Dsign of Low-voltage Power Supply Drive Circuit Based on the Piezoelectric Ceramic Transformer

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Abstract—**The piezoelectric ceramic transformer has the advantages of high conversion efficiency, high pressure, electromagnetic compatibility,etc.It overcomes the shortcomings of large electromagnetic interference, low conversion efficiency , a large volume, etc. Using IR2184,the paper designs piezoelectric ceramic transformer full-bridge driver circuit. It greatly improves the conversion efficiency of the power system and power.**

Keywords- piezoelectric ceramics ; transformer; power ; drive circuit

I. INTRODUCTION

With the development of science and technology, electrical equipment are increasing miniaturization. The low-voltage power has been widely used in various types of electrical equipment.But people commonly use traditional magnetic transformer to design power. The magnetic switching power has disadvantages of large range of electromagnetic interference, rich harmonic ,current and voltage shocks, poor reliability ,etc.

Piezoelectric Transformer is a new type of electronic transformers. Compared with conventional electromagnetic transformer, which has the following advantages(1) simple structure, small size, light weight;(2)safe, not bursting into flames;(3) No electromagnetic interference, without electromagnetic shielding;(4) high efficiency, energy density, etc. The power made of piezoelectric ceramic transformer, useing of the inverse piezoelectric effect of the piezoelectric ceramics and piezoelectric effects. has the characteristics of the ultrasound mechanical wave energy coupling and transmission . It output waveform closing to sine wave. Thus fundamentally it greatly reduced strength and bandwidth of the electromagnetic interference, while eliminating the large current and voltage shocks. The working status of the circuit element and circuit reliability are greatly improved.

II. PIEZOELECTION CERAMIC TRANSFONMER

A. Piezoelectric ceramic transformer equivalent circuit model

The basic equivalent circuit of Pt working in the mechanical resonance frequency is shown as Figure 1 (a) . According to the energy conversion, the simplified equivalent circuit is shown in Figure 1(b). Further parallel circuit is converted to a series circuit shown in Figure 1 (c).

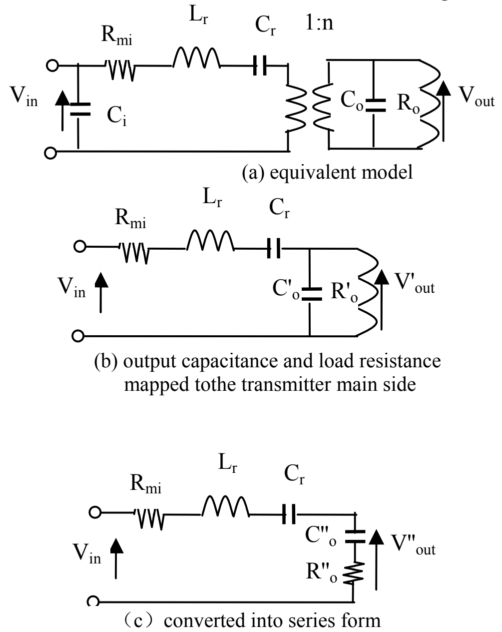

Figure 1. The equivalent circuit of the PT

PT 's input-output electrode has a parallel metal layer. Therefore, the input capacitance Ci and the output capacitor CO are decided by the structure of the PT. Since Ci does not affect the input voltage Vin, so Ci doesn't appear in simplified circuit as figure 1 (b), (c).The relationship about CO in figure 1(a), output resistance RO, output voltage Vout, mapping capacitance C'i in figure 1(b), mapped resistance R′o and mapped voltage is

$$C_o' = n^2 C_o \qquad (1)$$

$$R_o' = R_o / n^2 \qquad (2)$$

$$V_{out}' = V_{out} / n \qquad (3)$$

The series circuit composed C′o and R′o in figure 3 (c) is equivalent to a parallel circuit,and

$$R_o'' = \frac{R_o'}{1 + (\omega C_o' R_o')^2} \qquad (4)$$

Published by Atlantis Press, Paris, France.

