United States Patent

Massa

[15] **3,707,131**

[45] **Dec. 26, 1972**

[54] **ELECTROACOUSTIC TRANSDUCERS OF THE BILAMINAR FLEXURAL VIBRATING TYPE**

[72] Inventor: **Frank Massa,** Cohasset, Mass.

[73] Assignee: **Massa Division Dynamics Corporation of America,** Hingham, Mass.

[22] Filed: **Oct. 19, 1970**

[21] Appl. No.: **81,842**

[52] **U.S. Cl.**.....**179/110 A,** 310/8.2, 310/8.3, 310/9.2

[51] **Int. Cl.** **H04r 17/10**

[58] **Field of Search**.....179/110 A, 179; 310/8.2, 9.4; 340/8 L, 8 FT, 10, 15

[56] **References Cited**

UNITED STATES PATENTS

3,370,187 2/1968 Straube 340/10

Primary Examiner—Kathleen H. Claffy
Assistant Examiner—Thomas L. Klundert
Attorney—Louis Bernat

[57] **ABSTRACT**

A sound opaque mask, contained within a spider-like frame structure, is assembled in accurate alignment with a piezoelectric transducer element. The mask is positioned so that only those portions of the vibrating bilaminar elements, which vibrate in phase, are exposed to the medium. The piezoelectric elements and the mating plate portions of the frame structure cooperate to form a bilaminar flexural vibrating element having combined dimensions which determine the resonant frequencies.

