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L. W. CAMP

2,760,181

TRANSDUCER HAVING ADJUSTABLE ELECTRICAL IMPEDANCE

Filed Oct. 8, 1951

Fig. 2

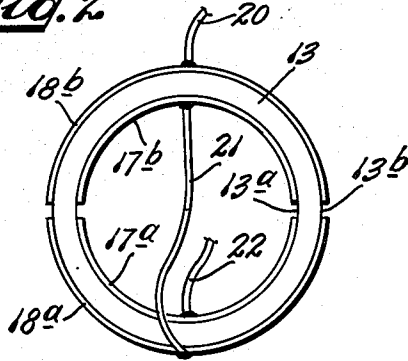


Fig. 1

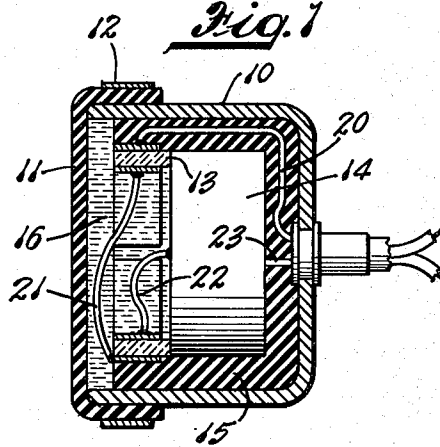


Fig. 3

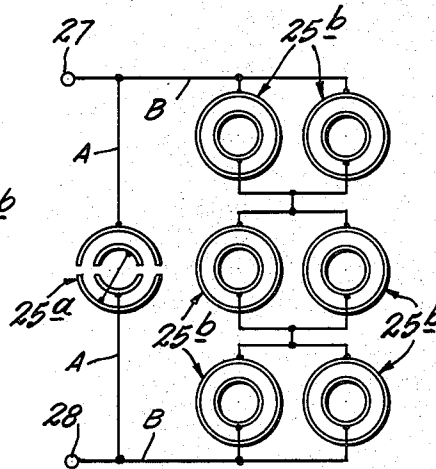
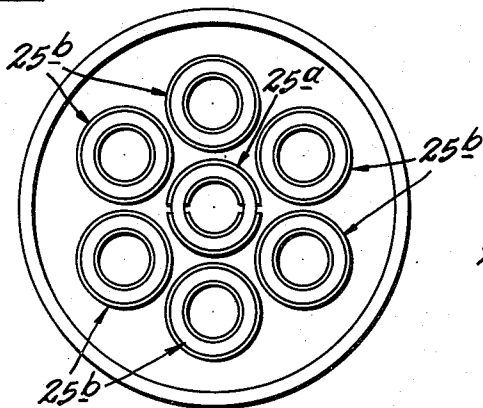


Fig. 5

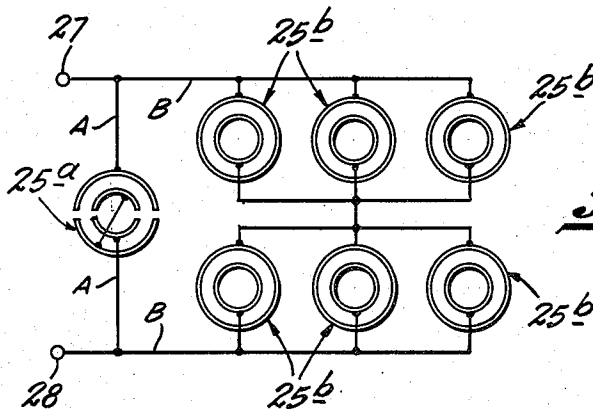
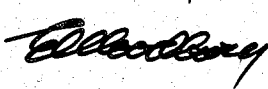


Fig. 4

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TRANSDUCER HAVING ADJUSTABLE ELECTRICAL IMPEDANCE

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4 Claims. (Cl. 340—10)

This invention relates to transducers utilizing an electromechanically sensitive element having opposed electrodes for applying or taking off electrical potential.

