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Oct. 29, 1963 A. M. WIGGINS 3,109,111

ULTRA-SONIC MICROPHONE

Filed Oct. 30, 1961 2 Sheets-Sheet 1

FIG. 1.

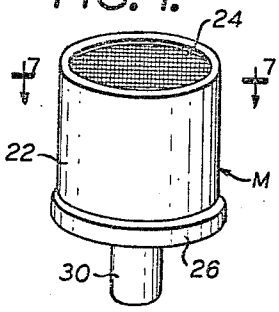


FIG. 2.

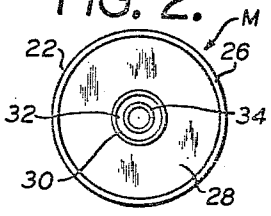


FIG. 3.

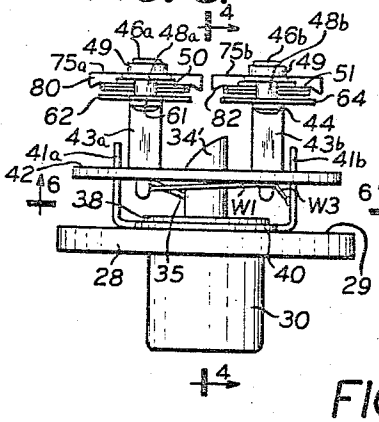


FIG. 4.

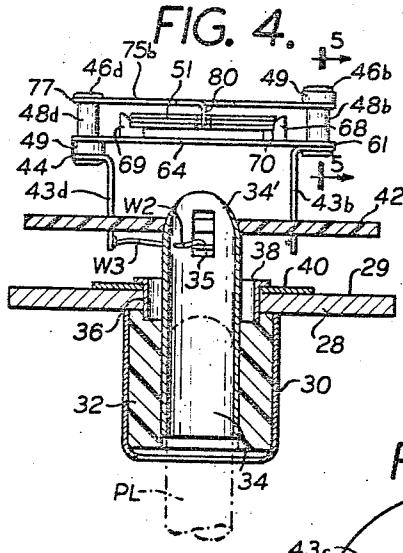


FIG. 5.

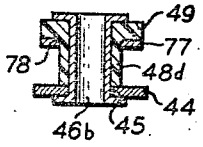


FIG. 6.

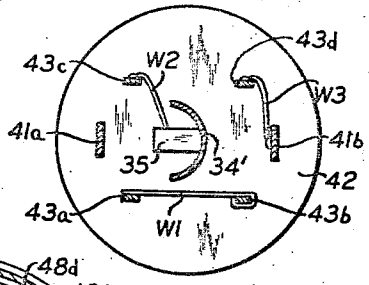


FIG. 7.

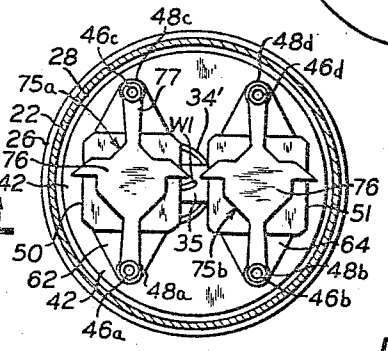


FIG. 8.

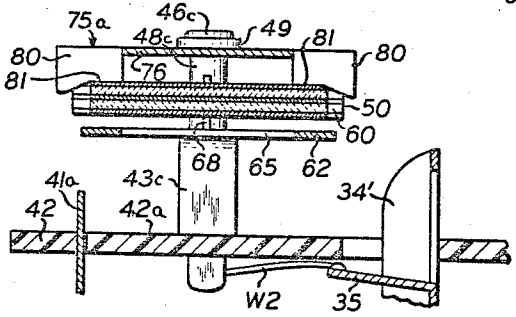
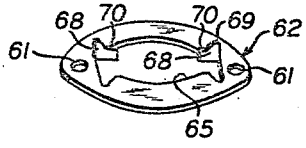


FIG. 9.



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ULTRA-SONIC MICROPHONE

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FIG. 10.

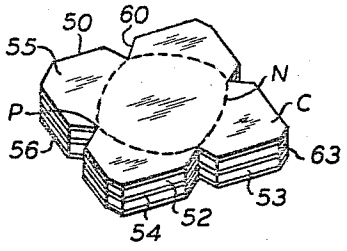


FIG. 11.

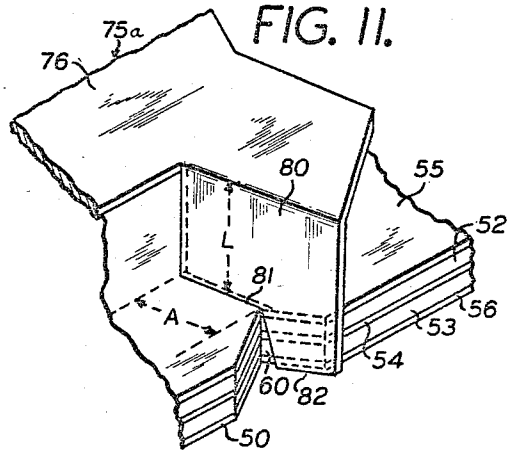


FIG. 12.