20 Claims, 6 Drawing Figures

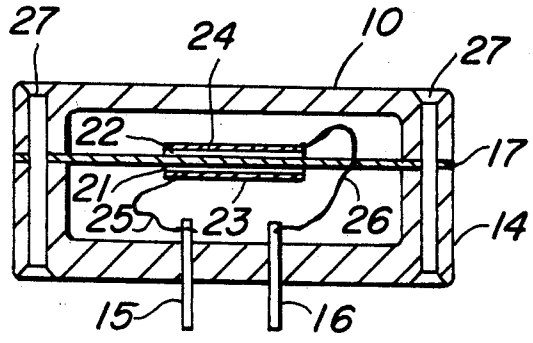


FIG - 1

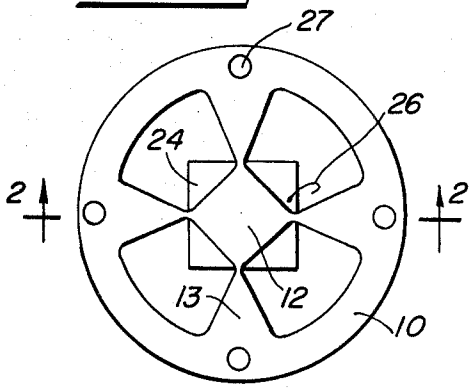


FIG - 2

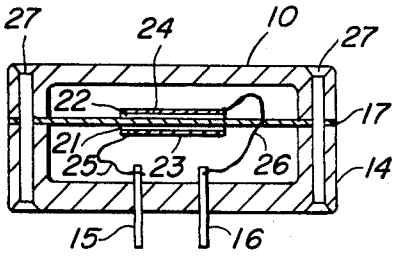


FIG - 3

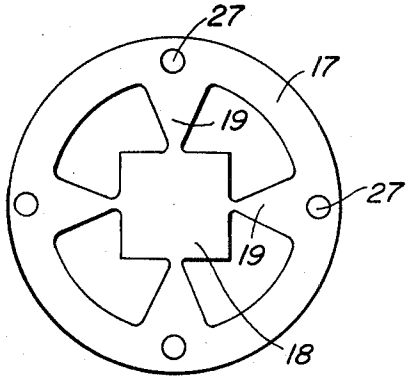


FIG - 4

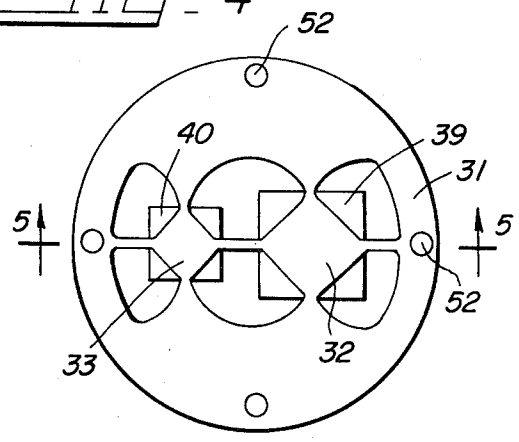


FIG - 5

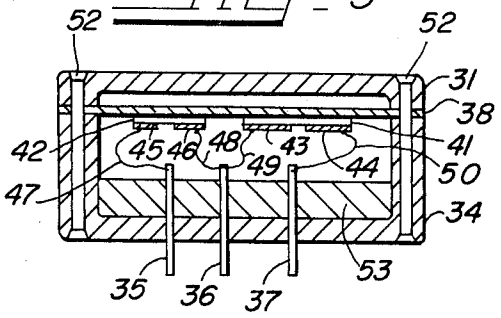
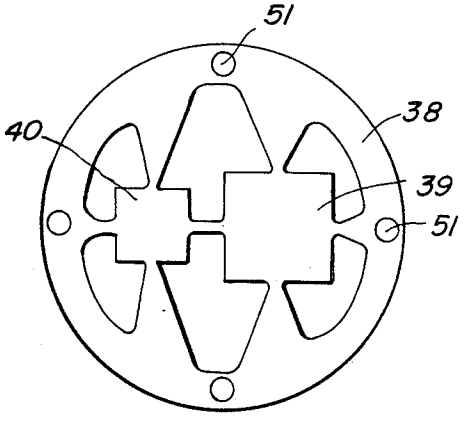


FIG - 6



INVENTOR.
FRANK MASSA

BY Louis Penner

Atty

ELECTROACOUSTIC TRANSDUCERS OF THE BILAMINAR FLEXURAL VIBRATING TYPE

This invention relates to electroacoustic transducers employing a bilaminar resonant plate operating at its fundamental flexural mode of vibration, and more particularly, to simplified structures having reduced cost.

Reference may be made to a co-pending application Ser. No. 17,430, filed Mar. 9, 1970 by Frank Massa and Gilbert C. Barrow, entitled "ELECTROACOUSTIC TRANSDUCERS," and assigned to the assignee of this invention. The principal effort of the present invention is to achieve all of the advantages of the earlier invention at a reduced cost and with a simplified structural configuration.

Accordingly, an object of this invention is to design new and more efficient, low-cost electroacoustic transducers utilizing a bilaminar plate operating at a fundamental free resonant mode.

Another object of this invention is to combine a plurality of bilaminar plate, flexural mode transducer elements, within a very simple spider-like frame structure. Here, an object is to assemble the elements within a common housing having a plurality of flexural vibrating plate transducer elements, each operating in a different frequency region.

A still further object of this invention is to accurately position the bilaminar plates within a spider-like frame structure having plate sections, which form parts of the bilaminar resonant structures.

A further object of this invention is to provide an inexpensive housing structure which includes sound opaque masking elements that cover portions of the vibrating bilaminar resonating elements.

Other objects, features, and advantages will become more apparent from the following description when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a plan view of one embodiment of the inventive transducer construction;

FIG. 2 is a cross-sectional view taken along the line 2—2 of FIG. 1;

FIG. 3 is a plan view of a flat spider-like frame member containing a square center plate portion for supporting a piezoelectric transducer;

FIG. 4 is a plan view of another embodiment of the inventive transducer including a unitary spider-like frame member containing two independent flexural transducer elements, operating at different resonant frequencies;

FIG. 5 is a cross-sectional view taken along the line 5—5 of FIG. 4; and

FIG. 6 is a plan view of the flat spider-like frame member containing two independent square vibratile plate portions of different sizes, held together by thin connecting spoke-like members.

In FIGS. 1, 2 and 3, the reference character 10 identifies a portion of a housing structure which might be fabricated from a molded plastic material, for example. In the center of the flat surface of the housing member 10, a square or somewhat diamond-shaped portion 12 is connected, at its four corners, by spoke-like members 13 extending to the main peripheral rim portion of the structure. A second, mating, cup-shaped portion of the housing structure 14 contains electrical terminals 15 and 16 which extend through its base, as illustrated in FIG. 2.

A vibratile transducer element is contained within a spider-like frame member 17 which may be punched from a thin metallic sheet, for example. A square center plate portion 18 is connected by four spoke-like members 19 to the peripheral rim portion of the structure. Four holes are located in the periphery of the member 17 to enable an assembly of the housing portions 10 and 14.

A first, thin square polarized piezoelectric ceramic plate 21 is rigidly bonded to one side of the central square plate portion 18 (FIG. 3). A second ceramic plate 22 is bonded to the opposite side of plate portion 18 (FIG. 2). Electrode surfaces 23 and 24 are formed on the outside surfaces of the ceramic plates 21 and 22. Electrical conductors 25 and 26 are connected between these electrodes and the terminals 15 and 16. The other electrode surfaces on the piezoelectric ceramics 21 and 22 (not seen in FIG. 2) are in common electrical contact with the metallic plate member 18. The polarization of the ceramic plates is such that a conventional series electrical circuit is achieved by means of the wiring arrangement shown in FIG. 2.

The complete transducer assembly is achieved by placing the assembled ceramic and frame member 17 between the housing portions 10 and 14 and securing the structure together by means of four rivets 27. The assembly just described results in a very low manufacturing cost for a transducer having the same general characteristics as the transducer described in the co-pending parent application Ser. No. 17,430.

