

Analysis of the Radiation Noise and Efficiency Characteristics in a Quasi-resonant Converter

Hironobu SHIROYAMA^{1,2}, Hirofumi MATSUO² and Yoichi ISHIZUKA²

¹ Fuji Electric Device Technology Co., Ltd.

Gotanda NN Bldg. 2-12-19, Nishigotanda, Shinagawa-ku, Tokyo 141-0031, Japan

² Graduate School of Science and Technology, Nagasaki University

1-14, Bunkyo-Machi, Nagasaki, 852-8521, Japan

E-mail: ¹ shiroyama-hironobu@fujielectric.co.jp, ² h-matsuo@nagasaki-u.ac.jp

Abstract: In this paper, the radiation noise and efficiency of the quasi-resonant converter are analyzed. A quasi-resonant converter using the flyback topology can realize the soft switching with simpler circuit. However, switching devices with the high withstand voltage is necessary to achieve the complete ZVS and it causes the low power efficiency because a switching device with the high withstand voltage has the high on-voltage. On the other hand, the switching device with the low withstand voltage and then the low on-resistance can be used with the non-ZVS. Therefore the performance characteristics such as the efficiency and radiation noise are analyzed on the quasi-resonant converter with the ZVS and the non-ZVS. As a result, it is clarified that the low radiation noise and high power efficiency are achieved with the non-ZVS.

1. Introduction

Generally, smaller size, lower weight, higher efficiency and low noise have been required for switching power supplies. Many types of power supplies with the zero voltage switching (ZVS) have been presented to realize these requirements. However, as to most of the power supplies with the ZVS, there exist deteriorated problems that main power and control circuits are complicated and that auxiliary switching devices have to be added. Consequently, size of switching power supplies is larger. Furthermore, when the input voltage is high, switching devices with the high withstand voltage is necessary to achieve the complete ZVS. Then, the low power efficiency is caused because a switching device with the high withstand voltage has the high on-voltage.

From the above discussion, the control strategy of the quasi-resonant converter is important to realize both the high efficiency and low conduction noise. [1] Then, the quasi-resonant converters have been often employed in many applications.

The noise generation mechanism has been analyzed from the view point of the frequency related to conductive noise. [2], [3] However, the characteristics of the radiation noise and efficiency have never been clarified.

In this paper, the performance characteristics such as efficiency and radiation noise are analyzed on the quasi-resonant converter with the ZVS and the non-ZVS taking the resonant capacitance as a parameter. As a result, it is clarified that using the small resonant capacitor, low radiation noise and high power efficiency are achieved with the non-ZVS.

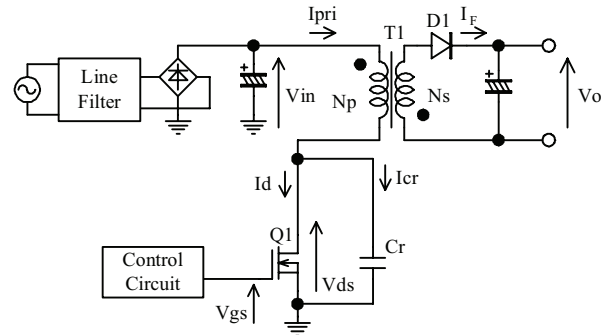


Fig.1 Circuit configuration

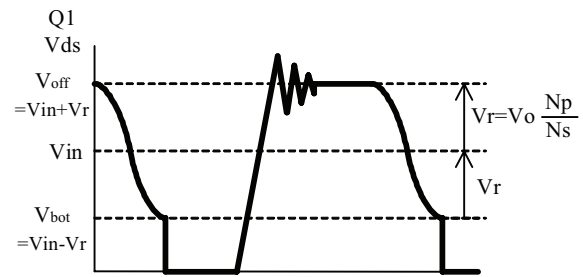


Fig.2 Vds waveform of Q1

2. Circuit Configuration and Operation

Fig.1 shows the circuit configuration of the analyzed quasi-resonant converter. The circuit topology is the flyback converter with the transformer T_1 , the switching power device Q_1 , the diode D_1 and the resonant capacitor C_r .

Fig.2 shows V_{ds} waveform of Q_1 . As shown in Fig.2, we define the voltage applied to Q_1 just before turn-on as V_{bot} . V_{bot} is represented by expression (1).

$$V_{bot} = V_{in} - V_r \quad (1)$$

Where V_{in} is the voltage rectified AC line input. V_r is the transformer primary voltage in Q_1 off period and it depends on the turns ratio of transformer.

