Feb. 1, 1966 P. WEATHERS 3,233,047

STEREO PIEZOELECTRIC TRANSDUCER

Filed Oct. 2, 1961 2 Sheets-Sheet 1

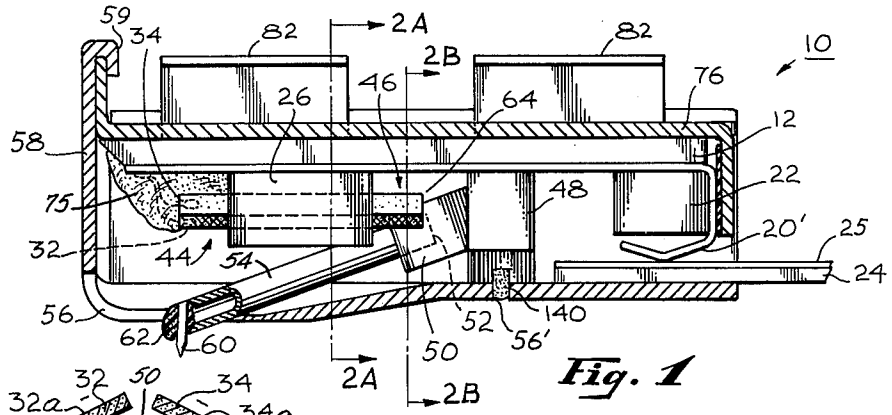



Fig. 1




Fig. 2B

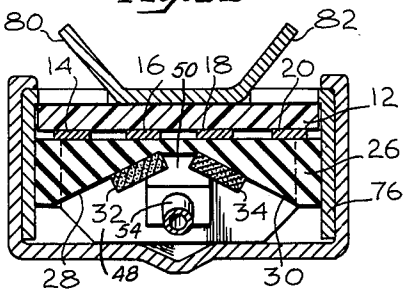



Fig. 2A

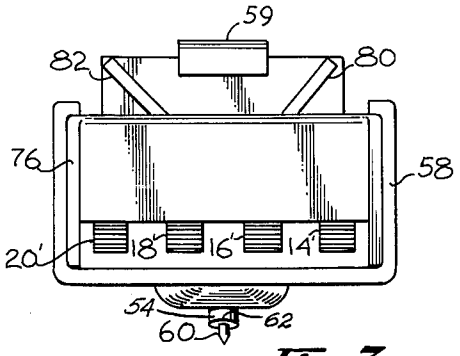



Fig. 3

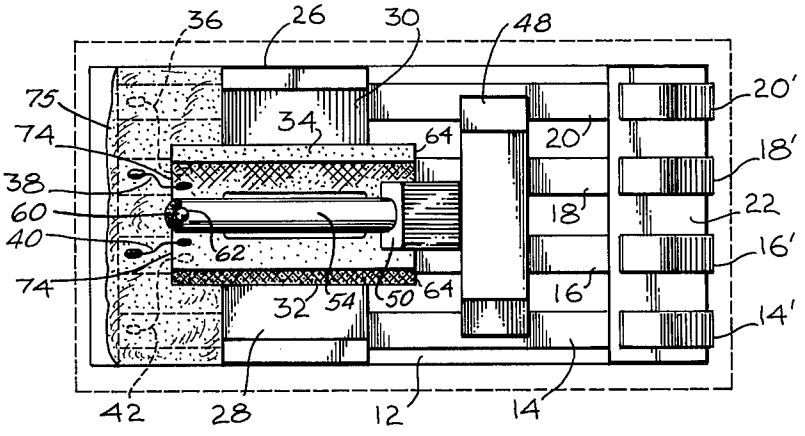


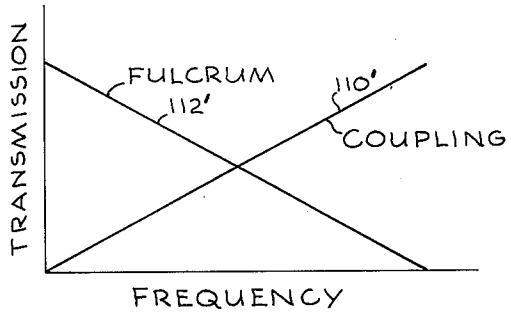

Fig. 4

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STEREO PIEZOELECTRIC TRANSDUCER

