United States Patent

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Continuation-in-part of application Ser. No. 557;120, June 13, 1966, now abandoned, Continuation-in-part of application Ser. No. 634,642, Apr. 28, 1967, now abandoned.

[54] **TRANSDUCER HAVING SPACED APART OPPOSITELY FLEXING PIEZOELECTRIC MEMBERS**
13 Claims, 13 Drawing Figs.

[52] U.S. Cl. 179/110, 310/8.6
[51] Int. Cl. H04r 17/00
[50] Field of Search 179/110, 110.1, 110 4, 310/8.6, 8.8, 9.1, 9.8, 10

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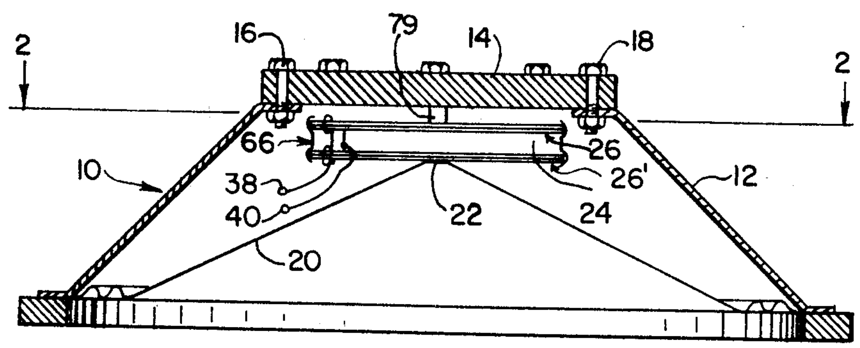
ABSTRACT: An electroacoustic transducer having piezoelectric driving means consisting of first and second spaced apart bimorphs having a central portion and an edge portion. A spacer couples the same portion of each bimorph together. The other portion of each bimorph is coupled respectively to support means and a diaphragm. The bimorphs are electrically interconnected so that they flex in opposite directions. A further embodiment includes third and fourth spaced apart bimorphs operating similar to and directly attached to the first and second bimorphs.