When V_r is designed larger by changing the turns ratio of the transformer, V_{bot} becomes smaller and loss of discharging C_r also becomes smaller. When $V_r > V_{in}$, V_{bot} becomes less than 0V. It means that the ZVS is achieved at turn-on. On the other hand, when V_r is larger, there is a worry that the EMI noise becomes larger by the influence of the large voltage amplitude and that the efficiency becomes lower by the influence of the higher on-resistance of the high withstand voltage switching device.

Table 1: Specification of Transformer

	Turn-on operation	Spec. of transformer			Drain voltage just before turn-on [V _{bot}] (V)
		N _p (turns)	N _s (turns)	L _p (μH)	
No.1	Non-ZVS	57	10	366	230
No.2	Non-ZVS	72	6	762	130
No.3	ZVS	72	4	1011	0

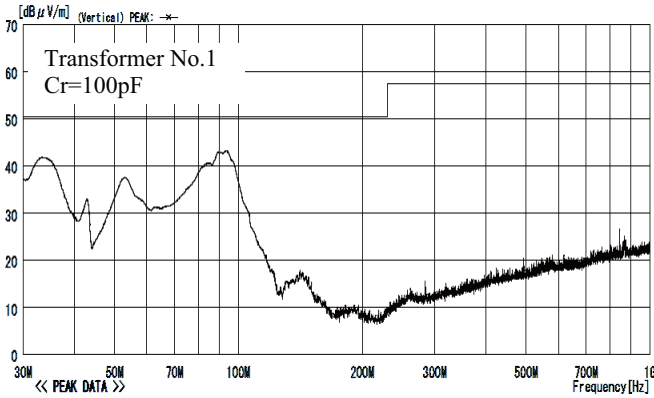


Fig.3 Radiation noise data (1)

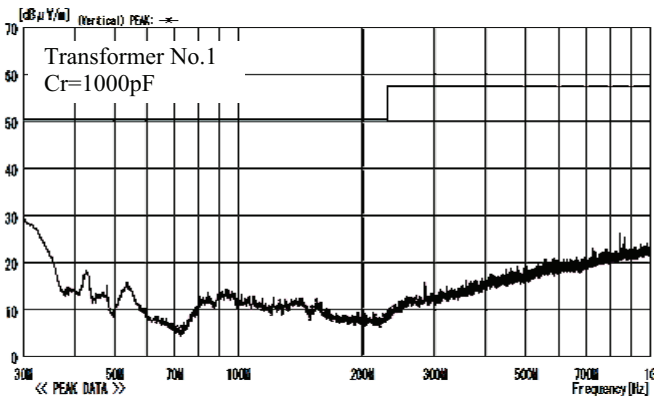


Fig.4 Radiation noise data (2)

To clarify the characteristics, we measured the efficiency and the noise of a prototype power supply with 3 types of transformer. The difference among 3 transformers is turns ratio of N_p and N_s. Different turns ratio generates different V_{bot}. The specifications of the 3 transformers are listed in Table 1.

The specifications of the prototype power supply used in the test are as follows:

Input voltage is 240Vac, Output voltage is 19Vdc
Output current is 5A

3. Measured Radiation Noise

Fig.3 and Fig.4 shows the examples of measured radiation noise. We compared noise level of three transformers at the frequency of 30MHz, 50MHz and 100MHz. The result is shown on Fig.5 to Fig.7.

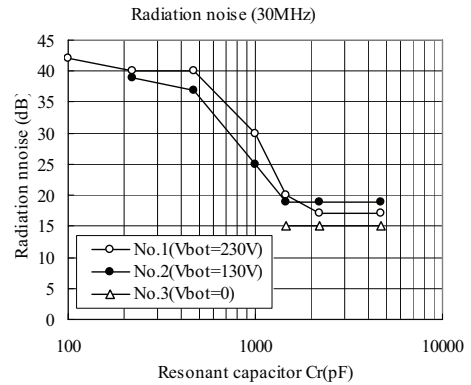


Fig.5 Radiation noise at 30MHz

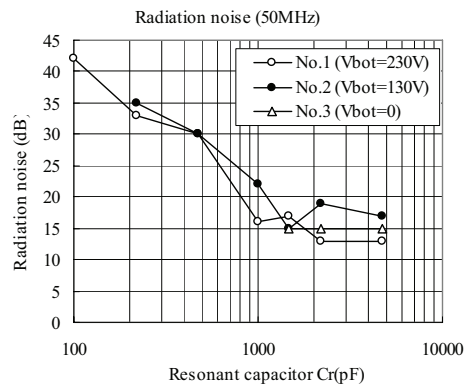


Fig.6 Radiation noise at 50MHz

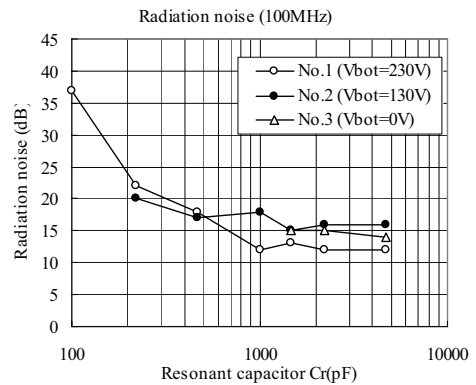


Fig.7 Radiation noise at 100MHz

We can find the followings:

- 1) The radiation noise level becomes lower as the resonant capacitor C_r becomes larger.
- 2) The radiation noise level difference among 3 transformers is very little.

