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Electrical characteristics of central driving type piezoelectric transformers with different electrode distributing

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Abstract

In this study, three kinds of central driving type piezoelectric transformers, Types A, B and C with different electrode distributing were investigated by using impedance analyses. With the increase of the input electrode area, the resonant resistance of input section decreased and the effective electromechanical coefficient increased. With the decrease of the length of the generator section, the resonant resistance of generator section increased and the effective electromechanical coefficient decreased. The voltage step-up ratio increased with the increase of the ratio of the input and output resonant resistance. The temperature rise of Type A was lower because the impedance matching between the load resistance and the output impedance was achieved. Taking into consideration of the mechanical quality factor (Q_m), the output impedance (Z_{out}) and the temperature rise (ΔT) of each transformer, Type A with the input electrode length ratio of 1:1:1 could be selected as the optimum structure to drive the LCD backlight.

Keywords: Piezoelectric transformers; Impedance matching; Effective electromechanical coefficient; Voltage step-up ratio; Temperature rise

1. Introduction

Recently, the piezoelectric transformers have been widely supplied to the LCD backlight inverter for notebook, camcorder, and PDA, etc. Because their electrical characteristics are in accordance with required ones of LCD backlight that needs high igniting voltage at burst state and low operating voltage in static one [1–3]. Compared with magnetic transformers, piezoelectric transformers are thinner, nonflammable and electromagnetic-noise-free, they also have a high power-to-volume ratio and a high efficiency.

The conventional structure of piezoelectric transformers is Rosen-type. However, Rosen-type piezoelectric transformers have the following disadvantages. (i) Rosen-type piezoelectric transformers utilize only the one side of a drive unit at the input side, and do not utilize the other side. As a result, such conventional piezoelectric transformers cannot fetch the large electric current efficiently from the output side. (ii) Rosen-type transformers work in single output mode and fail to meet the multi-output requirements of many electronics equipment, which considerably limit the application of the piezoelectric transformers. But in many modern applications, low-profile and high-efficiency inverters are required for lightening of the LCD backlight, which require the piezoelectric transformers with miniaturized structures and high power density [4,5]. Some patents have referred to central driving type piezoelectric transformers to solve the above disadvantages [6,7].

The central driving type piezoelectric transformers have a symmetric structure in the length direction. The input part is located at the centre portion with multilayer structures. So far, a few reports about the relationships between the internal electrode distributing and electrical characteristics of piezoelectric transformers have been found. However, our experimental data clearly indicate that the electrode distributing of the piezoelectric transformers considerably affects the voltage step-up ratio (γ), the temperature rise (ΔT), the mechanical quality factor (Q_m) and the effective electromechanical coefficient (K_{eff}), etc. It is preferable to piezoelectric transformers with a higher output power and a lower heat generation simultaneously. Therefore, in this study, we investigated three kinds of

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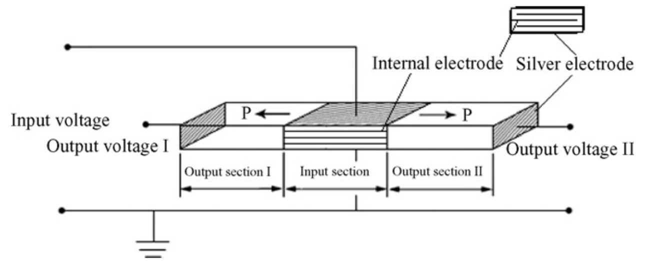

Fig. 1. Schematic diagram of central driving type piezoelectric ceramic transformers.

central driving type piezoelectric transformers with different electrode distributing. Through comparison electrical characteristics of central driving type piezoelectric transformers with different electrode distributing, the relationship among the heat generation, the voltage step-up ratio, the impedance of input section and output section and the electrode area was investigated.

2. Construction and principle

Fig. 1 shows a schematic diagram of the length vibration mode central driving type piezoelectric transformers. The length of the transformer is divided into three sections. The input part is located at the centre portion with multilayer structures and the polarization aligned in the thickness direction. The two outputs are located at both ends of the transformer with a single layer structures and its bottom surfaces are fully covered by silver electrode. As shown in Fig. 1, the two output parts of the piezoelectric transformer are polarized in opposite longitudinal directions with each other. These output regions can be connected together to enable a doubling of the available output current.