Filed Oct. 2, 1961 2 Sheets-Sheet 2

*Fig. 5*



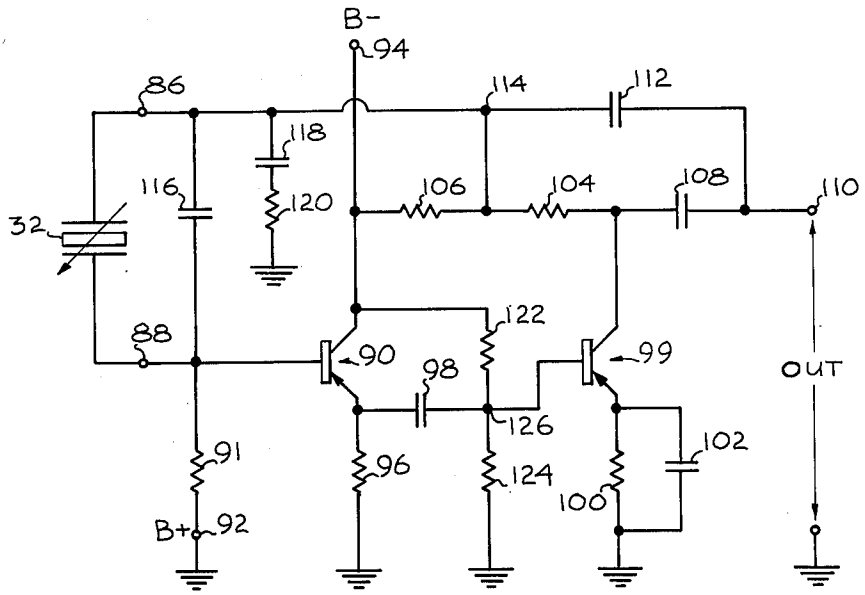




*Fig. 6*

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3,233,047

# STEREO PIEZOELECTRIC TRANSDUCER

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20 Claims. (Cl. 179—100.4)

The present invention relates to improved structures and arrangements useful in electromechanical transducers and systems of the type in which mechanical motion is transduced into representative electrical signals.

More particularly, the present invention relates to improved structures and arrangements useful in transducers of the type generally known as electromechanical phonograph pick-ups and/or systems, and especially such pick-ups and systems as are intended for use in reproducing stereophonically related sound signals as recorded on grooved stereophonic recordings. In such recordings, quadrature related undulations of the groove walls thereof represent records of two separate and distinct sound signals each corresponding to a different one of a pair of signals making up stereophonic sound program material.

One of the more common approaches taken in providing a transducer structure and system suitable for transducing mechanical motion into electrical signals, involves the use of a displacement sensitive element which is, in turn, mechanically coupled to a sensing arm or beam member which in turn is directly subjected to the motion to be transduced. The displacement sensitive element may take a variety of forms such a variable capacitor, a variable inductance, a variable resistance, a moving coil in a magnetic field, a movable magnetically permeable member forming part of a magnetic circuit, etc. In more recent years, bodies of electrically piezosensitive or piezo electric material have been employed which exhibit one or more electrical characteristics which change upon the production of mechanical stress or strain therein as by compressing, stretching, twisting or bending the body. Some piezosensitive compositions reflect a change in resistance when so stressed. A quartz crystal, on the other hand, is known to generate an E.M.F. across its faces upon producing strain therein. Similarly certain ceramic dielectric materials such as barium titanate or lead zirconate-lead titanate compositions exhibit electrical dielectric properties which change when bodies thereof are stressed. Such changes are in turn reflected in the development of an E.M.F. across surfaces of the bodies especially when the material has been electrically stressed or polarized during manufacture. Such electrically piezosensitive or piezoelectric bodies are usually provided with conductive electrodes on two or more of their surfaces whereby changes in one or more of their electrical characteristics may be sensed during stressing of the material.

Generally speaking, most of the more common electrically piezosensitive materials of the type described are quite stiff so that a substantial amount of work must be done in producing significant stresses therein. Because of this, the fabrication of a transduced based on their use becomes challenging where little motional restraint can be tolerated on the member whose motion is to be analyzed.

For example, a common form of transducer or pick-up useful in reproducing or "playing back" present day grooved sound disc recordings comprises a body of electrically piezosensitive material carried by a support structure. This structure is adapted for fastening to a pick-up arm. A beam member is resiliently mounted to the support structure and provided at its free extremity with



a pointed stylus so shaped as to engage the v-shaped groove of a disc recording while the disc is rotated on a turntable. Means are then provided in the transducer for mechanically coupling the beam to the body of piezosensitive material. Motion of the stylus in tracing the undulations of the disc grooves is thereby communicated to the piezosensitive body and the resulting changes in its electrical characteristic sensed and transformed into electrical signals.

In high fidelity grooved recordings, the undulations of the groove representing high frequencies are quite abrupt. Hence, to minimize wear on the material from which the record is made, the effective moving mass of the stylus should be as low as possible and the compliance of the beam to which it is attached should be as high as possible. Furthermore, if the electrical signals ultimately produced are to faithfully represent the recorded sound, the mechanical system comprising the stylus, beam and body of piezosensitive material should be free of mechanical resonances within the range of sound frequencies recorded on the disc. Thus, if the beam is directly coupled to the piezosensitive body at or near the stylus extremity thereof, the stiffness of the body is directly imposed on the stylus. Its effective mass is, therefore, high and its compliance low, resulting in undue record wear. On the other hand, if the mechanical coupling of the stylus to the body is reduced, as by resiliently mounting the body within the pick-up and coupling the beam to the body at a position on the beam more remote from the stylus, various mechanical resonances are invited and the output signal from the pick-up is reduced.

Such resonances tend to distort the signal ultimately reproduced. This type of distortion is particularly troublesome in pick-ups intended for the playback of present day stereophonic grooved recordings, for here the undulations of the grooves have to be faithfully resolved into two quadrature related vectorial components. In such pick-ups, two bodies of electrically piezosensitive material are employed and the motion of the beam coupled to these bodies in such a way that each body is subjected to stresses corresponding to a different one of these vectorial components. Mechanical resonances and other nonlinearities in the mechanical coupling of the beam to such bodies not only produce distortion in the resulting signals, but tend to intercouple or mix the two stereophonic signals which are sought. This "cross talk" acts to destroy the stereophonic effect of the signals when audibly reproduced. Moreover, in stereophonic type pick-ups, as well as standard monaural pick-ups, it is important that the effective degree of coupling of the beam to each of the bodies remain substantially the same for all positions of the stylus beam. Variations in such coupling tend to produce asymmetries in response whereby undesirable intermodulation distortion occurs between low and high frequency signals. This effect is mainly attributable to the fact that in present day grooved sound recordings, low frequency signals of a given energy level are represented by larger groove undulations than high frequency signals of the same energy level.

