Jan. 3, 1961 P. B. VANDERLYN 2,967,214

MOVING COIL ELECTRO-MECHANICAL TRANSDUCERS

Filed Sept. 18, 1956 2 Sheets-Sheet 1

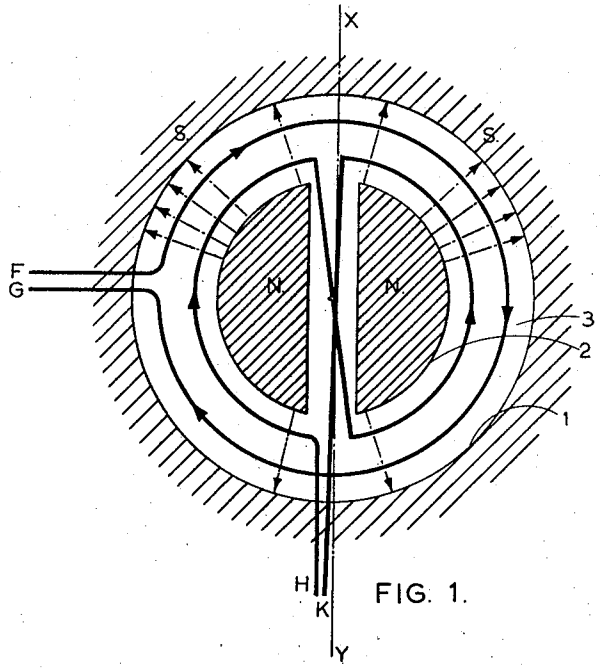

FIG. 1.

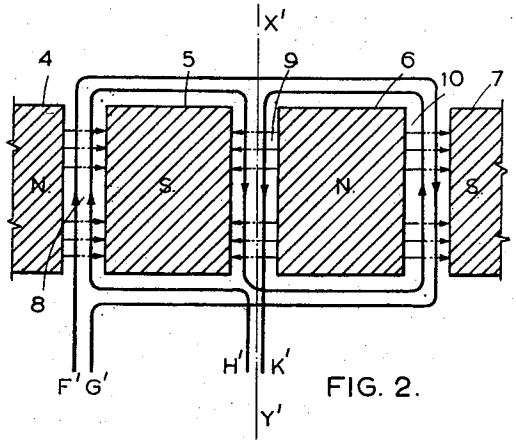

FIG. 2.

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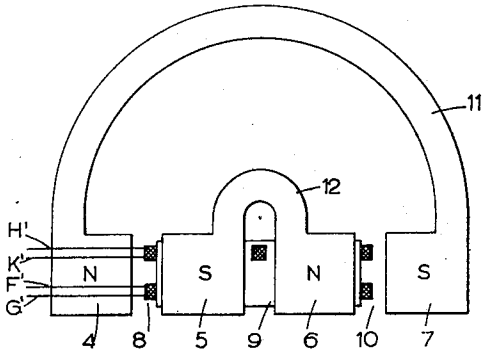

FIG. 3

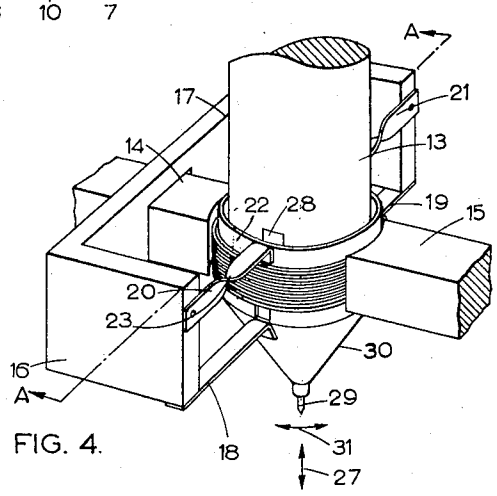

FIG. 4.

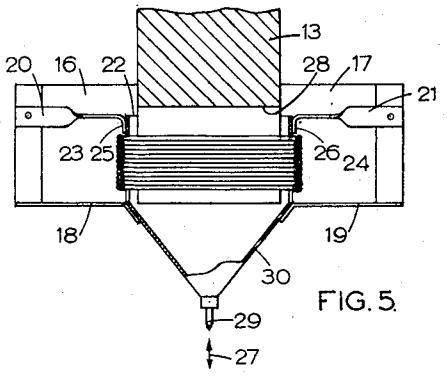

FIG. 5.