An object of the invention is to vary the effective electrical impedance of transducers of this type without altering the dimensions and vibrational characteristics of the electromechanical element.

Another object is to enable the connection in series-parallel relation of a prime number of similarly dimensioned transducer elements of electro-mechanically sensitive type.

Other more specific objects and features of the invention will appear from the description to follow:

Electro-mechanically sensitive transducer elements comprise a body of electro-mechanically sensitive material having opposed electrodes on opposite sides thereof. The electrical impedance between the electrodes is a function of the dimensions of the body, which also determine its frequency of mechanical vibration. As heretofore used, it has not been possible to alter the electrical impedance of an element without altering the shape or dimensions of the electro-mechanically sensitive body.

In accordance with the present invention I increase the electrical impedance of an electro-mechanically sensitive transducer element by dividing each electrode into a plurality of sections electrically insulated from each other, and connect each pair of opposed sections of the electrodes in series with the other pair or pairs of opposed sections, thereby multiplying the impedance in accordance with the square of the number of sections into which the electrodes are subdivided.

Further in accordance with the invention, the subdivision of the electrodes and their connection in series is applied to one element of a multi-unit transducer to enable the connection of the various elements in series-parallel relation where it would be impracticable to do so otherwise. Thus it is often desirable to employ, in a single transducer, a planar array consisting of a central element surrounded by six elements all of the same size. Since seven is a prime number, it is not possible to break seven transducer elements down into identical sub-groups for series-parallel connection. Hence the seven elements had to be connected all in parallel or all in series. The impedance with the series connection is seven times that of a single element and with parallel connection is one-seventh that of a single element. Hence the impedance of a transducer in which the elements are connected in series is forty-nine times that with the parallel connection. Often an intermediate impedance would be more desirable.

By splitting the electrodes of the central element into two pairs, and connecting them in series, the impedance of the central unit can be quadrupled. The six remaining elements can be connected in one or the other of two possible series-parallel patterns to have an impedance of

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either two-thirds or three-halves that of a single unit. With the first series-parallel pattern, equal distribution of energy in all seven elements can be obtained by connecting the two electrode sections of the central element in series with each other and in parallel with the series-parallel pattern of the other six elements; and the overall impedance will be four-sevenths that of a single element four times greater than with all the elements connected in parallel with each other.

With the six outer elements connected in the alternative series-parallel pattern, having an impedance three-halves that of a single element, the overall impedance is twelve-elevenths that of a single element, and the energy distribution is greater in the central element than in each of the six surrounding elements. This is desirable in some installations, as it reduces the magnitude of the side lobes of the directivity pattern of the transducer.

A complete understanding of the invention can be had from the following detailed description with reference to the drawing, in which:

Fig. 1 is a longitudinal section through a single element transducer in accordance with the invention;

Fig. 2 is a front elevational view of the vibrator element of the transducer of Fig. 1;

Fig. 3 is a front elevational view of a multi-element transducer similar to the transducer of Figs. 1 and 2 but having seven elements in a planar array instead of a single element;

Fig. 4 is a schematic diagram showing one manner of interconnecting the various elements of the transducer shown in Fig. 3; and

Fig. 5 is a schematic diagram showing an alternative method of interconnecting the elements of the transducer shown in Fig. 3.

Referring first to Fig. 1 the transducer therein disclosed comprises a cup-shaped casing 10 having an open end which is closed by a sound transparent window 11 of rubber or the like. The window is shown retained in position on the casing by a band clamp 12. The casing 10 contains a single electro-mechanically sensitive element which may be in the form of a ring 13 of a ceramic such as barium titanate. The ring 13 may be backed by a solid disc 14 of steel or the like, and both the ring 13 and disc 14 may be supported within the casing 10 by a mass of sound absorbent material 15 such as rubber, a mixture of cork and rubber, or the like. The space within and in front of the ring 13 is filled with a suitable liquid 16 which serves to conduct vibrations from the inner annular surface of the ring 13 to and through the window 11 to the water or other liquid in which the transducer may be immersed.

