July 18, 1967 T. M. DUNDON ETAL 3,331,970

SONIC TRANSDUCER

Filed Sept. 29, 1964 2 Sheets-Sheet 1

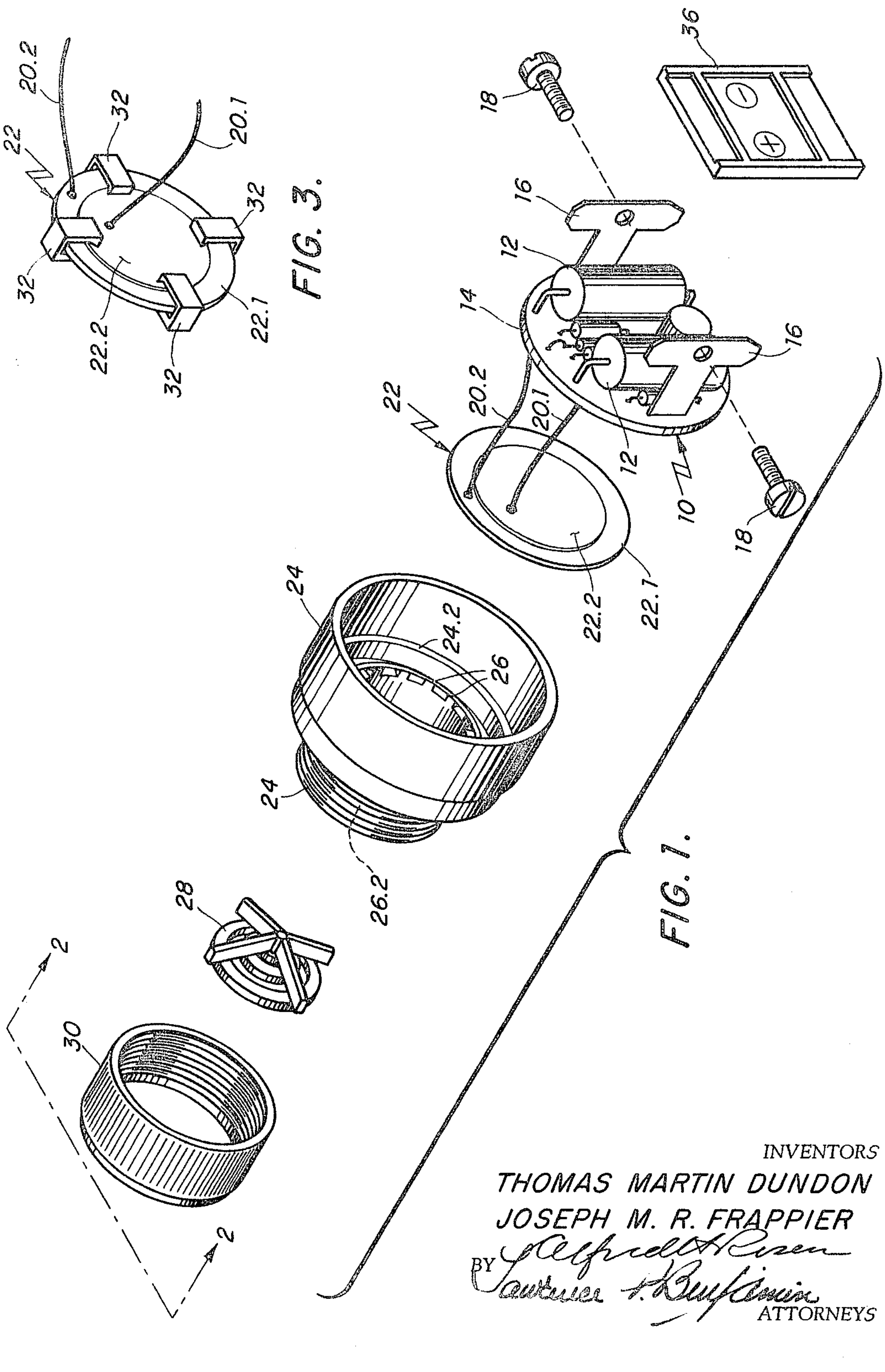

FIG. 3.

FIG. 1.

