OPTIMAL DESIGN FOR RESONANT POWER TRANSFORMER*

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Abstract

The energy and dc to dc conversion of the resonant transformer are required to achieve optimal design and working condition of the resonant region frequency. To meet this requirement, the core loss will be checked first by data book for calculation. Using a reliable precise instrument is needed to scan the resonant cure of the resonant transformer as we designed the resonant cure. We calculated the conduction loss in second design step. We design a resonant transformer which the conduction loss equal core loss does not meet optima design, because the core loss is very high when the transformer works in resonant frequency. Thus, we only reduce the conduction loss is optima design aspect.

INTRODUCTION

The plan developed in our research is hoping to improve the power bus of the TPS correction power supplies it changes the way of conversion energy in the power supplies with traditional 60Hz current transformer to the soft switching mode ones using the LLC resonant transformer. This is a new technique that converts the AC line power to the setting voltage as we expect, also analyses, and applies the characteristic of the LLC resonant transformer to get the optima design. Various kinds of characters of the LLC resonant transformer are needed to understand in this study. For example, we need to calculate the core loss and conduction loss for a resonant transformer. Following the curve of its circuit model has different behaviour, analysis to the entity, and then designs the convert circuit of the LLC resonant transformer. It somewhat differs from the common study of the hard switching transformer, as we all know the conduction loss equal core loss such that its output power performance can meet the optimal required. But we design a resonant transformer of the essentials are considered in detailed discussion in this paper [1-4].

In this paper, the design of a new resonant transformer deployed in NSRRC is described. This resonant transformer is capable of delivering energy conversion with optima design. The optimal resonant transformer has been tested and proven to be working well in power conversion with excellent efficiency and performance.

In order to improve the efficiency to get the optima design transformer in this research. We have utilized a novel equipment to measure the resonant frequency and response curve of the LLC resonant transformer in frequency spectrum domain. We can smoothly design the soft switching mode PWM power convert. In this way, it can make the whole conversion efficiency significantly; however, these working frequency range are designed in fixed region [5-6].

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BOBBIN STRUCTURE

According to the physical characteristic of the LLC resonant transformer, we design a special bobbin of the LLC resonant transformer, and its two indents structure shows as figure 1.

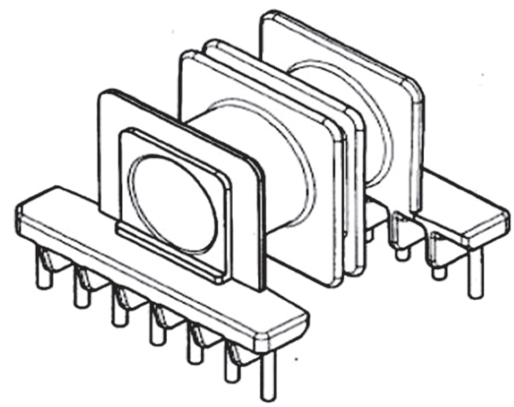

Figure 1: The two indents structure of LLC resonant bobbin.

The LLC resonant topology as figure 2, it's a half bridge circuit and power bus come from PFC is 400V. In this suitable resonant region, it produce the primary voltage is 200V in transformer for all switching device.

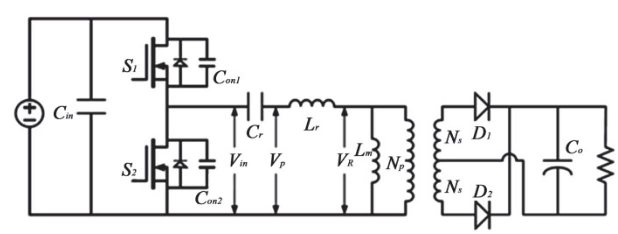

Figure 2: Resonant half bridge topology.