As explained in the parent application, the sound mask portion 12 covers those portions of the ceramic 21, 23 which are vibrating out-of-phase with respect to the vibrations of the uncovered portions of the ceramic. Thus, the uncovered portions of the ceramic cause a transmission of in-phase sonic energy. If the mask 12 were not present, much of the transducer energy would be dissipated by mutual cancellation of the out-of-phase vibrations.

A second embodiment of the transducer construction is illustrated in FIGS. 4, 5 and 6. In this design, the housing portion 31 (which may be molded plastic) contains two separate square or somewhat diamond-shaped mask portions 32 and 33. These masks are interconnected by thin spoke-like members extending to the peripheral rim portion of the housing structure 31 (FIG. 4). A second cup-shaped housing portion 34 contains electrical terminals 35, 36 and 37, which extend through its bottom surface (FIG. 5).

The vibratile transducer element assembly comprises a spider-like frame member 38 (FIG. 6) which contains two central square plate portions 39 and 40, connected by thin spoke-like members to the outer rim portion of the frame member. One face of the square plate portion 39 has a large polarized piezoelectric ceramic plate 41 bonded thereto. The face of the square plate member 40 has a small ceramic plate 42 bonded thereto (FIG. 5).

Split electrodes 43 and 44 are attached to the exposed surface of the large ceramic plate 41. Similar split electrodes 45 and 46 are attached to the exposed surface of the small ceramic plate 42. Each of the ceramic plates has another electrode (not shown) located on the face of the ceramic plate which is bonded to the metallic center plate portions 39 and 40. This electrode arrangement is one of several that might

be used and is not necessarily a required part of this invention. A more complete description of the split electrode shown may be found in U.S. Pat. No. 3,128,532.

Electrical conductors **47**, **48**, **49** and **50** connect the various electrode surfaces of the ceramic plates to the terminal pins **35**, **36** and **37** (FIG. **5**). For the electrical connection illustrated, electrodes **43** and **46** are connected to the common terminal **36**. It is, of course, obvious that the electrodes could be connected to separate terminals if a four terminal arrangement were desired.

Lining the inside bottom surface of the housing member **34** is a layer of soft sound absorbing material **53** which prevents standing waves from occurring during operation of the transducer.

In the transducer structure, just described, there is an assembly of two separate flexural vibrating elements mounted within a common low-cost housing structure. The resonant frequency of each of the vibratile transducer elements is determined by the width and thickness dimensions of the plate members **39** and **40** and the attached ceramic elements **41** and **42**. The resonant frequencies of the two elements may be widely separated, if desired. Or, the two resonant frequencies may be adjusted to lie close to one another in order to achieve a broad band performance by overlapping the response characteristic of both units.

The final assembly of the transducer (FIGS. **4**, **5** and **6**) is completed in the same manner as described above for the embodiment of FIG. **1**. The housing portions **31** and **34** are assembled with the frame member **38** located with the holes **51** lined up to receive the rivets **52**.

The described construction effectively achieves the mounting of a resonant square vibratile plate at its nodal points. These point appear at the centers of the sides of the square bilaminar elements. The thin spoke-like strips offer negligible restraint to the vibrating freedom of the transducer element assembly since they are attached to the nodal points of the square resonating bilaminar structure.

During the operation of the vibrating plates at the flexural fundamental resonant frequency, the four corners of the square bilaminar elements vibrate together and in the same phase. The amplitudes of the four corners are in phase opposition to the center portion of the bilaminar square plate.

Therefore, to improve the radiation efficiency of the vibratile transducer elements, the square or somewhat diamond-shaped masks **12**, **32** and **33** follow the shape of the nodal lines on the surface of the vibratile plates. Thus, by the arrangement of these simple component parts, only the four corners of the vibratile resonant bilaminar elements are exposed to the medium. The diamond-shaped opaque portions of the housing structures **10** and **31** prevent the out-of-phase radiation from the center areas of the vibratile transducer elements from neutralizing the radiation from the four corners of the vibratile plates.

Thus, an inexpensive transducer design is achieved by the illustrative construction. This construction enables the mass production of an efficient electroacoustic transducer at very low cost. Although, only two vibratile elements have been shown in the dual frequency transducer construction, it is obvious that more than two vibratile elements may be used. There is no exact limit to the frequency range over which the described design may be utilized. However, the design lends itself extremely well for operational frequencies within the upper audible region or within the ultrasonic region ranging from approximately 5 kHz to 100 kHz.

While several specific embodiments of the present invention have been shown and described, it should be understood that modifications and alternative constructions may be made. Therefore, the appended claims are intended to cover all equivalents falling within their true spirit and scope.