The present invention makes possible the realization of improved transducers and transducer systems of the type described which exhibit high compliance, low mass, low distortion and a wide range frequency response and are characterized by high signal output and high discrimination in resolving the separate vectorial components of a given motion.

In accordance with one aspect of the present invention, high compliant beam motion in an electrical piezosensitive transducer is realized by resiliently mounting the piezosensitive body to a support structure along a substantial portion of but one of its surfaces. A beam is then also resiliently supported at one of its extremities to

the support structure and also resiliently coupled to one extremity of the electrically piezosensitive body at a position on the beam at or near that extremity thereof which is resiliently supported. A stylus adapted to engage the grooves of a grooved disc sound recording is then fastened to the other extremity of the beam. Ratios of 80 to 150 to 1 are thereby realized between stylus motion and the motion imparted to the piezosensitive body.

In further accordance with the invention, increased beam compliance in such a transducer is realized by employing an electrical signal amplifier incorporating a substantial amount of degeneration at least in part produced by the application of a negative feed back signal to the transducer itself. By using a piezoelectric material having appropriate polarization characteristics this same degenerative feed back signal is made to produce a degree of positive electromechanical feed back which aids stylus motion but is in degree less than the overall degeneration produced in the amplifier.

In accordance with a further aspect of the present invention, increased signal output is realized by rigidly fastening that extremity of the piezosensitive body most remote from the area thereof which is coupled to the beam to the support structure itself.

In accordance with still another aspect of the present invention, decreased intermodulation distortion between low and high frequency signals delivered from transducers of the type described and specifically employed for the playback of grooved phonograph disc recordings is realized by coupling the stylus carrying beam to a resiliently mounted body of piezosensitive material through a body of resilient material having a tapered surface in direct contact with the body of piezosensitive material.

In accordance with still another aspect of the invention, increased signal output realized from transducers employing a polarized piezoelectric ceramic dielectric body as a stress sensitive element is increased through the use of means applying a direct current bias voltage across the body with such polarity that the instantaneous variations in the voltage across the body attributable to capacitance changes supplement and enforce voltages otherwise produced by variations in the stress applied to the body.

In accordance with yet another aspect of the invention, cross talk between the two signals developed by a stereophonic phonograph pick-up employing two bodies of piezosensitive material is reduced by arranging the major surface areas of the bodies to which pressure variations are applied so that the surfaces lie in planes which intersect one another at an angle greater than 90° but less than 180°.

The above as well as other novel features or advantages embraced by the present invention will be better understood through the following specification especially when read in connection with the accompanying drawings, in which:

FIG. 1 is a partially sectioned side view of a transducer embodying features of the present invention and particularly adapted for the reproduction of stereophonic sound recordings;

FIG. 2A is a sectional view of the structure shown in FIG. 1 taken along the arrowed lines 2A—2A thereof looking in the direction of the arrows;

FIG. 2B is another sectional view of the structure shown in FIG. 1 taken along the arrowed lines 2B—2B looking in the direction of the arrows;

FIG. 3 is a rear end projection view of the structure shown in FIG. 1;

FIG. 4 is a bottom view of the structure shown in FIG. 1 with part of the outer casing of the transducer removed;

FIG. 5 is a graphical representation of the manner in which certain characteristics of the structure shown in FIG. 1 affect the overall frequency response of the transducer; and

FIG. 6 is a schematic representation of a polarized degenerative amplifier circuit suitable for use in connection with the transducer structure shown in FIG. 1.

Turning now to FIGS. 1 through 4, one form of transducer embodying novel features in accordance with the present invention is illustrated. The particular form of transducer shown is one suited for use in the reproduction or playback of grooved disc stereophonic recording of the 45°–45° type commonly in use today. The transducer comprises a support member 12 upon one surface of which four electrically conductive metallic strips 14, 16, 18 and 20 have been placed and adhesively or otherwise firmly held into position. The supporting member 12 may be nothing more than a thin sheet of electrical insulating material such as Bakelite or plastic while the conductive strips may be made of phosphor bronze or spring brass. Extensions 14', 16', 18' and 20' of the metallic strips are bent (as best shown in FIG. 1 and FIG. 4) and crimped around a body 22 of insulative elastic material, such as rubber, to form four electrical female contact terminals adapted for respective sliding contact engagement with corresponding conductive strips held on the surface of a detachable male plug 24. Only one of such latter strips is shown at 25.

