The EMI study of Self-resonant Frequency Effect on a Ćuk Converter

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Abstract: This paper presents the effect of self-resonant frequency (SRF) of input inductor on a Ćuk converter. The effect of SRF via conducted EMI observes by fixing the input inductance but the structure can be modified from single input inductor to parallel input inductors. The 100 W a Ćuk converter in discontinuous mode and opened loop control is presented. The simulated results are compared based on the equal of input inductance between single inductor and parallel inductors. The measured results to confirm the SRF effect.

1. Introduction

In theoretical, the conducted EMI composes of common mode and differential mode noise. Normally, the differential mode noise is dominant at frequency range less than 2 MHz and common mode noise is dominant at frequency range greater than 2 MHz until 30 MHz. Generally, the common mode noise in SMPS is affected by component resonances at frequency range between 2 MHz until 10 MHz and printed circuit layout resonances at frequency range between 10 MHz until 30 MHz [1]. Therefore, the component resonance or SRF of electronic components directly affect to conducted EMI. Switched mode power supplies (SMPS) are the main source of EMI emission. Thus, this paper focuses on Ćuk converter. The relation between SRF of circuit component and conducted EMI of Ćuk converter is presented. The effect of input inductor via conducted EMI is verified by simulation and experiment. The results of conducted EMI emission are compared based on the equal of inductance between single input inductor and parallel input inductors.

2. Theory

2.1 Ćuk converter circuit

Fig. 1 shows the Ćuk converter circuit, while the input voltage 24 V_{dc}, output voltage 48 V_{dc}, switching frequency (f_{sw}) 50 kHz, resistance load, power output 100 W in discontinuous mode and opened loop control.

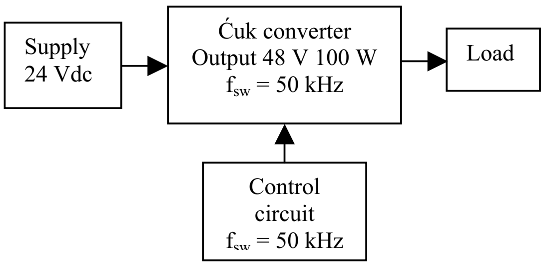

Fig. 1. Circuit diagram of the implement

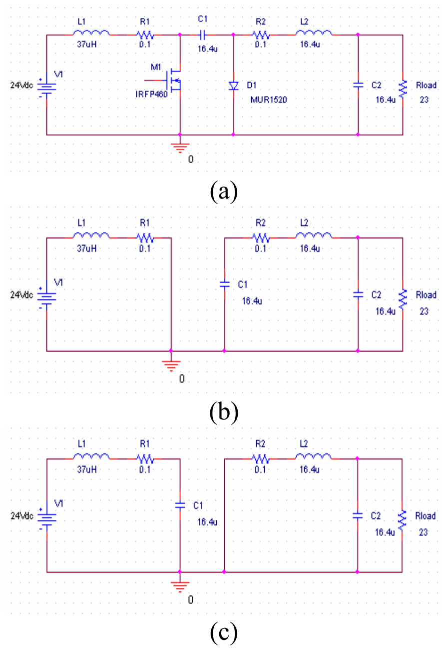

Fig. 2. (a) Ćuk converter (b) switch on (c) switch off

Fig. 2(a) shows the circuit diagram of a Ćuk converter. The capacitor C_1 and inductor L_1 are directly connected to the input voltage source, the capacitor C_1 is stored the energy while the switch is turned off as shown in Fig. 2 (b). When the switch is turned on, this energy is released through L_2 to the load as shown in Fig. 2(c).

2.2 Parasitic of circuit components

In high switching frequency operation, the components are not ideal because the impedance of components are varied with switching frequency. At the frequency that impedance changing the behavior is called the self-resonant frequency (SRF) of the component. The effect of SRF via the impedance characteristic of capacitor and inductor is shown in Figs. 3 and 4, respectively.

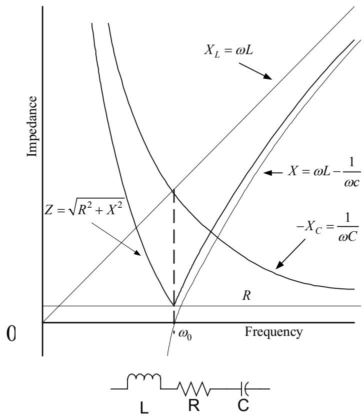

Fig. 3. Impedance curve and capacitor modeling at high frequency

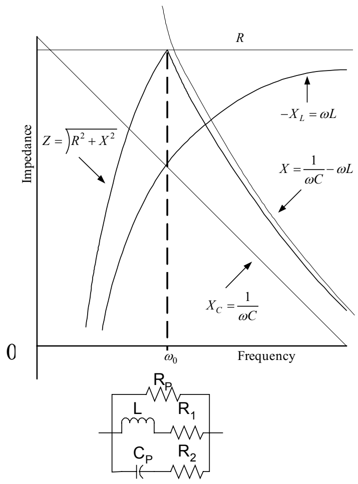

Fig. 4. Impedance curve and inductor modeling at high frequency

3. Experimental conditions

The experiment method is divided in two cases. All of the experiments fix the value of inductor. The L1 and L2 are always equal to 36 µH and 72 µH, respectively. In case 1, the SRF of L1 and L2 is different. In case 2, the SRF of L1 is equal to L2. Furthermore, in case 2, the structure of input inductor (L1) can be changed from where those parameters are shown in Figs. (5) and (7). Figs. (6) and (8) show their structures in single input inductor to parallel input inductors.

