Jan. 15, 1963 J. W. CROWNOVER 3,073,915

STEREOPHONIC TRANSDUCER MEANS

Filed Sept. 8, 1959

Fig. 1

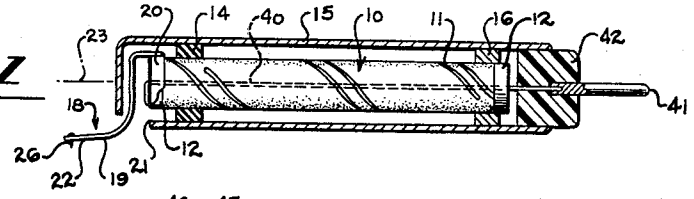
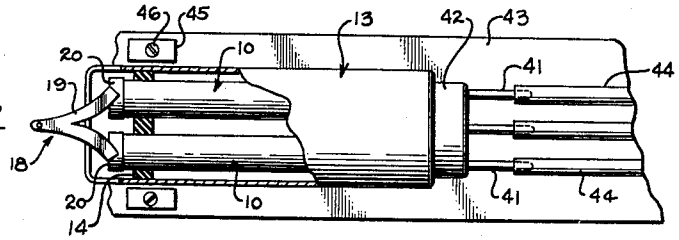


Fig. 2



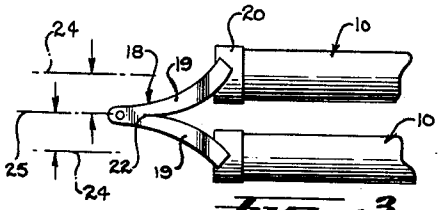


Fig. 3

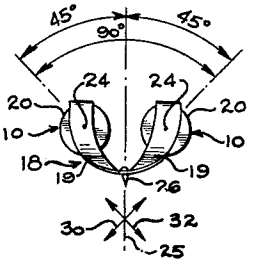


Fig. 4

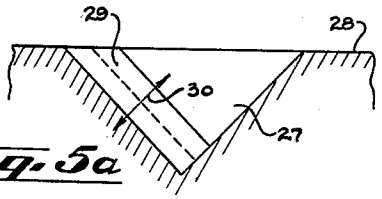


Fig. 5a

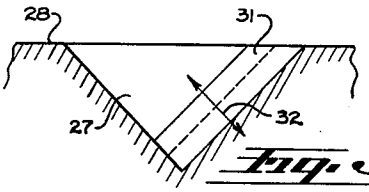


Fig. 5b

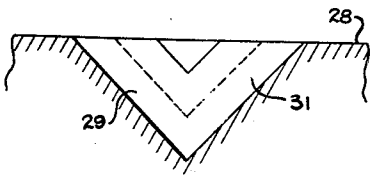


Fig. 5c

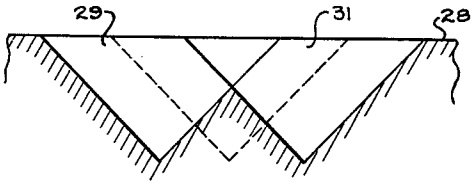


Fig. 5d

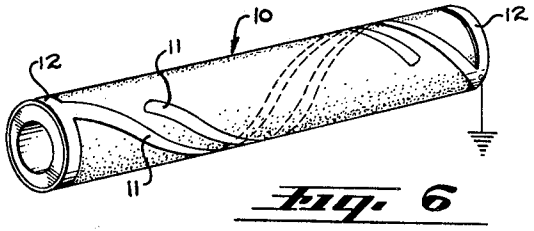


Fig. 6

JOSEPH W. CROWNOVER
INVENTOR

BY White & Haefliger

ATTORNEYS

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STEREOPHONIC TRANSDUCER MEANS

Joseph W. Crownover, La Jolla, Calif., assignor of twenty-five percent to William W. Haefliger, Pasadena, Calif.

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9 Claims. (Cl. 179—100.41)

This invention relates generally to stereophonic sound reproduction systems, and more particularly concerns the provision of a new stereophonic cartridge, the use of which leads to substantially improved sound reproduction fidelity.

Stereophonic sound reproduction systems, as they exist today, owe their public acceptance to the excellence of present day equipment intermediate what is known as the pickup cartridge and the speaker device. It is generally realized, however, that perfect reproduction of sound equivalent to natural sound, can only be accomplished if all elements of the total recording and reproducing system function with high fidelity, for otherwise there is little need of the stereophonic effect. Considering commercially known pickup cartridges, these devices are incapable of true high fidelity due at least in part to their basic construction incorporating the use of simple cantilever bi-elements of crystal or ceramic which in the absence of damping exhibits a natural resonance frequency of approximately 1000 cycles per second. Such a condition leads to the generation of phase distortion which is not completely corrected by heavy damping that is used to facilitate a flat amplitude response over the required audio frequency spectrum.