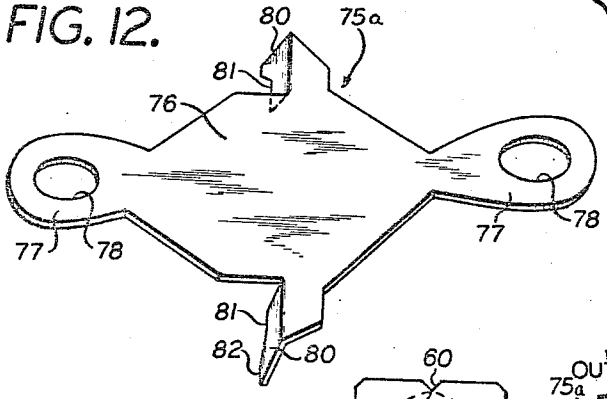


FIG. 13.

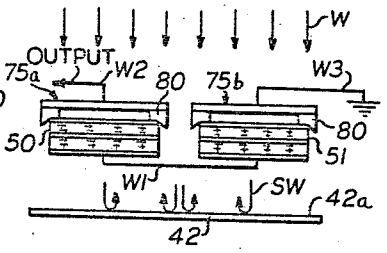


FIG. 14.

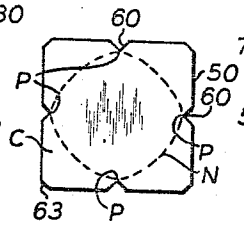


FIG. 16.

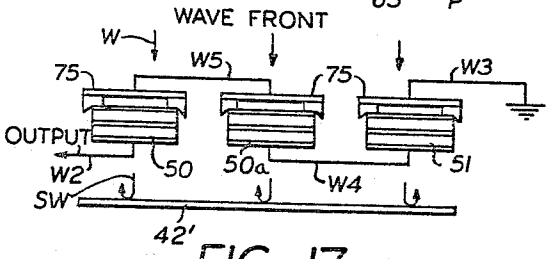


FIG. 17.

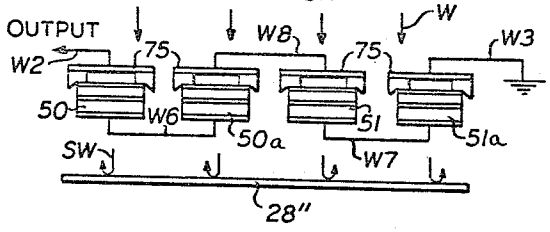
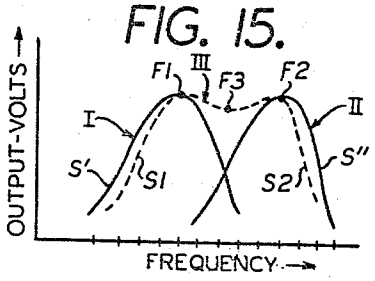


FIG. 15.



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United States Patent Office 3,109,111 Patented Oct. 29, 1963

3,109,111

ULTRA-SONIC MICROPHONE

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Filed Oct. 30, 1961, Ser. No. 148,362
17 Claims. (Cl. 310—8.2)

This invention concerns an electro-acoustic ultrasonic microphone operable at superaudible frequencies.

According to the invention, there is provided an ultrasonic microphone having a higher sensitivity in a prescribed frequency bandwidth or range than prior known microphones of this type. The frequency range or bandwidth for maximum output is more sharply defined. The mechanical structure is simpler, smaller, and more economical to manufacture, than prior microphones of this type. The microphone requires no supplemental coil to broaden its frequency range as has been conventional heretofore.

The microphone embodying the invention includes two or more ceramic piezoelectric plates mechanically resonant at different frequencies. The plates are electrically connected in opposite phase or anti-phase. Mechanical wave phasing plates are disposed adjacent to the respective piezoelectric plates and spaced therefrom so as to obtain maximum drive of the piezoelectric plates by supersonic compressional waves applied thereto. A reflector plate is located behind the piezoelectric plates and serves to reflect back to the piezoelectric plates compressional waves emitted thereby so as to reinforce mechanical vibrations of the piezoelectric plates. The microphone has particular utility in connection with remote control systems for radio and television apparatus, appliances and other devices adapted for control by supersonic compressional wave signals or pulses.

It is therefore one object of the invention to provide an ultrasonic microphone having at least two piezoelectric elements individually resonant at different frequencies, connected electrically in anti-phase and having a wide bandwidth at maximum voltage output with minimized output at frequencies outside of that bandwidth.