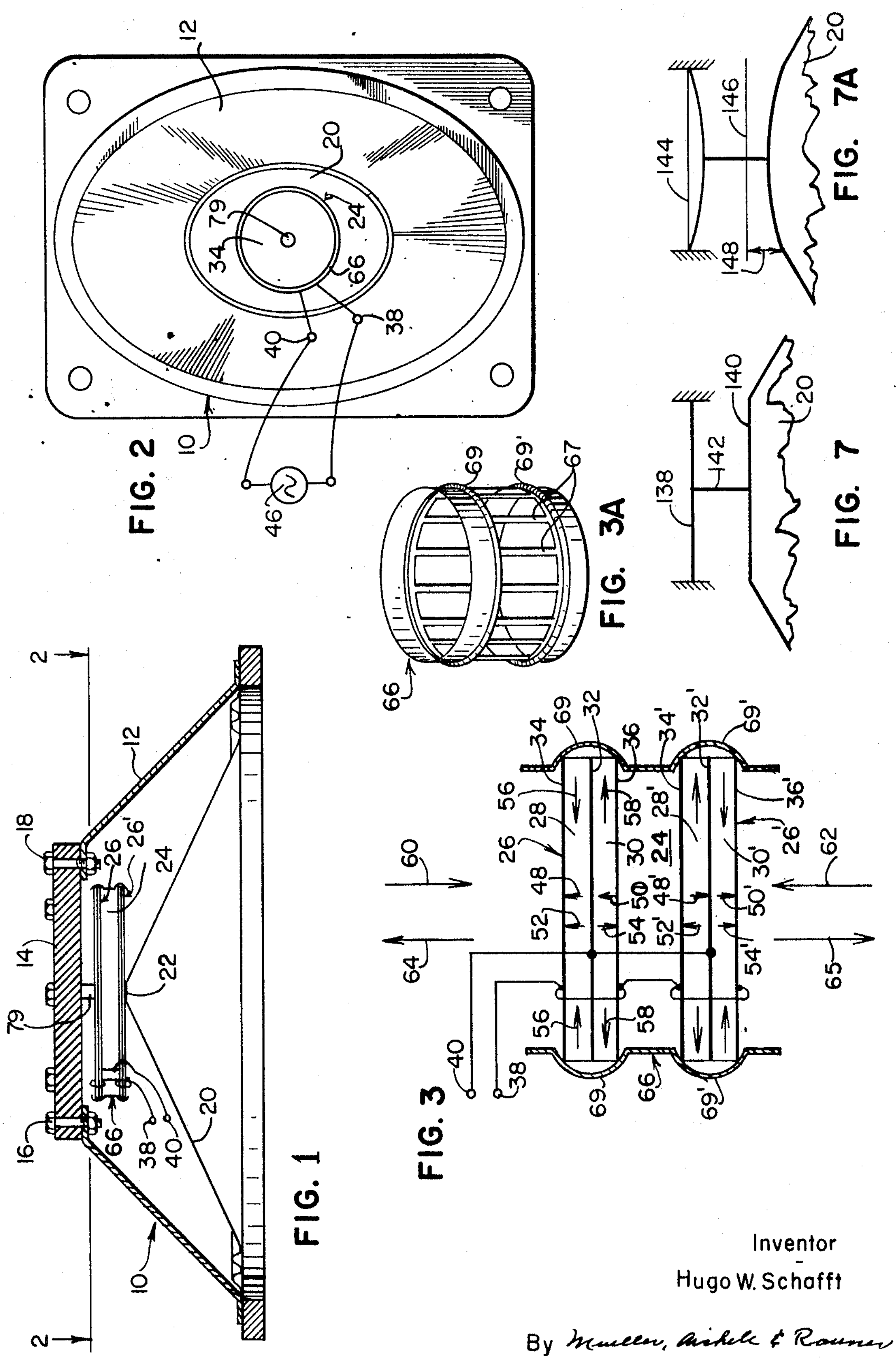


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FIG. 4

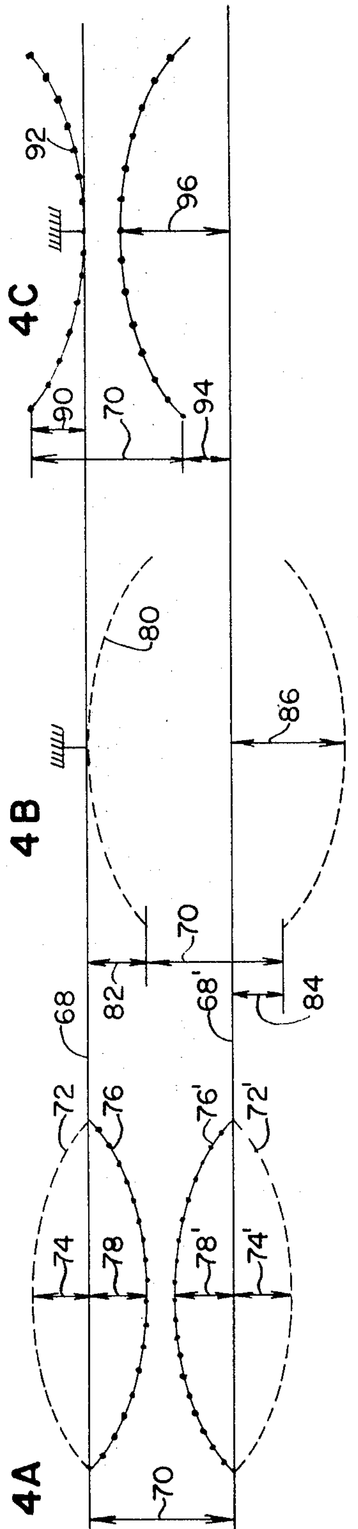

FIG. 6

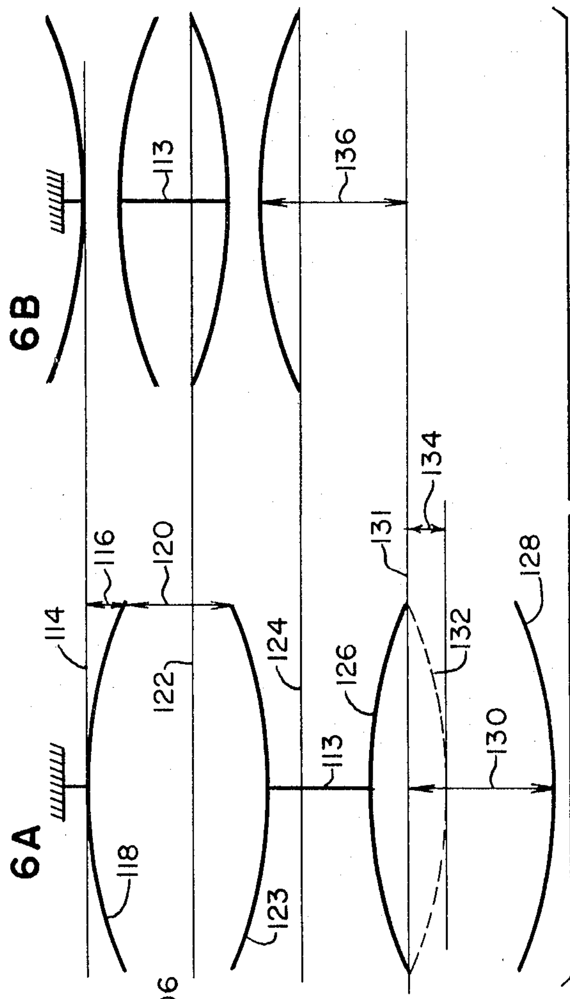

FIG. 5

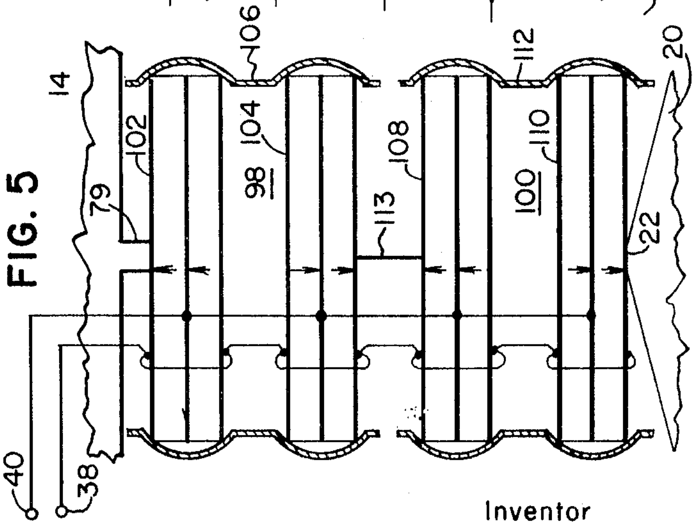

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FIG. 8

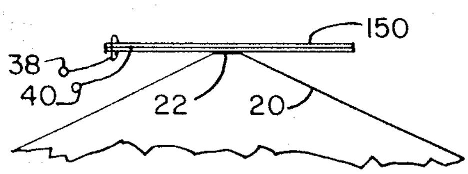


FIG. 9

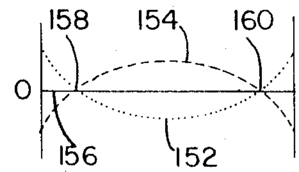


FIG. 10

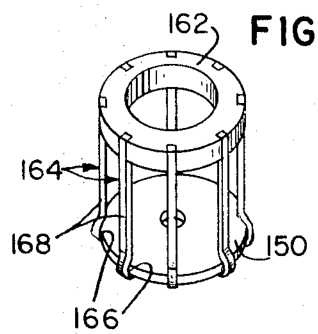
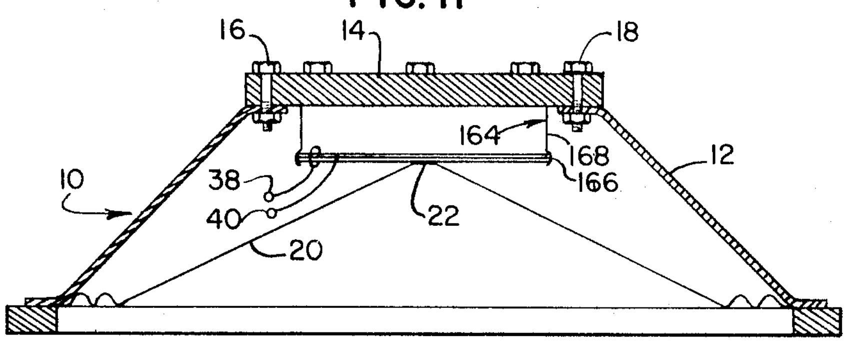


FIG. 11



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ATTYS.

TRANSDUCER HAVING SPACED APART OPPOSITELY FLEXING PIEZOELECTRIC MEMBERS

This application is a continuation in part of application Ser. No. 634,642 filed Apr. 28, 1967 now abandoned, and a continuation in part of application Ser. No. 557,120, filed June 13, 1966 now abandoned for continuation Ser. No. 852,985.

BACKGROUND OF THE INVENTION

The desirability of using piezoelectric material as the means to convert between electrical and mechanical stimuli has become increasingly apparent in recent years. A piezoelectric converter does not suffer the disadvantages inherent in an electromagnetic type converter such as large size, susceptibility to breakdown between windings and poor reliability.

There have been several proposals utilizing piezoelectric material in a transducer to convert between electrical and sound stimuli but most are directed towards a high frequency audio transducer where the inherent capacitive characteristic of piezoelectric material provides the necessary output at higher frequencies. Because the frequency of resonance of a piezoelectric bimorph driver is inversely proportional to its area, an adequate output at low frequencies would necessitate a converter of such a large size that it would be flimsy so that losses would be introduced in converting between electrical and mechanical stimuli.

SUMMARY OF THE INVENTION

It is, therefore, an object of this invention to provide a transducer capable of converting between electrical and sound stimuli at the lower end of the audio frequency range.

