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IMPROVING OF PARAMETERS PIEZOELECTRIC TRANSDUCERS FOR MEDICAL ACOUSTICS DEVICES

The creation and improvement of special piezoceramic sensors for medical acoustic diagnostics is very important. Such sensors are characterized by high sensitivity and linearity of the amplitude-frequency characteristic in a wide frequency range.

Issues of improving piezoceramic electroacoustic transducers using the method of additional elements are considered in this paper. If the additional oscillatory circuits, which are created using the additional inductance and the interelectrode capacitance of the piezoelectric element, are connected to a relatively high-frequency transducer, it is possible to create acoustic low-frequency oscillations. Also can increase the sound pressure level, expand the bandwidth of the transducer, which is important for transducers used in medical acoustics. Transducers with the properties of differentiating and integrating circuits can be obtained by connecting active resistances to the piezoelectric element.

Key words*: *piezoelectric element, transducer, equivalent circuit, inductance, capacitance, amplitude-frequency characteristic.

Piezoelectric transducers are widely used in other areas of science and technology: electroacoustic, underwater acoustics, in the ultrasound, measuring equipment, in scanning probe microscopes, piezoengines [1–3].

Currently, acoustic control devices are widely used in medicine. They have in their design one or several piezoelectric transducers and allow to obtain many data on the state of human health.

A transducer is a device that converts one physical quantity or energy into another physical quantity or energy, for example, thermal energy - into electrical energy, force - into displacement, pressure - into electrical voltage or current, electrical voltage of one level - into electrical voltage of another level etc [4].

Methods of piezoelectric transducers synthesis are described in work [4]. These methods allow creating transducers with necessary characteristics. The technology of additional elements is of particular interest among the described technologies, since in this case the change in transducers characteristics is due to external circuits of piezoelement.

At least two options are possible here. In the first case, the metal plate, the second piezoelectric element or the ultrasonic concentrator is mechanically attached to the piezoelectric element. In the second case, the capacitance, inductance, resistance, another piezoelectric element or part of the piezoelectric element is electrically connected to the piezoelectric element.

The attachment of a metal plate to the piezoelectric element turns the monomorphic piezoelement into bimorph. At the same time, a new type of vibration appears - bending. These oscillations are the lowest frequency for piezoelectric transducers. In this case, the sensitivity of the transducer increases by an order of magnitude or more. A similar result is achieved when two piezoelectric elements are connected [1, 4].

Attaching an ultrasonic concentrator to the piezoelement reduces the operating frequency of the device and increases the displacement amplitude. Such devices are used in ultrasonic technology [4, 5] and in measuring devices [1].

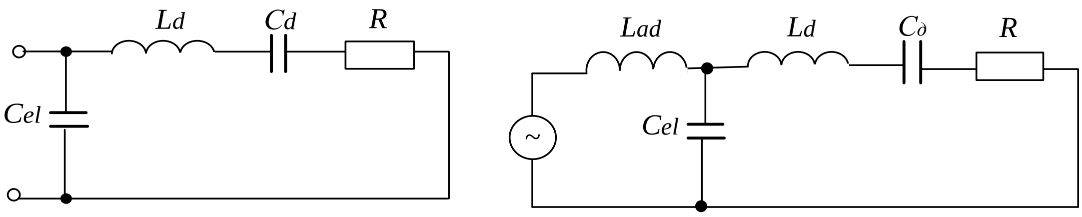
The addition of electrical elements - inductance, capacitance, active resistance and circuits composed of these elements to the piezoelectric element is also interesting.

A simplified equivalent electric circuit of the piezoelectric element is shown on Fig.1,a.

On this scheme C_{el} – capacity between piezoelement electrodes, L_d, C_d R – dynamic inductance, capacity and active losses in a piezoelement.