Many acoustical engineers believe that phase distortion in a pickup cartridge is a contributing factor to the loss of subtle elements of true fidelity, one reason being that phase distortion in a pickup cartridge produces what is known as Doppler distortion in many speaker systems. This results in an audio frequency shift of certain high frequency components of the sound at low frequency rates, and is detected by the human ear as loss of fidelity.

Such phase distortion is due to the fact that the displacement of the electro mechanical bender element, the cartridge cantilever, can only be in phase with the driving mechanical force generated by the displacement of the cartridge needle below the effective resonance of the bender element. Therefore, for mechanical frequencies picked up by the needle, and above the effective resonance frequency of the element, i.e., approximately 1000 cycles per second, the displacement of the bender element is subject to being out of phase with the driving mechanical force generated by the displacement of the needle. One solution to this phenomenon is to make the fundamental resonance of the cantilever fall above the audio frequency spectrum, i.e., above about 15,000 cycles per second. This however, results in an exceedingly stiff and insensitive pickup element, and therefore is no solution. In addition, it is observed that attempted damping of resonance displacement of the cantilever by-element requires materials that act as acoustic resistive elements and thereby absorb mechanical energy transmitted by the needle to the element, which energy would otherwise be transformed into an electrical signal.

As a solution to the above problems, the present invention contemplates the provision of a novel stereophonic pickup cartridge or transducer for simultaneously producing 2-channel electrical signals in response to movement of tracking means such as needle in a 2-channel groove. As broadly conceived, the novel transducer comprises a pair of twist responsive transducer elements having twist axes, each element being operable to produce an electrical signal in response to element twisting about the element axis. Further, actuating means is connected

with both of these twist elements for twisting them in response to the tracking means movement, one element being twisted in accordance with tracking means movement in one channel of the recording groove, and the other element being twisted in response to movement of the tracking means in the second channel of the recording groove.

More particularly, each of the twist elements preferably comprises a cylindrical body or tube of piezoelectrical material and a pair of spaced electrodes extending longitudinally on the body and twisting about the axis thereof so that twisting of the body about its axis results in a voltage change across the spiral electrodes. Such a transducer is disclosed in my co-pending application entitled "Transducer," Serial No. 705,687, filed December 27, 1957, now Patent Number 3,035,126. In this connection it will be noted that such a tubular transducer utilizing the torsional mode of vibration permits a design of the tube which will place the first resonance frequency well above the desired audio frequency spectrum. For example, it may be shown that the fundamental resonance frequency of a rod or tube is independent of the rod diameter, and inversely proportional to rod length which facilitates a large manufacturing tolerance. On the other hand, the fundamental resonance frequency of a cantilever bender type element is not independent of the element thickness but is directly proportional thereto, and furthermore, is inversely proportional to the square of the cantilever length, indicating high criticality in length and thickness. For a cantilever, a small change in length in order to adjust to proper cutoff frequency drastically effects what is known as the compliance of the cantilever so that it is not easy to arrive at a useable compromise between frequency response and compliance of a cantilever element. On the other hand, for a tube or twister element, the design is much more flexible in that accurate control over cutoff frequency may be had and at the same time it is possible conveniently to adjust the tube compliance to some high value without concern of affecting substantially the design cutoff frequency.

Other objects and advantages of the invention include the provision of specific actuating means connected with both twist responsive transducer elements, and having a pair of arms respectively projecting away from the twist element axes, so that the arms twist the elements about their axes in response to movement of the tracking means in directions having components normal to radii from the element axes. Such arms are, in accordance with one form of the invention to be described, in the form of a yoke, the yoke arms being convergent at radially equal distances from extensions of the twist element axes beyond the element free ends to which the yoke is connected.

These and other objects and advantages of the invention, as well as the details of the illustrative embodiment, will be more fully understood from the following detailed description of the drawings, in which:

FIG. 1 is a side elevation taken through a typical stereophonic cartridge assembly;

FIG. 2 is a view showing the underside of the FIG. 1 cartridge and also a phonograph pickup arm to which the cartridge is attached;

FIG. 3 is a plan view of the yoke actuator attached to the two twist elements;

FIG. 4 is a frontal view of the yoke attached to the two twister elements;

FIGS. 5*a* through 5*d* are schematic showings of modulated phonograph record groove walls, and particularly stereophonic type groove walls; and

FIG. 6 is a perspective showing of a typical ceramic transducer element in tubular form.