The principle of the piezoelectric transformers is to excite a piezoelectric element at its mechanical resonance frequency. Applying an electrical input to the driver part of the piezoelectric transformers generates a mechanical vibration, which is converted into electrical voltage from the two generator parts of the piezoelectric plate [8].

3. Experiment

In this study, all the piezoelectric transformers are made of the same lead zirconate titanate (PZT)-based ceramic materials, the relevant properties of the PZT-based ceramics are shown in Table 1.

Table 1
The piezoelectric properties of PZT ceramics

Properties	Values
Dielectric constant ε_r	2600
Mechanical quality factor Q_m	840
Electromechanical coefficient K_p	0.593
Piezoelectric coefficient d_{33} ($\times 10^{-12}$ C/N)	410
Frequency constant N_r (mm Hz)	2200
Dielectric loss $\tan\delta$ ($\times 10^{-4}$)	65

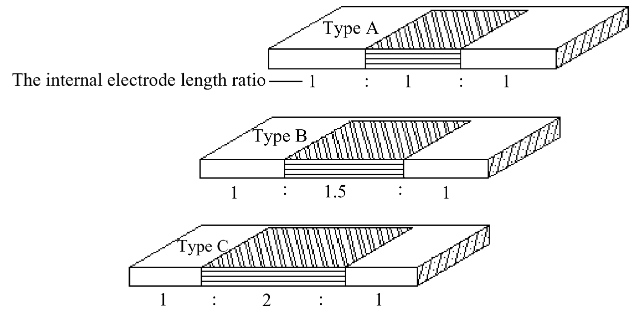

Fig. 2. Internal electrode distributing of each piezoelectric transformer.

The piezoelectric transformers were fabricated by using the tape-casting technique. The internal electrode distributing of each type of the piezoelectric transformers are shown in Fig. 2. A silver–palladium alloy (85/15) was applied to the each electrode layers. All the 13-layer ceramics films were connected to each other electrically in parallel through electrodes, and then were sintered at 1000 °C for 4 h in a sealed alumina crucible. The input internal electrode length ratio (output section I/input section/output section II) was 1:1:1 (Type A), 1:1.5:1 (Type B) and 1:2:1 (Type C). The dimensions of the three kinds of piezoelectric transformers were 36 mm long, 6 mm wide and 3 mm thick. Silver-paste was coated to transformers on both sides by the screen-printing method, and then subsequently fired at 850 °C for 30 min. The input parts were polarized in the thickness direction and the output parts were polarized in the longitudinal direction in air at an electrical field of 0.75 kV/mm at 320 °C for 10 min.

In order to identify the frequency characteristics of the three transformers, the input and output resonant (f_r) and anti-resonant frequencies (f_a) of the transformers were measured using impedance analyzer (HP 4294A). The capacitance was determined with the LCR meter (TH2818) at 1 kHz. The mechanical quality factor (Q_m), the effective electromechanical coefficient (K_{eff}) and the output impedance (Z_{out}) were calculated using the following equations:

$$Q_m = \frac{1}{2\pi f_r (1 - f_r/f_a)^2 RC} \quad (1)$$

$$k_{eff} = \sqrt{\frac{f_a^2 - f_r^2}{f_a^2}} \quad (2)$$

$$Z_{out} = \frac{1}{2\pi f_r C_{out}} \quad (3)$$

where f_r and f_a are resonant and anti-resonant frequencies, and R and C are resonant resistance and capacitance, respectively, C_{out} represents the capacitance of the generator section.

The experimental equipments for measuring transformers characteristics are shown in Fig. 3. The input voltage is supplied by a function generator (DF 1631L) and then amplified by a high-speed power amplifier (NF4010). Pure resistive load (R_L) is used and the temperature rise of the piezoelectric transformers is measured by an infrared thermometer. In addition, the ambient temperature during the experiments is 25 °C.