Dec. 1, 1964 E. M. WEISS 3,159,719

ELECTROACOUSTIC TRANSDUCERS

Filed Nov. 13, 1961

Fig. 1

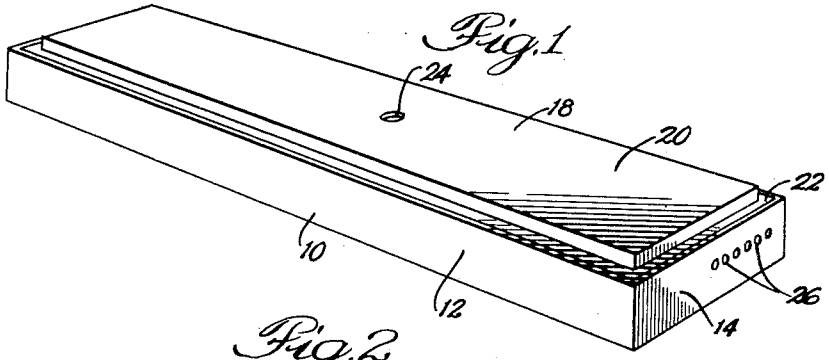


Fig. 2

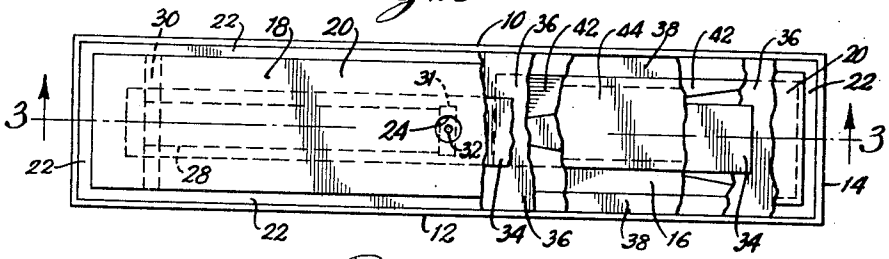


Fig. 3

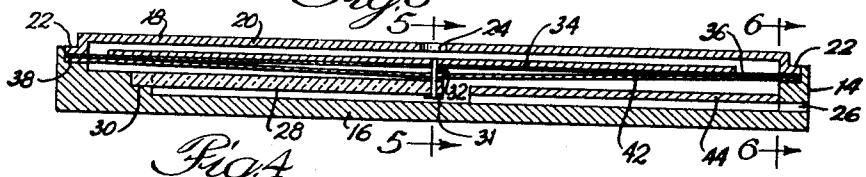


Fig. 4

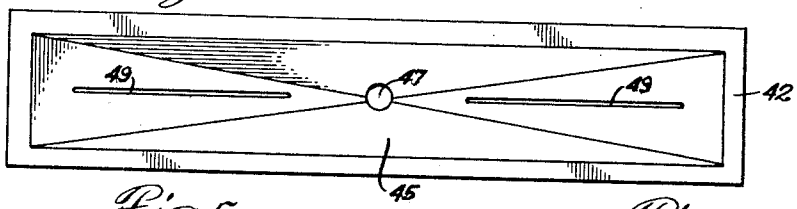


Fig. 5

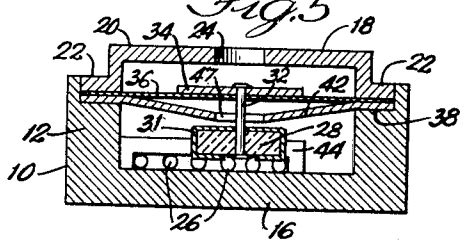
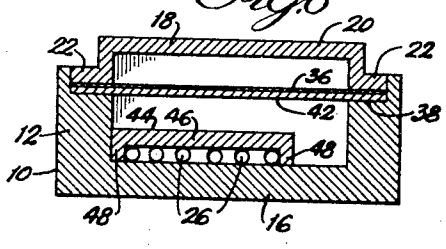


Fig. 6



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ELECTROACOUSTIC TRANSDUCERS

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This invention relates generally to improved transducer constructions and more particularly to a novel electroacoustic transducer of relative thinness for a given volume which is adapted for advantageous use in compact electrical apparatus such as hearing aids and the like.

