

PATENT SPECIFICATION

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DRAWINGS ATTACHED

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(54) ELECTROMECHANICAL TRANSDUCERS

(71) We, FONOFILM INDUSTRI A/S, a Danish Company, of 5, Trommesalen, Copenhagen, Denmark, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to electromechanical transducers, for example electromagnetically operating transducers embodied in pick-up assemblies for the playing of stereophonic phonograph records.

Such a pick-up assembly may have a magnetic structure defining an airgap and comprising four magnetic legs, each surrounded by an individual coil, together with permanent magnetic means for producing a magnetic field in said airgap in which a stylus-carrying armature is pivotally mounted. By arranging the magnetic legs in two pairs defining respective planes perpendicular to each other the signals produced by movements of the stylus can be resolved into two components corresponding respectively to the two recorded tracks of a stereophonic record.

In one such pick-up assembly the armature itself is constituted by a permanent magnet. However, the requirements as to reproduction of the signals at the upper end of the audio frequency spectrum have lead to the development of a pick-up assembly in which the effective stylus mass has been reduced by using a permanent magnet placed outside the oscillating stylus system for producing the magnetising force, so that the armature may be constituted by a light tube of magnetically conducting material such as soft iron. The armature is coupled magnetically in series with the coil-carrying legs, so that signal-producing flux changes are produced by alterations of the overall reluctance of the magnetic circuit caused by movements of the armature.

According to the present invention there is provided an electromechanical transducer device, comprising a pair of permanent

magnet portions arranged to provide respective components of magnetic flux that are similarly directed in an airgap between the permanent magnet portions, yoke means providing a magnetically conductive connection between respective pole faces, of like polarity, of the permanent magnet portions, electrical output coil means surrounding portions of the yoke means for delivering electrical output signals induced by flux changes produced in the yoke means, and an armature made of magnetic material mounded adjacent to the permanent magnet portions so as to act thereon as a magnetic shunt taking up the said respective components of magnetic flux, the armature being capable of movement with respect to the permanent magnet portions so as to alter, relatively to one another, the respective shunting effects of the armature on the two permanent magnet portions and thereby produce said flux changes.

Such a device may be embodied in a monophonic pick-up assembly. A stereophonic pick-up assembly embodying the invention further comprises a second pair of permanent magnet portions arranged to provide in the said airgap, which extends therebetween, respective components of magnetic flux that are directed similarly to those mentioned in the last preceding paragraph, the magnet portions of the second pair being spaced apart in a direction transverse to that in which the magnet portions of the pair mentioned in the last preceding paragraph are spaced apart, the said yoke means providing a magnetically conductive connection between respective pole faces, of like polarity, of the permanent magnet portions of the second pair, and there being second electrical output coil means surrounding further portions of the yoke means for delivering second-channel electrical output signals induced by flux changes produced in the yoke means, the said armature being also adjacent to the permanent magnet portions of the second pair so as to act thereon as a magnetic shunt and being capable of movement with respect to

the second pair of permanent magnet portions so as to alter, relatively to one another, the respective shunting effects of the armature on the permanent magnet portions and thereby produce said flux changes that induce the said second-channel electrical output signals when the assembly is in use, the said further portions not forming part of the magnetically conductive connection specified in the last preceding paragraph, and the portions specified in that last preceding paragraph not forming part of the said magnetically conductive connection between the permanent magnet portions of the second pair. The permanent magnet portions, yoke means, and armature, are preferably perfectly symmetrical about a central longitudinal axis of the armature when in a rest position.

The said permanent magnet portions may be constituted by respective bar magnets. Alternatively they may be constituted by respective integral parts of a hollow cylindrical body which is made of magnetisable ceramic material and is permanently magnetised parallel to its central axis and surrounds the said airgap.

Reference will now be made, by way of example, to the accompanying drawings, in which:—

Figure 1 shows a central longitudinal section (in a vertical plane) through a pick-up assembly embodying the present invention,

Figure 2 is a partial section in the plane corresponding to a line II—II of Figure 1.

Figure 3 shows a perspective view of parts of the assembly, seen from underneath and forward of a front end (the left-hand end in Figure 1) of the assembly, and

Figure 4 is a schematic diagram of parts of the assembly, for illustrating its operation.