Another object is to provide a piezoelectric converter to transfer energy between an electrical circuit and a diaphragm with the converter having a relatively small size.

In brief, the transducer according to the invention comprises one or more bimorphs each having an edge portion and a central portion. One of said portions is mechanically connected to the axially movable portion of a diaphragm and the other of such portions is coupled through a spacer to a reference support to preclude axial movement of such other portion with respect to the support and to permit axial movement of said one portion.

More specifically, the transducer includes a diaphragm with an axis and an axially movable portion. The transducer also includes a piezoelectric device which has first and second spaced apart bimorphs of selected polarization each of which extends transversely to the axis of the diaphragm. A spacer hingedly joined to the edge portions of the bimorphs maintains the distance between such portions substantially fixed but permits independent axial movements along the individual extents of the bimorphs. The bimorphs are electrically interconnected relative to their respective polarizations such that they will flex in opposite directions when stimulated. The central portion of one bimorph is mechanically connected to the axially movable portion of the diaphragm for coupling mechanical stimuli therebetween and the central portion of the other bimorph is rigidly attached to a support. This will improve the response of the transducer at lower frequencies first, because the effective area is increased, and second, because its excursion over the entire frequency range to which the transducer is responsive also increases.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view of a speaker constructed in accordance with the teachings of this invention;

FIG. 2 is a sectional and reduced view of the FIG. 1 speaker as taken along line 2–2 in the direction of the arrows;