$$C_o'' = C_0' \frac{1+(\omega C_o' R_o')^2}{(\omega C_o' R_o')^2} \tag{5}$$

In the formula ω is the the PT operating frequency , that is, the excitation signal frequency. The Vout is the max when PT work at the mechanical resonance frequency. According to figure (3) the resonance frequency fm is

$$f_m = \frac{1}{2\pi\sqrt{L_r C_{eq}}} \tag{6}$$

In the formula the Ceq is the series values of C″o and Cr ,and

$$C_{eq} = \frac{C_r C_o''}{C_r + C_o''} \tag{7}$$

From the above equation, fm is determined by the C″o. When the output in the Figure 3 (a) Connectes the external capacitor C1 (parallel),we get

$$\begin{cases} C_o' = n^2(C_o + C_1) \\ f_{r1} = \dfrac{1}{2\pi\sqrt{L_r C_r C_o/(C_r + C_o)}} \end{cases} \tag{8}$$

When the output is open

$$f_{ro} = \frac{1}{2\pi\sqrt{L_r C_r C_o/(C_r + C_o)}} \tag{9}$$

According to figure 3, $R''_O$is equivalent changed from R_O. So, the output power is the highest when $R''_O=R_m$. Simultaning equations (8) and (9), the f_{r1} and f_{r0} is obtained by experiment.So we can obtained the model parameters L_r and C_r of PT. C_O in the equation can be measured directly by the instrument.

B. The working principle of the piezoelectric transformer

When pt is working,AC voltage is applied at its input. When the frequency of the voltage applied is equal to the resonant frequency of the piezoelectric transformer, the piezoelectric transformer generates the inverse piezoelectric effect.The power input to the piezoelectric transformer is converted into the mechanical vibration energy. The vibration wave is passed longitudinaly along the piezoelectric transformer, reaching the output terminal, generating the positive piezoelectric effect. So we can obtain the highest sine wave output voltage at the resonant frequency of the piezoelectric transformer.

Only working at resonant state ,the piezoelectric transformer has the most significant AC voltage output at its output terminal. Then the piezoelectric transformer has Maximum efficiency and maximum utilization. But, when the piezoelectric transformer working at the non-resonant state, the AC voltage at its output and work efficiency are lower. If the frequency of the input voltage of the piezoelectric transformer is excessive deviation from the resonant frequency, the output terminal of the piezoelectric transformer will be extremely weak AC voltage output, or even no voltage output, the output voltage is severely attenuated.

III. THE LOW-VOLTAGE POWER DRIVE CESIGN

A. Power system structure

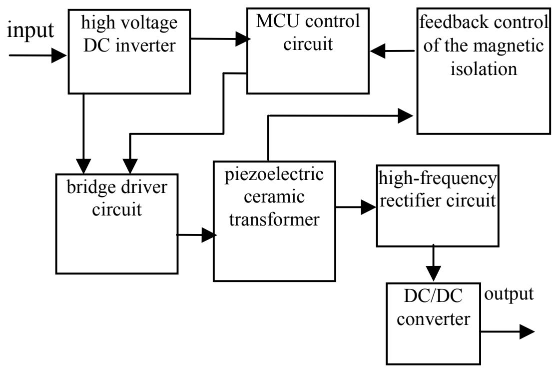

Figure 2. Block diagram of the power system

The block diagram of power system based on the piezoelectric ceramic transformer is shown in Figure2. The inverter circuit of the high voltage DC is the power part of the whole system. It provides operating power for the control part of the full-bridge inverter and microcontroller . It has good reliability and high efficiency. The bridge driver circuit is the power inverter part of the entire circuit system. providing high-frequency and high-voltage square wave power for piezoelectric transformer. The electromagnetic isolation feedback control circuit samples the output of the piezoelectric ceramic transformer ,and then get feedback voltage. The voltage changes proportionally to the frequency rectifier output DC voltage. The feedback voltage is sent to the microcontroller, controling indirectly the output of piezoelectric ceramic transformer. After rectified by the high-frequency rectifier circuit ,the voltage output three voltage.