Those skilled in the art appreciate that the present trend towards miniaturization of electrical assemblies has required a considerable reduction in the size of the components forming such assemblies. In the case of electrical components, such as resistive or capacitative elements, for example, remarkable progress has been made in the production of such components in sub-miniature and even micro-miniature sizes. There are some elements however which, although necessary for the proper operation of an electrical assembly, have not readily lent themselves to such miniaturization. For example, the electroacoustic transducers utilized in hearing aids, such as the microphones, have not been susceptible to great reductions in size without a sacrifice of output amplitude and/or fidelity. Further, it is desirable to provide hearing aids sufficiently thin so as to fit within an eyeglass temple member of standard thinness. Heretofore, such transducers have been a limiting factor in the design of small hearing aids of the type adapted to be worn on the head, as in an eyeglass temple member, or in the ear of a hard of hearing person.

Accordingly, it is a general object of this invention to provide a new and improved transducer construction adapted to overcome the above-mentioned difficulties.

It is another object of this invention to provide a unique electroacoustic transducer construction having an improved form factor advantageously adapted for use in compact electrical assemblies such as hearing aids and the like.

It is still another object of this invention to provide a new and improved electroacoustic transducer assembly having a generally elongated rectangular shape characterized by its extreme thinness for a given volume, so as to be highly useful in an eyeglass hearing aid temple member.

It is a further object of this invention to provide such an electroacoustic transducer assembly, as above, wherein an elongated casing of relatively small depth is formed of a plurality of walls so as to define a cavity therewithin, said cavity containing a beam of piezo-electric material positioned within said cavity wth one end of the beam fastened to the casing such that its remote end is free to vibrate at the center of the cavity, and a vibratable diaphragm coupled to the remote end of the beam and positioned in spaced relation to the beam adjacent the cavity opening of the casing, said cavity opening being provided with a cover in spaced relation to said vibratable diaphragm with said cover defining a sound receiving opening for permitting the diaphragm and the beam to vibrate in response to sound received by said transducer.

It is a still further object of this invention to provide an improved electroacoustic transducer assembly, constructed as above, wherein the low frequency response characteristics of the transducer are enhanced by a channel member positioned on the bottom wall of the casing to define a slotted air path in communication with an opening formed in a side wall of the casing and acting in combination with the volume of air enclosed in the compartment of the instrument housing the transducer assembly.

It is a still further object of this invention to provide an improved electroacoustic transducer assembly, constructed as above, wherein the mid-frequency response characteristics of the transducer are enhanced by a rigid sub-plate positioned between the vibratable diaphragm and the beam, said sub-plate being advantageously formed of thin sheet metal with angularly bent portions so as to define a sub-cavity between the sub-plate and the diaphragm.

It is a still further object of this invention to provide an improved electroacoustic transducer assembly, as above, which is characterized by its unique form factor, its wide range of frequency response, and its particular adaptability to slim housings such as the temple member of an eyeglass hearing aid.

It is still another object of this invention to provide an electroacoustic transducer assembly, constructed as above, which is further characterized by its relative simplicity and ruggedness of construction.

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

FIGURE 1 is a perspective view of an improved electroacoustic transducer assembly, embodying the invention;

FIGURE 2 is a top plan view of the embodiment of an electroacoustic transducer assembly shown in FIGURE 1 with portions partially broken away to illustrate its construction;

FIGURE 3 is a side elevational view, in cross-section, taken substantially as shown along line **3—3** of FIGURE 2;

FIGURE 4 is a top plan view illustrating the subplate forming a part of the electroacoustic transducer assembly.