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MOVING COIL ELECTRO-MECHANICAL TRANSDUCERS

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11 Claims. (Cl. 179—100.41)

This invention relates to moving coil electro-mechanical transducers, and in particular to transducers of this type suitable for use in the production or reproduction of grooved sound records having either or both of two different types of groove modulation.

In a binaural sound transmission system such as that described and illustrated in United States Patent Number 2,093,540 separate channels are required for the transmission of two complementary signals to spaced loudspeakers whereby a listener is enabled to obtain positional impressions corresponding to the location of the original sounds picked-up, transmitted and reproduced by said system. Various methods are described in said specification whereby said complementary signals can be recorded for subsequent reproduction, and according to one of the methods described said complementary signals are recorded in a single groove which is cut in such a manner that said complementary signals are caused to modulate said groove in different vibrational modes. For example one of said signals may be recorded as a "hill-and-dale" cut whilst the other signal is recorded as a lateral cut, so that the respective recording axes are mutually at right angles, the "hill-and-dale" recording axis being substantially perpendicular to the surface of the record, and the lateral recording axis being substantially parallel to said surface. Alternatively, the two recording axes may each lie at an angle to said surface, and, conveniently, said angle may be about 45 degrees.

In the production of a grooved sound record having a complex cut as described above, it is necessary to provide a special type of electro-mechanical transducer by means of which two substantially independent motions are imparted to the cutting stylus. Conversely, reproduction from such a sound record requires a similar type of transducer from which two substantially independent electrical outputs can be obtained in response to the different modes of vibrations of the reproducing stylus.

The object of the present invention is to provide an improved electro-mechanical transducer capable of producing different modes of vibration in response to independent electrical signals fed thereto.

It is also an object of the present invention to provide an improved electro-mechanical transducer capable of delivering substantially independent electrical outputs in response to different modes of mechanical vibration imparted thereto.

According to the invention, a moving coil electro-mechanical transducer comprises a magnetic circuit having an air-gap with means for establishing a steady magnetic flux in said air-gap, and first and second coils carried by a single support which is so mounted that said coils are capable of movement within said air gap in two different vibrational modes, the arrangement being such that said first coil is responsive to or produces one mode of vibration of said support substantially independently of said second coil, and said second coil is responsive to or produces another mode of vibration of said support substantially independently of said first coil.

The invention also provides a moving coil electro-mechanical transducer for cutting sound records having either or both of two different types of groove modulation, said

transducer comprising a magnetic circuit having an air gap with means for establishing a steady magnetic flux in said air-gap, first and second coils carried by a single support which is so mounted that said coils are capable of movement within said air gap in two different vibrational modes, and a cutting stylus coupled to said support, the arrangement being such that when an alternating electric signal current is fed only to said first coil, one mode of vibration of said stylus is produced, and when another alternating electric signal current is fed only to said second coil, another mode of vibration of said stylus is produced.

Furthermore, the invention provides a moving coil electro-mechanical transducer for reproducing grooved sound records having either or both of two different types of grooves modulation, said transducer comprising a magnetic circuit having an air-gap with means for establishing a steady magnetic flux in said air-gap, first and second coils carried by a single support which is so mounted that said coils are capable of movement within said air gap in two different vibrational modes, and a reproducing stylus coupled to said support, the arrangement being such that one mode of vibration of said reproducing stylus produces a corresponding electrical output from said first coil but substantially no electrical output from said second coil, and another mode of vibration of said reproducing stylus produces a corresponding electrical output from said second coil but substantially no electrical output from said first coil.

In order that the invention may be clearly understood and readily carried into effect, embodiments thereof will now be described by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram of one embodiment of the invention,

Figure 2 is a schematic diagram of another embodiment of the invention,

Figure 3 illustrates schematically a magnetic circuit arrangement suitable for use with the embodiment of Figure 2,

Figure 4 is a perspective view of the operative portions of a practical embodiment of a transducer according to the invention, and

Figure 5 is a vertical section in a plane containing the line A—A of Figure 4 viewed in the direction of the arrows.