Due to fix the transformer primary inductance value, we use the ETD-32 ferrite and grind an air gap in the center as figure 3. The primary inductance value can be keep in 500 μH for big among produce. The tolerance is ± 25 μH Thus, we can get the primary inductance value is 500μH ± 25μH of the transformer when we produce the resonant transformer working 100kHz to 120kHz. This is important for optima design transformer which can be easy control the primary inductance value for manufacture in factory.

KEY DESIGN

From the experiment, we understand the frequency response range being about 100 kHz to 120 kHz, and this is fairly different from traditional hard switching transformers. From the figure 4, consider skin effect for spool wire.

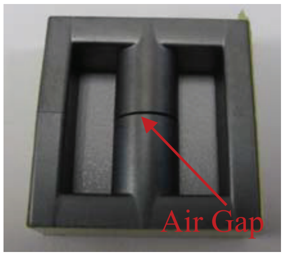

Figure 3: The ferrite ETD-32 and with air gap.

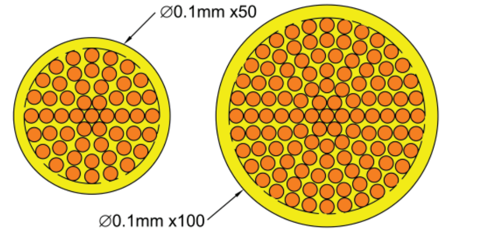

Figure 4: Fundamental structure of the extraordinary wire for resonant transformer.

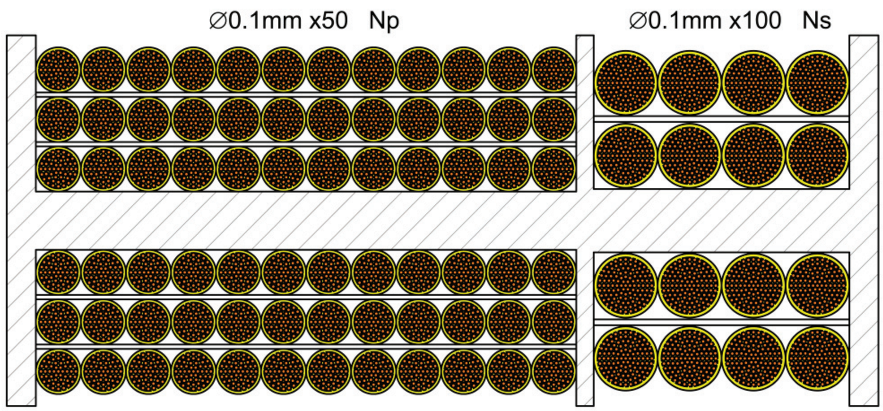

Figure 5: The two indent structure of LLC resonant transformer with extraordinary wire.

Table 1: The Specification of Transformer

Name	Primary	Secondary	Ferrite
Transformer_1	35T 0.5 mm×1	6-6T 1.0 mm×10	2500 gauss
Transformer_2	35T ϕ 0.1 mm×50	6-6T ϕ 0.1 mm×100	2500 gauss

We have two kinds specification transformer can be chose as Table 1. To care skin effect for switching frequency is 100 kHz. We follow equation (1) to calculate:

$$\delta = \frac{6.61}{\sqrt{f}}\,\text{cm} = \frac{66.1}{\sqrt{100000}}\,\text{mm} = 0.209027\ \text{mm} \qquad (1)$$

Checking the Transformer_1 is using 0.5mm wire and large 2.0mm, thus the Transformer_1 can't match class A request because the working temperature is too high by skin effect. We use the extraordinary wire to make the two indent resonant transformer as figure 5. The 0.1mm isolation wire small then 0.2mm can pass class A request. The energy is unable to produce any conversion if the frequency is working in the non-resonant and excites the input of this transformer and there is no output power when switching frequency is out of the resonate band. This is another important advantage of using the LLC resonant technique. Therefore, we can regard it as a band pass transformer. For that reason, it is more complicated to design the convert circuit; nevertheless we can control the output power quality and noises.