FIGURE 5 is an end view, in cross-section, taken substantially as shown along line **5—5** of FIGURE 3; and

FIGURE 6 is an end view, in cross-section, taken substantially as shown alone line **6—6** of FIGURE 3.

Referring now to the drawing wherein one specific embodiment of the present invention is illustrated, there is shown an electroacoustic transducer assembly which is characterized by its highly advantageous form factor. It there can be seen that the electroacousitc transducer assembly of the present invention is of greatly reduced thickness with respect to its width to provide an extremely slim transducer of the type adapted for advantageous use in compact electrical apparatus. For example, the electroacoustic transducer of the present invention is readily adaptable for use in compact electrical apparatus such as eyeglass hearing aid temple members and the like, wherein the thickness of the casing should not exceed the relatively small size of standard eyeglass temples.

As shown in the drawing, the illustrative embodiment of the invention comprises an elongated casing **10** formed of a pair of illustratively long side walls **12**, a pair of shorter side walls **14**, and a bottom wall **16** so as to define a cavity therewithin. The cavity is adapted to be enclosed by a cover **18** comprised of a top portion **20** having an outwardly extending flange **22** depending therefrom. The flange **22** of cover **18** is adapted to be telescopically received within the side walls **12** and **14** of the casing and to be supported by a recessed shoulder **38** of the side walls in the manner described in greater detail hereinbelow.

An elongated beam **28** of a suitable piezo-electric material, such as barium titanate or the like, is positioned within the cavity of casing **10** with one end of the beam

28 being fastened to a recessed shoulder 30 of the casing adjacent one end thereof. Advantageously, the piezo-electric beam 28 may be secured to the shoulder 30 of casing 10 in any suitable fashion as by a clamp, cement, or the like.

Only one end of the piezo-electric beam 28 is clamped or cemented to the casing such that the remote end of the beam is free to vibrate at the center of the casing cavity. Positioned above the piezo-electric beam 28 and spaced therefrom is a vibratable diaphragm comprised of a thin metallic sheet 34 supported by a thin plastic sheet 36. The thin plastic sheet 36 extends outwardly of the metallic sheet 34 on all sides thereof so as to be supported by the recessed shoulder 38 provided around the inner periphery of the casing 10.

In one illustrative embodiment of the invention, the metallic sheet 34 was formed as an aluminum sheet while the thin plastic sheet was made of Mylar, with the diaphragm having a general thickness in the range of .001" to .002". However, those skilled in the art will appreciate that other metallic materials may be substituted for the aluminum sheet 34 and that other resilient supports may be substituted for the thin plastic Mylar sheet 36. As particularly shown in FIGURES 3 and 5, this arrangement enables the vibratable diaphragm to vibrate within the cavity of the casing 10 in response to sound energy received through an opening 24 in the cover 18.

In the practice of the invention, the vibratable diaphragm is coupled to the piezo-electric beam 28 so that the latter will be vibrated in a manner corresponding to the vibration of the diaphragm when sound energy is received by the transducer, thereby causing the piezo-electric beam to generate electrical signals corresponding to the sound waves in a manner well known to those skilled in the art. As shown in FIGURES 3 and 5, for example, the free end of the piezo-electric beam 28 may be coupled to the vibratable diaphragm as by means of a metal clamp 31 around the free end of beam 28 and an elongated fastener 32, such as a suitable rivet which is enlarged at each end to insure mutual vibration of the diaphragm and the piezo-electric beam.