In Figure 1 a magnetic circuit, which may incorporate a permanent or electro-magnet, has an apertured pole portion 1 and a central pole portion 2 arranged to form an annular air gap 3, the pole portions 1 and 2 having opposite polarities denoted S and N respectively so as to provide means for establishing a steady flux in the air gap 3, the lines of which are substantially radial as indicated by the arrows. A single support (not shown) which may be a thin cylindrical tube, is mounted in the air gap 3 so as to be capable of movement in two different vibrational modes, namely about the axis X—Y extending diametrically across the air gap 3, and also bodily along the axis of the air gap 3 at right-angles to the axis X—Y. Said support has two coils FG and HK wound thereon, the coil FG being wound in a non-reversing manner so as to encircle the central pole portion 2, whilst the coil HK is wound in a "figure of 8" pattern the crossover of which is located substantially along the axis X—Y in a transverse hole or slot in the central pole portion 2. It is to be understood that the coils FG and HK will in practice, each comprise a plurality of turns following the single turns illustrated in Figure 1.

When alternating electric signal currents are fed to the coils FG and HK the instantaneous directions of current flow will be as shown by the arrow heads, and consequently the coil FG will cause the aforementioned sup-

port to be vibrated bodily in a direction perpendicular to the transverse plane containing axis X—Y so that a cutting stylus (not shown) coupled to said support can be motivated to perform "hill-and-dale" cutting movements in the surface of a recording medium such as a disc. However, the alternating signal current fed to coil HK will not result in any bodily movement of said support because the configuration of coil HK is such that the tendency for the portion of coil HK to one side of axis X—Y to move bodily in one direction is balanced by an equal tendency for the other half of the coil HK to move bodily in the opposite direction. Thus a torque is produced which results in vibration of said support about the axis X—Y whereby said cutting stylus can be motivated to execute lateral cutting movements.

By virtue of the astatic property of coil HK produced by its "figure of 8" configuration, there is substantially no electro-magnetic coup ing between the coils FG and HK, and if these coils have a suitably low impedance and/or suitable screening therebetween electrostatic coupling can be reduced to negligible proportions. Thus a transducer embodying the principles described with reference to Figure 1 is capable of being energised by separate signal inputs to produce simultaneous vibrations of said support in two different modes, and said cutting stylus coupled to said support can be motivated to produce in the surface of a recording disc a complex cut representative, for example, of the signa's derived from the two channels of a binaural transmission system.

A transducer embodying the principles of the invention can also be employed to reproduce a sound record having a single groove with a complex cut. Thus a reproducing stylus coupled to said support and vibrated by said groove will impart to said support vibrations having components which cause bodily movements of said support in a direction perpendicular to the transverse plane containing the axis X—Y and components which cause rotary movements of said support about the axis X—Y. Said bodily movements will result in the induction of corresponding electric currents in the coil FG but the sum of the currents induced in the opposed halves of coil HK due to bodily movements thereof will be substantially zero. Conversely rotary movements of said support about the axis X—Y will result in the induction of corresponding electric currents in the coil HK, and substantially no net output from coil FG. Thus a transducer according ot the invention is capable of delivering substantially independent outputs from the coils FG and HK in response to the different modes of vibration of said support.

In the schematic arrangement illustrated in Figure 2, the coils F'G' and H'K' are similar to the coils FG and HK of Figure 1 except that the windings are rectangular instead of circular, and thus the single support (not shown) for said coils will have a corresponding shape. The magnetic circuit comprises four pole portions 4, 5, 6 and 7 so polarised that adjacent pole pieces have opposite polarities as indicated in the drawing by the letters N and S, the pole portions being arranged to form an air gap having spaced parallel portions 8, 9 and 10 which are symmetrically disposed with reference to an axis X'—Y' passing through gap portion 9. As shown in Figure 3 the pole portions 4 and 7 may be attached to or may form part of a U-shaped member 11 of ferro-magnetic material, and similarly the pole portions 5 and 6 may be attached to or may form part of a second smaller U-shaped member 12 of ferro-magnetic material. In this arrangement one of said U-shaped members 11 or 12 may be a permanent- or electro-magnet and the other U-shaped member may be of magnetically soft material such as soft iron. Alternatively both said U-shaped members 11 and 12 may be permanent- or electro-magnets.

A steady magnetic flux is established in the air gap portions 8 and 10 as indicated by the arrows between the pole portions, and in addition a steady magnetic flux will be established in the gap portion 9 but the strength thereof will depend on the form of the magnetic circuit. If the U-shaped member 12 is made of magnetically soft material, the arrangement may be such that only a leakage flux of relatively low density is established in gap portion 9. Coil F'G' is wound in a non-reversing manner so as to encircle pole portions 5 and 6, and coil H'K' has a "figure of 8" configuration with parts of the winding disposed in each of the air gap portions 8, 9 and 10, the cross-over being positioned in the air-gap portion 9. As indicated by the instantaneous directions of alternating electric signal currents fed to or induced in the coils, the coil F'G' produces or is responsive to rotary movements of said support about the axis X'—Y' whilst coil H'K' produces or is responsive to bodily movements of said support in a direction perpendicular to the transverse plane containing axis X'—Y'.