The pick-up assembly comprises a housing member 1 cast in a suitable plastics material. At a rear end (the righthand end in Fig. 1) the housing member has a recess 7 in which is mounted a contact support 2 provided with four connection pins 3, of which only two are seen in Fig. 1. At the front end of the housing member is provided a replaceable stylus assembly comprising a cast plastics support body 4 having a projecting hollow guide pin 5, of non-circular cross-section, which is engaged and retained frictionally within a recess 6 formed in the housing member 1 and having the same cross-section as the pin 5.

Between a lower part of the recess 7 and the front face of the housing member 1 is provided a through-going passageway with a rear portion 8, of substantially square cross-section, and a front portion 9 the cross-section of which, as indicated in Fig. 2, comprises a middle circle and four peripheral circles tangential to the middle circle and symmetrically disposed about the centre of the middle circle.

The said through-going passageway 8, 9 extends obliquely downwards from rear to front of the housing member 1, and serves as accommodation for a magnetic structure which comprises four thin cylindrical rods 10 of permalloy, front portions of which are disposed respectively in the cylindrical peripheral portions of the passageway portion 9 and which extend rearwardly through the passageway portion 8. The rear ends of the rods 10 are attached to and interconnected magnetically by a cross-piece 11, for example a cruciform cross-piece, also made of permalloy, so as to serve as magnetic yoke means. About each rod 10 is disposed a coil 12 which is mounted in the passageway portion 8, and the coils of each diametrically opposed pair are connected to one another in series between two of the pins 3 by means of leads 13. Abutting against the front ends of the rods 10, in extension thereof, is mounted an annular permanent magnet 14, of hollow cylindrical form, which is magnetised in an axial direction and consists of a ceramic magnetically-anisotropic material. The magnet 14 is disposed in an enlarged part of the passageway portion 9, at the front of the housing member 1.

In the lower portion of the support body 4 of the stylus assembly is formed an obliquely inclined cylindrical through-going passageway 15 opening at its front end in an under face of the body 4 and forming an extension of the central cylindrical part of the passageway 9 in the housing member 1. In this passageway 15 is secured a tube 16 of a non-magnetic material, for instance aluminium, which projects from the support body 4 and, when the stylus assembly is fitted, enters the cylindrical central part of the passageway 9.

Within the tube 16 a tubular soft iron armature 17 is mounted by means of a ring of resilient material 18, for instance of rubber or neoprene, to be freely pivotable in all directions about a point disposed in or adjacent to the centre of the ring. The armature 17 is longer than the annular magnet 14 and is disposed co-axially and symmetrically with respect to that magnet. To the armature is attached one end of a tubular, thin-walled aluminium stylus arm 19 extending through the passageway 15. The free end of the stylus arm 19 projecting outwardly of the support body 4 is flattened and carries a stylus 20.

On an under face of the housing member 1 is mounted a magnetic screen 21 which extends upwardly along the front face of the housing member, between the housing member and the support body 4 of the stylus assembly.

To illustrate the operation of the pick-up assembly, Fig. 4 presents a schematic view of one half of the electromagnetic system cor-

responding to one sound channel of a stereo recording. The oscillation point of the armature is here designated 22. The anisotropic ceramic annular magnet 14 shows great reluctance in all directions perpendicular to the axial direction and is therefore magnetically equivalent, so far as this half of the electromagnetic system is concerned, to two permanent bar magnets disposed at the end, and in extension, of respective rods 10 of a diametrically opposed pair, as indicated in Fig. 4, in which the said magnets are presumed to have their north pole faces abutting against the rod ends. Assuming that two magnets to be of equal strength, the magnetically conductive connecting yoke formed by the rods 10 and the cross-piece 11 will have the same magnetic potential at its two end faces, when the armature 17 is in the illustrated rest position, so that no flux will pass along the path provided by the connecting yoke. A relatively high flux will pass from the north pole of each magnet through the armature to the south pole of the magnet, as indicated by the dotted lines, and as the armature has a much lower reluctance than the ceramic magnets, and the spaces between the armature and the magnets in actual practice are very small, this flux may with some justification be described as a short circuit flux.