FIG. 3 is a diagrammatic and enlarged side view of the two bimorphs and the connecting spacer used in the FIG. 1 speaker;

FIG. 3A illustrates a perspective view of the spacer of FIG. 3;

FIG. 4 illustrates the flexure patterns of the bimorphs of FIG. 3;

FIG. 5 is a diagrammatic and enlarged side view of a plurality of bimorphs according to another embodiment of the invention;

FIG. 6 illustrates the flexure patterns of the bimorphs of FIG. 5;

FIG. 7 illustrates a further embodiment;

FIG. 7A illustrates the flexure patterns of the bimorphs of FIG. 7;

FIG. 8 illustrates a mode of driving a diaphragm with a bimorph;

FIG. 9 illustrates the flexure patterns of the bimorph of FIG. 8;

FIG. 10 illustrates an alternate embodiment of the invention; and

FIG. 11 illustrates how the embodiment of FIG. 10 may be used in a speaker.

DETAILED DESCRIPTION

Referring now to FIGS. 1 and 2 there is shown a transducer or more specifically a speaker mounted in a housing 10 which includes a conical portion 12 and an annular slab 14 joined to the portion 12 by a pair of fasteners 16 and 18. The transducer includes a compliant diaphragm 20 having an apex 22 which is movable along the axis of the diaphragm 20 when mechanically stimulated. The diaphragm, due to its inherent characteristics, has a "number" of resonances within a frequency range primarily determined by its size, with the lower the frequency range to be reproduced by the speaker, the larger the diaphragm must be. This "number" of resonances causes the diaphragm to have a relatively flat response within a range of frequencies rather than the normal peaked response of a resonant circuit.

A piezoelectric driver 24 for converting electrical energy into mechanical energy to axially move apex 22 is shown in detail in FIG. 3 and includes bimorphs 26 and 26'. Bimorph 26 includes two piezoelectric wafers 28 and 30 which preferably are annular in shape to provide maximum electromechanical conversion. The wafers are joined together by epoxy or the like with an intermediate electrode 32 interposed between their innerfaces. Bimorph 26 also has a pair of outer electrodes 34 and 36 which may be plated onto the respective outer surfaces. Bimorph 26' has corresponding parts indicated by similar reference numerals which are primed. Outer electrodes 34 and 36 of bimorph 26 and outer electrodes 34' and 36' of bimorph 26' are connected together and to an input terminal 38. Intermediate electrodes 32 and 32' are connected to a second input terminal 40. An electrical signal within the audio frequency range is supplied by a source 46 (FIG. 2) to the input terminals 38 and 40.

The following explanation as to the action of the bimorph 26 to convert electrical stimuli to corresponding mechanical stimuli for driving diaphragm 20 assumes that such bimorph is not attached. The wafers 28 and 30 are each permanently electrically polarized in directions indicated by the arrows 48 and 50 respectively. When the electrical signal on terminal 38 is positive with respect to terminal 40, the electric fields in the respective wafers will be in the directions indicated by the arrows 52 and 54. Since the electric field and the polarization in wafer 28 are in the same direction, wafer 28 contracts radially inward as indicated by arrows 56. Since the polarization and the electric field in wafer 30 are in opposite directions, it will expand radially outward as indicated by the arrows 58. Bimorph 26 is constructed to be relatively thin so that it will flex along its axial dimension and with the above described polarization and electric fields the bimorph 26 tends to flex at its center axis axially downward as indicated by arrow 60.

Using the same analysis on bimorph 26' and assuming the polarization to be in the direction shown by arrows 48' and 50', it will flex in an opposing direction as indicated by arrow 62 when terminal 38 is positive with respect to terminal 40. Reversing the polarity between the terminals 38 and 40 causes a reversal in the directions of the electric fields in bimorph 26 so that wafer **28** expands radially outward and wafer **30** contracts radially inward to flex the bimorph **26** at its center in a direction indicated by arrow **64**. By using similar analysis, the bimorph **26'** will flex in an opposing direction indicated by arrow **65**. Impressing an alternating electrical signal across the input terminals **38** and **40** causes the bimorphs **26** and **26'** to oscillate between simultaneous outward flexure by both bimorphs and simultaneous inward flexure thereof. In order to obtain the flexing of the bimorphs **26** and **26'** in opposite directions, a variety of interconnections of the electrodes to the input terminals with respect to the polarizations of the wafers may be used of which the one shown is merely illustrative.

A hinge or spacer **66** schematically shown in cross section may be annular to conform to the shape of the bimorphs. The spacer has annular grooved portions (schematic representation) **69** and **69'** hingedly joined respectively to the circumferential edges of the bimorphs **26** and **26'**, and ideally maintains a fixed distance between them so that when the bimorphs flex, there is no relative motion between such edges. Also, such a construction permits the midpoint of the circumferential edge to be substantially stationary with the sides of such edge pivoting about the midpoint. The losses in such an arrangement would be considerably less than if the edges were rigidly clamped. Although the spacer dimensions are shown out of proportion for ease in illustration, in practice the distance between the grooved portions **69** and **69'** of spacer **66** may be on the order of eight times as great as the thickness of each bimorph. The spacer **66** should also have the characteristic that the bimorphs be free to move independently in the axial direction along their separate extents. FIG. 3A shows a spacer composed of aluminum and having a ladder shape with a multiplicity of cross bars **67** maintaining the distance between grooved portions **69** and **69'** relatively fixed. The bimorphs **26** and **26'** are respectively attached to these portions.