Another object is to provide an ultrasonic microphone including a ceramic piezoelectric element with an associated phasing plate located in front of the element and spaced therefrom to increase mechanical vibration and electrical output of the element.

Still another object is to provide an ultrasonic microphone as described with a reflecting plate disposed behind the piezoelectric element or elements to further increase mechanical vibration and electrical output of the element or elements.

A further object is to provide an ultrasonic microphone having a high sensitivity and wide bandwidth obtained by piezoelectric elements having different mechanical resonant frequencies, the elements being connected electrically in series, without use of tuning coils.

The invention will be best understood from the following detailed description taken together with the drawing wherein:

FIG. 1 is a perspective view of an assembled encased microphone embodying the invention.

FIG. 2 is a bottom plan view of the microphone.

FIG. 3 is a side elevational view on an enlarged scale of the microphone assembly with case removed.

FIG. 4 is a vertical sectional view taken on line 4—4 of FIG. 3.

FIG. 5 is a sectional view on an enlarged scale taken on line 5—5 of FIG. 4.

FIG. 6 is a horizontal or cross-sectional view taken on line 6—6 of FIG. 3.

FIG. 7 is a cross-sectional view on an enlarged scale taken on line 7—7 of FIG. 1.

FIG. 8 is a vertical sectional view on an enlarged scale taken through a portion of the assembly of FIG. 3.

FIG. 9 is a perspective view of a contact plate employed in the assembly.

FIG. 10 is a perspective view of a piezoelectric element.

FIG. 11 is a fragmentary perspective view on an enlarged scale showing parts of a piezoelectric element with phasing plate mounted thereon.

FIG. 12 is a perspective view on an enlarged scale of a phasing plate.

FIG. 13 is a diagrammatic representation of certain microphone elements illustrating operation of the microphone.

FIG. 14 is a top plan view of a piezoelectric element indicating schematically a mode of operation thereof.

FIG. 15 is a graphic diagram illustrating operation of the microphone.

FIGS. 16 and 17 are schematic diagrams of different piezoelectric element arrangements, according to the invention.

Referring to the drawing, there is shown in FIGS. 1 and 2 an ultrasonic microphone M embodying the invention. The microphone is shown encased in a cylindrical casing 22 having an open front or top and covered by a screen 24. The screen freely admits ultrasonic compressional waves required to operate the microphone. The casing 22 may have a rear or bottom annular flange 26 crimped around the edge of a base plate 28. This plate is a flat annular member with a depending shielded axial tubular connector 30 to facilitate installation in a suitable electric circuit. Inside the connector 30 is cylindrical insulator 32 supporting a conductive sleeve 34 in axial bore 35 of the insulator; see FIG. 4. The sleeve extends upwardly or forwardly of the front surface 29 of plate 28 and is semi-cylindrical at 34'. In a central hole 36 of plate 28 is an eyelet 38 engaging an annular mounting and contact plate 40; see FIGS. 3 and 4. The plate 40 has a pair of diametrically opposed upstanding fingers 41*a*, 41*b* which support a circular insulator disk or plate 42 parallel to and spaced forwardly of the front surface 29 of plate 28. On plate 42 are supported four spaced contact strips 43*a*–43*d*. These strips stand upwardly parallel to each other. Each strip has an upper lug portion 44 bent outwardly parallel to disk 42. Each lug portion has an opening 45; see FIG. 5. Eyelets 46*a*–46*d* are engaged by the lug portions of the respective strips 43*a*–43*d*. Surrounding the eyelets are respective plastic insulator sleeves 48*a*–48*d*. Each sleeve has a radially extending flange 49 at one end serving as an insulated spacer ring.

Two generally rectangular piezoelectric elements 50, 51 are mounted in side-by-side coplanar disposition above plate 42. Each element, as best shown in FIGS. 3, 4, 7 and 10, is a laminated structure including two thin ceramic wafers or plates 52, 53 secured to opposite sides of a thin metal wafer 54. The outer exposed sides of each ceramic wafer are coated with thin conductive films 55, 56, respectively, which serve as electrodes. Notches 60 are cut at the center of each edge of the elements 50 and 51. These notches are located at nodal points P, as indicated in FIG. 14. The arcuate dotted lines N in FIGS. 10 and 14 indicate the loci of nodes of vibration of the element. Along these loci, vibration is negligible during operation and activation of the piezoelectric elements.

The ceramic elements are supported below or at their rear sides by two contact plates 62, 64 (best shown in FIGS. 3, 4 and 7–9). Each of these plates is a generally oval, flat frame-like annular conductive member with two spaced holes 61 near the ends of its major

axis. The member has a rather large central opening 65 and two struck-up flaps or tabs 68 disposed parallel to each other perpendicular to the plane of the member. Each tab is formed with a narrow ledge or land 70 which engages the under or rear side of the element 50 or 51 supported thereby. The ledges engage at notches 60, which are nodal points of opposite edges of the supported element 50 or 51. Apertured ends 61 of plates 62, 64 engage lugs portions 44 of contact strips 43*a*, 43*b*, as shown in FIGS. 3 and 4, for direct electrical connection therewith. Opposite apertured ends 61 of both plates 62, 64 engage on insulator sleeves 48*c* and 48*d* and are thereby insulated from contact strips 43*c* and 43*d*. Corners 63 of the elements 50, 51 can be ground off to adjust the mass and mechanical resonant frequency of each element.