If the armature as a result of the stylus movement oscillates upwards in the plane of the paper (or effectively in that plane) about the point 22 it will approach the upper magnet and thereby reduce the reluctance in the short circuit flux path for said magnet and simultaneously move away from the lower magnet, with the result that the short circuit flux thereof meets increased reluctance. In other words, the upper short circuit flux will be increased and the lower short circuit flux will be reduced. On account of the relatively high inherent reluctance of the magnets this will cause the magnetic potential at the north pole of the upper magnet to be reduced, while the magnetic potential at the north pole of the lower magnet will be increased. Thus a magnetic potential difference is created between the two ends of the magnetic conductor path provided by the yoke 10, 11, 10 in response to the armature movement, which results in an increasing flux in that conductor path, inducing in the coil windings 12 electrical voltages. Thus the oscillations of the armature in the plane of the rods 10, as the stylus tracks a stereophonic recording groove, produce electrical signals, in the coils 12, which together represent the sensed sound channel signal.

Armature oscillations resulting from the other sound channel are effectively in a plane perpendicular to the plane of Fig. 4 and are converted in the same manner to electrical voltages in the other two coils of the electro-

magnetic system, which coils surround the two rods 10 whose axes lie in that perpendicular plane.

The magnetic yoke components 10 and 11 carry only the effective signal flux, which changes direction in response to the armature oscillations, and the rods 10 can therefore be made very thin without risking deviation of the magnetic point of operation from the rectilinear part of the magnetisation curve. This thinness of the rods 10 permits the use of signal output coils 12 having low resistance and capacity.

Such a pick-up assembly can be produced fairly easily and cheaply, with good sound reproduction characteristics particularly at the upper end of the audio frequency range.

The stereo pick-up assembly shown in Figs. 1 to 3 of the drawings can be changed into a mono pick-up assembly merely by removing one opposed pair of the rods 10 and rotating the remaining pair through an angle of approximately 45°, about the central axis of symmetry of the magnetic structure, with respect to the stylus assembly.

In the assembly illustrated the armature 17 is constituted by a thin-walled tube of soft iron, by which the effective inertia of the oscillating stylus arrangement is minimised. It is possible, however, to replace the soft iron armature by a permanent magnet, which may be tubular or rod-shaped and which is poled oppositely to the fixed ceramic magnet, so that it increases the short circuit flux. In this way the sensitivity of the pick-up assembly can be increased to some degree.

It will be understood that it would be possible to modify the structure in various other respects. Thus, for example, the rods 10 may be square or rectangular in cross-section, instead of circular, and the armature may have other cross-sectional shapes.

WHAT WE CLAIM IS:—

1. An electromechanical transducer device, comprising a pair of permanent magnet portions arranged to provide respective components of magnetic flux that are similarly directed in an airgap between the permanent magnet portions, yoke means providing a magnetically conductive connection between respective pole faces, of like polarity, of the permanent magnet portions, electrical output coil means surrounding portions of the yoke means for delivering electrical output signals induced by flux changes produced in the yoke means, and an armature made of magnetic material mounted adjacent to the permanent magnet portions so as to act thereon as a magnetic shunt taking up the said respective components of magnetic flux, the armature being capable of movement with respect to the permanent magnet portions so as to alter, relatively to one another, the respective shunting effects of the armature on the two per-

responding to one sound channel of a stereo recording. The oscillation point of the armature is here designated 22. The anisotropic ceramic annular magnet 14 shows great reluctance in all directions perpendicular to the axial direction and is therefore magnetically equivalent, so far as this half of the electromagnetic system is concerned, to two permanent bar magnets disposed at the end, and in extension, of respective rods 10 of a diametrically opposed pair, as indicated in Fig. 4, in which the said magnets are presumed to have their north pole faces abutting against the rod ends. Assuming that two magnets to be of equal strength, the magnetically conductive connecting yoke formed by the rods 10 and the cross-piece 11 will have the same magnetic potential at its two end faces, when the armature 17 is in the illustrated rest position, so that no flux will pass along the path provided by the connecting yoke. A relatively high flux will pass from the north pole of each magnet through the armature to the south pole of the magnet, as indicated by the dotted lines, and as the armature has a much lower reluctance than the ceramic magnets, and the spaces between the armature and the magnets in actual practice are very small, this flux may with some justification be described as a short circuit flux.