Referring to FIG. 4A, bimorph **26** has a rest position axis **68** and bimorph **26'** has a rest position axis **68'** with the circumferential edges being separated by the spacer **66** by a distance **70**. When the polarity of the electrical signal is such as to move the bimorphs **26** and **26'** respectively in the directions indicated by arrows **64** and **65** (FIG. 3), the flexure patterns thereof are respectively indicated by dashed lines **72** and **72'** with the centers moving distances **74** and **74'**. When the polarity of the electrical signal reverses, the patterns are indicated by dotted lines **76** and **76'** with the centers moving distances **78** and **78'**. Since the bimorphs are annular in shape, the motions indicated are only a representation of the actual "oil canning" or "dishing" of the bimorphs.

Referring back to FIG. **1**, the central portion of the upper surface of the bimorph **26** is rigidly attached to a protrusion **79** on the annular slab **14** by epoxy or the like so that when the bimorph **26** tends to flex as indicated by the dashed line **72**, the circumferential edge of bimorph **26** will move downwardly from rest position axis **68** a distance **82** (as shown by the flexure pattern **80** of FIG. 4B) equal to the distance **74** that the center portion of such bimorph would move if free. Since the spacer **66** maintains the distance **70** between the circumferential edges fixed, the rest position axis of the bimorph **26'** is shifted downwardly by a distance **84** equal to distance **82** to move the entire flexure pattern downwardly so that the total excursion of the central portion of the lower surface from rest position axis **68'** will be a distance **86** double that of distance **74'** (FIG. 4A). Since the apex **22** of the diaphragm **20** is connected to the central portion of bimorph **26'** by epoxy for example, the diaphragm generates a sound wave having a magnitude proportional to distance **86**.

When the polarity of the electrical signal is reversed so that the bimorph **26** tends to flex as indicated by the dotted line **76**, such motion will also be inhibited. Therefore, its circumferential edge, as shown by the flexure pattern **92** of FIG. 4C, will move upwardly from the rest position axis **68** a distance **90** equal to distance **78** (FIG. 4A). The distance **70** between the circumferential edges is fixed by the spacer **66** so that the rest position axis of the bimorph **26'** is shifted upwardly by a distance **94** equal to distance **90** so that the total excursion from rest position axis **68'** will be a distance **96** double that of **78'**.

As the polarity of the electrical signal applied between terminals **38** and **40** alternates between positive and negative values, the excursion of the central portion of bimorph **26'** alternates between the flexure patterns of FIGS. **4B** and **4C**. As the amplitude of the electrical signal changes, the distances **86** in FIG. **4B** and **96** in FIG. **4C** will change in proportion thereto as will the magnitude of the sound waves emanated by the diaphragm **20**.

The advantage of the construction just explained may be appreciated by considering the characteristics required for a single bimorph-type driver having the central portion of one side connected to the apex **22** of diaphragm **20** and the other side unattached. The excursion of such central portion rapidly decreases as the frequency of the electrical signal applied to the bimorph decreases below its resonant frequency but since piezoelectric material is essentially capacitive, its excursion at higher frequencies will not be significantly less. Thus, if the bimorph has a resonant frequency of 400 hertz, its excursion in response to an electrical signal of a given amplitude at 400 hertz or higher will be a given magnitude and substantially less for the same amplitude electrical signal but of a lower frequency. The volume of the sound emanated by diaphragm **20**, as previously stated, is directly proportional to such excursion so that if a 400 hertz (resonant frequency) bimorph is used, the volume of sound, in response to a 400 hertz signal, will be substantially greater than the response to a 100 hertz signal. In order to overcome such inaccurate reproduction, the area of the bimorph may be increased according to the inverse proportional relationship between the resonant frequency and area (diameter squared) of a piezoelectric bimorph driver. If a 2 inch diameter disc has a resonant frequency of 400 hertz and thus has an excursion of a given magnitude when an electrical signal at 400 hertz is applied, doubling its diameter to 4 inches (multiplying area by four) reduces the resonant frequency of the bimorph to 100 hertz.

A 4 inch driver, in addition to being too large to be usable in a conventional size speaker housing, would be flimsy to therefore introduce losses into the converter. This problem is solved by the use of two smaller diameter bimorphs **26** and **26'** connected to the spacer **66** to have the effect of doubling the area and thus halving the resonant frequency. Thus, if two of the 2 inch diameter bimorphs are used, each having a resonant frequency of 400 HZ, the resonant frequency of the combination is 200 hertz. Whereas there would be a negligible response of a 400 hertz bimorph to a 200 hertz signal, the response of a 200 hertz pair of bimorphs to such signal is substantial. In addition, as previously explained, the excursion is doubled over the entire frequency range to which the driver **24** is response (above its resonant frequency) that is, 200 hertz and up. In order to decrease the resonant frequency to 100 hertz, the area of each bimorph is doubled so that each has a diameter of 2.8 inches ($2x\sqrt{2}$ inches) which is substantially less than the 4 inches required of a single bimorph.