B. The design of piezoelectric transformer bridge driver circuit

Driving circuit is shown in Figure3. U7 and U8 in the circuit are IR2184 chip. It has characteristics of good reliability, high efficiency, high-side power bootstrap circuit.

IR2184 is powered directly with low-voltage power 12 volt. The two complementary half-bridge output driver signal when reversing with a fixed, small dead zone, to prevent the series power tube common conduction. The output of the two IR2184 form a full bridge drive signal to drive the power MOS transistor Q3 ~ Q6 ,obtained after excluding a DC high-voltage square wave AC voltage.Then it output high-voltage square wave AC excluding the DC.

After the high-voltage square wave AC voltage through two series resonant circuit connected in parallel with L7,C30 and L8,C29, the circuit outputs high-frequency, high-voltage alternating current closing to sine wave. The signal attenuation is very small in the working frequency range, while has a strong damping effect to the high-order harmonic. Sine wave applied to the input end of the piezoelectric ceramic transformer,making the piezoelectric transformer and high-frequency rectifier circuit in good working condition. It improves the reliability and efficiency of the system, while reducing the electromagnetic radiation of the circuit.

IR2184 pin 7 output voltage signal Ho.Its internal has bootstrap circuit. D6, C15 and D7, C16 is an external circuit. It eliminates the need for a separate isolated power and isolated control circuit.

IV. CONCLUSION

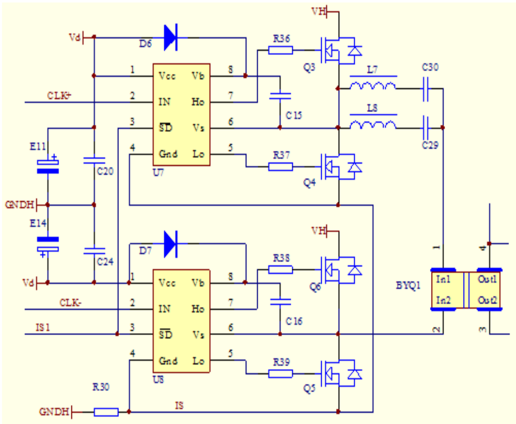

Figure 3. The bridge drivers piezoelectric transformer circuit

The experiments show that this drive circuit make the piezoelectric ceramic transformer has high conversion efficiency (not less than 90%). Due to MCU constantly sampling the output voltage of the piezoelectric transformer and tracking, it can reliably control piezoelectric ceramic transformer and make that always work at the resonant state.When working the power is larger. Small size, low cost IC and piezoelectric ceramic transformer cansupport assembly into a variety of power module. Products supplied to the market, to facilitate the promotion and application of piezoelectric ceramic transformer. Therefore, the power system has broad application prospects.

REFERENCES

[1] Guangchong Liu. Development Status and Trends of the Piezoelectric Seramic Transformer. National Electronic Transformer Industry Association Proceedings(6),2006

[2] Zhijun Hou. Ultra-compact High Voltage Power Supply Based on Piezoelectric Ceramic Transformer. Electronic Component Applications,2002(2)

[3] Xingwu Mao,ZHU Da-wei. New Electronic Ballast Circuit Schematic and Design. People's Posts and Telecommunications Press,Beijing,2007

[4] Liyang Yu, De-miao Wang, Shu-rong Dong. The Latest Research Progress of Piezoelectric Transformer Peripheral Circuits[J]. Electronic Components and Materials, 2005,24(6):51-53

[5] Idogaki T Kanayama, H Ohya N, et al. Characteristics of piezoelectric locomotive mechanism for an inpipe microinspectionmachine . In: Sixth International Symposium on Micro Machine and Human Science, 1995: 193-198