Impact of the Isolation Gap Position on the Voltage Gain Characteristics of Disc-Shaped Piezoelectric Transformers

Nedyu Nedev[1], Zvezditza Nenova[2], Toshko Nenov[3]

Abstract – **Piezoelectric transformers have various areas of application as electronic components. This paper presents the investigations of the voltage gain characteristics of disk-shaped piezoelectric transformers with a chord oriented isolation gap between the electrodes. It shows the impact of the isolation gap position and of the load resistance on the frequency characteristics and on the maximum voltage gain.**

Keywords – **piezoelectric transformer, piezoelectric disk, isolation gap, voltage gain**

I. Introduction

The development of technologies and of new ceramic materials leads to widening of the application fields of piezoelectric transformers (PTs) not only as an alternative to magnetic transformers in portable devices - laptops, PDA, etc., but also in medical devices, instrumentation, even in the field of space technology [1]. PTs have a lot of advantages compared to electromagnetic transformers [2]: high efficiency at resonance, possibility of miniaturization, insensibility to the electromagnetic fields, operation in a wide frequency range, simple production technology, etc.

The piezoelectric transformer is a solid state element from a piezoelectric material (often piezoceramics) with applied electrodes of different configuration. PTs can be formed in various shapes. Most often they are rectangular, disk or ring-shaped [1, 3, 4]. Disc-shaped PTs convert mechanical energy into electrical energy more effectively [5].

The operation principle of PT is based on the direct and inverse piezoelectric effect [6, 7]. The electrodes to which the source of the electrical signal is connected create the excitation section of the PT and the electrodes to which the load is connected – the generator section. In the excitation section the sine wave electrical signal is converted into mechanical vibrations as a result of the inverse piezoelectric effect. These oscillations are formed on the border of the electrodes and they spread through the whole volume of the piezoelectric elements. Reflecting from the areas with different acoustic impedance, they form direct and backward waves. Their collection results in a standing wave. The amplitude of the standing wave reaches a peak when the direct and reflected waves are in phase. This occurs when the frequency of the excitation source is near to one of the resonance frequencies of the mechanical oscillations of the piezoelectric element. In the generator section of the PT the mechanical vibrations resulting from direct piezoelectric effect are converted into an electrical signal. Since the mechanical tension in the standing wave has maximum at the resonance frequency, then the voltage gain has a maximum value of this frequency.

On this principle operate all structures of piezoelectric transformers. Since the energy from the excitation to the generator section is transmitted only mechanically, the PT gives the opportunity for galvanic separation of the input from the output circuit [6, 8-10]. Depending on the shape and dimensions of the piezoelectric element, the resonance mode is obtained at different frequencies of the input signal.

When the volumes of excitation and generator sections are equal (symmetrical design) the voltage gain of the PT is determined only by the resonance properties of the piezoelectric element. When the design is unsymmetrical, the transformation ratio depends not only on the resonance properties of a piezoelectric element, but also on the design parameters [11].

In the literature known, various monolayer and multilayer PTs and the possibility of their application to different devices were studied [3,12-14]. There are few investigations of the influence of the geometric dimensions and the shape of the electrodes of the PTs on their voltage gain characteristics [15].

This paper presents the results of the studies of the impact of the isolation gap position between the electrodes of the disk-shaped piezoelectric transformers on their voltage gain characteristics.

II. Experimental Procedure

A. Studied samples

Piezoelectric transformers as well as electromagnetic transformers can amplify the signal voltage and current, to divide galvanically the electric circuit, to invert the phase of the input signal, etc. The investigated samples were prepared as disk-shaped piezoelectric transformers with a diameter of 30mm and a thickness of 2.5mm from SPZT-8 piezoceramic, with a set of chord oriented isolating gaps. The design of the studied samples is shown in Fig. 1.

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The design includes excitation and generator electrodes and a common electrode which form two sections of electrodes – an excitation and a generator section.