Also rigidly fastened to the supporting member 12 is a body of resilient material 26 which, by way of example, is preferably made of ebonite rubber having a durometer rating between 50 and 80. In the practice of the invention, ebonite rubber suitably loaded with frictionally lossy materials (such as silicone) and cured by heating at a temperature of 350° to 450° F. for a period of five to ten minutes is found to be very satisfactory. The body 26 of resilient material is formed to have two supporting surfaces 28 and 30. To each of these surfaces there is in turn fastened a body of electrically piezosensitive material as shown at 32 and 34. In a preferred form of the invention, these bodies are comprised of a ceramic compound made up of barium lead titanate-lead zirconate which is well known to have piezoelectric properties. Other materials having electrical characteristics which change with pressure may be used. Typically each of the bodies 32 and 34 are approximately .250" in length, .06" wide and .02" deep. Opposite major side surfaces of each body, to wit, surfaces 32*a*, 32*b*, 34*a* and 34*b* have affixed thereto an electrically conductive coating or electrode whereby changes in the electrical characteristics of the material when placed under stress may be sensed. Wires 36, 38, 40 and 42 conductively fastened to these conductive coatings are in turn conductively affixed to a respectively different one of the metallic strips 14, 16, 18 and 20 whereby the electrical characteristics of the electroded bodies 32 and 34 may be externally sensed from connections (not shown) made to the male plug 24.

As indicated in the drawings, in a preferred form of the invention, the electroded bodies 32 and 34 are affixed to the resilient supporting body 26 over a substantial portion of the area of their major side surfaces 32*a* and 34*a*. These areas are central to and between two smaller end areas of the major side surfaces 32*a* and 34*a* generally shown at 44 and 46. In the particular arrangement shown, the lengths of the central areas are approximately .15" each while the lengths of the end areas are approximately .05" each. Another body 48 of resilient material, which may be of the same character as the material forming body 26, is also rigidly fastened to the supporting member 12 and is provided with an integral extension generally rectangular in cross section shown at 50. The body 48 is spaced away from the ends of the ceramic bodies 32 and 34 by approximately .1" while the mean length of the extension 50 is approximately .70". The rectangular cross section is approximately .06" square. Within a recess generally indicated by the dotted line 52, one extremity of a tubular beam member 54 is rigidly fastened to the extension 50 as, for example, through the use of an adhesive or a cement. The member 54 may be made of a lightweight aluminum tubing .25" long such

as 24 ST available from the Precision Tube Company, Philadelphia, Pennsylvania, the tube having a .029" diameter with a .002" wall. The beam member 54 thus positioned extends generally along but away from the major side surfaces 32*b* and 34*b* of the ceramic bodies 32 and 34 and through an opening generally shown at 56 in the lower portion 58 of the transducer case. A stylus 60 shaped to engage the groove of a disc recording is cemented or otherwise held to the thus exposed extremity of the beam 54 within an aperture 62 therein. The resilient body 48 which supports the beam 54 through the protrusion 50 is so positioned relative to the end extremities 64 of the ceramic bodies 32 and 34 that the tapered edge portions 66 and 68 of the rectangular extension 50 engage the end extremities 64 of the ceramic bodies 32 and 34.

In a preferred form of the invention, the other end extremities of the ceramic bodies 32 and 34 generally shown by the lines 74 are rigidly fastened to the supporting structure 12 by means of a cement, wax, epoxy resin, etc. shown at 75. Where, in a preferred form of the invention, the ceramic bodies 32 and 34 are polarized, the bodies are positioned so that the major side surfaces 32*b* and 34*b* of the bodies exhibit the same polarity of polarization relative to their opposing major side surfaces 32*a* and 34*a*. This is generally indicated by the polarity signs in FIG. 2B.

An upper portion 76 of the encasing structure is adapted for close sliding fit within the lower encasing structure 58 and is provided with winged extensions 80 and 82 which are useful in supporting the transducer in a phonograph pick-up arm (not shown) in accordance with well known practice. The upper and lower portions of the transducer encasing structure are held together by means of crimping an extension 59 of structure 58 over and around the end surface of structure 76.

In a preferred form of its utilization, the transducer shown in FIGS. 1 through 4 is employed in connection with two degenerative signal amplifiers each of which may take the form schematically illustrated in FIG. 6. As shown in FIG. 6, the electroded surfaces of either of the ceramic bodies 32 and 34 are respectively applied to the input terminals 86 and 88 of the amplifier arrangement. For purposes of illustration only, the ceramic body 32 is indicated as being connected to the amplifier, it being understood that the ceramic body 34 will be connected to a similar circuit arrangement when using the transducer for reproduction of stereophonic records.

In FIG. 6, the input terminal 88 of the amplifier is connected to the base of a transistor 90 which is connected as an emitter follower amplifier. This causes a relatively high impedance to appear between the input terminals 86 and 88. For the purposes of the particular circuit shown, circuit ground terminal 92 is connected to the positive terminal of a source of operating potential (not shown). The negative terminal of this same source of operating potential is in turn connected to power supply terminal 94. A resistor 91 is connected between the base of transistor 90 and circuit ground. The emitter of transistor 90 is also connected to ground through load resistor 96 while capacitor 98 couples signals appearing across the resistor 96 to the base of the output amplifier transistor 99. The emitter of the transistor 99 is in turn connected to ground through a biasing resistor 100 which is in turn by-passed by capacitor 102. The collector of transistor 90 is directly connected to the negative power supply terminal 94 while the collector of transistor 99 is connected through loading resistors 104 and 106 to the negative power supply terminal 94. An output coupling capacitor 108 is then connected from the collector of transistor 99 to an output terminal 110. Signals appearing at the output terminal 110 are in turn coupled through capacitor 112 to terminal 114 which is galvanically connected to the junction of resistors 104 and 106.