If attach the inductance to the input of a piezoelement L_{ad}, this inductance and capacity between electrodes C_{el} forme a consecutive oscillatory contour $L_{ad}C_{el}$ [6] (Fig. 1,b), which resonant frequency can be defined by the known formula

$$f_{ad} = \frac{1}{2\pi\sqrt{L_{ad}C_{el}}} \quad (1)$$



a) b)

Fig.1. The equivalent electric circuit of a piezoelement (a), The equivalent circuit of piezoelement with additional inductance (b)

Resonant frequency of a piezoelement

$$f_{PE} = \frac{1}{2\pi\sqrt{L_d C_d}}. \quad (2)$$

Besides, there is a resonance on frequency

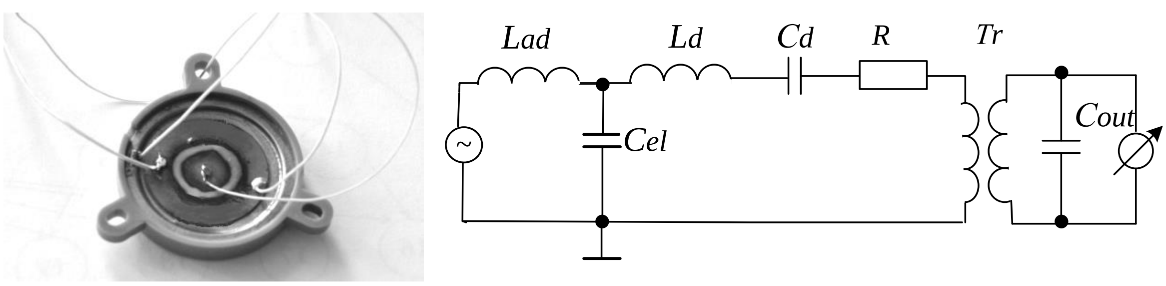
$$f = \frac{1}{2\pi\sqrt{(L_{ad} + L_d)C_d}} \quad (3)$$

Depending on values C_{el} and L_{ad} three cases are possible:

$$f_{ad} = f_{PE};$$
$$f_{ad} < f_{PE}; \quad (4)$$
$$f_{ad} > f_{PE}.$$

We will test the electro-acoustic transducer ЗП-19. The transducer consists of bimorph piezoelement (a steel plate 40X with diameter 32 mm and thickness 0,15 mm and of piezoelement with diameter 23 mm and thickness 0,2 mm made of piezoceramic ЦТС-19), fixed on the generating line in the case made of polystyrene.

We will perform the test in the piezotransformer mode, for which we divide one of the electrodes of the piezoelectric element into two parts - the ring and the disk (Fig. 2,a).



a) b)

Fig. 2. The electro-acoustic transducer ЗП-19 (a), The equivalent electric circuit (b)

The equivalent circuit of such a transducer is shown on Fig 2,b. On this circuit, T_r is the ideal transformer, C_{out} – capacitance between the output electrodes of the piezotransformer.

The amplitude-frequency characteristics (AFC) of this transducer Fig. 3. The basic resonant frequency of transducer curving oscillations is ~ 2,5 kHz.

Measurements were carried out in piezotransformer mode. The sound pressure was also measured on resonant frequency by the sound level meter RFT.

The inductance coils (L_{ad}) 0,24, 1,0 and 2,4 H were made for carrying out the experiments. These inductances with capacity C_{el} (17 nF) form resonant frequencies 2,5, 1,22 and 0,8 kHz (Fig. 3). AFC of the transducer were measured by the connection of each of inductances (Fig. 7, b,c,d).