Above or in front of the elements 50, 51 are two phasing plates 75*a*, 75*b*, shown in FIGS. 3, 4, 5, 7, 8, 11 and 12. Each of these plates has a flat, generally rectangular body portion 76 with elongated loops 77 extending from two opposite diagonal corners. A hole 78 is provided in each loop. The other two opposite diagonal corners are partially cut and bent to form two flat flaps or tabs 80, each having a ledge or land portion 81 which bears on the top of one of the elements 50, 51. The tab includes a finger portion 82 which extends in the plane of the flap beyond the ledge 81. Tabs 68 of contact plates 62, 64 have similar finger portions 69 extending beyond ledges 70.

FIG. 11 shows clearly how ledge portion or land 81 bears on the top or forward side of the piezoelectric element 50 at notch 60 while the body portion 76 is spaced from the element. The finger portion 82 is centered in notch 60. The body portion 76 is disposed over the generally rectangular central area of the element outlined by the dotted nodal lines N shown in FIGS. 10 and 14. The loops 77 extend over the nodal junctions P. For optimum operation, the distance L indicated in FIG. 11 is critical and the tabs must be precisely formed so that the presence of the plate 75*a* or 75*b* causes a maximum increase in amplitude of vibration of the element 50 or 51 during operation thereof. The distance A, which is the length of ledge or land portion 81 bearing on the piezoelectric element, should be small and confined as nearly as possible to the nodal junction P to avoid interference with vibration of the element. However, the ledge portion 81 must have sufficient length to provide good elecrtical contact and to engage and support the element securely in cooperation with tabs 68, whose ledge portions 70 engage the underside or rear side of the elements 50, 51, while finger portions 69 extend upwardly and are centered in notches 60.

Loops 77 of the phasing plates at contact strips 43*a*, 43*b* engage on the insulated sleeves 48*a*, 48*b* and are thereby insulated from the contact strips. Loops 77 of the phasing plates at contact strips 43*c*, 43*d* engage the eyelets 45*c*, 46*d* in direct electrical contact therewith.

Contact strips 43*a*, 43*b* are connected together by a wire W1, as shown in FIG. 6. Contact strip 43*c* is connected by a wire W2 to a lug 35 struck out of sleeve extension 34'. The sleeve 34 has a generally cylindrical portion engaged in insulator 32, and the semi-cylindrical portion 34' extends thorugh the hole in disk 42 and terminates forwardly thereof. Lug 35 is located just behind or below the plane of disk 42. Sleeve 34 serves as the electrical output terminal of the microphone and a suitable plug PL may be inserted into this sleeve, as indicated by dotted lines in FIG. 4. Contact strip 43*d* is grounded by a wire W3 connected to conductive finger 41*b*.

From the above description it will thus be understood that the active elements of the assembly each consists of a ceramic sandwich 50 or 51, an upper contact plate 75*a* or 75*b*, a bottom contact plate 62 or 64, insulated spacers 48*a*, 48*c* or 48*b*, 48*d*, rivets 46*a*, 46*c* or 46*b*, 46*d*, mounting lugs and contact strips 43*a*, 43*c* or 43*b*, 43*d*. The spacers 48*a*–48*d* are identical and the lugs 44 are arranged on the spacers to contact either upper contact plates 75*a*, 75*b* or lower contact piates 62, 64. Strips 43*a*–43*d* provide mechanical support and space the ceramic sanwdwich a predetermined distance from the insulator plate 42, which serves as a reflector for compressional waves and as a support for the active elements.

Upper plates 75*a*, 75*b* serve as mechanical supports, provide electrical contact and function as phasing elements. Bottom contacts 62, 64 provide a mechanical support and electrical contact.

The ceramic elements must not shift in their supports or substantial changes will occur in their resonant frequencies. In the present invention, secure mounting of the elements is accomplished by the tab and notch arrangement shown in FIG. 11.

The ceramic sandwiches 50 and 51 are of bimorphic type. A center conductor 54 is employed in polarizing the sandwich during manufacture. This conductor is isolated from the outer contacts 55. 56. The tabs 68, 80 are angled at 69 and 82 to avoid touching conductor 54 while providing rigid mechanical support at notches 60. After assembly on disk or plate 42, the ceramic elements 50, 51 may be finally tuned by removing material from their corners, as shown in FIG. 10.