Practically, the spacer **66** used to connect the bimorphs **26** and **26'** will not provide zero relative motion between the circumferential edges of the bimorphs, and yet provide complete freedom for rectilinear motion at the center portions so that some loss may be introduced, although practical constructions have minimized losses quite satisfactorily.

In a practical construction, the bimorphs had a diameter of 1.7 inches and a thickness of 0.019 inches, and when mounted to a diaphragm, the assembly had a lower cutoff frequency or resonant frequency of 200 hertz.

A further embodiment of the invention shown in FIG. **5** includes a pair of piezoelectric drivers **98** and **100** each of which is similar in construction to that shown in FIG. **3**. The circumferences of the pair of bimorphs **102** and **104** in driver **98** are hingedly joined to spacer **106**, and the bimorphs **108** and **110** in driver 100 have their circumferential edges hingedly joined to a further spacer 112. The center portion of the upper surface of bimorph 102 is rigidly attached to the protrusion 79 of the slab 14. The center portion of the lower surface of bimorph 110 is attached to the apex 22 of the diaphragm 20. The center portions on the opposite outer surfaces of the bimorphs 104 and 108 are attached by a spacer 113 to maintain the distance between such portions fixed. Each bimorph has a pair of outer electrodes plated onto the respective outer surfaces all of which are connected together and to one of the input terminals 38. The intermediate electrodes of the four bimorphs are also joined together and to the other of the input terminals 40 with the bimorphs being polarized in the directions indicated by the arrows. An electrical signal applied between input terminals 38 and 40 will cause the bimorphs in driver 98 to flex in opposite directions and similarly will cause the bimorphs in driver 100 to flex in opposite directions and further the bimorphs 102 and 108 will flex in the same direction as will the bimorphs 104 and 110.

If the electrical signal is instantaneously positive, the circumferential edge of bimorph 102 will move downwardly from its rest position axis 114 a distance 116 as shown by the the flexure pattern 118 of FIG. 6A. Since the spacer 106 maintains the distance 120 between the circumferential edges fixed, the rest position axis 122 of the bimorph 104 is shifted downwardly by a distance equal to distance 116 to move the entire flexure pattern 123 downwardly. Since the distance between the bimorphs 104 and 108 is fixed by the spacers 113, the flexing of the bimorph 104 in effect displaces the rest position axis 124 of the bimorph 108 which itself bends according to the flexure pattern 126. Since the distance between the circumferences of the bimorphs 108 and 110 is substantially flexed by the spacer 112, the flexure pattern 130 of bimorph 110 moves downwardly so that the center portion of the lower surface of bimorph 110 moves a distance 130 from its rest position axis 131. The dashed line 132 represents the flexure pattern of a single bimorph with its excursion at its center being a distance 134 which is about one-quarter that of distance 130.

This analysis may be further continued to show that when the polarity of the electrical compressed cross terminals 38 and 40 is reversed, the distance that the center portion of the bimorph 110 moves is equal to distance 136 as shown in FIG. 6B. In addition to providing 4 times the excursion, the area of the driver of FIG. 5 is effectively quadrupled so that its resonant frequency is one-fourth that of a single bimorph.

Additional bimorphs could be connected to increase the excursion of the bimorph 110 in response to a given amplitude signal by attaching the center portion of the first bimorph to a given amplitude signal by attaching the center portion of the first bimorph to the housing 10, attaching the center portion of the last of the bimorphs to the diaphragm and attaching spacers between succeeding ones of the intermediate bimorphs. The method of interconnecting the electrodes and the directions of polarization of the respective papers in each bimorph is merely exemplary and other methods could be utilized with the criteria being that the bimorphs in each driver simultaneously flex in opposite directions while corresponding bimorphs in all the drivers flex simultaneously in the same direction.

A further embodiment of the invention shown in FIG. 7 includes a pair of piezoelectric drivers 138 and 140 each of which is similar in construction to that shown in FIG. 3. The edges of the bimorph 138 are hingedly connected to the housing 10 (schematically indicated as a support) and the edge of the bimorph 140 is hingedly connected to an axially movable portion of the diaphragm 20. The central portions of the respective bimorphs are connected together by a spacer 142 to maintain the distance between such portions fixed. Again the electrical interconnections between the bimorphs 138 and 140 with respect to their polarization are such as to cause them to flex in opposite directions.

As shown in the flexure patterns of FIG. 7*a*, when electrical signals of one polarity are applied, the central portion of bimorph 138 will move downwardly from its rest position axis 144 to cause the center of bimorph 140 to move downwardly from its rest position axis 146. And due to the simultaneous opposite direction flexing of bimorph 140, its edge moves downwardly by a distance 148 to mechanically stimulate the diaphragm 20. An opposite polarity electrical signal moves the edge of bimorph 140 in the other direction. Also additional bimorphs could be connected in series in which case the edge of a third bimorph would be hingedly connected to the edge of bimorph 140 and a spacer would be connected between the center of the third bimorph and the center of the fourth bimorph with the edge of the fourth bimorph being hingedly connected to the axially movable portion of the diaphragm 20.