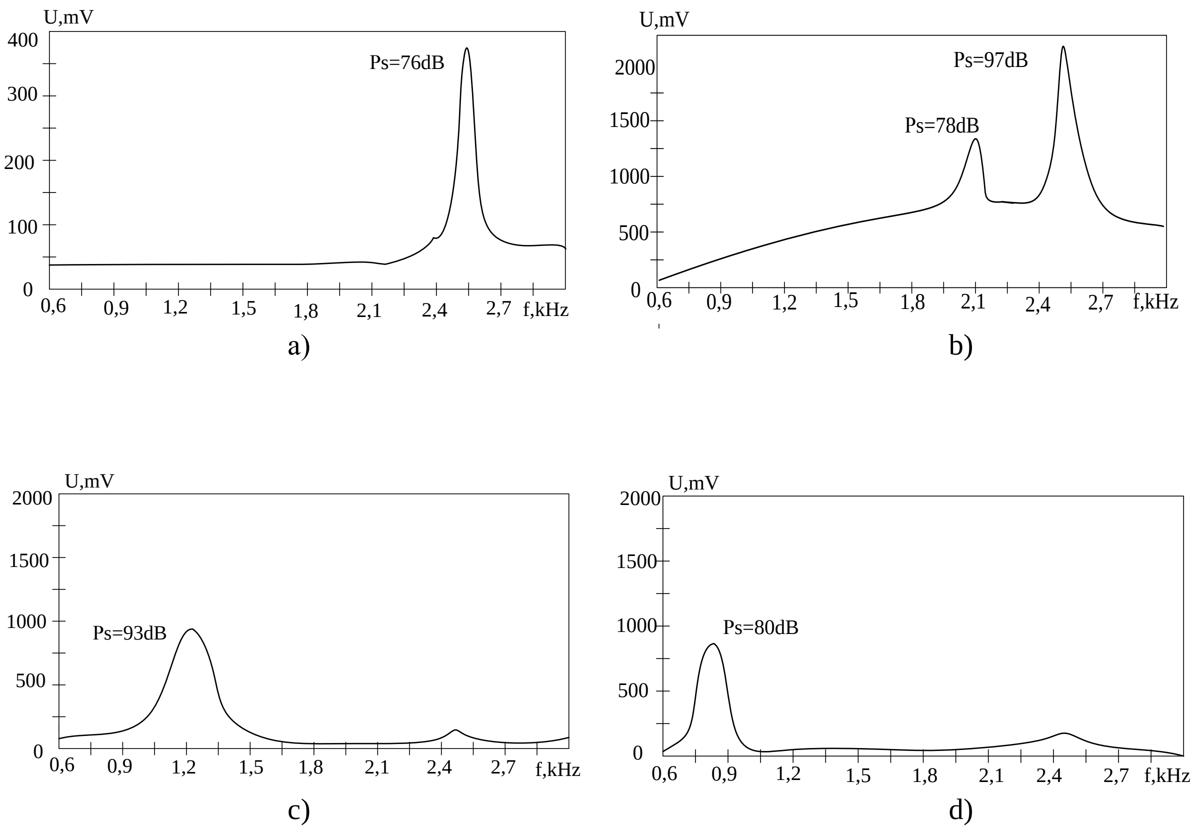


Fig. 3. AFC of transducer ЗП-19 at inductance addition (Fig. 2):
a) L_{ad} = 0; b) L_{ad} = 0,24 H; c) L_{ad} = 1,0 H; d) L_{ad} = 2,4 H

The own (active) resistance of losses r_0 has been measured simultaneously on the specified frequencies r_0 (Tab. 1) [7]. Table 1 It is visible, that the value of losses in piezoelement increases with fall of frequency.

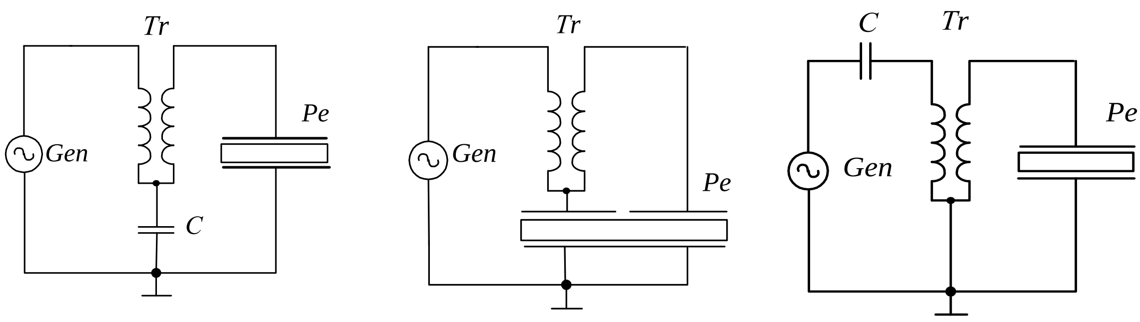
Table 1

The main parameters of the piezoelectric element at different frequencies

Frequency, kHz	0,8	1,2	2,5
r_0, *kOhm*	9,3	5,9	3,9
Sound pressure, dB	80	93	97

It is visible, that, using additional oscillatory contours, created by means of additional inductance and interelectrode capacity of a piezoelement, there is a possibility of creation of low-frequency acoustic fluctuations by means of rather high-frequency transducer (Fig. 3).