INVENTORS
THOMAS MARTIN DUNDON
JOSEPH M. R. FRAPPIER
BY Alfred H. Rosen
Laurence B. Benjamin
ATTORNEYS

SONIC TRANSDUCER

Filed Sept. 29, 1964 2 Sheets-Sheet 2

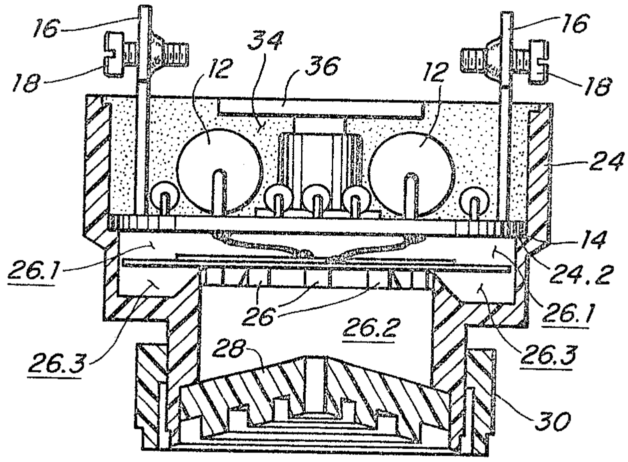

FIG. 2.

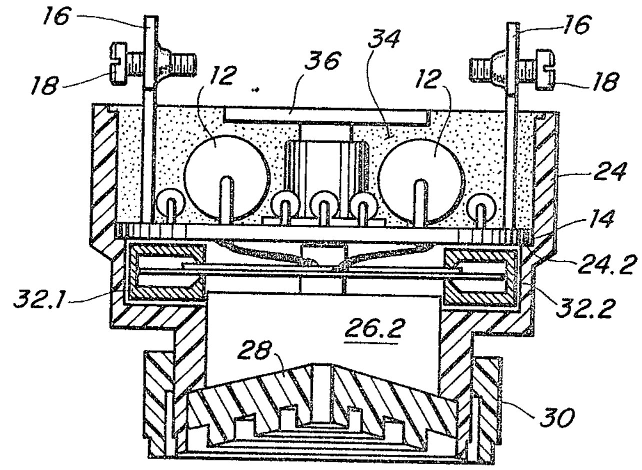

FIG. 4.

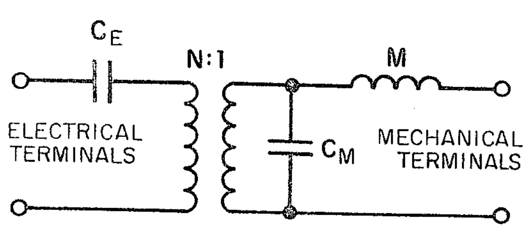

FIG. 5.

INVENTORS
THOMAS MARTIN DUNDON
JOSEPH M. R. FRAPPIER
BY Alfred E. Rosen
Laurence P. Benjamin
ATTORNEYS

United States Patent Office

3,331,970

Patented July 18, 1967

1

3,331,970
SONIC TRANSDUCER

Thomas Martin Dundon, Sudbury, and Joseph M. R. Frappier, Holliston, Mass., assignors, by mesne assignments, to Honeywell Inc., a corporation of Delaware

Filed Sept. 29, 1964, Ser. No. 400,009
9 Claims. (Cl. 310—9.1)

This invention relates to vibratory sonic transducers and more particularly to an improved method of coupling the vibrating element to the atmosphere.

Ceramic ferroelectric materials such as barium titanate or other similar materials are desirable as sonic transducers because of their high degree of piezoelectric activity. However, these materials are also noted by the fact that they exhibit high internal losses and thus, by themselves, represent relatively inefficient transducers. It is well known that when the piezoelectric or vibrating element is mounted on a metallic plate or disc, the combination is then capable of vibrating with higher efficiencies at some frequency other than the natural frequency of the piezoelectric element alone. The medium on which the piezoelectric material is mounted is usually metal having a high elastic modulus and a relatively low density.

When resorting to this technique, it has been noted that the acoustic impedance of the resulting device is inordinately high. Since the acoustic impedance of the surrounding ambient medium (i.e.: air) is relatively low, it is desirable to interpose some sort of impedance matching device between the transducer element and the air so that the maximum energy will be transferred with the least amount of losses.

One matching approach is to place a transducer at one end of a tube whose length is about ¼ wavelength ($\lambda/4$) at the operating frequency. The transducer then "looks" into a higher impedance (in the tube) than it would if it faced the air directly. Assuming for example a transducer impedance of Z_1, and an air impedance of Z_2, it will be seen that the tube then acts as a transformer to match the impedance of Z_1 and Z_2 with lower losses than if no transformer were used. While under ordinary circumstances this is highly desirable, the use of the tube alone does not quite achieve the most desirable match and in fact, there is a noticeable mismatch although not as much as there would be if no tube were present. At best, this impedance match leaves much to be desired.