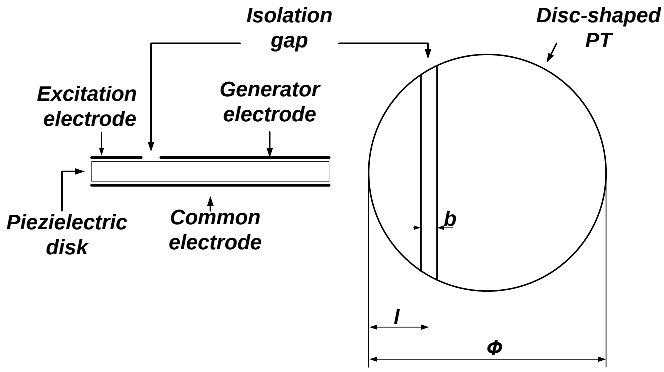


Fig. 1. Design of the samples

The isolating gap with a width *b*=1,5 mm separates the excitation and generator electrodes. The position of the isolation gap is marked by *l*. For the different samples this parameter is 7.5, 15.0 and 22.5mm, respectively. The studied samples are presented in Fig. 2.

Fig. 2. Studied samples

B. Measurement system

The study of the piezoelectric transformer elements is performed according to the measurement system shown in Fig. 3.

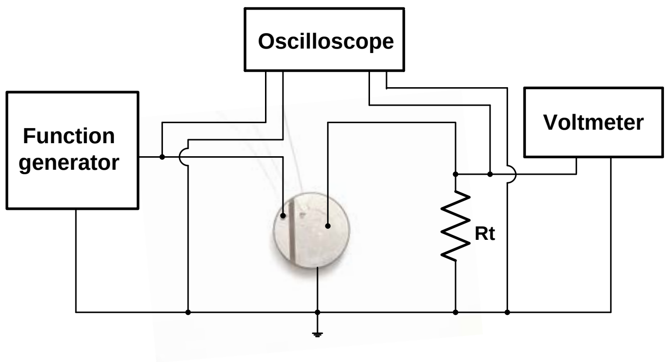


Fig. 3. Measurement system

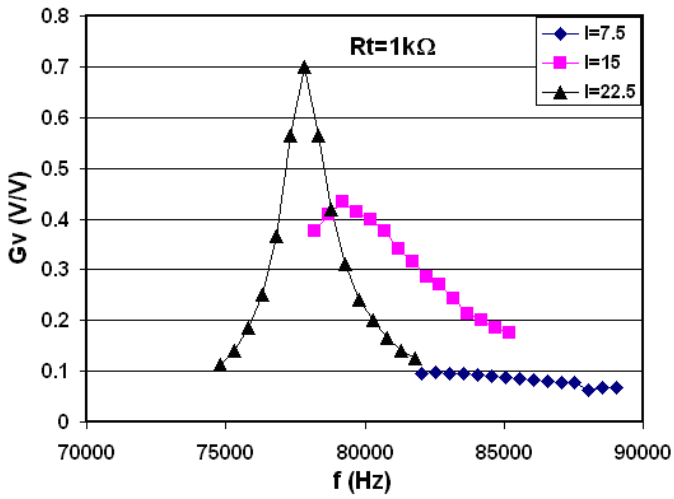
The system comprises HAMEG HM8150 functional generator with a voltage range from 20mV to 20V and a frequency range from 10mHz to 12,5 MHz, B3-57 voltmeter with a voltage range from 0,03mV to 300V and a frequency range from 40Hz to 10GHz. To control the form of the input and output signals a Philips PM3212 oscilloscope with a frequency range of 25MHz is used. As load of PT standard resistors R331 with values 1kΩ, 100kΩ with accuracy of 0.01, R4010 with 1MΩ value and accuracy of 0.02 are used. Measurements are taken also in an open circuit (Rt =∞).