Several variants of transducer circuits with additional oscillatory circuits are shown on Fig. 4.



a) b) c)

Fig. 4. Transducers with additional oscillatory circuits

Such transducers allow to increase the output power (sound pressure). If you choose the value of f_{ad} close to f_r, you can increase the sound pressure level and expand the transducer bandwidth. This is true for transducers that are used in medical acoustics.

Transducers with the properties of differentiating and integrating circuits can be obtained by connecting active resistances to the piezoelectric element.

Conclusions. If use additional oscillatory circuits with the help of additional inductance and the interelectrode capacitance of the piezoelectric element, can create acoustic low-frequency oscillations, increase the sound pressure level, expand the transducer bandwidth. If active resistances are connected to the piezoelectric element, then transducers with the properties of differentiating and integrating circuits can be obtained.

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ПОКРАЩЕННЯ ПАРАМЕТРІВ П'ЄЗОЕЛЕКТРИЧНИХ ПЕРЕТВОРЮВАЧІВ ДЛЯ МЕДИЧНИХ АКУСТИЧНИХ ПРИЛАДІВ

Створення і вдосконалення спеціальних п'єзокерамічних датчиків для медичної акустичної діагностики має дуже велике значення. Такі датчики характеризуються високою чутливістю і лінійністю амплітудно-частотної характеристики в широкому діапазоні частот.

У даній роботі розглянуті питання вдосконалення п'єзокерамічних електроакустичних перетворювачів за допомогою методу додаткових елементів. Використовуючи додаткові коливальні контури, що створюються за допомогою додаткової індуктивності і міжелектродної ємності п'єзоелемента, існує можливість створення акустичних низькочастотних коливань на базі порівняно високочастотного перетворювача. Також *можна не тільки підвищити рівень звукового тиску, а й розширити смугу пропускання перетворювача, що актуально для перетворювачів, які використовуються в медичній акустиці. При підключенні до п'єзоелемента активних опорів можуть бути отримані перетворювачі з властивостями диференціюючих та інтегруючих ланцюгів.*

Ключові слова: *п'єзоелектричний елемент, перетворювач, еквівалентна схема, індуктивність, ємність, амплітудно-частотна характеристика.*

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УЛУЧШЕНИЕ ПАРАМЕТРОВ ПЬЕЗОЭЛЕКТРИЧЕСКИХ ПРЕОБРАЗОВАТЕЛЕЙ ДЛЯ МЕДИЦИНСКИХ АКУСТИЧЕСКИХ ПРИБОРОВ

Создание и совершенствование специальных пьезокерамических датчиков для медицинской акустической диагностики имеет очень большое значение. Такие сенсоры характеризуются высокой чувствительностью и линейностью амплитудно-частотной характеристики в широком диапазоне частот.

В данной работе рассмотрены вопросы совершенствования пьезокерамических электроакустических преобразователей с помощью метода добавочных элементов. Используя дополнительные колебательные контуры, создаваемые с помощью дополнительной индуктивности и межэлектродной емкости пьезоэлемента, существует возможность создания акустических низкочастотных колебаний на базе сравнительно высокочастотного преобразователя. Также можно не только повысить уровень звукового давления, но и расширить полосу пропускания преобразователя, что актуально для преобразователей, используемых в медицинской акустике. При подключении к пьезоэлементу активных сопротивлений могут быть получены преобразователи со свойствами дифференцирующих и интегрирующих цепей.

Ключевые слова: *пьезоэлектрический элемент, преобразователь, эквивалентная схема, индуктивность, емкость, амплитудно-частотная характеристика.*

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