It must be realized that transducer-to-air impedance matching is not the sole consideration. Another important fact that must be faced is that commercially available transducers have such a high impedance that matching with a ¼ wave tube is virtually impossible. It is, however, highly desirable to utilize the transducers that have the higher impedance since it represents a significant saving in manufacturing costs.

We propose loading the transducer so that the impedance of the transducer element is substantially lowered to provide a better acoustic transformation between the transducer and the ambient atmosphere.

At this point, it might be wise to review the action of a transducer which by definition transforms energy of one form to energy of another form. In our particular situation, we are interested in transforming electrical energy to mechanical energy and the system may be viewed as an electromechanical transformer. That is, the transformer action associated with a pair of coupled coils (note FIG. 5 of the appended drawings). The primary or input winding is connected to the electrical terminals through a series capacitor Ce. The coils perform the coupling. In the output or secondary winding, there is a shunt capacitor Cm, with an inductor M in series between the secondary winding and the mechanical terminals. In this particular situation, Ce represents the capacity of the piezoelectric material and is usually determined by parameters such as the area (A), the thickness (t) and the dielectric constant (K) and may be expressed approximately by the formula $Ce=KA/t$. The capacitor Cm across the output winding or mechanical terminals represents the stiffness of the vibrating element while the series inductor M represents in this particular instance the moment of inertia of the transducer-disc combination. (In expanding type transducers, this element would be equal to the mass.) The coupling, represented by coils N:1, provides the transforming action and it may thus be seen that if the system is to satisfy our needs, the mechanical or output terminals should work into a low impedance since its load (air) has a low impedance, while the input or electrical impedance is fixed by the characteristics of the transducer at some higher level.

We have found that we can effectively lower the impedance of commercially available transducers by providing circular, disc type flexural mode transducers with mass loading means extending beyond the edge of the transducer and providing both the active material and the mass loading means with a common pressure or loading chamber. The transducer assembly with its lowered impedance presents a noticeably better acoustic match to the surrounding or ambient medium. With the better match and efficiencies we are able to achieve a higher sonic output level for a given input power level.

It is therefore, a principal object of the subject invention to provide an improved sonic transducer device capable of being more efficiently coupled to its surrounding medium.

Another principal object of the subject invention is to provide an improved sonic transducer device noted by the fact that it has an impedance that is more readily matched to the surrounding atmosphere than heretofore possible.

A further object of the present invention is to provide an improved sonic transducer device capable of being readily mass produced because of its particular configuration.

A still further object of the present invention is to provide an improved sonic transducer device that is noted by the fact that it may be mass produced at a relatively low cost.

The present invention is a composite structure consisting of a thin layer of piezoelectric material element mounted in a housing. The associated circuitry together with the housing form an acoustical loading chamber that significantly reduces the impedance of the transducer element and thereby achieves better impedance match between the transducer element and the ambient atmosphere. The active piezoelectric material is mounted on a thin metallic diaphragm approximately the same thickness as the piezoelectric material with the diaphragm having an extension or loading ring attached thereto whereby when the metallic diaphragm flexes, the rarefications and compressions of the atmosphere produced by the vibrating extension or loading ring, compliments or reinforces those compressions and rarefactions that appear adjacent the active transducer portion. In addition, we also provide mounting means which allows the diaphragm to move freely while controlling the transfer of change of pressure from the outer ends to the inner portion of the diaphragm assembly.

The features of our invention which we believe to be novel are set forth with particularity in the appended claims. Our invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawings in which:

FIG. 1 is an exploded view, one part thereof in partial section, indicating the relative order of the parts of our transducer assembly;

FIG. 2 is a sectional view of our transducer assembly, taken along lines 2—2 of FIG. 1;

FIG. 3 represents another transducer mounting arrangement;

FIG. 4 is a cross sectional view of our assembled device utilizing the mounting arrangement of FIG. 3; and

FIG. 5 is a schematic representation of the transducer operation.