III. Results and Discussion

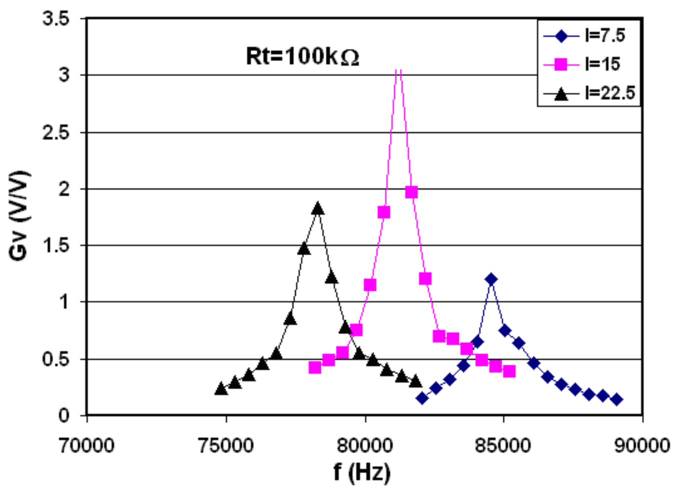
The frequency responses for three values of the parameter *l* of the piezoelectric transformers at the input sinusoidal signal with amplitude of 2V in the frequency range from 71 to 93kHz are studied. Based on them, the voltage gain characteristics *Gv* = *Uo*/*Ui* as a function of frequency *f* and the maximum voltage gain *Gvm* as a function of *Rt* and the position *l* of the insulation gap are obtained.

The frequency characteristics of the voltage gain *Gv=F*(*f*) for different values of parameter *l* and load resistance *Rt* are shown in Fig. 4.

On the basis of the results shown in Fig. 4, the characteristics of the maximum voltage gain frequency *fm* as a function of the load resistance *Rt* and the position *l* of the isolating gap are obtained and presented in Fig. 5**.**



a)



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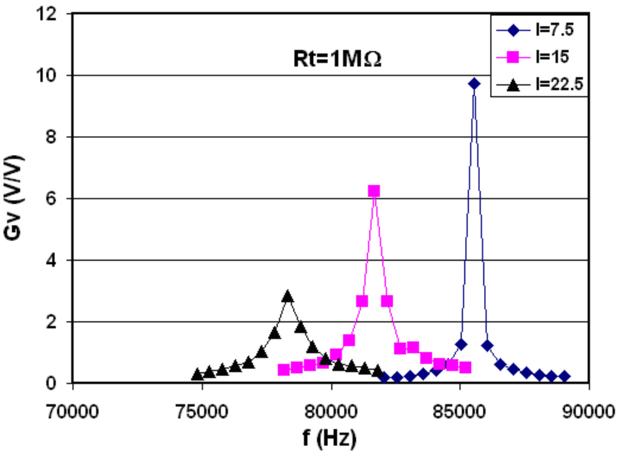

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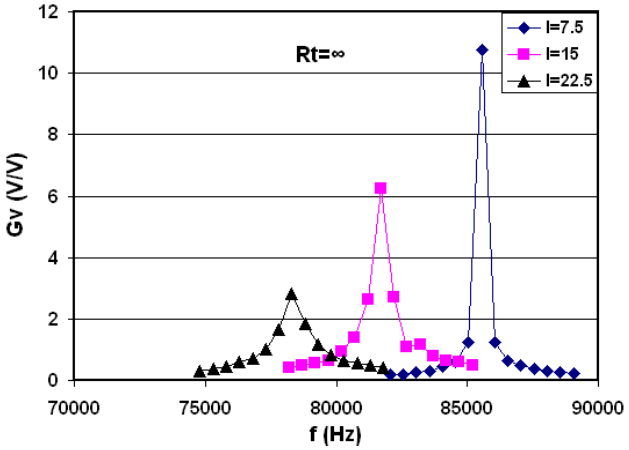


d)

Fig. 4. Frequency characteristics *Gv* = *F* (*f*) for various values of position *l* and of load resistance *Rt*: a) *Rt*=1kΩ; b) *Rt*=100kΩ; c) *Rt*=1MΩ; d) *Rt*=∞