Referring now to FIG. 8, there is shown a single annular bimorph wafer 150 similar in construction to the bimorph 26 of FIGS. 1 and 3. It is mounted at its center to the apex 22 of diaphragm 20. Such a construction is shown and described in U.S. Pat. application Ser. No. 557,120 assigned to the assignee of the present invention. The bimorph wafer 150 has a pair of outer electrodes plated on to the respective outer surfaces which are connected to one of the input terminals 38. The intermediate electrode is connected to the input terminal 40. With no additional mechanical connections to the wafer 150, an electrical signal applied to such input terminals will cause the wafer to flex as indicated in the edge view of the wafer shown in FIG. 9. The dotted line 152 represents the flexure pattern resulting from one polarity electrical signal and the dashed line 154 represents the pattern resulting from an opposite polarity electrical signal. The axis 156 represents zero motion of the wafer. It is to be understood that at any instant of time, the mass above the axis 156 equals the mass below the axis. In other words, the mass inwardly of a null circle represented by the points 158 and 160 equals the mass outwardly of such circle. As is known, the lower the frequency of sound a speaker is to reproduce, the larger in size (and thus mass) the diaphragm must be. Increasing the mass of the diaphragm 20 which is attached at the center of the wafer 150, moves the null circle inwardly which will serve to reduce the available excursion of the wafer 150 and thus the speaker output. This could be compensated for by adding mass to the periphery of the wafer 150 to move the null circle outwardly, but for practical low frequency speakers, it would become too heavy to be properly supported on the diaphragm.

This problem may be solved by using the embodiment of FIG. 10 wherein a mass in the form of a ring 162 is attached to the outer periphery of the wafer as by a plurality of clips 164. Ring 162 serves to decrease the resonant frequency of wafer 150, permits a heavier diaphragm 20, but increases mechanical losses.

More specifically, the clips 164 form a hinge somewhat similar to the hinge 69 of FIG. 3A. The notches 166 in each of the clips 150 correspond generally to the grooved portion 69′ of the hinge 66, that is, the bimorph wafer 150 is retained in position by these notches. The elongated portion 168 of the clips 164 correspond to the cross bars 67 of the hinge 66. The top of the elongated portions 168 are connected to a mass in the form of ring 162.

Such a construction is particularly useful in the speaker of FIG. 11 where components corresponding to those of FIG. 1 are given the same reference numeral. Here the tops of the elongated portions 168 are attached to the annular slab 14 which is the top of the housing 10 to provide the mass represented by the ring 162 of FIG. 10. In a similar fashion to the embodiments of FIG. 3 and FIG. 5, the circumferential edge of the wafer 150 is hingedly joined to the notches 166 in the clips 164. The center portion of wafer 150 is attached to the apex 22 of the diaphragm 20. It is as if additional mass were attached to the circumferential edge of wafer 150 so that axial movement of the circumferential edge with respect to the housing 10 is precluded and only pivoting within the notches 166 is permitted. An electrical signal applied between input terminals **38** and **40** will cause the wafer **150** to flex in a fashion similar to that shown by the dotted line **76** and dashed line **72** of FIG. 4A. Now the central portion of the wafer **150** will have a substantial excursion even though the mass of the diaphragm **20** is rather large to reproduce low frequency sounds.

Although the invention has been explained as being adapted for use in a loudspeaker, it may be appreciated that such bimorph configurations may also be used in a microphone. In such case, audio signals will cause vibration of the diaphragm **10** according to the amplitude and frequency thereof to displace the lower bimorph of the piezoelectric device. By an operation reverse to that explained with reference to a speaker, such movement causes an electrical signal to be developed between terminals **38** and **40**.

I claim:

1. A transducer including in combination; support means, a diaphragm having an axis and an axially movable portion, piezoelectric means including first and second spaced apart bimorphs of selected polarization each extending transversely to the axis of the diaphragm and each having an edge portion and a central portion, said piezoelectric means further including spacer means connecting one of said portions of said first bimorph to the corresponding portion of said second bimorph, means electrically interconnecting said bimorphs relative to their respective polarizations such that said bimorphs tend to flex in opposite directions, first means mechanically coupling the other portion of said first bimorph to the axially movable portion of said diaphragm for coupling mechanical stimuli therebetween, and second means rigidly attaching said support means to the portion of said second bimorph corresponding to the portion of said first bimorph which is coupled to said diaphragm.

2. The transducer set forth in claim **1** wherein each of said bimorphs have a annular shape.

3. The transducer set forth in claim **1** wherein said spacer means is connected between the central portions of said bimorphs, said first means hingedly coupling said edge portion of said first bimorph to the axially movable portion of said diaphragm, and said second means hingedly attaching said edge portion of said second bimorph to said support means.

4. The transducer set forth in claim **1** wherein said spacer means is hingedly connected to the edge portions of said bimorphs, said first means mechanically coupling said central portion of said first bimorph to the axially movable portion of said diaphragm, and said second means rigidly attaching said central portion of said second bimorph to said support means.

5. The transducer set forth in claim **4** wherein said first means comprises a direct connection to the axially movable portion of said diaphragm, and said second means comprises a direct rigid attachment to said support means.