In accordance with a further feature of this invention, the useful frequency range of the transducer is enhanced by means of several acoustically responsive elements incorporated within the cavity of the casing 10. Towards this end, the low frequency response of the transducer is enhanced in part by the U-shaped channel member 44 positioned on the bottom wall 16 of casing 10 and extending from a point near the center of the cavity to a side wall 14 thereof. The channel member 44 is formed by the upper flat member 46 from which the pair of legs 48 depend into contact with the bottom wall 16 of casing 10. As shown by the FIGURES 3, 5, and 6 of the drawings, the channel member 46 together with the bottom wall 16 of casing 10 define a thin slotted air path which communicates with one or more openings 26 formed in a side wall 14 of casing 10. It will be appreciated by those skilled in the art that the channel member defining the thin slotted air path together with the cavity volume formed by the compliance of the vibratable diaphragm in combination with the volume of air enclosed in the compartment of the apparatus housing the transducer, which communicates with the slotted air path through the side wall opening, all determine the low frequency response characteristics of the transducer. It will further be appreciated that other means may be employed to define the slotted air path, as for example, a tubular member within the cavity having one end contacting an opening of the side wall.

In accordance with a further feature of this invention, the mid-frequency response characteristics of the transducer are enhanced by a rigid sub-plate 42 positioned between the vibratable diaphragm and the piezo-electric beam 28. The rigid sub-plate 42, which advantageously may be stamped from thin sheet metal, such as beryllium copper, is formed in accordance with one specific embodiment of the invention with outwardly bent triangular portions 45 so as to define a sub-cavity between the sub-plate 42 and the diaphragm. This sub-cavity may be seen in FIGURES 3 and 5 of the drawing. The center of the sub-plate 42 is formed with an opening 47 sufficiently large enough to permit the coupling fastener 32 to be positioned therethrough for unimpeded movement in accordance with the diaphragm vibration.

It will be appreciated by those skilled in the art that the mid-frequency response characteristics of the transducers are determined by the mass and compliance of the diaphragm, by the compliance of the piezo-electric beam 28, by the air annulus formed between the coupling fastener 32 and the sub-plate 42, and by the sub-cavity formed between the bottom surface of the vibratable diaphragm supporting sheet 36 and the top surface of the rigid sub-plate 42. This sub-cavity, as explained hereinabove, is particularly defined by the angular extent of the outwardly bent triangular portions 45 of the sub-plate. The elongated slots 49 in sub-plate 42 provide damping for the mid-frequency response range.

It further will be appreciated that the high frequency response characteristics of the transducer are determined by the cavity defined by the top surface of the vibratable diaphragm and the bottom surface of the top cover 18, and by the dimensions of the sound receiving aperture 24 in the top cover 18.

In accordance with a further feature of this invention, the piezo-electric beam may be damped (at the resonant frequency of the unsupported beam, which affects the mid-frequency response of the transducer) by the addition of the visco-elastic member having good internal damping characteristics, such as butyl rubber for example. It has been found advantageous to add such a damping member between the beam and any fixed surface within the cavity, such as an interior wall of the casing or any part affixed thereto. Alternatively, a metal plate may be secured to the beam so as to extend outwardly from the free end thereof in close proximity to a fixed surface with a film of viscous fluid maintained therebetween, as by surface attraction.

It has been found that an electroacoustic transducer assembly constructed in accordance with the above description, as illustrated by the drawings, provides a relatively wide and highly desirable frequency response characteristic of sufficient amplitude to render the transducer highly useful in compact electrical apparatus, such as hearing aids and the like. The further feature of extreme slimness for a given volume characteristic of this transducer makes it desirable for use in hearing aids where the thickness and width of the casing are limiting factors. Obviously, those skilled in the art will appreciate that the transducer case may be formed of any suitable material, such as plastic or metal, and they will appreciate further that the relative ruggedness and simplicity of the transducer construction gives rise to a highly economical and relatively trouble-free transducer which results in a substantial advance in the art of hearing aid transducers.

In one highly desirable embodiment of the invention, the casing comprised of brass or beryllium copper had a length of 1.196", a width of .267", and a thickness of .078". The advantages of the form factor obtained are manifest in view of the description given hereinabove.