As to the result 1), the characteristics are effects of resonant capacitor C_r. When C_r is larger, the gradient of V_{ds} at rising and falling edge becomes smaller and the high frequency component also becomes smaller.

As to the result 2), we applied FFT analysis to the V_{ds} waveform of Q₁, in order to make the frequency characteristics clear.

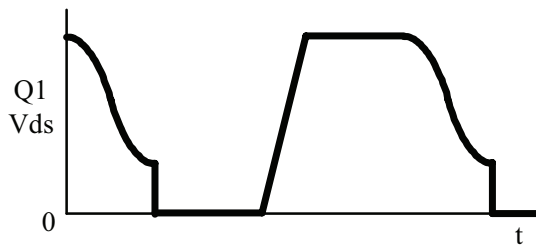


Fig.8 Theoretical Q1 waveform applied to FFT

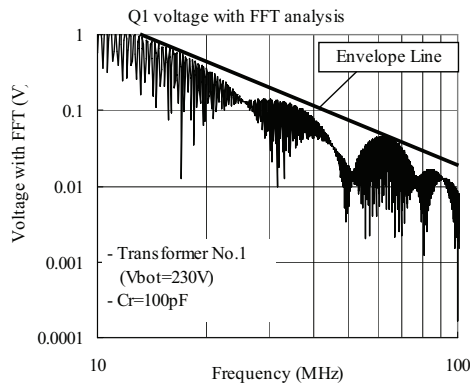


Fig.9 Result of FFT analysis

4. Analysis of the Radiation Noise

We applied FFT analysis to the theoretical waveform of Q1 removed ringing waveform as shown in Fig.8, though the actual waveform includes much ringing waveform. We already make it clear that the ringing waveform mainly consists of the frequency components around 1MHz [1]. In this paper, we analyze radiation noise in the frequency range over 30MHz. Therefore the ringing waveform can be ignored. One of the results of FFT analysis is shown in Fig.9.

As shown in Fig.9, though the result of FFT analysis includes many peak and valley, we employed the envelope line to make the tendency clear. Voltage level of the envelope line at 30MHz, 50MHz and 100MHz is shown in Fig.10 to Fig.12. Difference between the transformers is very small. Analytical results show good agreement with measurement results. The result of measurements and analysis indicate that the difference of the radiation noise between the ZVS and the non-ZVS is very little.

5. Efficiency

Fig.13 shows the peak voltage applied to the switching device Q1 when resonant capacitor C_r is changed. Surge voltage on Q1 at turn-off is suppressed as the resonant capacitor C_r becomes larger. In the case of the transformer No.2 ($V_{bot}=130V$, non-ZVS) and the transformer No.3 ($V_{bot}=0$, ZVS), MOSFET which have 900V of the withstand voltage should be used. On the other hand, in the case of the transformer No.1 ($V_{bot}=230V$, non-ZVS), MOSFET which have 700V of the withstand voltage can be used with 470pF or larger capacitor of C_r .