One practical form of transducer according to the invention suitable for cutting or reproducing sound records having either or both of two different types of groove modulation, for example, hill-and-dale and lateral cut, is illustrated in Figures 4 and 5. The magnetic circuit is similar in principle to that shown in Figure 1 and comprises a central pole portion 13 of one polarity and two co-operating pole portions 14 and 15 both having the same polarity opposite to that of pole portion 13, the inner ends of portions 14 and 15 being cylindrically concave so that the three pole portions 13, 14 and 15 cooperate to provide an air gap having two opposite portions of part-annular form. It is to be understood that the pole-portions 13, 14 and 15 are fixedly mounted in any suitable manner in order to ensure that the aforementioned air-gap portions are accurately maintained. Brackets 16 and 17 of non-magnetic material are secured to pole portion 14 so as to extend on opposite sides of the pole portion 13, and a lightweight support 22 also of non-magnetic material is joined to the brackets 16 and 17 by means of two pairs of spring strips 18, 19 and 20, 21 which may be made of Phosphor-bronze. Strips 18 and 19 are flat and they are arranged with their p'anes horizontal, the outer end of strip 18 being secured to the underside of bracket 16, and the outer end of strip 19 being similarly secured to bracket 17. The inner ends of strips 18 and 19 are secured in any suitable manner to diametrically opposite points at the lower end of support 22. Each of the strips 20 and 21 is twisted through a right angle intermediate its ends as indicated at 23 and 24. The outer portion of strip 20 is arranged vertically and is attached to bracket 16 whilst the horizontal inner portion of strip 20 has a downturned end 25 which is secured in any suitable manner to the upper end of support 22 at a point in vertical alignment with the point of attachment of the strip 18. Similarly the outer portion of strip 21 is attached to bracket 17 and the downturned end 26 of strip 21 is secured to support 22 at a point diametrically opposite the point of attachment of the end 25 of strip 20. Thus the strips 18—21 in combination with the brackets 16 and 17 provide means whereby the support 22 is mounted so as to be capable of vibrational movement in the direction of the longitudinal axis of pole portion 13 as indicated by the arrow 27, and also rotary vibrational movement about a transverse axis in the plane containing the vertical outer portions of strips 20 and 21. Two coils are carried by the support 22, the first coil corresponding to the coil HK of Figure 1 being wound in a "figure-of-8" pattern with the cross-over thereof positioned in a transverse hole or slot 28 in the pole portion 13 as clearly shown in Figure 5. The second coil, corresponding to the coil FG of Figure 1, is wound in a non-reversing manner over the first coil. A stylus 29 is coupled to support 22 and for this purpose the support 22 comprises an inverted conical portion 30 to the apex of which the stylus 29 is secured.

When the stylus 29 is vibrated in the direction of arrow 27, the corresponding movement of support 22 and the coils carried thereby in the air gap portions of the

magnetic circuit will result in the induction of a corresponding electrical signal in said second coil but substantially no response from said first coil. However when the stylus 29 is vibrated laterally in the direction indicated by arrow 31 (Figure 4), the resulting rotary vibrational movement of the support 22 will give rise to the induction of a corresponding electrical signal in the second (figure-of-8) coil but there will be substantially no response from said first coil.

It will be appreciated that if the transducer of Figures 4 and 5 (with any appropriate modifications) is used as a record cutter, an alternating electric signal input to said second (figure-of-8) coil will produce vibrational movement of the stylus 29 in the direction of arrow 27, and a similar input to said first coil will cause lateral vibrations of the stylus 29 in the direction of arrow 31.

The coils FG and F'G' are each wound in a "non-reversing manner" which term is to be understood to mean a coil which is so wound, effectively about an axis, that if said coil were energized by direct current the current flow in all portions of said coil about said axis would be in one and the same direction. However, the coils HK and H'K' are each wound in a "reversing manner" which term is to be understood to mean a coil which is so wound, effectively about an axis, that if said coil were energized by direct current the current flow about said axis would be in one direction in a portion or portions of said coil lying to one side of a plane containing said axis, and would be in the opposite direction in a portion or portions of said coil lying to the other side of said plane.