Terminal 114 of the circuit arrangement shown in FIG. 6 is in turn directly connected to the other input terminal 86 of the amplifier. Loading capacitor 116 is connected directly across the input terminals 86 and 88. A frequency compensating network made up of capacitor 118 and resistor 120 is connected from the terminal 86 to circuit ground. Proper operating bias voltage for the transistor 99 is obtained by means of a resistive voltage dividing network made up of resistor 122 and resistor 124 which is connected between the negative power supply terminal 94 and circuit ground, the junction 126 between the two resistors being connected to the base of the transistor 99.

In the operation of the arrangement shown in FIG. 6, it can be seen that the ceramic body 32 of the transducer shown in FIGS. 1 through 4 will be subjected to a polarizing potential substantially equal in magnitude to the power supply potential applied to the amplifier itself. If, in the practice of the present invention polarized ceramic elements are used, the polarization of the ceramic elements are so arranged that the portion of the output signal appearing at terminal 110 which is coupled back to input terminal 86 via capacitor 112 acts upon the body 32 to assist stylus motion. At the same time, the fed back voltage acts to electrically degenerate the signal appearing at terminal 88 of the amplifier. By adjusting the values of resistors 104 and 106, the degree of the positive electromechanical feed back can be established at a lower magnitude than the magnitude of the degree of electrical degeneration described. In a preferred form of the invention, the degenerative negative electrical feed back is established at approximately 6 db greater than the positive electromechanical feed back. This provides greatly increased signal output and at the same time maintains overall system stability.

In a typical embodiment of the transducer structure, as shown in FIGS. 1 through 4, it can be seen that the beam 54 extends generally away from the major surfaces 32*b* and 34*b* of the ceramic bodies 32 and 34. In accordance with the present invention, it has been found that to cause the signals developed by the ceramic elements 32 and 34 to represent truly quadrature related components of the motion of the stylus 60, the angle of reference planes passing through the major side surfaces 32*b* and 34*b* must be made greater than the 90°. It is found that the greater the angle which the longitudinal axis of the beam 54 makes with the surfaces 32*b* and 34*b* the greater the angle must be between the above reference planes. In the particular arrangement shown, this angle is approximately 125°.

Moreover, in connection with the transducer shown in FIGS. 1 through 4, assymmetrical distortion of signals produced as a function of beam displacement (as above described) is reduced by adjusting the pressures which the tapered surfaces 66 and 68 of the extension 50 exert against the major surfaces 32*b* and 34*b* of the ceramic bodies. In final assembly of the transducer, the resilient member 48 is adjustably positioned (as by a needle placed through aperture 56' in the encasing structure 58) and ultimately affixed to the inner surface of the encasing structure 58 through the use of an adhesive or cement shown at 140 applied through aperture 56'. By this adjustment, the area of contact between the edges of the resilient extension 50 and the surfaces of the ceramic bodies 32 and 34 can be adjusted and their compressional characteristics made to complement the compressional elastic characteristics of the resilient supporting body 26. Thus, referring to FIG. 2B, as the stylus beam 54 is moved toward the ceramic body 34, the increased area of contact between the protrusion 50 and the surface 34B will compensate for the forces acting upon the surface 34*a* owing to the compressional characteristics of the resilient body 26.

Furthermore, in the practice of the present invention, it is contemplated that the configuration of the tapered edge surfaces 66 and 68 of the extension 50 be tailored

(as through the use of emory paper) to effect an almost perfect balance between the transmissivity-versus-frequency characteristics of the resilient material making up the extension 50 and the composite effective transmissivity-versus-frequency characteristics of the ceramic elements as mounted on the resilient support body 26. More specifically, at higher frequencies, the silicone loaded material making up extension 50 tends to increase its transmissivity (as generally indicated by curve 110′ in FIG. 5), thus increasing the effective coupling between the beam 54 and the ceramic bodies 32 and 34. On the other hand, owing to the fact that each of these bodies is rigidly fastened along a substantial portion of one of their surfaces to the loaded resilient body 26, a smaller length of the body is effectively stressed at higher frequencies. Thus, the fulcrum arm, about which the bodies are stressed, becomes smaller as frequency increases. This is generally shown by curve 112′ in FIG. 5. Hence, by properly tailoring the edge surfaces 66 and 68 of the extension 50, the effective volume of the material which couples the beam to the ceramic bodies can be controlled and a balance between the above effects realized. It will be understood that the curves of FIG. 5 are only exemplary of general effects above discussed and are in no way intended to depict specific characteristics of any particular material or combination of elements.

From the above, it will be clear that the novel features of the present invention, although described in connection with a stereophonic type phonograph pick-up transducer, are useful in other types of electromechanical transducers such as monaural phonograph pick-up transducers or transducers intended for general use in mechanical vibration studies.

Having thus described the invention, what is claimed is:

1. In a transducer for transducing mechanical motion into representative electrical signals, the combination of: a support member; a body of strain responsive material exhibiting a given electrical characteristic which changes upon the production of mechanical strain therein, said body having a first and a second end extremity and a first and a second major side surface opposing one another, each major side surface being comprised of two end areas each embracing a different one of said end extremities and a central area intermediate said two end areas, said central area being substantially larger than either of said end areas; means resiliently affixing said body within the central area of said first major side surface to said support member; means substantially rigidly affixing said body within the first end area of said first major side surface to said support member; a beam member having a first and a second end extremities; means resiliently and directly coupling said first beam extremity to both said support member and a variable area of that end area of said second major side surface which directly opposes the second end area of said first major side surface; the area coupled varying with the movement of said second beam extremity relative to said support member; and means electrically connected to said body for sensing changes in said given electrical characteristic in response to movement of said second beam extremity relative to said support member.