If the armature as a result of the stylus movement oscillates upwards in the plane of the paper (or effectively in that plane) about the point 22 it will approach the upper magnet and thereby reduce the reluctance in the short circuit flux path for said magnet and simultaneously move away from the lower magnet, with the result that the short circuit flux thereof meets increased reluctance. In other words, the upper short circuit flux will be increased and the lower short circuit flux will be reduced. On account of the relatively high inherent reluctance of the magnets this will cause the magnetic potential at the north pole of the upper magnet to be reduced, while the magnetic potential at the north pole of the lower magnet will be increased. Thus a magnetic potential difference is created between the two ends of the magnetic conductor path provided by the yoke 10, 11, 10 in response to the armature movement, which results in an increasing flux in that conductor path, inducing in the coil windings 12 electrical voltages. Thus the oscillations of the armature in the plane of the rods 10, as the stylus tracks a stereophonic recording groove, produce electrical signals, in the coils 12, which together represent the sensed sound channel signal.

Armature oscillations resulting from the other sound channel are effectively in a plane perpendicular to the plane of Fig. 4 and are converted in the same manner to electrical voltages in the other two coils of the electro-

magnetic system, which coils surround the two rods 10 whose axes lie in that perpendicular plane.

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Such a pick-up assembly can be produced fairly easily and cheaply, with good sound reproduction characteristics particularly at the upper end of the audio frequency range.

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In the assembly illustrated the armature 17 is constituted by a thin-walled tube of soft iron, by which the effective inertia of the oscillating stylus arrangement is minimised. It is possible, however, to replace the soft iron armature by a permanent magnet, which may be tubular or rod-shaped and which is poled oppositely to the fixed ceramic magnet, so that it increases the short circuit flux. In this way the sensitivity of the pick-up assembly can be increased to some degree.

It will be understood that it would be possible to modify the structure in various other respects. Thus, for example, the rods 10 may be square or rectangular in cross-section, instead of circular, and the armature may have other cross-sectional shapes.

WHAT WE CLAIM IS:—

1. An electromechanical transducer device, comprising a pair of permanent magnet portions arranged to provide respective components of magnetic flux that are similarly directed in an airgap between the permanent magnet portions, yoke means providing a magnetically conductive connection between respective pole faces, of like polarity, of the permanent magnet portions, electrical output coil means surrounding portions of the yoke means for delivering electrical output signals induced by flux changes produced in the yoke means, and an armature made of magnetic material mounted adjacent to the permanent magnet portions so as to act thereon as a magnetic shunt taking up the said respective components of magnetic flux, the armature being capable of movement with respect to the permanent magnet portions so as to alter, relatively to one another, the respective shunting effects of the armature on the two per-





manent magnet portions and thereby produce said flux changes.

2. A device as claimed in Claim 1, further comprising a second pair of permanent magnet portions arranged to provide in the said airgap, which extends therebetween, respective components of magnetic flux that are directed similarly to those specified in claim 1, the magnet portions of the second pair being spaced apart in a direction transverse to that in which the magnet portions of the pair specified in claim 1 are spaced apart, the said yoke means providing a magnetically conductive connection between respective pole faces, of like polarity, of the permanent magnet portions of the second pair, and there being second electrical output coil means surrounding further portions of the yoke means for delivering second-channel electrical output signals induced by flux changes produced in the yoke means, the said armature being also adjacent to the permanent magnet portions of the second pair so as to act thereon as a magnetic shunt and being capable of movement with respect to the second pair of permanent magnet portions so as to alter, relatively to one another, the respective shunting effects of the armature on those permanent magnet portions and thereby produce said flux changes that induce the said second-channel electrical output signals when the device is in use, the said further portions not forming part of the magnetically conductive connection specified in Claim 1, and those portions of the yoke means that are specified in Claim 1 not forming part of the said magnetically conductive connection between the permanent magnet portions of the second pair.

3. A device as claimed in Claim 1 or 2, wherein the said armature is mounted so as to have a rest position extending along an axis about which the said permanent magnet portions are substantially symmetrically distributed and so as to be capable of pivotal oscillatory movement with respect to the said permanent magnet portions.

4. A device as claimed in Claim 3, wherein the armature is mounted so as to be capable of such pivotal movement in all directions about a pivot point which is on the said axis but is spaced therealong from the mid-point, as measured along the axis, of the structure constituted by the permanent magnet portions.