While there has been shown and described a specific embodiment of the present invention, it will, of course, be understood that various modifications and alternative constructions may be made without departing from the true spirit and scope of the invention. Therefore, it is intended by the appended claims to cover all such modifications and alternative constructions as fall within their true spirit and scope.

What is claimed as the invention is:

1. The improvement of an electroacoustic transducer characterized by its relatively thin form factor comprising

the combination of an elongated casing of a width substantially greater than its depth, said casing having bottom and side walls defining a cavity therewithin, a beam of piezo-electric material positioned within said cavity, said beam being fastened at one end thereof to said casing such that its remote end is free to vibrate at the center of said cavity, a vibratable diaphragm coupled to said remote end of the beam and positioned in spaced relation to said beam adjacent the cavity opening of the casing, a cover for the cavity opening supported by the side walls of said casing in spaced relation to said vibratable diaphragm, said cover defining a sound receiving opening for permitting said diaphragm and said beam to vibrate in response to sound received by said transducer to produce corresponding electrical signals, means for enhancing the low frequency response characteristics of said transducer comprising a channel member positioned on the bottom wall of said casing so as to define a slotted air path, a side wall of said casing being formed with an opening communicating with said slotted air path, and means for enhancing the mid-frequency response characteristics of said transducer comprising a rigid sub-plate positioned between said vibratable diaphragm and said beam, said sub-plate being formed of thin sheet metal with angularly bent portions so as to define a sub-cavity between the sub-plate and said diaphragm.

2. The improvement of an electroacoustic transducer characterized by its relatively thin form factor comprising the combination of an elongated casing having bottom and side walls defining a cavity therewithin, a beam of piezo-electric material positioned within said cavity, said beam being fastened at one end thereof to said casing such that its remote end is free to vibrate within said cavity, a vibratable diaphragm coupled to said remote end of the beam and positioned in spaced relation to said beam adjacent the cavity opening of the casing, a cover for the cavity opening supported by the side walls of said casing in spaced relation to said vibratable diaphragm, said cover defining a sound receiving opening for permitting said diaphragm and said beam to vibrate in response to sound received by said transducer to produce corresponding electrical signals, means for enhancing the low frequency response characteristics of said transducer comprising a channel member positioned on the bottom wall of said casing so as to define a slotted air path, a side wall of said casing being formed with an opening communicating with said slotted air path, and means for enhancing the mid-frequency response characteristics of said transducer comprising a rigid sub-plate positioned between said vibratable diaphragm and said beam, said sub-plate being formed of thin sheet metal with angularly bent portions so as to define a sub-cavity between the sub-plate and said diaphragm.

3. The improvement of an electroacoustic transducer characterized by its relatively thin form factor comprising the combination of an elongated casing having bottom and side walls defining a cavity therewithin, a beam of piezo-electric material positioned within said cavity, said beam being fastened at one end thereof to said casing such that its remote end is free to vibrate within said cavity, a vibratable diaphragm coupled to said remote end of the beam and positioned in spaced relation to said beam adjacent the cavity opening of the casing, a cover for the cavity opening supported by the side walls of said casing in spaced relation to said vibratable diaphragm, said cover defining a sound receiving opening for permitting said diaphragm and said beam to vibrate in response to sound received by said transducer to produce corresponding electrical signals, and means for enhancing the low frequency response characteristics of said transducer comprising a channel member positioned on the bottom wall of said casing so as to define a slotted air path, a side wall of said casing being formed with an opening communicating with said slotted air path.