Two similar polarized ceramic piezoelectric plates are used. They are polarized plus-minus-minus-plus, with the center conductor being minus and the outer electrodes being plus; see FIG. 13. During operation when a ceramic element bends voltages are generated instantaneously between the outer electrodes. When the element bends in any one direction, one ceramic layer is in compression while the other is in tension while both outer surfaces of the layers become more positive electrically. One surfaces goes more positive (+) than the other, resulting in a net voltage. When the element bends in the opposite direction, both surfaces (outer) go more negative (—) but one goes more negative than the other, again resulting in a net voltage but of opposite polarity.

FIG. 13 illustrates diagrammatically the basic arrangement of the assembly. The front of a supersonic compressional wave W impinges directly on the four exposed, generally triangular corner portions C of each of the piezoelectric elements and causes flexure of the elements to generate alternating voltages as the elements vibrate. The phasing plates shield the central portions of the elements from the direct impingement of the wave W. However, due to the presence of the phasing plates, a state of resonance is set up in the space between each phasing plate and its associated piezoelectric element to increase amplitude of vibration. The resulting output of the assembly of piezoelectric elements may be increased as much as four or five decibels due to the presence of the phasing plates.

The rear sides of the elements 50, 51 are connected together in opposite phase or anti-phase electrically by wire W1. Plate 75*b* is grounded via wire W3 and plate 75*a* is connected to the output of the microphone via wire W2. Secondary waves SW are emitted at the rear sides of the elements 50, 51, pass through openings 61 in elements 62, 64 and impinge on the flat forward side of plate 42, which then serves as a reflector to reflect these waves back to the elements 50, 51. These elements are so spaced from the reflector that the returning reflected wave components reinforce the mechanical wave applied to the piezoelectric elements and an increase in amplitude of vibration results. An increase in electrical output of as much as four or five decibels is obtained due to the action of the reflector plate 42.

FIG. 15 illustrates graphically several important and advantageous results obtained by the present invention. Curve I represents the voltage output of one element, element 50 for example, taken alone and plotted against vibration frequency. The output is maximum at the point

of mechanical resonant frequency F1. Curve II represents the voltage output of the other element, element 51 for example, taken alone and plotted against vibration frequency. The output is maximum at a higher mechanical resonant frequency F2 since the dimensions of the elements are adjusted to obtain two different mechanical resonant frequencies. At intermediate frequency F3 the output is substantially equal to the maximum output of each element taken alone. The dotted-line curve III shows the resultant effect of connecting the two elements in phase opposition is to obtain a broadened frequency range of maximum and almost constant output extending from frequency F1 to frequency F2. The microphone thus has maximum sensitivity over a greater range than the sharply peaked response of each element taken alone. The output curve III shows that the cooperating elements 50, 51 have steep skirts S1, S2 so that response of the microphone attenuates rapidly outside of the desired frequency range of response or bandwidth. Actually the skirts S1 and S2 are somewhat steeper than the skirts S' and S'' of the response curves I and II of the elements 50, 51 taken alone.

FIG. 15 clearly illustrates the manner in which the valley between two adjacent resonant peaks is filled in. Between frequencies F1 and F2, the elements I and II are acoustically out of phase, since element I appears inductive and element II appears capacitive. The anti-phase electrical connection W1 corrects this (see FIG. 13) and provides additive voltages. Above frequency F2 or below frequency F1 the elements are acoustically in phase. Thus, the anti-phase electrical connection provides subtractive voltages, causing steeper slopes or skirts outside the desired band. The effect is the same when more than two elements connected sequentially in anti-phase are employed, as shown in FIGS. 16 and 17.

While the invention has been explained in connection with a microphone employing two piezoelectric elements, three, four or more similar elements can be properly arranged for even greater output. Thus in FIG. 16 three elements are shown connected in series. A third element 50*a* is shown inserted between elements 50 and 51. Elements 50*a* and 51 are connected in common at their rear sides opposite the wave front W by wire W4. Elements 50 and 50*a* are connected in anti-phase at their front sides by wire W5. The forward side of element 51 is grounded by wire W3. The rear side of element 50 provides the high voltage output via wire W2. Individual phasing plates 75 are provided for the respective elements and a reflector 42 is provided for the assembly. In FIG. 17, four piezoelectric elements 50, 50*a* and 51, 51*a* are connected in series. Elements 50, 50*a* and 51, 51*a* are connected together at their rear sides in anti-phase by wires W6, W7. Elements 50*a* and 51 are connected together by wire W8 at their front sides in anti-phase. The front side of element 51*a* is grounded by wire W3 and the rear side of element 50*a* provides the high voltage output via wire W2. Phasing plates 75 are provided for the respective elements and reflector plate 42'' is provided for the assembly.