2. In a transducer for transducing mechanical motion into representative electrical signals, the combination of: a support member; a body of strain responsive material exhibiting a given electrical characteristic which changes upon the production of mechanical strain therein, said body having a first and a second end extremity and a first and a second major side surface opposing one another, each major side surface being comprised of two end areas each embracing a different one of said end extremities and a central area intermediate said two end areas, said central area being substantially larger than either of said end areas; means resiliently affixing said body within a portion of said first major side surface to said support member leaving one end area thereof free from direct coupling to said support member; a body of resilient material fixed to said support member adjacent said first extremity of said body of strain responsive material; a beam member having one extremity thereof fastened to said body of resilient material and extending generally along said second major side surface; means resiliently coupling said beam member to a variable area of that end area of said second major side surface which opposes said free end area of said first major side surface at substantially the position on said beam member where said beam member is fastened to said body of resilient material; the area coupled varying with the movement of said second beam extremity relative to said support member; and means electrically connected to said body for sensing said changes in said given electrical characteristic of said body upon the movement of said beam relative to said support member.

3. In a system for transducing mechanical motion into representative electrical signals: a support structure; a first and a second electrical conductor carried by said support structure in electrically insulated relationship to one another; a beam member having two extremities; means fastened to said support structure and holding one of said beam member extremities to permit resilient movement of said beam member relative to said support structure; an electrical signal amplifier having two input terminals; degeneration means included in said amplifier for producing a degree of electrical degeneration of signals conditionally appearing across said amplifier input terminals, said degeneration means including structure for developing and applying a degenerative feed back signal to one of said input terminals; means connecting each of said first and second electrical conductors to a different one of said amplifier input terminals; a body of piezoelectric material fastened to said support structure, a variable area of which is mechanically coupled to said beam member to cause force conditionally produced by movement of either said body or said beam member to be intercoupled between said body and said beam thereby varying the area of coupling between said body and said beam, said body having a first and a second electroded surfaces; means holding at least a portion of said body in mechanically coupled relationship to both said support structure and said beam; and means electrically connecting each of said first and second conductors to that respectively different one of said electroded surfaces which produces a degree of electromechanical regenerative action between said body and said beam in response to said degenerative feed back signal applied to said one amplifier input terminal.

4. In a system for transducing mechanical motion into representative electrical signals: a support structure; a first and a second electrical conductor carried by said support structure in electrically insulated relationship to one another; a beam member having two extremities; means fastened to said support structure and holding one of said beam member extremities to permit resilient movement of said beam member relative to said support structure; an electrical signal amplifier having two input terminals; degeneration means included in said amplifier for producing a degree of electrical degeneration of signals conditionally appearing across said amplifier input terminals, said degeneration means including structure for developing and applying a degenerative feed back signal to one of said input terminals; means connecting each of said first and second electrical conductors to a different one of said amplifier input terminals; a body of piezoelectric dielectric material fastened to said support structure, a variable area of which is mechanically coupled to said beam member to cause force conditionally produced by movement of either said body or said beam member to be intercoupled between said body and said beam thereby varying the area of coupling between said body and said beam, said body having a first and a second electroded surface between which has been established

a given fixed dielectric polarization; means holding at least a portion of said body in mechanically coupled relationship to both said support structure and said beam; and means electrically connecting each of said first and second conductors to that respectively different one of said electroded surfaces which produces a degree of electromechanical regenerative action between said body and said beam in response to said degenerative feed back signal applied to said one amplifier input terminal.

5. In a system for transducing mechanical motion into representative electrical signals: a support structure; a first and a second electrical conductor carried by said support structure in electrically insulated relationship to one another; a beam member having two extremities; means fastened to said support structure and holding one of said beam member extremities to permit resilient movement of said beam member relative to said support structure; an electrical signal amplifier having two input terminals; degeneration means included in said amplifier for producing a degree of electrical degeneration of signals conditionally appearing across said amplifier input terminals, said degeneration means including structure for developing and applying a degenerative feed back signal to one of said input terminals; means connecting each of said first and second electrical conductors to a different one of said amplifier input terminals; a body of piezoelectric dielectric material fastened to said support structure, a variable area of which is mechanically coupled to said beam member to cause force conditionally produced by movement of either said body or said beam member to be intercoupled between said body and said beam thereby varying the area of coupling between said body and said beam, said body having a first and a second electroded surface between which has been established a given fixed polarization; means holding at least a portion of said body in mechanically coupled relationship to both said support structure and said beam; means electrically connecting each of said first and second conductors to that respectively different one of said electroded surfaces which produces a degree of electromechanical regenerative action between said body and said beam in response to said degenerative feed back signal applied to said one amplifier input terminal; and means included in said amplifier for establishing a direct current voltage bias between said amplifier input terminals.

6. In a system for transducing mechanical motion into representative electrical signals: a support structure; a first and a second electrical conductor carried by said support structure in insulated relationship to one another; a beam member having two extremities; means fastened to said support structure and holding one of said beam member extremities to permit resilient movement of said beam member relative to said support structure; an electrical signal amplifier having two input terminals; means connecting each of said first and second electrical conductors to a different one of said amplifier input terminals; a body of piezoelectric material fastened to said support structure, a variable area of which is mechanically coupled to said beam member to cause force conditionally produced by movement of either said body or said beam member to be intercoupled between said body and said beam thereby varying the area of coupling between said body and said beam, said body having a first and a second electroded surface; means holding at least a portion of said body in mechanically coupled relationship to both said support structure and said beam; means electrically connecting each of said first and second conductors to that respectively different one of said electroded surfaces which produces a degree of electromechanical regenerative action between said body and said beam in response to said degenerative feed back signal applied to said one amplifier input terminal; and means included in said amplifier for establishing a direct current voltage bias between said amplifier input terminals.