Referring first to FIG. 6, a piezoelectric and particularly an electrostrictive ceramic cylinder or tube 10 is shown with two relatively narrow helical bands 11 of silver or other suitable electroding material applied to the surface of the cylinder. These bands run parallel to one another in winding about the cylinder axis, yet remain narrowly separated as illustrated. One spiral band joins a ring shaped silver band 12 at one end of the cylinder, while the other band 11 joins with a similar ring shaped band 12 at the opposite cylinder end, bands 12 providing suitable connections for snap on or other type terminals. The cylinder 10 with its applied electrodes constitutes a twist type transducer element of a particularly advantageous type for use in the present invention; however, other types of twist type transducer elements may be used so long as they fulfill the functional requirements of the invention.

FIGS. 1 and 2 show the manner in which a pair of twist type transducer elements 10 are combined to form a cartridge type stereophonic transducer generally indicated at 13. The tubular elements 10 are therein positioned to extend in parallel spaced apart relation as indicated, with a flexible support pad 14 holding the free end portions of the elements 10 as indicated within a cartridge case 15. The opposite end portions of the elements 10 are fixed relative to the case 15 as by attaching a conductor ring or holder 16 to both the case and to those fixed end portions of the elements indicated at 17. Also, the conductor ring preferably contacts and grounds to the case 15 the ring electrode 12 and one of the spiral electrodes 11 of each transducer element.

An actuating means shown in the form of a yoke 18 is rigidly attached to the free ends of the transducer elements 10, as by joining the yoke arms 19 to the ring shaped bands 12 of the transducer elements. Specifically, caps 20 are tightly fitted over the bands 12 and the yoke arms 19 are rigidly joined to the upper portions of the caps as viewed in FIG. 1, so that the yoke arms extend downward opposite the ends of the transducer elements and through an opening 21 in the cartridge case. The yoke arms are convergent toward one another and merge at a location 22 generally forward of the transducer elements and the case 15, that location 22 being radially equally distant from forward extensions 23 of the transducer element axes 24. In other words, the arms 19 merge toward a central vertical plane 25 as seen in FIG. 4, that is equidistant from the transducer element axes 24. The yoke carries a needle 26 for travel in a 2-channel recording groove of the stereophonic recording type.

The elements of such a 2-channel groove are shown in FIGS. 5*a* and 5*b*, the former illustrating a V-groove 27 cut in a phonograph record 28, with the left wall 29 being modulated along the wall length and in the opposite directions indicated by the arrows 30, the latter extending generally at 45° from the horizontal. Similarly, the right wall 31 of the groove 27 is modulated as indicated in FIG. 5*b* in the directions of the arrows 32 which extend normal to the arrows 30. FIGS. 5*c* and 5*d* respectively, illustrate the groove channels 29 and 31 when they are in phase and out of phase.

Referring back to FIG. 4, it will be observed that the yoke arms 19 appear to extend at right angles when viewed from the front of the transducer assembly shown. Also, each of the arms 19 appears in FIG. 4 to extend at a 45° angle with respect to the vertical plane 25, and at opposite sides of that plane. Accordingly, it will be understood that when the needle 26 moves in the directions of arrows 30, i.e., in channel 29 it will twist the left element 10 about its axis and will merely bend the right transducer element 10 but not twist the latter. Likewise, when the needle 26 travels in the directions of the arrows 32, i.e., in the channel 31, it will twist the right transducer element 10 but will merely bend the left transducer element 10. Since there is no electric signal production associated with transducer element bending, and since the only electric signal production occurs as a result of transducer element twist about its axis, it is clear that there will exist very sharp discrimination as between electric signals produced by the transducer elements 10 in response to needle movement in the 2-channels 29 and 31. Also, it is clear that the transducer is particularly adapted for use with presently accepted systems of stereo recording, i.e., the 45°-45° groove system.