A transducer according to the invention has the advantage that the number of movable components thereof is reduced to a minimum, since all that is required is a single support for the two coils, and a cutting or reproducing stylus coupled to said support. Ideally said support would be so mounted as to prevent movements of said support other than the required rotational and bodily movements thereof, and in this manner undesired mechanical interference between the two modes of vibration can be minimised.

When required for the reproduction of grooved sound records, a transducer embodying the principles of the present invention is capable of reproducing records having only hill-and-hale groove modulation or only lateral groove modulation. In addition said transducer is capable of delivering directly from the two coils substantially independent output signals from a so-called complex cut record in which a single groove has both hill-and-dale and lateral modulations.

What I claim is:

1. A moving coil electro-mechanical transducer comprising a magnetic circuit having an air gap across which a steady magnetic flux is established, first and second coils one of which is wound in a non-reversing manner, and means mounting said coils in co-operative relation with said air gap so that said first coil is capable of effecting an electro-mechanical transducing operation in respect of vibrational movements in one direction, and said second coil is capable of effecting an electro-mechanical transducing operation in respect of vibrational movements in another direction.

2. A moving coil electro-mechanical transducer according to claim 1 wherein said coil wound in a reversing manner has its turns arranged in a figure-of-8 pattern.

3. A moving coil electro-mechanical transducer according to claim 2, wherein said magnetic circuit comprises a central pole portion of one polarity and at least one co-operating pole-portion of opposite polarity with said pole-portions arranged to provide therebetween an air-gap of annular form, said mounting means serving to position said coils to surround said central pole portion with substantially inactive portions of said figure-of-8 coil constituted by the crossover thereof disposed in a transverse slot in said central pole portion.

4. A moving coil electro-mechanical transducer according to claim 2 wherein said magnetic circuit comprises four pole portions arranged to provide therebetween three substantially parallel air-gap portions, the pairs of adjacent pole portions defining said air-gap portions being of opposite polarity, and said mounting means serving to position said coils to surround the two inner pole portions with the cross-over of said figure-of-8 coil positioned in the air-gap portion between said two inner pole portions, and with active portions of said coils disposed in said air-gap portions.

5. A moving coil electro-mechanical transducer according to claim 4 wherein said magnetic circuit comprises a pair of U-shaped magnetic members.

6. A moving coil electro-mechanical transducer comprising a magnetic circuit having an air gap across which a steady magnetic flux is established, and first and second coils one of which is wound in a non-reversing manner and the other of which is wound in a reversing manner, said coils having active portions effectively disposed about a common axis, and means mounting said coils so as to be capable of movements together both translationally and angularly in said air gap, said translational movements being substantially in the direction of said common axis, and said angular movements being about an axis substantially at right angles to and substantially intersecting said said common axis.

7. A moving coil electro-mechanical transducer according to claim 6 wherein said coil wound in a reversing manner has its turns arranged in a figure-of-8 pattern.

8. A moving coil electro-mechanical transducer for cutting a grooved sound record having either or both of two different directions of groove modulation, said transducer comprising a magnetic circuit having an air gap across which a steady magnetic flux is established, and first and second coils one of which is wound in a non-reversing manner and the other of which is wound in a reversing manner, said coils having active portions effectively disposed about a common axis, means mounting said coils so as to be capable of movements together both translationally and angularly in said air gap, said translational movements being substantially in the direction of said common axis, and said angular movements being about an axis substantially at right angles to and substantially intersecting said common axis, and means coupled to said coils for supporting a cutting stylus.

9. A moving coil electro-mechanical transducer according to claim 8 wherein said coil wound in a reversing manner has its turns arranged in a figure-of-8 pattern.

10. A moving coil electro-mechanical transducer for reproducing a grooved sound recording having either or both of two different directions of groove modulation, said transducer comprising a magnetic circuit having an air gap across which a steady magnetic flux is established, and first and second coils one of which is wound in a non-reversing manner and the other of which is wound in a reversing manner, said coils having active portions effectively disposed about a common axis, means mounting said coils so as to be capable of movements together both translationally and angularly in said air gap, said translational movements being substantially in the direction of said common axis, and said angular movements being about an axis substantially at right angles to and substantially intersecting said common axis, and means coupled to said coils for supporting a reproducing stylus.

11. A moving coil electro-mechanical transducer according to claim 10 wherein said coil wound in a reversing manner has its turns arranged in a figure-of-8 pattern.

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