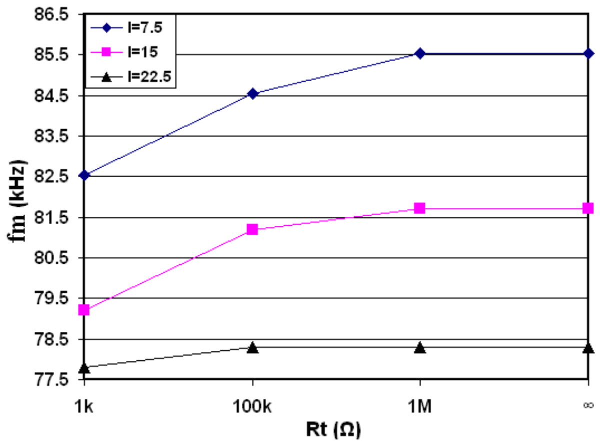
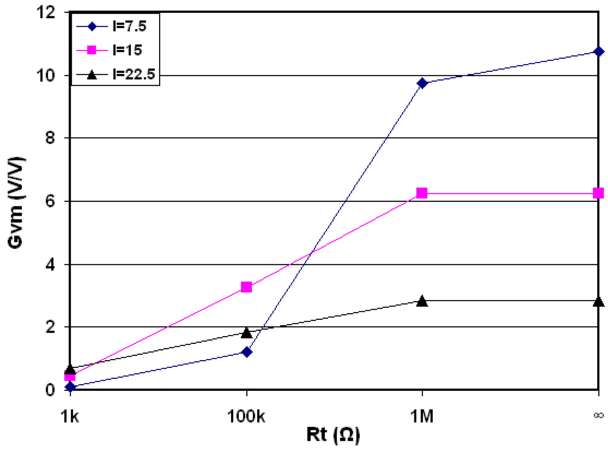


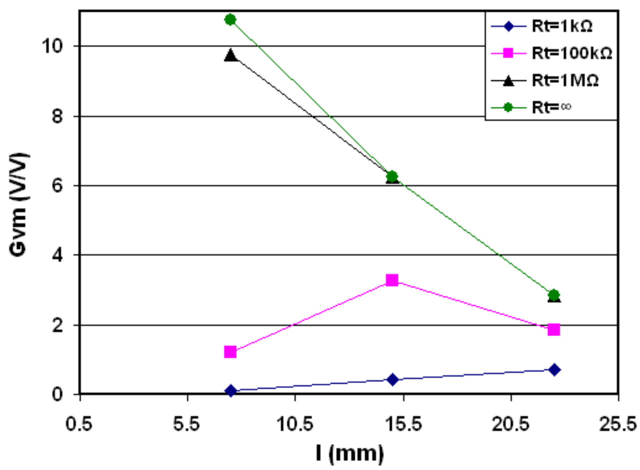
Fig. 5. Characteristics *fm*=*F*(*Rt*) for different values of parameter *l*

The increase in *Rt* leads to an increase in frequency *fm* for different values of parameter *l*. The impact of *l* on *Gvm* is bigger than the one of *Rt*. Frequency *fm* increases with the decrease in *l* and has a maximum value at *l* = 7.5mm. For all samples tested at various load resistances frequency *fm* varies within the range 77.6 - 85.6kHz.

The impact of *Rt* and *l* on *Gvm* for the studied samples is shown in Fig. 6.



a)



b)

Fig.6 Impact of: a) the load resistance *Rt* and b) the position *l* of the isolation gap on the maximum voltage gain *Gvm*

On the basis of these characteristics it is found, that for values of *Rt* > 1MΩ the highest value is observed when *l* = 7.5mm. When *Rt* = 100kΩ the function *Gvm* has a maximum at *l* = 15mm as for smaller values of *Rt* the characteristic is changed and when *Rt* = 1kΩ, *Gvm* increases with the increase in *l*. It has a maximum value at *l* = 22.5mm. For all values of parameter *l* investigated the increase in *Rt* leads to an increase in the voltage gain *Gvm*, i.e. the increase in the value of load resistance leads to improved performance of the PTs. For samples and parameters investigated the highest value of *Gvm* is observed at *Rt* = ∞ and *l* = 7.5mm.

IV. CONCLUSION

Piezoelectric transformers with a different position *l* of a chord oriented isolation gap with a fixed width *b* have been investigated. Measurements have been taken to establish the influence of the position *l* and the load resistance *Rt* on the frequency characteristics and on the maximum voltage gain of piezoelectric transformers. The frequency *fm* of piezoelectric transformers depends on both parameters. For large values of *Rt* a decrease in *l* leads to an increase in *fm*.

From the measurements taken it has been found, that the increase in the load resistance *Rt* leads to an increase in the maximum voltage gain *Gvm*. The position *l* of the isolation gap has a significant impact on *Gvm*. At high load resistance the decrease in *l*, i.e. a decrease in the area of the excitation and the increase in the area of the generator electrode, results in an increase in maximum gain voltage *Gvm*. This makes it possible to control its value depending on the design position of the electrodes.

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