6. The transducer set forth in claim **4** wherein said first means includes further piezoelectric means, said further piezoelectric means having third and fourth spaced apart bimorphs of selected polarization each extending transversely to the axis of the diaphragm and each having an edge portion and a central portion, said further piezoelectric means having spacer means hingedly connected to the edge portions of said third and fourth bimorphs, means electrically interconnecting said first, second, third and fourth bimorphs relative to their respective polarizations such that: said first and second bimorphs simultaneously tend to flex in opposite directions with respect to each other, said third and fourth bimorphs simultaneously tend to flex in opposite directions with respect to each other, said first and third bimorphs simultaneously tend to flex in the same direction, and said second and fourth bimorphs simultaneously tend to flex in the same direction, third means connecting the central portion of said third bimorph to the axially movable portion of said diaphragm, and fourth means connecting the central portion of said fourth bimorph to the central portion of said first bimorph.

7. The transducer set forth in claim **6** wherein said fourth means comprises a direct rigid attachment between said first and fourth bimorphs and said third means comprises a direct connection between said third bimorph and said axially movable portion of said diaphragm.

8. A loudspeaker including in combination; a support means, a diaphragm having an axis and an axially movable portion capable of receiving mechanical stimuli thereat and converting the same into sound waves, piezoelectric means having a pair of input terminals for receiving an electrical signal and converting the same into mechanical stimuli, said piezoelectric means including first and second spaced apart bimorphs of selected polarization and each extending transversely to the axis of the diaphragm, and each having an edge portion and a central portion, said piezoelectric means further including spacer means hingedly connected to the edge portions of said bimorphs and having a construction to maintain the distance between said edges substantially fixed and yet permit independent axial movements along the individual extents of said bimorphs, means electrically interconnecting said bimorphs to said input terminals relative to their respective polarizations such that when the electrical signal is applied to said terminals said bimorphs tend to flex in opposite directions, first means mechanically coupling the central portion of said first bimorph to the axially movable portion of said diaphragm for coupling mechanical stimuli thereto, and second means rigidly attaching the central portion of said second bimorph to said support means.

9. The loudspeaker set forth in claim **8** wherein said first means includes further piezoelectric means, said further piezoelectric means having third and fourth spaced apart bimorphs of selected polarization each extending transversely to the axis of the diaphragm and each having an edge portion and a central portion, said further piezoelectric means having spacer means hingedly connected to the edge portions of said third and fourth bimorphs and having a construction to maintain a substantially fixed distance between such edge portions and yet permit independent axial movements along the individual extents of said third and fourth bimorphs, means electrically interconnecting said first, second, third and fourth bimorphs relative to the respective polarizations such that: said first and second bimorphs simultaneously tend to flex in opposite directions, said third and fourth bimorphs simultaneously tend to flex in opposite directions, said first and third bimorphs simultaneously tend to flex in the same direction, and such that said second and fourth bimorphs simultaneously tend to flex in the same direction, third means connecting the central portion of said third bimorph to the axially movable portion of said diaphragm, and fourth means connecting the central portion of said fourth bimorph to the central portion of first bimorph.

10. A transducer including in combination; support means, a diaphragm having an axis and an axially movable portion, a plurality of piezoelectric means and a corresponding plurality of spacer means individually associated with said piezoelectric means, each of said piezoelectric means including first and second spaced apart bimorphs of selected polarization, each of said bimorphs extending transversely to the axis and having an edge portion and a central portion, each spacer means hingedly connected to the edge portions of associated first and second bimorphs, means electrically interconnecting all of said bimorphs relative to said polarizations such that said first and second bimorphs in each of said piezoelectric means simultaneously tend to flex in opposite directions, and such that all of said first bimorphs simultaneously tend to flex in the same direction, and such that all of said second bimorphs simultaneously tend to flex in the same direction, means connecting the central portion of said first bimorph of the first of said piezoelectric means to the axially movable portion of said diaphragm for coupling mechanical stimuli therebetween, means connecting the central portion of said second bimorph of the last of said piezoelectric means to said support means, and means including a spacer device connecting the central portion of said second bimorph of said first of said piezoelectric means to the central portion of said first bimorph of said last of said piezoelectric means.

11. A transducer, including in combination, support means, a diaphragm having a portion which is movable along an axis, first and second piezoelectric members of selected polarization which extend transversely to said axis and each member having an edge portion and a central portion, spacer means connecting one of said portions of said first member to the corresponding portion of said second member, means electrically interconnecting said first and second members such that they flex in opposite directions in response to an electrical potential of a given polarity, first means mechanically coupling the other portion of said first member to the movable portion of said diaphragm for intercoupling mechanical stimuli therebetween, and second means mechanically coupling said support member to the portion of said second member corresponding to the portion of said first member which is coupled to said diaphragm.

12. The transducer set forth in claim 11 wherein said spacer means is hingedly connected to said edge portions of the members, said first means mechanically coupling said central portion of the first member to said diaphragm, and said second means rigidly attaching said central portion of said second member to said support means.

13. The transducer of claim 12 wherein said members are circular in shape and said spacer means is comprised of two annular rings whose circumferences are joined together by a plurality of substantially rigid bars and whose inside surfaces hingedly engage said edge portions of said members.