

May 20, 1941.

T. J. POPE

2,242,756

PIEZOELECTRIC DEVICE

Filed Feb. 11, 1939

FIG. 1

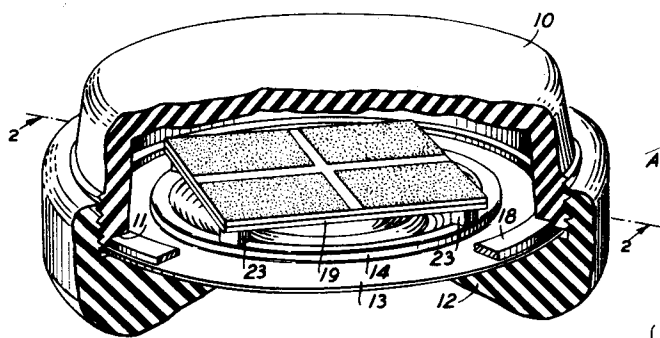


FIG. 2

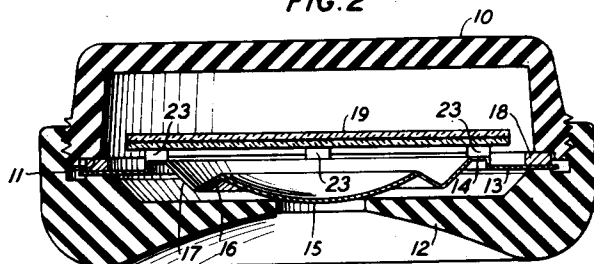


FIG. 4

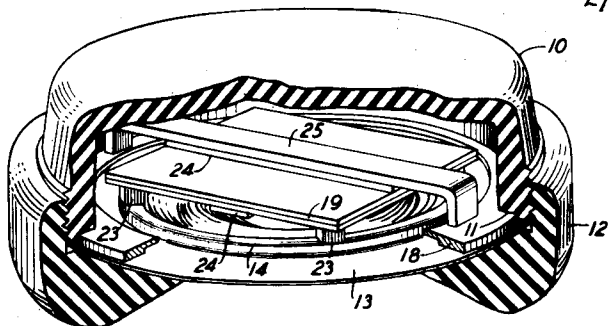
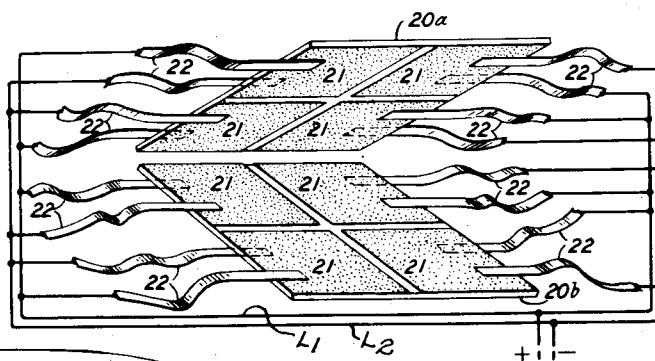


FIG. 6

FIG. 3

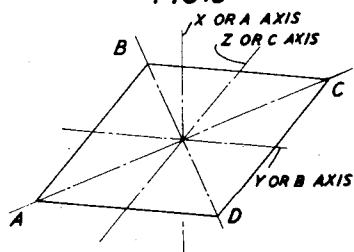
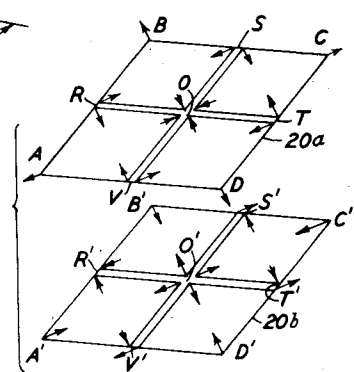


FIG. 5



INVENTOR
T. J. POPE

BY

Walter C. Kiesel
ATTORNEY

UNITED STATES PATENT OFFICE

2,242,756

PIEZOELECTRIC DEVICE

Thomas J. Pope, Brooklyn, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application February 11, 1939, Serial No. 255,818

12 Claims. (Cl. 179—110)

This invention relates to piezoelectric devices and more particularly to such devices of the type disclosed in my application, Serial No. 255,817, filed February 11, 1939, including a diaphragm and a piezoelectric element in energy translating relation with the diaphragm.