Case 1: SRF of input inductor (L1) is not equal to SRF of inductor (L2).

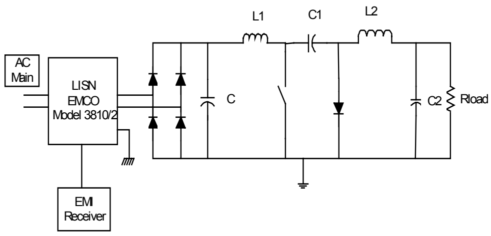

Fig. 5. The circuit diagram of case 1

Fig. 6. Ćuk converter for case 1

Case 2: SRF of parallel inductors (L1) are equal to SRF of inductor (L2).

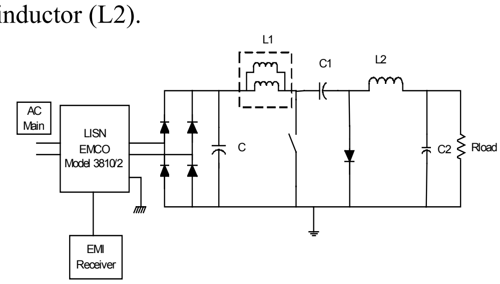

Fig. 7. The circuit diagram of case 2

Fig. 8. Ćuk converter for case 2

4. Simulation and Experiments

The effect of SRF of input inductor (L1) in case 1 and case 2 via conducted EMI on Ćuk converter are compared between simulation and experiments. Table 1 shows the SRF of parameters of Ćuk converter for 2 cases.

Table 1: The SRF of Ćuk converter for two cases

Condition	Component	SRF of measurement	SRF of simulation
Case 1: SRF of L1 ≠ L2	L1 = 36 µH	14.95 MHz	14.21 MHz
	L2 = 72 µH	15.2 MHz	14.67 MHz
	C1=C2=16 µF	128 kHz	115 kHz
Case 2: SRF of L1= L2	L1(1)= 72µH	13.20 MHz	12.58 MHz
	L1(2) = 72µH	14.10 MHz	14.07 MHz
	L2 = 72 µH	15.20 MHz	14.67 MHz
	C1=C2=16 µF	128 kHz	115 kHz

Table 1: Self-resonant frequency of components

4.1 Case 1: single input inductor (L1)

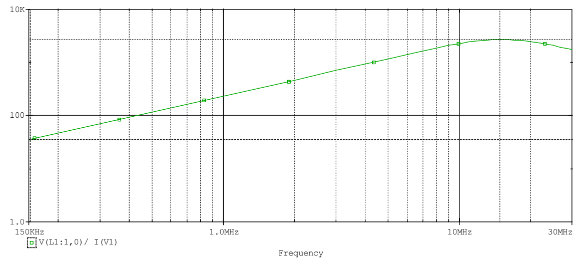

Fig. 9. Impedance curve of single input inductor for case 1

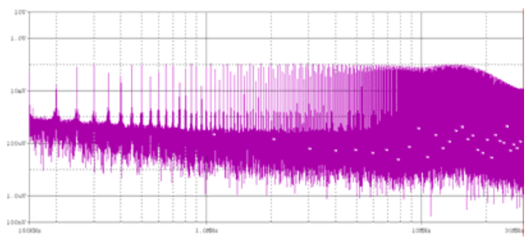

Fig. 10. Simulation conducted EMI of Ćuk converter for case 1

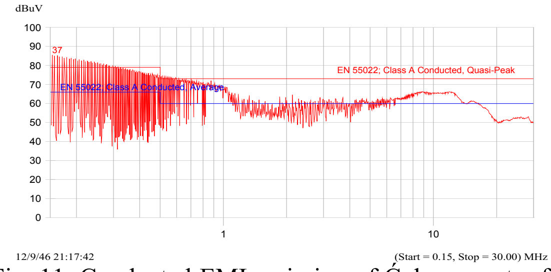

Fig. 11. Conducted EMI emission of Ćuk converter for case 1

Fig. 9 shows the simulated result of impedance curve of single input inductor which equals to 14.21 MHz. Figs. 16 and 10 show the simulation circuit and simulated result of conducted EMI emission for case 1, respectively. Fig. 11 shows the experimental result of conducted EMI in case 1.