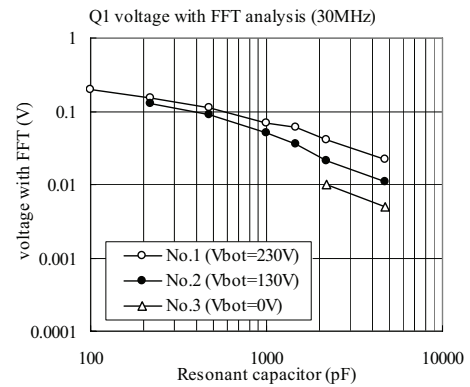


Fig.10 Q1 voltage with FFT at 30MHz

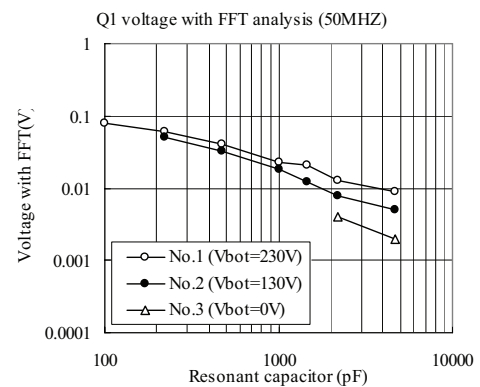


Fig.11 Q1 voltage with FFT at 50MHz

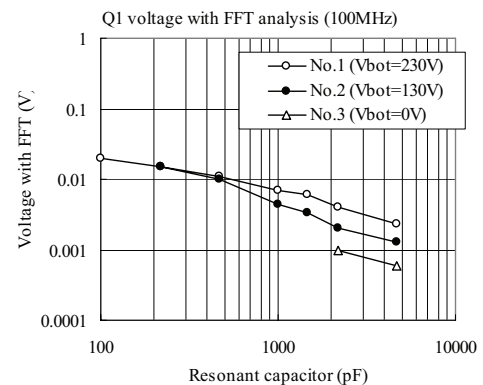


Fig.12 Q1 voltage with FFT at 100MHz

The conduction loss can be reduced by using MOSFET with the low withstand voltage because the MOSFET with low withstand voltage has low on-resistance in the same package. The MOSFET used in the measurement are listed in Table II.

In the case of non-ZVS, C_r is charged to V_{bot} just before Q1 turns on and discharging C_r causes power loss at turn-on.

The efficiency data measured in test circuit is shown in Fig.14.

The condition is as follows: in the case of transformer No.1 ($V_{bot}=230V$, non-ZVS), a capacitor of 470pF or larger is used as resonant capacitor C_r and 700V MOSFET is used as the switching device. In the case of transformer No.2 and No.3, 900V MOSFET is used.

It is found that the efficiency is highest with the transformer No.1 ($V_{bot}=230V$, non-ZVS) and with 1000pF or smaller capacitance as C_r . Conduction loss is reduced because of low on-resistance of 700V MOSFET.

In addition, it is found that the efficiency is higher with the transformer No.2 ($V_{bot}=130$, non-ZVS) when C_r is between 1000pF and 4700pF.

6. Conclusion

We conclude as follows:

- 1) The radiation noise of the quasi-resonant converter does not depend on the switching condition at turn on whether the ZVS is used or not (non-ZVS), though it depends on the resonant capacitor C_r .
- 2) The efficiency of the quasi-resonant converter is higher with the non-ZVS condition and small C_r because MOSFET with the low withstand voltage and low on-resistance can be used.

Therefore, if a small resonant capacitor C_r can be used considering the radiation noise, high efficiency can be achieved with the non-ZVS condition and smaller resonant capacitor C_r .

References

[1] H. Shiroyama, H. Matsuo, Y. Ishizuka, Y. Asako, "Analysis of the Noise and Efficiency Characteristics in a Quasi-resonant Converter" Intelec '07. pp899-903, 2007
 [2] K. Harada, T. Ninomiya, "On the Mechanism of Switching-Noise Generation and Its Suppression Techniques in a DC-to-DC Converter" Trans. IECE vol. 62-C No.12, pp795-802, December 1979
 [3] M. Nakahara, T. Ninomiya, K. Harada, "Analysis of Surge and Noise Generation Mechanism in a Forward DC-to-DC Converter", Trans. IECE vol J69-C No.1, pp139-147, January 1986.

Table 2: Specification of MOSFET

Trans-former	MOSFET	Withstand voltage	On resistance	Package
No.1	2SK3677	700V	0.72Ω	TO-220F
No.2, 3	2SK3679	900V	1.22Ω	TO-220F

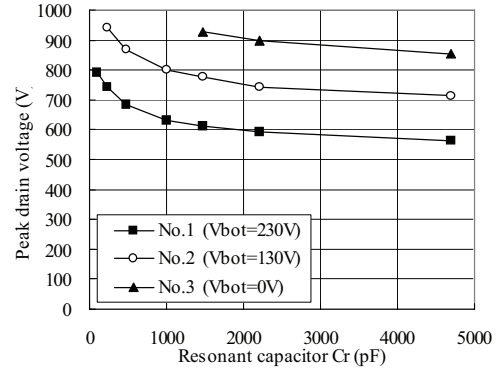


Fig.13 Peak drain voltage versus resonant capacitor

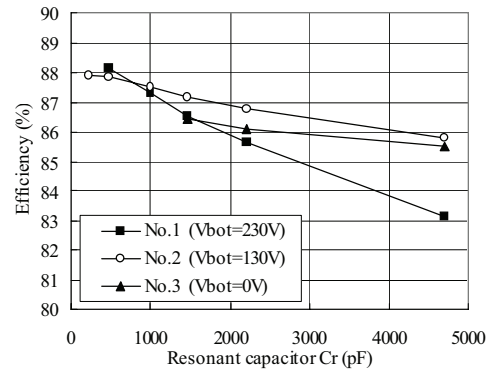


Fig.14 Efficiency characteristics