One object of this invention is to improve the efficiency of telephone receivers.

Another object of this invention is to obtain a relatively simple mode of movement or vibration of piezoelectric elements in acoustic devices.

A further object of this invention is to decrease the load upon the driving points of a diaphragm actuating piezoelectric element in acoustic devices.

Still another object of this invention is to increase the amplitude of the forces produced by a piezoelectric element in response to electrostatic stresses therein.

In one illustrative embodiment of this invention, a telephone receiver comprises a diaphragm and a rectangular, for example square, piezoelectric element including a pair of thin crystal plates or slabs, for example of Rochelle salt, secured together in face to face relation. The faces of each plate or slab are provided with sectionalized electrically conductive coatings and the two slabs or plates are so oriented and the coatings so connected electrically that when the piezoelectric element is energized all four corners of the composite element move in the same direction. The corners of this element are connected to equally spaced points on the diaphragm.

The composite piezoelectric element may be unrestrained except by virtue of its connection to the diaphragm or it may be restrained along the medians thereof.

The invention and the various features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is a perspective view of a piezoelectric acoustic device illustrative of one embodiment of this invention, a portion of the casing being broken away to show the internal structure more clearly;

Fig. 2 is a view in section along line 2—2 of Fig. 1;

Fig. 3 is a diagrammatic view of one of the crystal plates or slabs, illustrating the relation of the sides, faces and characteristic axes thereof;

Fig. 4 is an enlarged exploded view showing

the construction of the composite piezoelectric element;

Fig. 5 is a diagrammatic view of the composite piezoelectric element illustrating the directional relationship of the various stresses produced therein by electrostatic forces; and

Fig. 6 is a perspective view of another illustrative embodiment of this invention.

Referring now to the drawing, the telephone receiver shown in Figs. 1 and 2, which is of the inertia type, comprises a casing 10, for example of molded insulating material such as a phenolic condensation product, having a shoulder 11 in its rim, and a centrally apertured cap or earpiece 12 threaded to the casing 10. Disposed within the casing and coaxial with the opening in the earpiece or cap 12 is a diaphragm having an annular flexible supporting portion 13, a central bodily vibratile portion and an intermediate annular portion 14, L-shaped in section. The central portion comprises a concavo-convex portion 15 and two frusto-conical portions 16 and 17. The diaphragm may be fabricated in one piece and preferably is of a light weight metal such as duralumin. The flexible supporting portion 13 is seated upon an annular spacer 18 seated on the shoulder 11, and the diaphragm and spacer are clamped in position by the cap 12.

A rectangular, for example square, piezoelectric element, designated generally as 19, is located within the casing 10 and comprises a pair of crystal plates or slabs 20a and 20b, which may be of Rochelle salt, secured together in face to face relation. The plates or slabs 20 may be cut from a mother crystal as described in the pending application identified hereinabove, so that the faces thereof, as shown in Fig. 3, are parallel to the Z or C and Y or B (mechanical) axes and normal to the X or A (electrical) axis. As illustrated in Fig. 4, each face of each of the crystal plates or slabs 20 has thereon four identical, for example square, electrodes 21, which may be films of metal foil suitably affixed to the plates or slabs or may be a graphite coating applied to the plates or slabs by depositing graphite from a colloidal suspension known commercially as Aquadag.

Extending from each electrode 21 is a leading-in conductor 22, which may be a platinum-rhodium ribbon secured to the electrode by cementing the ribbon to the plate or slab and in intimate electrical connection with the electrode. The conductors 22 are connected electrically into two groups as by conductors L₁ and L₂, Fig. 4. Electrical connection to the two groups of con-

ductors may be established through suitable leading-in conductors connected to terminals (not shown) in the casing 10, to which terminals the two groups of conductors 22 are connected.

When a piezoelectric crystal is subjected to electrostatic stresses resulting from potentials applied between the surfaces thereof, the crystal will expand and contract along axes determined by the relationship of the X, Y and Z axes. A square crystal having its axes as described above will expand and contract along its diagonals (AC and BD in Fig. 3), the stresses being such that when the crystal expands along one diagonal, for example AC, it will contract along the other diagonal, for example BD, and vice versa. Furthermore, it has been found that each section of the crystal plates or slabs 20 between corresponding superposed electrodes 21 may expand and contract along the diagonals thereof much as though it were a separate and individual crystal.