It should be observed that the caps 20 to which the yoke 18 is attached may be made of an electrically insulative material, for example a suitable plastic or glass, so that the electrical signals appearing at the end rings 12 of the transducer elements will not be mixed. In FIG. 1 a wire 40 is shown extending back through each transducer element 10 from its corresponding electrode ring 12 to the free end of the element, the wire being electrically connected to a bayonet terminal or pin 41 of the plug-in type. The two terminals associated with the wires 40 and the pair of transducer elements 10 are carried in an insulative plug 42 which is in turn inserted within the cartridge case 15, thereby forming a complete cartridge assembly. Such an assembly is shown in FIG. 2 as being carried by a phonograph arm 43 with the bayonet terminals 41 plugged into sockets 44 from which the signals are led to a suitable amplifier. The cartridge unit 13 in FIG. 2 is also shown as typically firmly connected to the phonograph arm 43 as by the bracket 45 and screws 46 joining the bracket supporting the cartridge unit to the phonograph pickup arm 43.

I claim:

1. A transducer for simultaneously producing two-channel electrical signals in response to movement of tracking means in a two-channel recording groove, said transducer comprising a pair of twist responsive transducer elements having twist axes, each element being operable to produce an electrical signal in response to element twisting about the element twist axis, and actuating means connected with both said elements for twisting one element without substantially twisting the other element in response to tracking means movement variation in one channel of the groove and for twisting said other element without substantially twisting said one element in response to tracking means movement variation in the other channel of the groove, said elements comprising generally continuous and cylindrical bodies of piezoelectric material having surface electrodes extending lengthwise of and about the axes thereof so that twisting of the bodies about said axes results in voltage changes at said electrodes.

2. A transducer for simultaneously producing two-channel electrical signals in response to movement of tracking means in a two-channel recording groove, said transducer comprising a pair of twist responsive transducer elements having twist axes, each element being operable to produce an electrical signal in response to element twisting about the element twist axis, and actuating means connected with both said elements for twisting one element without substantially twisting the other element in response to tracking means movement variation in one channel of the groove and for twisting said other element without substantially twisting said one element in response to tracking means movement variation in the other channel of the groove, said elements having axially spaced fixed and free portions and said actuating means being connected to said free portions, each of said elements comprising a lengthwise continuous cylindrical body of piezoelectric material and a pair of spaced electrodes extending longitudinally on a surface of said body and winding about the axis thereof so that twisting of the body about said axis results in a voltage change across said electrodes.

3. A transducer for simultaneously producing two-channel electrical signals in response to movement of tracking means in a two-channel recording groove, said transducer comprising a pair of twist responsive transducer elements having twist axes, each element being op-

erable to produce an electrical signal in response to element twisting about the element twist axis, and actuating means connected with both said elements for twisting one element without substantially twisting the other element in response to tracking means movement variation in one channel of the groove and for twisting said other element without substantially twisting said one element in response to tracking means movement variation in the other channel of the groove, said elements having axially spaced fixed and free portions and said actuating means being connected to said free portions, said actuating means having a pair of arms respectively projecting away from the element axes whereby said arms twist said elements about said axes in response to movement of said tracking means in directions having components normal to radii from the element axes, each of said elements comprising a lengthwise continuous cylindrical body of piezoelectric material and a pair of spaced electrodes extending longitudinally on a surface of said body and winding about the axis thereof so that twisting of the body about said axis results in a voltage change across said electrodes.

4. The combination, comprising a pair of like twist responsive transducer elements having substantially parallel twist axes, each of said elements being operable to produce an electrical signal in response to element twisting about said twist axes, said transducer elements having axially spaced apart fixed and free end portions, an assembly mounting said elements with said free end portions thereof laterally spaced apart, said assembly including a housing for said elements, and actuating means including a pivotless yoke connected with said element free end portions for twisting one element without substantially twisting the other element in response to tracking means movement variation in one channel of the groove and for twisting said other element without substantially twisting said one element in response to tracking means movement variation in the other channel of the groove, each of said

elements comprising a lengthwise continuous cylindrical body of piezoelectric material and a pair of spaced electrodes extending longitudinally on a surface of said body and winding about the axis thereof so that twisting of the body about said axis results in a voltage change across said electrodes.

5. The invention as defined in claim 4 including a phonograph pickup arm detachably supporting said assembly, and electrical leads carried by said arm and electrically connected with at least one electrode on each element.

6. The invention as defined in claim 4 in which said yoke includes a pair of arms respectively projecting away from said element axes and converging toward a central plane equidistant from said element axes.

7. The invention as defined in claim 6 in which said arms are convergent at a location radially equidistant from extensions of said element axes beyond said element free ends.

8. The invention as defined in claim 4 in which said elements comprise tubes of piezoelectric ceramic material.

9. The invention as defined in claim 8 in which said electrodes extend in helices about said tubular ceramic material.

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