I claim:

1. An electroacoustic transducer of the flexural vibrating type comprising a single spider-like frame member including a peripheral rim portion and a central vibratile plate portion connected to said peripheral rim portion by a plurality of spoke-like members, two plates of piezoelectric material, one of said piezoelectric plates being bonded to each opposite surface of said central vibratile plate portion, a first housing member comprising a perforated lid portion surrounded by a peripheral rim portion, said perforated lid portion including a central plate portion and a plurality of spoke-like members connecting said central plate portion to said peripheral rim portion, a second and closed housing member including a peripheral rim portion, means for mounting and capturing said single spider-like frame member between said peripheral rim portions of said first and second housing members, and means for securing together said two housing members and said single frame member into a unitary structure.

2. The invention in claim **1** wherein said central vibratile plate portion of said spider-like frame member is square.

3. The invention in claim **2** wherein said central plate portion of said first housing member is square, and the area of said central plate portion of said first housing member is less than the area of said central vibratile plate portion of said spider-like frame member.

4. The invention in claim **3** wherein said central square plate portions of said frame member and said first housing member are spaced parallel to one another with their centers located on a common axis and one of said square plate portions is oriented with its sides rotated 45° with respect to the corresponding sides of the other of said square plate portion.

5. The invention in claim **4** further characterized in that the area of said central plate portion of said housing member is approximately one-half the area of said central vibratile plate portion of said spider-like frame member.

6. The invention in claim **5** further characterized in that the spoke-like connecting members of said spider-like frame member are attached to the centers of each side of said central vibratile square plate portion.

7. The invention in claim **6** further characterized in that the spoke-like connecting members of said first housing member are attached to the corners of said central square plate portion contained within the perforated lid portion of said first housing member.

8. An electroacoustic transducer of the flexural vibratile type comprising a spider-like frame member including a peripheral rim portion and a plurality of central vibratile plate portions connected to said

peripheral rim portion by a plurality of spoke-like members, means comprising piezoelectric transducer material bonded to each of said central vibratile plate portions for generating sonic energy, a first housing member comprising a lid portion having open spaces surrounded by a peripheral rim portion, said lid portion including a plurality of central plate portions and a plurality of spoke-like members connecting said central plate portions to the said peripheral rim portion, a second housing member comprising a structure with a peripheral rim portion which mates with the peripheral rim portion of said first housing member, means for mounting said spider-like frame member between said first and said second housing members with said plurality of said central plate portions in said lid portion of said first housing member being located in axial alignment with said plurality of said central vibratile plate portions in said spider-like frame member.

9. The invention in claim **8** characterized in that said plurality of said central vibratile plate portions contained within said spider-like frame members are substantially square.

10. The invention in claim **9** further characterized in that said plurality of said central plate portions contained within said lid portion of said first housing member are substantially square and still further characterized in that the area of each of said central plate portions in said lid portion are less than the respective areas of the vibratile plate portions in said spider-like frame member.

11. The invention in claim **10** further characterized in that said central vibratile plate portions in said frame member are spaced parallel to the central plate portions in said lid portion of said first housing member and further characterized in that the sides of the plates portions contained within said lid portion of said housing member are rotated 45° with respect to the corresponding sides of the vibratile plate portions in said spider-like frame member.

12. The invention in claim **11** further characterized in that the area of each of said plate portions in the lid portion of said housing member is approximately one-half the area of the corresponding aligned vibratile plate portions contained within said spider-like frame member.

13. The invention in claim **12** further characterized in that the spoke-like connecting members in said spider-like frame member are attached to the centers of the sides of the said vibratile plate portions.

14. The invention in claim **13** characterized in that the spoke-like connecting members in said lid portion of said housing member are attached to the corners of said plate portions contained within said lid portion of said housing member.

15. An electroacoustic transducer of the flexural vibrating type comprising a first spider-like frame member including a peripheral rim portion and a plurality of central vibratile plate portions connected to said peripheral rim portion by a plurality of spoke-like members, a second spider-like frame member including a peripheral rim portion and a plurality of central plate portions connected to said peripheral rim portion by a plurality of spoke-like members, and means for holding said first and said second frame members in fixed spaced parallel alignment with the center of each plate portion in said second frame member aligned with the center of each corresponding vibratile plate member in said first frame member.

16. The invention in claim **15** characterized in that said plate members in both of said frame members are substantially square.

17. The invention in claim **16** further characterized in that the area of each of said plate members within said second frame member is approximately one-half the area of the vibratile plate member within said first frame member.

18. The invention in claim **17** characterized in that the sides of the plates in said first frame member are rotated 45° with respect to the sides of the plates in the said second frame member.

19. The invention in claim **18** characterized in that the spoke-like members in said first frame member are attached to the centers of the sides of said vibratile plate member.

20. The invention in claim **19** further characterized in that the spoke-like members in said second frame member are attached to the corners of said plate members.

* * * * *