Referring to Figs. 1 and 2, the inner annular face 13a of the ring 13 is covered with an inner electrode consisting of two semi-cylindrical sections 17a and 17b, and the outer annular surface 13b is covered with two semi-cylindrical electrode sections 18a and 18b. This construction differs from the prior art construction in that heretofore the inner electrode has consisted of a single element, and the outer electrode has consisted of a single element. The electrode sections 17a and 17b substantially completely cover the inner surface 13a of the ring, sufficient spacing being left between the two sections only to provide electrical insulation therebetween. The same is true of the two outer electrode sections 18a and 18b.

The two electrode sections 17b and 18b are connected in series-aiding relation with the two sections 18a and 17a. Thus one of the transducer leads 20 is connected directly to the outer electrode section 18b, and the

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corresponding inner electrode section 17b is connected by a jumper lead 21 with the other outer electrode 18a. The inner electrode 17a is connected by a jumper lead 22 to the disc 14 which in turn is connected to the other electrode lead 23.

In the transducer of Figs. 1 and 2, the electrical impedance between the transducer leads 20 and 23 is four times as great as it would be in a conventional transducer of the same type employing single inner and outer electrodes. This will be readily apparent, since the two juxtaposed electrode sections 17b and 18b have only half the area of a full electrode section, the impedance between these electrodes and also the impedance between the electrode sections 17a and 18a is twice that between the inner and outer electrodes of a conventional construction. Since the two pairs of sections, each having an impedance twice that of the usual arrangement, are connected in series with each other, the total impedance is again doubled.

The invention as applied to a single element transducer as illustrated is often useful because the impedance of the electrical circuit to which the transducer is connected may be higher than that of the conventional transducer, and it is desirable in order to obtain highest efficiency that the impedance of the transducer match the impedance of the electrical circuit to which it is connected.

However the invention has special utility in multi-element transducers such as that disclosed in Fig. 3. This transducer contains seven rings 25, each corresponding to the ring 13 of Fig. 1. One of the rings 25a is positioned in the center and the other six rings 25b are distributed around the central ring in as close proximity thereto and to each other as is possible without actual contact. It is well known that an array of seven identical rings provides a particularly close positioning of the rings that cannot be obtained with an other number than seven and that has proved highly desirable in transducers where directivity is desired. Heretofore it has been the practice to use a single inner and a single outer electrode on each of all seven rings of an array such as shown in Fig. 3, and it was possible to interconnect these electrodes only in series or in parallel. As pointed out hereinabove, the overall impedance when all the rings are connected in parallel is one-seventh that of a single ring, and when all of the rings are connected in series the impedance is seven times that of a single ring, and forty-nine times that of a transducer in which the rings are connected in parallel. It is not possible to use seven identical rings and break them down into a series-parallel connection because of the fact that seven is a prime number, i. e. it is not divisible by anything other than seven and one.

In accordance with the present invention a single inner and a single outer electrode is used on each of the six outer rings 25b but multi-section electrodes such as shown in Fig. 2 are used on the central element 25a.

Because of the fact that the six outer elements 25b can be broken down into either three groups of two or two groups of three, the circuits shown in Figs. 4 and 5 are possible. In each circuit the two sets of electrodes on the central element 25a are connected in series with each other between the line terminals 27 and 28.

In Fig. 4 the six elements 25b are arranged in two groups of three each. The three elements in each group are connected in parallel with respect to each other, and the two groups are connected in series with each other between the line terminals 27 and 28.

In Fig. 5 the six elements 25b are arranged in three groups of two each and the three groups are connected in series with each other between the line terminals 27 and 28.