Referring now to FIG. 1 there is shown an oscillator circuit assembly **10** consisting of circuit elements **12** mounted on a printed circuit board **14**. In a device of this sort, transducer assembly **22** represents the frequency determining element of the oscillator in much the same manner as a crystal in a crystal controlled oscillator. Terminals **16**, mounted on terminal board **14** and screw clamping means **18** associated with terminals **16** are utilized as terminal means to which an appropriate source of power may be applied (not shown), so that the oscillator will have an appropriate source of operating potential. Leads **20.1** and **20.2** provide the means for electrically connecting the transducer assembly **22** into the oscillator circuit. The active elements of the assembly **22** are comprised, in part, of a thin layer of piezoelectric material **22.2** and a thin metallic disc or diaphragm **21.1** having a thickness that very closely approximates the thickness of the piezoelectric material **22.2**.

The oscillator circuit assembly **10** and the transducer assembly **22** are placed within the confines of housing **24**, with the diaphragm plate **22.1** resting on the castellated members **26** and the oscillator circuit assembly **10** resting on lip **24.2**. Sound diffuser or grille **28** is contained within aperture **26.2**, while cover **30** may be utilized to protect the outer portion of the sound chamber end of the housing **24** and to provide a convenient means for mounting housing **24** in a panel.

Referring now to FIG. 2, there is shown a sectional view of the completed assembly taken along lines **2—2** of FIG. 1. It should be noted that similar elements are similarly numbered. In this view, the printed circuit board **14** having circuit element **12** mounted thereon, is shown in position on lip **24.2** of housing **24** while the transducer assembly **22** is affixed to the upper edges of castellated members **26** by means of either cement or any other appropriate fastening means. A typical cement or adhesive that may be used is Silastic.

It should be noted that elements **12** and a portion of terminals **16** have been potted into housing **24** by means of potting material **34**. This forms an open area above the potting material allowing clamping screws **18** to accept leads (not shown) connected to a suitable source of power to operate the oscillator. Further, when transducer assembly **22** is properly mounted in the housing, the upper edges of castellated members **26** contact the diaphragm element **22.1** in the region just at or within an area corresponding to the outer perimeter of piezoelectric material **22.2**.

When all of the elements forming the novel device are assembled into housing **24** and thereby assume their indicated positions, it will be seen that transducer assembly **22** is located at one end of the resonant tube or cavity **26.2**. At the same time, the use of the indicated arrangement permits the formation of an acoustic loading or pressure chamber **26.1** and a vent chamber **26.3**, both of which are common to the transducer assembly **22**. It is the interaction of these three chambers with assembly **22** that causes the acoustic impedance of transducer assembly **22** to be significantly lowered.

Let us assume, for purposes of illustration that, when transducer assembly **22** is first pulsed, the radiation pressures developed in the assembly **22** will cause the whole assembly to assume a convex, curved or domed configuration. That is, the ends or loading means will extend down into chamber **26.3**, while the center of the piezoelectric material **22.2** (FIG. 1) has an upward bow (convex) towards circuit board **14**. The dimensions of chambers **26.1** and **26.3** are chosen so that when the domed configuration exists there is a net pressure change (either positive or negative) in chamber **26.1**.

The loading means as herein referred to, denotes that area of transducer assembly **22** that extend beyond the edges of castellated members **26** to thereby form the dividing means between chambers **26.1** and **26.3**.

The next position to be assumed by transducer assembly **22** is one in which the piezoelectric material **22.2** assumes a concave position with respect to circuit board **14** and wherein the loading means now extends into chamber **26.1**. As in the situation of the prior domed or convex configuration, there is again a net pressure change (now either negative or positive) in chamber **26.1** immediately above the piezoelectric material **22.2**. In this manner, the central area of transducer assembly **22** (the area located immediately above resonant tube **26.2**) is caused to vibrate at its design frequency to produce sound. With our novel design, only this central area of transducer assembly **22** is coupled to the ambient air, and then, only by reason of resonant tube **26.2**. Thus, the flexing action of the loading means or peripheral portion (that portion of the transducer assembly **22** extending beyond members **26**) cooperating with the central portion of the transducer cause the pressures developed by both the central portion and the peripheral portion of transducer assembly **22** to reinforce each other due to the presence of chamber **26.1** thereby effectively lowering the impedance of transducer assembly **22**. With a lowered transducer impedance at its input, resonant tube **26.2** is now able to provide a better output impedance match to the ambient air.

It must be realized that a small but significant space must be provided between the outermost edge of the loading means and the inside wall of housing **24** so that there is only a minimum transfer of change of pressure from chamber **26.1** to chamber **26.3**. The area of chamber **26.3** must be sufficiently large and preferably vented, to prevent any net pressure from being developed therein due to transducer flexing. Thus, by providing the common loading chamber **26.1** to enhance the interaction between the loading means or peripheral portion and the central portion of transducer assembly **22**, the effective transformer ratio N:1 (FIG. 5) is significantly changed to thereby provide a better impedance match between the transducer assembly **22** and the ambient air.