The LLC band pass resonant transformer as figure 6, its step down ratio is about 6:1 and frequency band is from 100 kHz to 120 kHz, via design and test. In this suitable resonant region, we must consider skin effect. Thus we chose transformer_2; it can produce the isolated energy power at safety temperature. The transformer working temperature is under 75°C.

The precision of the input frequency band is quite important, especially in measuring the resonant reactions of the LLC resonant transformer. The Qm value of LLC resonant transformer is very high form reading the reports and papers, but resonant region is setting form Lr and Cr. We follow the transformer_2 of the table 1 to make resonant transformer as figure 7.

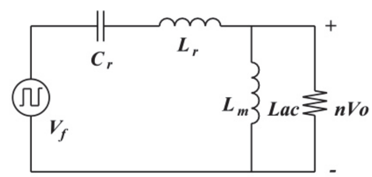

Figure 6: The structure of the LLC band pass resonant transformer.

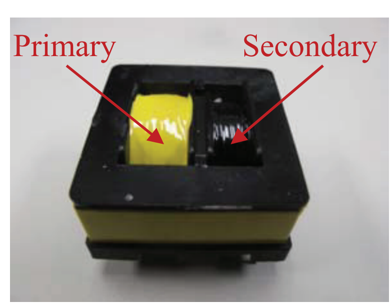

Figure 7: The optima LLC resonant transformer.

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TESTING EQUIPMENT

Viewing from the systematic research to analyze and measure the LLC resonant transformer, the essential equipment as table 2. Agilent 4294A is an instrument measuring impedance relative to the change of frequency of the LLC resonant transformer. It can make us find the impedance changing value in the frequency range we established. What we will look for is the minimum of impedance value Z produced by the LLC resonant transformer, and it is also the maximum value of Y=1/Z. That is the resonant frequency of the LLC resonant transformer and the working curve of efficiency to produce energy.

Table 2: The Essential Equipment for Design LLC Resonant Transformer

No.	Equipment Name	Type
1	Signal Generator	NF WF 1946A
2	Power Amplifier	NF HAS 4052
3	Oscilloscope	Tektronix TPS 2024
4	Impedance Analyzer	Agilent 4294A

After finding out the resonant frequency from the scan frequency by impedance analyzer, we can set the resonant frequency to the signal generator. Under the operating mode, specific energy waveform produced by power amplifier delivers to the primary connection of the LLC resonant transformer. From the oscilloscope, we can observe the waveform and amplitude of the primary and secondary behavior for the LLC resonant transformer. Certainly, the resonant frequency may drift a little, because high-energy excitation results in non-linear mode for the LLC resonant transformer. Another situation, it's the influence produced by the load effect. These are what we should look for while measuring [7].

CALCULATION RESULT

We can calculate the transformer data for increasing temperature as equation (2). The result of the ETD-32 as follow table 3.

Table 3: The Result of the ETD-32 Resonant Transformer

No.	Parameter	Result
1	l_W	210cm
2	$P_{L,CU}$	2.07^{-3}W
3	$P_{L,\,FE}$	9.6^{-2}W
4	ΔTr	22.6℃

$$\Delta T_r \times \frac{800 \times P_L}{\sqrt{A_S}} = \frac{800 \times 9.807^{-2}}{\sqrt{11.3}} \cong 23.34^{\circ}C \qquad (2)$$

The temperature increasing is under 35℃, thus the transformer should be working under 75℃. It is match specification of the class A.

CONCLUSION

Our study purpose is the development of resonant transformer and their control production for the fix the primary inductance. The essential methods in this research are scanned resonant region construction of the resonant transformer. By the measurement quantities is through the Agilent 4294A to confirm its band of the working frequency. We can calculation to get the core loss and conduction loss while designing the resonant switching frequency.

It provides a 48V dc power bus for the TPS correction power supply to solve the problems such as volume miniaturization, low weight, and universal ac input voltage with power factor control, independent power bus and efficient enhancement. On the other hand, the high quality and low current ripple are desperately required to the TPS correction power supply in the NSRRC. In this way, we should be prudent to develop this technology.

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