It is possible to operate the microphone with only a single piezoelectric element 50 or 51. One phasing plate 75*a* or 75*b*, one contact plate 62 or 64 and the reflector plate 42 would be used with the single element 50 or 51. The voltage output of the assembly would be taken off the outer electrodes 55, 56 of the single ceramic sandwich. The characteristic curve of operation would appear as shown by Curve I or II in FIG. 15. While the benefit of broad-band operation would not be obtained as in the multielement sequentially connected anti-phase arrays of FIGS. 13, 16 and 17, the microphone would still have the characteristic of high sensitivity, which is most essential in this type of microphone.

The invention makes it possible to provide an ultrasonic microphone of very small size and low cost, having a higher sensitivity over a prescribed frequency bandwidth

than is attainable with prior known microphones of corresponding size and equivalent cost. The structure is simpler, easier to manufacture, more rugged in construction and has a longer useful life.

What is claimed and sought to be protected by Letters Patent is:

1. An ultrasonic microphone, comprising at least two piezoelectric plates, means supporting said plates in coplanar spaced array, said plates having different mechanical resonant frequencies, electrodes on opposite sides of the plates, electrical contact elements supporting and electrically contacting said electrodes respectively, and means electrically connecting the elements sequentially in electrical anti-phase, whereby said voltage output is substantially the same over a range of frequencies including the resonant frequencies of the individual piezoelectric plates when compressional waves are applied to the plates, and whereby said voltage output drops sharply at frequencies outside of said range of frequencies.

2. An ultrasonic microphone, comprising at least two piezoelectric plates, means supporting said plates in coplanar spaced array, said plates having different mechanical resonant frequencies, electrodes on opposite sides of the plates, electrical contact elements supporting and electrically contacting said electrodes respectively, and means electrically connecting the elements sequentially in electrical anti-phase, whereby said voltage output is substantially the same over a range of frequencies including the resonant frequencies of the individual piezoelectric plates when compressional waves are applied to the plates, and whereby said voltage output drops sharply at frequencies outside of said range of frequencies, two of said contact elements being phasing members having body portions precisely spaced predetermined distances from said plates in the path of said waves, said body portions covering vibratable portions of the plates, said two contact elements having tabs engaging electrodes of the plates at nodal vibration points thereof, whereby said voltage output in said range of frequencies is substantially increased.

3. An ultrasonic microphone, comprising at least two piezoelectric plates, means supporting said plates in coplanar spaced array, said plates having different mechanical resonant frequencies, electrodes on opposite sides of the plates, electrical contact elements supporting and electrically contacting said electrodes respectively, means electrically connecting the elements sequentially in electrical anti-phase, whereby said voltage output is substantially the same over a range of frequencies including the resonant frequencies of the individual piezoelectric plates when compressional waves are applied to the plates, and whereby said voltage output drops sharply at frequencies outside of said range of frequencies, and a reflector plate spaced from said piezoelectric plates and disposed parallel thereto to reflect back to the piezoelectric plates compressional waves emitted thereby, whereby said voltage output in said range of frequencies is increased.

4. An ultrasonic microphone, comprising at least two piezoelectric plates, means supporting said plates in coplanar spaced array, said plates having different mechanical resonant frequencies, electrodes on opposite sides of the plates, electrical contact elements supporting and electrically contacting said electrodes respectively, means electrically connecting the elements sequentially in electrical anti-phase, whereby said voltage output is substantially the same over a range of frequencies including the resonant frequencies of the individual piezoelectric plates when compressional waves are applied to the plates, and whereby said voltage output drops sharply at frequencies outside of said range of frequencies, two of said contact elements being phasing members having body portions precisely spaced predetermined distances from said plates in the path of said waves, said body portions covering vibratable portions of the plates, said two contact elements having tabs engaging electrodes of the plates at nodal vibration points thereof, whereby said

voltage output in said range of frequencies is substantially increased, and a reflector plate spaced from said piezoelectric plates and parallel thereto oppositely of said phasing members to reflect back to the piezoelectric plates compressional waves emitted thereby, whereby said voltage output in said range of frequencies is further increased.

5. An ultrasonic microphone, comprising at least two piezoelectric plates, means supporting said plates in coplanar spaced array, said plates having different mechanical resonant frequencies, electrodes on opposite sides of the plates, electrical contact elements supporting and electrically contacting said electrodes respectively, and means electrically connecting the elements sequentially in electrical anti-phase, whereby said voltage output is substantially the same over a range of frequencies including the resonant frequencies of the individual piezoelectric plates when compressional waves are applied to the plates, and whereby said voltage output drops sharply at frequencies outside of said range of frequencies, two of said contact elements being phasing members having body portions precisely spaced predetermined distances from said plates in the path of said waves, said body portions covering vibratable portions of the plates, said two contact elements having tabs engaging electrodes of the plates at nodal vibration points thereof, whereby said voltage output in said range of frequencies is substantially increased, two others of said contact elements being frame members having openings therein and having tabs engaging other electrodes of the plates at nodal vibration points.