If the potentials applied to the electrodes 21 are of the polarity indicated in Fig. 4, the four sections of each of the crystal plates or slabs will contract and expand along the diagonals thereof as indicated in Fig. 5. That is to say, for example, the section AROV will tend to expand along the diagonal AO and to contract along the diagonal RV, the section BSOR will tend to expand along the diagonal OB and to contract along the diagonal RS. Similarly, the section SCTO will tend to expand along OC and to contract along ST and the section TDVO will tend to expand along OD and to contract along VT. Hence, it will be apparent that the four corners A, B, C and D of the plate or crystal 20a will tend to move in the same direction, i. e., outwardly.

As will be apparent from Fig. 4, corresponding electrodes on the plates or slabs 20a and 20b are of unlike instantaneous polarity. Hence, inasmuch as the Y and Z axes of the crystal 20a are parallel to the corresponding axis of the crystal 20b, the forces produced in the sections of the crystal 20b will be opposite in direction to those on the crystal 20a. Thus, for example, the portion A'R'O'V' will tend to expand along the diagonal R'V' and to contract along the diagonal A'O'. The direction of the forces in the other sections will be apparent from the arrows.

For any instantaneous potential impressed between the two groups of conductors 22, it will be noted that the forces at the corners A', B', C' and D' of the plate or crystal 20b are opposite to those of the corresponding corners of the crystal 20a. For example, for the conditions postulated, the forces at the corners of crystal 20a are directed outwardly and the forces at the corners of crystal 20b are directed inwardly.

As a result, the composite piezoelectric element will bend so that all four corners thereof will be moved in the same direction, substantially normal to the faces of the element. Thus, when the potentials are of the polarity resulting in forces of the direction indicated in Fig. 5, all four corners, AA', BB', CC' and DD' will move downwardly. The magnitude of the deflection will be dependent upon the magnitude of the potentials and the direction of deflection at any instant will be determined by the polarity of the potential at that instant. If the potential is varied at frequencies corresponding to speech and music, the corners of the composite piezoelectric element will vibrate accordingly so that the potential variations will be translated into mechan-

ical forces corresponding thereto in both magnitude and frequency.

It will be understood that the desired similar movement of the four corners of the composite element may be obtained with the Y and Z axes other than parallel as described above. For example, the two plates or slabs 20a and 20b may be oriented so that the Y and Z axes of one are at right angles to the corresponding axis of the other and the potentials upon the electrodes properly related in polarity. In this case the two crystal slabs or plates would be insulated from one another as by an insulating cement between the juxtaposed surfaces thereof. The two slabs or plates could be energized in series and the electrodes on the upper face of the crystal 20b connected together. The electrodes on the lower face of the crystal 20a likewise could be connected together.

The four corners of the composite element 10 may be connected to equally spaced points on the annular portion 14 of the diaphragm, as by balsa wood blocks 23 cemented to the portion 14 of the diaphragm and to the element 10, whereby the mechanical forces cause vibration of the central portion of the diaphragm. Inasmuch as the forces at the four corners of the composite element are equal, bodily or piston-like vibration of the central portion of the diaphragm will obtain. Furthermore, it will be appreciated that the load upon the element 10 is distributed among the four corners thereof so that relatively thin crystals may be employed. This, in turn, assures a relatively simple mode of vibration of the piezoelectric element and enables a reduction in the mass and stiffness associated with the diaphragm.

The forces at the centers O and O', it will be seen, are such that the center of the composite piezoelectric element will tend to move or deflect in the same direction, at any instant, as the corners, and the forces at the ends of the medians of the composite element, that is at RR', SS', TT' and VV', are such that the mid-points of the sides of the composite element will tend to move in the direction, at any instant, opposite to that of the corners of the composite element. Hence, the composite element will vibrate generally about a pair of coaxial circular axes.

If desired, the center and the mid-points of the sides of the composite piezoelectric element may be restrained to prevent vibration thereof and the amplitude of the driving forces thereby increased. For example, as shown in Fig. 6 wherein the casing, diaphragm, and crystal element are the same as in Fig. 1, the element 10 may have affixed to opposite faces thereof two rigid insulating bars 24 which are at right angles to each other and extend along medians of the element 10. One of the bars 24 may be secured, as by cementing, to a bracket or bridge member 25 affixed at its ends to the spacer 18 and carried thereby. If desired, the other bar may be secured similarly to a second bridge member or bracket, not shown.

