization of SEPIC converter, in order to measure the disturbances LED to validate the results obtained by the simulation, then the EMC passsive filter will be realized.

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