6. An ultrasonic miscrophone, comprising at least two piezoelectric plates, means supporting said plates in coplanar spaced array, said plates having different mechanical resonant frequencies, electrodes on opposite sides of the plates, electrical contact elements supporting and electrically contacting said electrodes respectively, means electrically connecting the elements sequentially in electrical anti-phase, whereby said voltage ouput is substantially the same over a range of frequencies including the resonant frequencies of the individual piezoelectric plates when compressional waves are applied to the plates, and whereby said voltage output drops sharply at frequencies outside of said range of frequencies, two of said contact elements being phasing members having body portions precisely spaced predetermined distances from said plates in the path of said waves, said body portions covering vibratable portions of the plates, said two contact elements having tabs engaging electrodes of the plates at nodal vibration points thereof, whereby said voltage output in said range of frequencies is substantially increased, two others of said contact elements being frame members having openings therein and having tabs engaging other electrodes of the plates at nodal vibration points, and a reflector plate spaced from said two other contact elements parallel to said piezoelectric plates to reflect back to the piezoelectric plates compressional waves emitted thereby through openings in said two other contact elements, whereby said voltage output in said range of frequencies is further increased.

7. An ultrasonic microphone, comprising at least two piezoelectric plates, means supporting said plates in coplanar spaced array, said plates having different mechanical resonant frequencies, electrodes on opposite sides of the plates, electrical contact elements supporting and electrically contacting said electrodes respectively, and means electrically connecting the elements sequentially in electrical anti-phase, whereby said voltage output is substantially the same over a range of frequencies including the resonant frequencies of the individual piezoelectric plates when compressional waves are applied to the plates, and whereby said voltage output drops sharply at frequencies outside of said range of frequencies, each of said contact elements having a body portion precisely spaced from said piezoelectric elements and having tabs engaging notches in electrodes of the plates only at nodal vibration points thereof.

8. An ultrasonic microphone, comprising at least two piezoelectric plates, means supporting said plates in coplanar spaced array, said plates having different mechanical resonant frequencies, electrodes on opposite sides of the plates, electrical contact elements supporting and electrically contacting said electrodes respectively, means electrically connecting the elements sequentially in electrical anti-phase, whereby said voltage output is substantially the same over a range of frequencies including the resonant frequencies of the individual piezoelectric plates when compressional waves are applied to the plates, and whereby said voltage output drops sharply at frequencies outside of said range of frequencies, each of said contact elements having a body portion precisely spaced from said piezoelectric elements and having tabs engaging notches in electrodes of the plates only at nodal vibration points thereof, two of said contact elements being frame members having openings therein, and a reflector plate spaced from said two contact elements parallel to said piezoelectric plates to reflect back to the piezoelectric plates compressional waves emitted thereby through the openings in said two contact elements, whereby said voltage output in said range of frequencies is materially increased.

9. An ultrasonic microphone, comprising at least two piezoelectric plates, means supporting said plates in coplanar spaced array in the path of incident compressional waves, said plates having different mechanical resonant frequencies, means connecting portions of said plates in electrical anti-phase, and means deriving a voltage output from other portions of said plates, whereby said voltage output is substantially the same over a range of frequencies including the resonant frequencies of the individual piezoelectric plates, and whereby said voltage output drops sharply at frequencies outside of said range of frequencies.

10. An ultrasonic microphone, comprising at least two piezoelectric plates, means supporting said plates in coplanar spaced array in the path of incident compressional waves, said plates having different mechanical resonant frequencies, means connecting portions of said plates in electrical anti-phase, means deriving a voltage output from other portions of said plates, whereby said voltage output is substantially the same over a range of frequencies including the resonant frequencies of the individual piezoelectric plates, and whereby said voltage output drops sharply at frequencies outside of said range of frequencies, and reflector means disposed adjacent to said piezoelectric plates and spaced therefrom to reflect back to said plates compressional waves emitted thereby, whereby said voltage output in said range of frequencies is materially increased.

11. An ultrasonic microphone, comprising at least two piezoelectric plates, means supporting said plates in coplanar spaced array in the path of incident compressional waves, said plates having different mechanical resonant frequencies, means connecting portions of said plates in electrical anti-phase, means deriving a voltage output from other portions of said plates, whereby said voltage output is substantially the same over a range of frequencies including the resonant frequencies of the individual piezoelectric plates, and whereby said voltage output drops sharply at frequencies outside of said range of frequencies, and phasing plates disposed near to and precisely spaced from said piezoelectric plates in the path of said waves, whereby said voltage output in said range of frequencies is materially increased.