4.2 Case 2: parallel input inductors (L1)

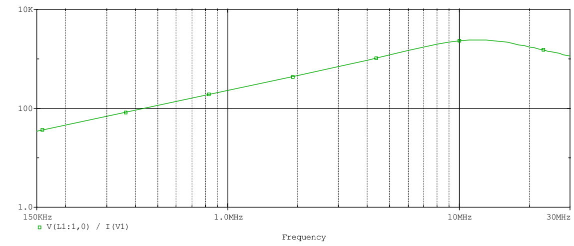

Fig. 12. Impedance curve of parallel input inductors for case 2

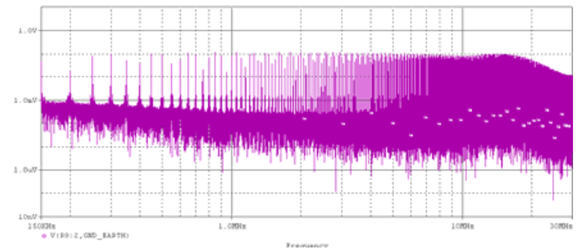

Fig. 13. Simulation conducted EMI of Ćuk converter for case 2

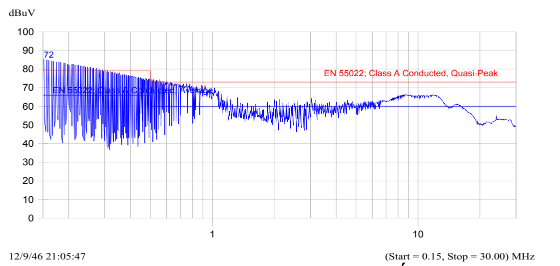

Fig. 14. Conducted EMI emission of Ćuk converter for case 2

Fig. 12 shows the simulated result of impedance curve of parallel input inductors which equals to 13.11 MHz. Figs. 17 and 13 show the simulation circuit and simulation result of conducted EMI. Fig. 16 shows the experimental result of conducted EMI in case 2.

Fig. 15 shows the EMI comparison between case 1 and case 2. The experimental results are verified that the structure of input inductor, even though single or parallel, has no any effect to the conducted EMI.

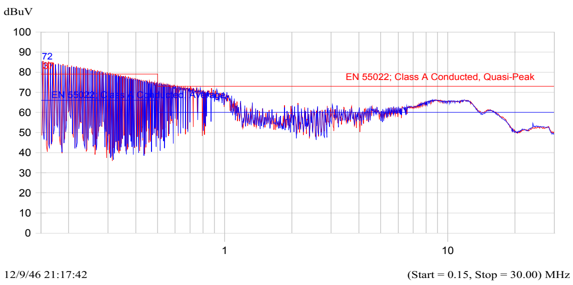

Fig. 15. The experimental result of conducted EMI emission for two cases

5. Conclusion

The Ćuk converter has many parameters that can affect to conducted EMI problem. However, the dominant parameter which difficult to control is the inductor.

This paper shows the effect of parallel inductors instead of single inductor on conducted EMI of Ćuk converter. The SRF of both inductors are controlled in the same condition. The experimental results are exactly with the simulation results. The EMI generates by single and parallel inductors are similar. It means, the power rating of Ćuk converter can be increased by parallel inductors with no any effect to conducted EMI problem.

References

[1] John C. Fluke. "Controlling Conducted Emission By Design". New York: VANNOSTRAND REINHOLD, Inc 1991.
[2] Daniel W. Hart. "Introduction to Power Electronics". Prentice-hall, Inc 1997.
[3] European standards EN55022: "Limits and methods of measurement of radio interference characteristics of information technology equipment", 1994.

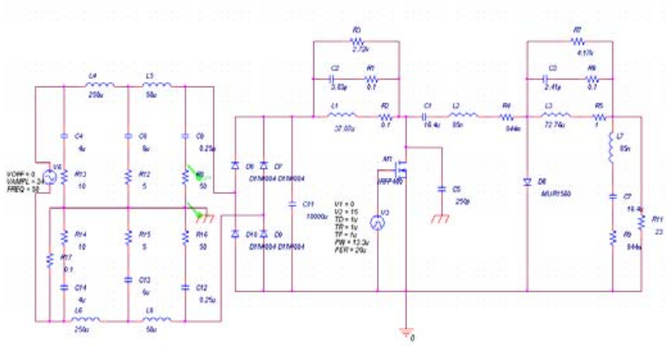

Fig. 16. Simulation circuit for conducted EMI

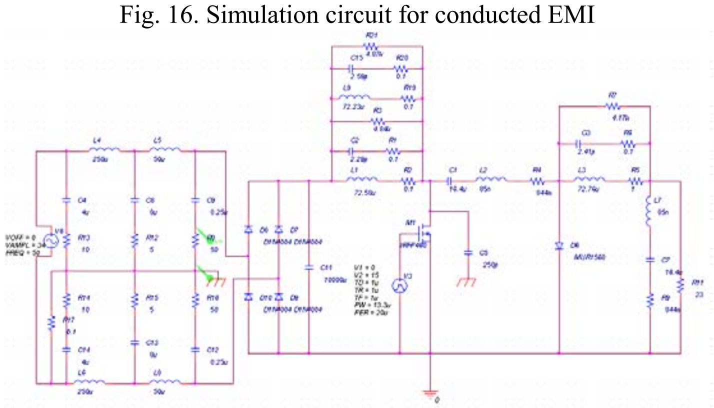

Fig. 17. Simulation circuit for conducted EMI