7. In a transducer for transducing mechanical motion into two electrical signals representing quadrature related components of the mechanical motion: a support member; a first and a second body of strain responsive material exhibiting a given electrical characteristic which changes upon the production of mechanical strain therein, each of said bodies having a substantially planar major side surface; means resiliently mounting said first and said second bodies to said support member with said major side surfaces thereof adjacent one another and falling in respective reference planes intersecting one another at an angle greater than 90° but less than 180°; a beam member having two extremities; holding means affixed to said support member and holding said beam at one of its extremities while permitting flexible movement of said other beam extremity relative to said support member in response to the motion to be transduced, said holding means orienting the longitudinal axis of a substantial portion of said beam along a direction generally away from the major side surface of said first and second bodies; means resiliently coupling said beam to both said major side surfaces; and means coupled to said first and second bodies for separately detecting changes in said given electrical characteristic in order to permit the development of two distinct electrical signals in response to movement of said beam member.

8. Apparatus according to claim 7 wherein said means resiliently coupling said beam to both said major side surfaces comprises a body of ebonite rubber having a durometer rating of 55 to 80 and which has been cured by heating at a temperature between 300° to 400° for a period of 5 to 10 minutes.

9. In a transducer for transducing mechanical motion into two electrical signals representing quadrature related components of the mechanical motion: a support member; a first and a second bodies of strain responsive material exhibiting a given electrical characteristic which changes upon the production of mechanical strain therein, each of said bodies having a substantially planar major side surface; means resiliently mounting said first and said second bodies to said support member with said major side surfaces thereof adjacent one another and falling in respective reference planes intersecting one another; a beam member having two extremities; holding means affixed to said support member and holding said beam at one of its extremities while permitting flexible movement of said other beam extremity relative to said support member in response to the motion to be transduced; a body of resilient material rigidly fastened to said beam and having two portions on its surface each tapering to a relatively thin edge, each edge directly contacting the major side surface of a different one of said bodies of strain responsive material; and means coupled to said first and second bodies for separately detecting changes in said given electrical characteristic in order to permit the development of two distinct electrical signals in response to movement of said beam member.

10. In a transducer for transducing mechanical motion into two electrical signals representing quadrature related components of the mechanical motion: a support member; a first and a second body of strain responsive material exhibiting a given electrical characteristic which changes upon the production of mechanical strain therein, each of said bodies having a substantially planar major side surface; means resiliently mounting said first and said second bodies to said support member with said major side surfaces thereof adjacent one another and falling in respective reference planes intersecting one another at an angle greater than 90° but less than 180°; a beam member having two extremities; holding means affixed to said support member and holding said beam at one of its extremities while permitting flexible movement of said other beam extremity relative to said support member in response to the motion to be transduced, said holding means orienting the longitudinal axis of said beam along a direction generally away from the major side sur-

face of said first and second bodies; a body of resilient material rigidly fastened to said beam and having two portions on its surface each tapering to a relatively thin edge, each edge directly contacting the major side surface of a different one of said bodies of strain responsive material; and means coupled to said first and second bodies for separately detecting changes in said given electrical characteristic in order to permit the development of two distinct electrical signals in response to movement of said beam member.

11. In a transducer for transducing mechanical motion into two electrical signals representing quadrature related components of the mechanical motion: a support member; a first and a second body of strain responsive material exhibiting a given electrical characteristic which changes upon the production of mechanical strain therein, each of said first and second bodies having a substantially planar major side surface; means resiliently holding said first and said second bodies to said support member with said major side surfaces thereof adjacent one another and the longitudinal extremities of said surfaces substantially mutually co-extensive but with said surfaces falling in respective reference planes intersecting one another at an angle greater than 90° but less than 180°; a resilient body of material rigidly fastened to said support member at a position immediately adjacent one set of said co-extensive longitudinal extremities of the major side surfaces of said first and second bodies, said resilient body having a substantially rectangular projection forming a part thereof with each of two adjacent corner portions of said projection contacting a respectively different one of said major side surfaces; a beam member having one extremity rigidly fastened to said resilient body and extending generally along but away from said first and second major side surfaces and said resilient body; and means connected to said first and second bodies for sensing changes in said given electrical characteristic in response to strains produced in said first and second bodies by forces developed by beam motion as communicated through said resilient body.

12. In a transducer for transducing mechanical motion into corresponding electrical signals, the combination of: a support structure; a body of strain responsive material having a given electrical characteristic which is subject to change upon the production of stress therein, said body having a substantially flat surface; means resiliently mounting said body to said support structure in an orientation exposing said surface; a beam member resiliently mounted to said support structure adjacent said surface of said body; a body of resilient material having a portion thereof tapering to a relatively thin edge with said edge interposed between said beam member and said surface with the apex of said edge directly contacting said surface; and means coupled to said body of strain responsive material to permit the sensing of changes in said given electrical characteristic in response to the relative motion between said beam and said surface which produces a variation in the area of contact between said edge and said surface.