Although the invention has been described with particular reference to telephone receivers, it will be understood, of course, that it is applicable as well to transmitters. Furthermore, although specific embodiments of the invention have been shown and described, it will be understood that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. A piezoelectric device including a composite piezoelectric element comprising a pair of polygonal crystal plates secured together in face to face relation and having their corners free to deflect, sectional electrodes on each face of said plates oriented and electrically grouped so that all corners of said element will deflect in the same direction in response to potentials applied to said electrodes, and energy translating means connected to said element at spaced points on diagonals thereof.

2. A piezoelectric device comprising a piezoelectric element including a pair of rectangular crystal slabs secured together in face to face relation and having all corners free to deflect, the Y and Z axes of one of said slabs being parallel to the corresponding axis of the other slab, a plurality of similar spaced conductive coatings on each face of both of said slabs, the coatings on opposite faces of each slab being arranged in corresponding relation, means electrically connecting said coatings so that all corners of said element will deflect in the same direction in response to potentials applied to said coatings, and vibratile means connected to the corners of one of said slabs.

3. A piezoelectric device including a composite element comprising a pair of rectangular crystal slabs the sides of which are parallel to the Y and Z axes thereof, said slabs being secured together in face to face relation and with corresponding Y and Z axes thereof parallel, sectional electrodes upon each face of each of said crystals oriented and grouped so that upon application of potentials thereto all corners of said element deflect in the same direction, and means supporting said element so that all corners thereof are substantially free to deflect.

4. A piezoelectric device comprising a composite piezoelectric element including a pair of square crystal slabs secured together in face to face relation, said slabs having their sides parallel to the Y and Z axes thereof and the corresponding Y and Z axes of said slabs being parallel, four square electrodes on each face of each of said slabs arranged side to side and on opposite sides of medians of the face, leading-in conductors connected to said electrodes, means supporting said composite element so that all corners thereof are substantially free to deflect, and means connecting said electrodes in two groups such that each electrode on each face is opposite in polarity to the next adjacent electrodes and is opposite in polarity also to the corresponding electrode on the opposite face.

5. A piezoelectric device comprising a polygonal composite element free to deflect at its corners and including a pair of piezoelectric plates secured together in face to face relation, sectionalized conductive coatings on opposite faces of each of said plates, means electrically connecting

said coatings into two groups such that upon application of a potential between said groups all corners of said composite element will deflect in the same direction, and a vibratory member coupled to said corners.

6. An electroacoustic translating device in accordance with claim 5 wherein said composite element is supported solely by said vibratory member.

7. A telephone receiver comprising a diaphragm, means for actuating said diaphragm including a composite element including a pair of substantially square piezoelectric crystals secured together in face to face relation and substantially free to deflect at their corners, four spaced substantially square electrodes upon each face of each of said crystals, means electrically connecting said electrodes into two groups such that upon application of a potential between said groups all corners of said element will move in the same direction, and means connecting said diaphragm to said element at the corners thereof.

8. An acoustic device in accordance with claim 7 wherein said composite element is supported solely by said diaphragm.

9. A piezoelectric device comprising a rectangular composite element including a pair of crystal plates secured together in face to face relation, sectional electrodes on each face of each of said plates, said electrodes being electrically connected so that upon application of a potential thereto all corners of said composite element deflect in the same directions, and means fixing the mid-points of the sides of said element against movement.

10. A piezoelectric device in accordance with claim 9 wherein said means comprises a pair of rigid members affixed to said composite element along the medians thereof.

11. An acoustic device comprising a pair of composite elements including square piezoelectric slabs secured together in face to face relation, each slab having the Y and Z axes thereof parallel to its sides and the Y and Z axes of one slab being parallel to the corresponding axis of the other slab, four electrodes on each face of each slab and arranged on opposite sides of the medians of the face, means electrically connecting said electrodes into two groups such that each electrode is opposite in polarity to the adjacent electrodes on the same face and to the corresponding electrode on the opposite face of the same slab, a diaphragm, means connecting the corners of said composite element to said diaphragm, and means restraining the mid-points of the sides of said element against movement.

12. An acoustic device in accordance with claim 11 wherein said second means comprises a pair of rigid members at right angles to each other and secured to said element along the medians thereof.

THOMAS J. POPE.