5. A device as claimed in Claim 3 or 4, wherein the armature is supported, so as to be capable of such movement, by a ring of resilient material through which the armature extends along the said axis.

6. A device as claimed in any one of Claims 3 to 5 when they are read as appendant to Claim 2, wherein the permanent magnet portions of the pair specified in Claim 1 have respective magnetic axes that lie in a first plane, and the magnet portions of

the said second pair have respectively magnetic axes that lie in a second plane which is perpendicular to the said first plane and intersects it along the said axis.

7. A device as claimed in Claim 6, wherein the said axis is parallel to and equidistant from the respective magnetic axes of the four permanent magnet portions.

8. A device as claimed in any one of Claims 3 to 7, further comprising a housing member within which are mounted the permanent magnet portions, the yoke means, and the electrical output coil means, and which is formed by a passageway extending along the said axis, which is an axis of symmetry of the magnetic structure constituted by the permanent magnet portions and yoke means together, so that the said airgap is constituted by a part of the passageway, the electrical output coil means being connected with output terminals which are fixedly mounted with respect to the housing member.

9. A device as claimed in Claim 8, wherein the armature forms part of a stylus assembly which is removably attached to the housing member by virtue of frictional engagement between respective mating portions of the housing member and the stylus assembly.

10. A device as claimed in Claim 9, wherein the stylus assembly includes a tube within which the armature is mounted to extend, when at rest, along the axis of the tube, the tube being received in the said passageway but being removed therefrom with the rest of the stylus assembly when the said mating portions are disengaged.

11. A device as claimed in any preceding claim, wherein the armature comprises magnetically soft material.

12. A device as claimed in any preceding claim, wherein the armature comprises a permanent magnet.

13. A device as claimed in any preceding claim, wherein the armature is tubular.

14. A device as claimed in any preceding claim, wherein the said permanent magnet portions are constituted by respective integral parts of a hollow cylindrical body which is made of magnetisable ceramic material and is permanently magnetised parallel to its central axis and surrounds the said airgap.

15. A device as claimed in any one of Claims 1 to 13, wherein the said permanent magnet portions are constituted by respective bar magnets.

16. A device as claimed in any preceding claim, wherein the yoke means comprise elongate magnetic core portions which are equal in number to the said permanent magnet portions and which are arranged as respective longitudinal extensions thereof and which are magnetically interconnected at their ends remote from the said permanent magnet portions and which at their other ends abut respectively against the said permanent magnet

portions and which provide those portions of the yoke means that are surrounded by the electrical output coil means.

17. A device as claimed in Claim 16, wherein the elongate magnetic core portions are constituted by relatively thin rods of a high permeability material and are interconnected at their ends remote from the said permanent magnet portions by a common cross-piece.

18. A device as claimed in Claim 16 or 17, wherein each of the elongate magnetic core portions is of circular cross-section.

19. A device as claimed in Claim 16, 17 or 18, wherein the two elongate magnetic core portions that abut respectively against the permanent magnet portions of Claim 1 extend axially through first and second coils respectively, which coils are connected together in series to constitute the electrical output coil means of Claim 1.

20. A device as claimed in Claim 19 when read as appendant to Claim 2, wherein the two elongate magnetic core portions that abut respectively against the permanent magnet portions of the said second pair extend axially through third and fourth coils respectively, the third and fourth coils being connected together in series to constitute the said second electrical output coil means.

21. A device as claimed in any preceding claim, further comprising a record-playing stylus connected mechanically to the armature for imposing such movement of the armature, as the stylus tracks an impressed audio recording, thereby to cause the electrical output coil means to deliver electrical output signals which can be used to reproduce the recorded matter audibly.

22. A pick-up assembly, on or for use on a pick-up arm of a record-playing unit, comprising a device as claimed in any one of Claims 1 to 20.

23. A stereophonic pick-up for use in playing stereophonic records, comprising a device as claimed in Claim 2, 6, 7, or 20, or as claimed in any one of Claims 3 to 5 and 8 to 19 when they are read as appendant to Claim 2.

24. A pick-up assembly, substantially as hereinbefore described with reference to Figures 1 to 3 of the accompanying drawings.

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