4. The improvement of an electroacoustic transducer

characterized by its relatively thin form factor comprising the combination of an elongated casing having bottom and side walls defining a cavity therewithin, a beam of piezo-electric material positioned within said cavity, said beam being fastened at one end thereof to said casing such that its remote end is free to vibrate within said cavity, a vibratable diaphragm coupled to said remote end of the beam and positioned in spaced relation to said beam adjacent the cavity opening of the casing, a cover for the cavity opening supported by the side walls of said casing in spaced relation to said vibratable diaphragm, said cover defining a sound receiving opening for permitting said diaphragm and said beam to vibrate in response to sound received by said transducer to produce corresponding electrical signals, and means for enhancing the mid-frequency response characteristics of said transducer comprising a rigid sub-plate positioned between said vibratable diaphragm and said beam, said sub-plate being formed of thin sheet metal with angularly bent portions so as to define a sub-cavity between the sub-plate and said diaphragm.

5. The improvement of an electroacoustic transducer characterized by its relatively thin form factor comprising the combination of an elongated casing of a width substantially greater than its depth, said casing having bottom and side walls defining a cavity therewithin, a beam of barium titanate material positioned within said cavity, said beam being fastened at one end thereof to said casing such that its remote end is free to vibrate at the center of said cavity, a vibratable diaphragm coupled to said remote end of the beam and positioned in spaced relation to said beam adjacent the cavity opening of the casing, said vibratable diaphragm comprising a thin sheet of flexible, resilient material forming a wall-to-wall partition between said cover and said beam, and a thin sheet of metallic material positioned on said sheet of flexible, resilient material, said sheet of metallic material being of lesser dimensions than said sheet of flexible, resilient material so as to be supported by the latter, and a cover for the cavity opening supported by the side walls of said casing in spaced relation to said vibratable diaphragm, said cover defining a sound receiving opening for permitting said diaphragm and said beam to vibrate in response to sound received by said transducer to produce corresponding electrical signals.

6. The improvement of a microphone having a relatively thin thickness for a given volume comprising an elongated casing of a width substantially greater than its depth, said casing having bottom and side walls defining a cavity therewithin, a beam of piezo-electric material positioned within said cavity, said beam being fastened at one end thereof to said casing such that its remote end is free to vibrate at the center of said cavity, a vibratable diaphragm coupled to said remote end of the beam and positioned in spaced relation to said beam adjacent the cavity opening of the casing, a cover for the cavity opening supported by the side walls of said casing in spaced relation to said vibratable diaphragm, said cover defining a sound receiving opening for permitting said diaphragm and said beam to vibrate in response to sound received by said microphone to produce corresponding electrical signals, means for enhancing the low frequency response characteristics of said microphone comprising a channel member positioned on the bottom wall of said casing so as to define a slotted air path, a side wall of said casing being formed with an opening communicating with said slotted air path, and means for enhancing the mid-frequency response characteristics of said microphone comprising a rigid sub-plate positioned between said vibratable diaphragm and said beam, said sub-plate being formed of thin sheet metal with angularly bent portions so as to define a sub-cavity between the sub-plate and said diaphragm.

7. The improvement of a microphone suitable for use in the temple member of hearing aid eyeglasses com-

prising the combination of an elongated casing of a width substantially greater than its depth for placing with a standard eyeglass temple member, said casing having bottom and side walls defining a cavity therewithin, a beam of piezo-electric material positioned within said cavity, said beam being fastened at one end thereof to said casing such that its remote end is free to vibrate at the center of said cavity, a vibratable diaphragm coupled to said remote end of the beam and positioned in spaced relation to said beam adjacent the cavity opening of the casing, a cover for the cavity opening supported by the side walls of said casing in spaced relation to said vibratable diaphragm, said cover defining a sound receiving opening for permitting said diaphragm and said beam to vibrate in response to sound received by said microphone to produce corresponding electrical signals, and means for enhancing the low frequency response characteristics of said microphone comprising means defining a slotted air path within said cavity, a side wall of said casing being

formed with an opening communicating with said slotted air path, and means for enhancing the mid-frequency response characteristics of said microphone comprising a rigid sub-plate positioned between said vibratable diaphragm and said beam, said sub-plate being formed of thin sheet metal with angularly bent portions so as to define a sub-cavity between the sub-plate and said diaphragm.

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