Referring now to FIGS. 3 and 4 there is shown another transducer mounting arrangement that has particular utility in our device. It should be noted that those elements in FIGS. 3 and 4 that have similar counterparts in FIGS. 1 and 2, are similarly numbered. In this mounting arrangement, the transducer assembly **22** has piezoelectric material **22.2** mounted on a metallic diaphragm **22.1** and, as described in FIG. 2, the thickness of the piezoelectric material and the metallic disc are approximately equal. In this embodiment, four clips **32** are arranged about the periphery of transducer assembly **22**. While in this embodiment only four clips are shown, it will be obvious to those skilled in the art that addition clips may, in some instances, be necessary. However, at least two or three clips may be required to provide a stable mounting for the transducer assembly **22**. As shown in FIG. 4, mounting means **32** comprises an outer retainer clip **32.2** and a C shaped transducer mounting clip **32.1**. When utilizing this latter mounting arrangement, the castellated members **26** (FIGS. 1 and 2) are removed or cut off and instead, appropriate radial grooves may be either milled into or integrally molded into housing **24** so that the outer retaining clip **32.2** may be firmly seated to prevent movement of transducer assembly **22**.

While we have described what is presently considered a preferred embodiment of a sonic transducer device as well as an alternate mounting arrangement for the transducer assembly, it will now be obvious to those skilled in the art that various other changes and modifications may be made without departing from the inventive concept contained therein and, it is therefore aimed in the appended claims to cover all such other changes and modifications that fall within the true spirit and scope of our invention.

What is claimed is:

1. In a sonic transducer device the combination comprising:
  a piezoelectric disc element having a given thickness and a first diameter;
  a metallic disc element having substantially the same thickness as the given thickness and a second diameter larger than the first diameter;
  the piezoelectric disc element mounted on the metallic disc element to define a transducer assembly;
  the transducer assembly consisting of a central portion of both elements and a peripheral portion of essentially the metallic disc element; and
  acoustic loading means acoustically coupling the peripheral portion to the central portion to lower the acoustic impedance of the transducer assembly.

2. The combination of claim 1 further comprising support means, within the housing, fixedly supporting the transducer assembly to form a chamber between the housing and the transducer assembly; the chamber providing the acoustic coupling between the peripheral portion and the central portion.

3. The combination of claim 2 wherein the support means comprises a plurality of castellated members formed integrally with the housing.

4. The combination of claim 3 further comprising a resonator tube formed integrally with the housing, having a length approximately one quarter wavelength at the operating frequency of the transducer assembly acoustically coupling only the central portion to the ambient air.

5. The combination of claim 2 wherein the support means comprises a plurality of C shaped clips affixed to the housing.

6. The combination of claim 5 further comprising a resonator tube formed integrally with the housing, having a length approximately one quarter wavelength at the operating frequency of the transducer assembly acoustically coupling only the central portion to the ambient air.

7. In a sonic transducer device the combination comprising:
  a piezoelectric disc element having a given thickness and a first diameter;
  a metallic disc element having substantially the same thickness as the piezoelectric disc and a second diameter larger than the first diameter;
  the piezoelectric disc element and the metallic disc element being concentrically fastened together to form a flexural mode vibrator transducer assembly having a central portion of both elements and a peripheral portion made essentially of the portion of the metallic disc element which extends beyond the piezoelectric disc element;
  housing means supportingly enclosing the transducer assembly;
  means in the housing means supporting the transducer assembly within but substantially close to the junction of the central portion and the peripheral portion; and
  acoustic loading means in the housing means including a chamber surrounding the peripheral portion and a chamber on one side of the central portion to reduce the acoustic impedance of the transducer assembly.

8. A combination according to claim 7 including a chamber on the other side of said central portion being in the form of a tube which is resonant at the operating frequency of the device for coupling said transducer assembly to ambient air.

9. A combination according to claim 7 in which the two chambers are acoustically coupled together.

References Cited

UNITED STATES PATENTS

2,167,254	7/1939	Skellett	310—8
2,506,608	5/1950	McLoad	340—10
2,911,484	11/1959	Spitzer	340—10
3,025,359	3/1962	Schilling	179—110
3,058,539	10/1962	Adler	310—83
3,187,300	6/1965	Brate	340—10

MILTON O. HIRSHFIELD, *Primary Examiner.*

J. D. MILLER, *Assistant Examiner.*