13. In a transducer for transducing mechanical motion into corresponding electrical signals, the combination of: a support structure; a body of strain responsive material having a given electrical characteristic which is subject to change upon the production of stress therein, said body having a substantially flat surface; means resiliently mounting said body to said support structure in an orientation exposing said surface; a beam member resiliently mounted to said support structure at a position closely spaced from one longitudinal extremity of said flat surface and extending along a direction adjacent said surface of said body; a body of resilient material having a tapered portion forming an edge interposed between said beam member and said surface with the apex of said edge directly contacting said surface substantiatly at said one extremity thereof; and means coupled to said body of strain responsive material to permit the sensing of changes in said given electrical characteristic in responsive to the relative motion between said beam and said surface which produces a variation in the area of contact between said edge and said surface.

14. In a transducer for transducing mechanical motion into corresponding electrical signals, the combination of: a support structure; a body of strain responsive material having a given electrical characteristic which is subject to change upon the production of stress therein, said body having a substantially flat surface; means resiliently mounting said body to said support structure in an orientation exposing said surface; a beam member resiliently mounted to said support structure at a position closely spaced from one longitudinal extremity of said flat surface and extending along a direction adjacent said surface of said body; a body of resilient material interposed between said beam member and said flat surface, said body having a tapered portion defining a surface of minimum area said surface of minimum area directly contacting said flat surface whereby incremental changes in the position of said beam member relative to said body produces a change in the total surface area common to said body of resilient material and said body of strain responsive material; and means coupled to said body of strain responsive material to permit the sensing of changes in said given electrical characteristic in response to relative motion between said beam and said surface.

15. In a transducer for transducing mechanical motion into corresponding electrical signals, the combination of: a support structure; a body of strain responsive material having a given electrical characteristic which is subject to change upon the production of stress therein, said body having a substantially flat surface; means resiliently mounting said body to said support structure in an orientation exposing said surface; a beam member resiliently mounted to said support structure of a position closely spaced from one longitudinal extremity of said flat surface and extending along a direction adjacent said surface of said body; a body of resilient material having a tapered portion forming an edge interposed between said beam member and said surface with the apex of said edge directly contacting said surface substantially at said one extremity thereof; means rigidly affixing the other extremity of said body to said support structure; and means coupled to said body of strain responsive material to permit the sensing of changes in said given electrical characteristic in response to the relative motion between said beam and said surface which produces a variation in the area of contact between said edge and said surface.

16. In a transducer for transducing mechanical motion into corresponding electrical signals, the combination of: a support structure; a body of strain responsive material having a given electrical characteristic which is subject to change upon the production of stress therein, said body having a substantially flat surface; means resiliently mounting said body to said support structure in an orientation exposing said surface; a body of resilient material rigidly fastened to said support structure at a position thereon closely spaced from one longitudinal extremity of said flat surface and having an extension thereon which physically contacts said surface; a beam member having one of its extremities embedded in and supported by said extension and extending therefrom in a direction generally along and adjacent said surface of said body; and means coupled to said body of strain responsive material to permit the sensing of changes in said given electrical characteristic in response to the relative motion between said beam and said surface which produces a variation in the area of contact between said edge and said surface.

17. In a phonograph pickup system for producing separate electrical signals each representing a different one of the two separate sound recordings defined by quadrature related undulations of the groove walls in a grooved stereophonic recording: a support structure; a first and a second plate-like bodies of piezoelectric dielectric material,

each of said plates having two major side surfaces each holding a separate conductive electrode and each plate bearing a preformed dielectric polarization between said major side surfaces thereof; means resiliently supporting said bodies adjacent one another upon said support structure with the longitudinally running edges thereof displaced from and substantially parallel to one another with the most closely adjacent major surfaces of said bodies falling in respective reference planes which intersect one another at an angle greater than 90° but less than 180°, the longitudinal extremities of said surfaces being substantially co-extensive and forming two pairs of co-extensive longitudinal extremities; a beam member having two extremities; holding means rigidly affixed to said support structure and holding said beam at a first one of its extremities while permitting flexible movement of the other beam extremity relative to said support structure and directing said beam in a direction generally away from but generally along said most closely adjacent major surfaces of said bodies; a groove engaging stylus rigidly fixed to said beam at a position thereon near the second one of said beam extremities; and means resiliently coupling said beam to both of said most closely adjacent major surfaces of said bodies within respective areas thereof immediately adjacent those co-extensive extremities of said bodies nearest said holding means.

**18.** Structure according to claim **17** wherein the orientation of said bodies is such that the most closely adjacent major surfaces of said plates correspond to the same polarity of dielectric polarization.

**19.** Structure according to claim **17** wherein said holding means comprises a solid body of resilient material



rigidly affixed to said support structure at a position closely displaced from one pair of said co-extensive longitudinal extremities of said bodies and wherein said means resiliently coupling said beam to the major surfaces of said bodies comprising an integral extension of said solid body the surface of which extension physically contacts both of said major surfaces.

**20.** A system according to claim **17** wherein there is additionally provided a first and a second electrical signal amplifier each amplifier having two signal input terminals and means for producing a fixed direct current bias voltage of given polarity between said input terminals, and electrical connections between each of the two conductive electrodes of said first body to a respectively different input terminal of said first amplifier in a given polarity sense and electrical connections between each of the two conductive electrodes of said second body to a respectively different input terminal of said second amplifier in said same given polarity sense.

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