Referring first to Fig. 4, let Z_A be the impedance of the branch A containing the element 25a having the sectioned electrodes connected in series, and let Z_B be

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the impedance of the branch B containing the six elements 25b.

$$Z_A = 4Z$$

$$Z_B = \frac{2Z}{3}$$

$$I_A = \frac{E}{4Z}$$

$$I_B = \frac{3E}{2Z}$$

Where:

Z =impedance of a single element 25b.

E =potential between terminals 27 and 28.

I_A =current in branch A.

I_B =current in branch B.

As is well known, power W at any given instant is computable from the equation:

$$W = EI$$

Hence the power W_A in branch A is:

$$W_A = E \frac{E}{4Z} = \frac{E^2}{4Z}$$

and the power W_B in branch B is:

$$W_B = E \frac{3E}{2Z} = \frac{3E^2}{2Z}$$

Since only one-sixth of the power in branch B is dissipated in each element 25b, the power in each element 25b is:

$$\frac{3E^2}{2Z} \cdot \frac{E^2}{4Z} = \frac{E^2}{6}$$

Since all the power in branch A is dissipated in element 25a, the ratio of the power in element 25a to each element 25b is:

$$\frac{\frac{E^2}{4Z}}{\frac{E^2}{6}} = 1$$

In other words, all seven elements are equally energized.

The impedance Z_4 of the complete transducer with the connections shown in Fig. 4 is obtained from the equation:

$$\frac{1}{Z_4} = \frac{1}{Z_A} + \frac{1}{Z_B}$$

Substituting for the values of Z_A and Z_B :

$$\frac{1}{Z_4} = \frac{1}{4Z} + \frac{3}{2Z}$$

Solving:

$$Z_4 = \frac{4}{7}Z$$

In Fig. 5, the impedance of, and the power in branch A is the same as in Fig. 4, but the impedance of branch B is greater, and the power is less.

Thus the impedance of branch B is

$$\frac{3Z}{2}$$

and the overall impedance of the complete transducer is

$$\frac{12Z}{11}$$

The current in branch B is

$$\frac{2E}{3Z}$$

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and the power is

$$\frac{2E^2}{3Z}$$

The power in each element 25b is one-sixth of this, or

$$\frac{E^2}{9Z}$$

and the ratio of the power in the central element 25a to that in each outer element is

$$\frac{\frac{E^2}{4Z}}{\frac{E^2}{9Z}} \text{ or } \frac{9}{4}$$

As previously stated, it is often desirable to work the outer six elements as a lower level than the center element to reduce the magnitude of side lobes in the directivity pattern.

Although for the purpose of explaining the invention, particular embodiments thereof have been shown and described, obvious modifications will occur to a person skilled in the art, and I do not desire to be limited to the exact details shown and described.

I claim:

1. In a transducer having a pair of electrical terminals: an electromechanically responsive vibratable dielectric element for acoustic coupling with a fluid medium, said element having a pair of juxtaposed faces; an electrode on each of said faces of said element, each electrode consisting of a plurality of sections electrically isolated from each other and each section being juxtaposed to and paired with a corresponding section of the other electrode; and means connecting each pair of sections in series aiding relation with the other pair of sections in

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a network to said terminals, whereby the potential gradient in all portions of said dielectric element is of the same polarity at any instant.

2. A transducer according to claim 1 having in addition to said mentioned dielectric element a plurality of other electromechanically-responsive vibratable dielectric elements symmetrically disposed about said first-mentioned element and forming therewith a directive array; a single section electrode on each face of each of said other elements; and means independent of said first mentioned network connecting the electrodes of said other elements in a second network between said terminals.

3. A transducer according to claim 2 in which said other elements are six in number and said second network comprises two groups of elements connected in series between said electrical terminals, each of said groups comprising three elements connected in parallel with respect to each other.

4. A transducer according to claim 2 in which said other elements are six in number and said second network comprises three groups of elements connected in series between said electrical terminals, each of said groups comprising two elements connected in parallel with respect to each other.

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