12. An ultrasonic microphone, comprising at least two piezoelectric plates, means supporting said plates in coplanar spaced array in the path of incident compressional waves, said plates having different mechanical resonant frequencies, means connecting portions of said plates in electrical anti-phase, means deriving a voltage output from other portions of said plates, whereby said voltage

output is substantially the same over a range of frequencies including the resonant frequencies of the individual piezoelectric plates, and whereby said voltage output drops sharply at frequencies outside of said range of frequencies, phasing means disposed near to said piezoelectric plates and precisely spaced therefrom in the path of said waves, whereby said voltage output in said range of frequencies is materially increased, and reflector means disposed near said piezoelectric plates and precisely spaced therefrom to reflect back to said plates compressional waves emitted thereby, whereby said voltage output in said range of frequencies is materially increased.

13. An ultrasonic microphone comprising a generally rectangular piezoelectric element including a pair of ceramic plates secured together with a conductor therebetween and with electrodes on outer sides of said plates, said plates being polarized so that outer surfaces of said plates have one electrical polarity and inner surfaces of said plates abutting said conductor have opposite electrical polarity, said element having notches formed each edge thereof at nodal points of vibration of the element, and electrical contact plates at opposite sides of said element, said contact plates having tabs contacting the electrodes at said notches with extensions engaged in the notches so that the contact plates are held in fixed spaced relationship with respect to said element.

14. An ultrasonic microphone comprising a generally rectangular piezoelectric element including a pair of ceramic plates secured together with a conductor therebetween and with electrodes on outer sides of said plates, said plates being polarized so that outer surfaces of said plates have one electrical polarity and inner surfaces of said plates abutting said conductor have opposite electrical polarity, said element having notches formed each edge thereof at nodal points of vibration of the element, and electrical contact plates at opposite sides of said element, said contact plates having tabs contacting the electrodes at said notches with extensions engaged in the notches so that the contact plates are held in fixed spaced relationship with respect to said element, one of said contact plates having a generally rectangular portion disposed over a central portion of said element subject to vibration and serving to increase the amplitude of vibration of said central portion of the element.

15. An ultrasonic microphone comprising a generally rectangular piezoelectric element including a pair of ceramic plates secured together with a conductor therebetween and with electrodes on outer sides of said plates, said plates being polarized so that outer surfaces of said plates have one electrical polarity and inner surfaces of said plates abutting said conductor have opposite electrical polarity, said element having notches formed each edge thereof at nodal points of vibration of the element, electrical contact plates at opposite sides of said element, said contact plates having tabs contacting the electrodes at said notches with extensions engaged in the notches so that the contact plates are held in fixed spaced relationship with respect to said element, the other of said contact plates being framelike with an open central portion, a reflector plate disposed parallel to the element with said other contact plate disposed therebetween, and electric contact members connected between said reflector plate and said element and holding the reflector plate a predetermined distance from said element to increase the amplitude of vibration of said central portion of the element, said electric contact members being connected electrically to said electrodes via the contact plates for deriving a voltage output therefrom when said element is vibrated by an impinging ultrasonic compressional wave.

16. An ultrasonic microphone comprising at least two generally rectangular piezoelectric elements, each of said elements including a pair of ceramic plates secured together with a conductor therebetween and with electrodes on outer sides of said plates, said plates being polarized so that outer surfaces of said plates have one electrical polarity and inner surfaces of said plates abutting said conductor have opposite electrical polarity, said element having notches formed each edge thereof at nodal points of vibration of the element, electrical contact plates at opposite sides of said element, said contact plates having tabs contacting the electrodes at said notches with extensions engaged in the notches so that the contact plates are held in fixed spaced relationship with respect to said element, one of said contact plates having a generally rectangular portion disposed over a central portion of said element subject to vibration and serving to increase the amplitude of vibration of said central portion of the element, the other of said contact plates being framelike with an open central portion, a reflector plate disposed parallel to the element with said other contact plate disposed therebetween, electric contact members connected between said reflector plate and said element and holding the reflector plate a predetermined distance from said element to increase the amplitude of vibration of said central portion of the element, said electric contact members being connected electrically to said electrodes via the contact plates for deriving a voltage output therefrom when said element is vibrated by an impinging ultrasonic compressional wave, and conductive circuit means sequentially connecting in electrical anti-phase one electrode of each of said elements with an electrode of another of said elements, said elements being tuned to different frequencies by removal of different amounts of material from corners thereof, whereby the microphone has maximum sensitivity over a broad frequency range bounded by the highest and lowest of said different frequencies.

17. An ultrasonic microphone, comprising a piezoelectric element, electrodes on opposite sides of the element, contact plates disposed on opposite sides of the element with portions of the contact plates precisely spacing the contact plates from said element, one of said contact plates having a body portion located over a vibratable portion of said element to increase the amplitude of vibration, the other of said contact plates having a central opening, a reflector plate disposed parallel to said element with said other contact plate disposed therebetween to increase further said amplitude of vibration, and electrical contact members connected between the reflector plate and the contact plates, said electrical contact members holding the reflector plate, contact plates and said element in fixed spaced disposition and deriving voltages generated by said element from said electrodes via the contact plates.

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