

AUDIO FREQUENCY ELECTROMECHANICAL VIBRATOR

5 This invention relates to electromechanical vibrators, and more particularly, to audio frequency electromagnetic vibrators adapted for a body-felt vibration reproduction in sound reproducing systems.

10 For example, US-A-4,064,376 discloses an electromechanical vibrator for a sound reproducing system which reproduces from an electric signal not only sound heard by ear but also mechanical vibration of, preferable undertones lower than 150Hz, to be directly transmitted to the listener's body. The
15 electromechanical vibrator for reproducing the mechanical vibration is fitted on a bed or a chair, and an audio signal to be fed to sound reproducing speakers is also applied to the vibrator, preferably after passing through a filter for removing a
20 frequency component higher than 150Hz. A person on the chair or bed feels vibration while enjoying music from the speaker through his ears.

 An electro-dynamic transducer is used for the vibrator in such sound reproducing system. A known
25 vibrator has an arrangement similar to an electro-dynamic speaker, as shown in US-A-4,064,376 and 4,354,067. As shown in Figure 1 of the accompanying drawings, which is vertical sectional view of a known audio-frequency electromechanical
30 vibrator, the vibrator 1 comprises a magnetic circuit constituted by a magnetic yoke 2 of a inverted T-shape having a central pillar 2a and a bottom plate 2b, a ring-shaped permanent magnet 3 disposed on the bottom plate 2b, and an annular top yoke plate 4
35 attached on the permanent magnet 3. An annular magnetic gap 5 is formed between a top portion of the central pillar 2a and an inner edge of the annular

plate 4. A drive coil 6 is loosely fitted in the magnetic gap 5. The magnetic circuit structure is resiliently supported by a housing 7 through a spring plate 8, and a drive coil 6 is supported by a cover 9 through a coil bobbin 10.

Since the drive coil is disposed in a static magnetic field generated in the magnetic gap 5, the drive coil 6 and the magnetic circuit structure (2-3-4) are relatively moved when an electrical A.C. current is applied to the drive coil 6. Thus, the vibrator 1 vibrates in response to an electrical audio signal applied to the drive coil 6.

In this construction of vibrator, the transmission efficiency of the vibrator 1 is determined by the magnetic flux density in the magnetic gap 5, and the number of turns and the impedance of the drive coil 6. In order to improve the efficiency of vibration, the magnetic gap 5 should be reduced, and the number of turns and the diameter of the wire of the drive coil 6 should be increased. However, the drive coil 6 works in the magnetic gap 6 without any contact with other moving parts. Thus, the drive coil 6 is formed of a small coil of a thin wire with a high density, and requires high circularity to improve the efficiency of transmission of vibration. As a result of these requirements for improving the efficiency of the vibrator, the production of the coil and the manufacturing of the vibrator require high accuracy and thus high cost.

Also, as clearly shown in Figure 1, the central pillar 2a of the magnetic yoke 2 should be disposed in the drive coil 6 to generate the vibration. Thus, the thickness of vibrator can not effectively be reduced for easy fitting in a supporting sheet of a bed or chair.

It is a primary object of this invention to

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provide an audio frequency electromechanical vibrator which is easily manufactured and assembled, at low cost, and which is generally flat and compact.

5 An audio frequency electromechanical vibrator in accordance with this invention comprises a flat plate shaped permanent magnet; an electromagnetic coil wound around the permanent magnet; a yoke in which the permanent magnet and coil are disposed; and a housing element, to which the yoke is resiliently
10 mounted, and which at least partly consists of a plate of magnetic material to form a magnetic flux circuit together with the yoke; the arrangement being such that when the coil is energized with an audio frequency signal, the yoke vibrates relatively to the
15 housing element.

Some examples of a vibrator constructed in accordance with the invention, and, for comparison, a prior vibrator, are illustrated in the accompanying drawings, in which:-

20 Figure 1 is an axial sectional view of a known audio-frequency electromechanical vibrator;

Figure 2 is diagrammatic view illustrating the theory behind the invention;

25 Figure 3 is a plan view of one example of vibrator in accordance with the invention;

Figure 4 is an axial section taken on the line A-A in Figure 3;

30 Figure 5 is a partially enlarged axial sectional view of a second example of vibrator in accordance with the invention; and,

Figure 6 is a perspective view of a chair using the vibrator shown in Figure 5.

35 This theory behind the invention will first be described with reference to Figure 2. When a coil 20 is wound on a U-shaped permanent magnet 21 and an electrical audio-frequency signal is applied to the

coil 20, the amount of magnetic flux passing through the permanent magnet 21 is changed in accordance with the audio signal. Therefore, if a plate of magnetic material, for example, a steel plate 22 is mounted on a stationary element 24 through a spring element 23 and disposed opposite the magnetic pole of the permanent magnet 21, the steel plate 22 is vibrated in correspondence with the variation in attractive force generated between the steel plate 22 and permanent magnet 21.

Referring to Figures 3 and 4, one example of a vibrator 30 according to the invention has an circular flat-disk-shaped permanent magnet 31, which is magnetized in its thickness direction (in Figure 4, in the vertical direction), and an annular coil 32 wound on an outer peripheral surface of the permanent magnet 31 crossing the direction of magnetisation of the permanent magnet 31. This permanent magnet 31 with the coil 32 is fixed within a cup-shaped magnetic yoke 33, i.e., an outer peripheral surface of the annular coil 32 is closely fitted within an inner surface of the yoke 33.

The yoke 33 is resiliently supported in a U-sectionally shaped annular housing 34, which is formed of non-magnetic material, through a spring element 35 which permits relative movement relatively to the housing 34. That is a plurality of flanges 351, vertically extending from the inner periphery of the spring plate 35 are attached and fixed on the outer peripheral surface of the yoke 33 by fastening means, for example screws 37, and the outer peripheral portion of the spring plate 35 is fixed on the inner surface of the housing 34 by screws 38. An open top of the housing 34 is covered by a flat plate of magnetic material, for example a steel plate 36, for forming a magnetic flux circuit together with the yoke 33.

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In the above mentioned construction of vibrator 30, since the magnetic flux circuit is formed by the magnetic yoke 33 and steel plate 36, when an audio frequency electrical signal is applied to the coil 32, the amount of magnetic flux passed through the magnetic circuit is varied. As the result of the changing magnetic flux, the attractive force generated between the yoke 33 and steel plate 36 is varied at the audio frequency. As the steel plate 36 is fixed on the housing 34 and the yoke 33 is elastically supported in the housing 34, the application of the audio signal to the coil 32 axially drives the yoke 33 reciprocatingly to produce vibration corresponding to the audio signal.

Since, the vibrator 30 is operated by the change of magnetic flux, the number of turns of the coil 32 should be maximised to maintained effective operation. However, if the number of turns of the coil 32 is increased, the inductance of the coil 32 is increased, and the transformed output is reduced in accordance with increasing frequency while maintaining the input voltage. But, as mentioned above, this vibrator 30 only receives an audio signal, usually under 150Hz, and the above phenomenon can be ignored.

Also, the prior vibrator receives the audio signal after passage through a filter for removing frequently components higher than 150Hz, but the output of this vibrator 30 can be controlled by adjusting the inductance of the coil 32 and the spring constant of the spring plate 35. Therefore, the previous filter device utilized in the audio signal supply circuit for removing the higher frequency components can be omitted.

Furthermore, the production and assembly of vibrator no longer require high accuracy, and the cost of the vibrator can be reduced. Also, the



thickness of vibrator is essentially determined by the thickness of the permanent magnet, so that the thickness of the vibrator can be reduced.

5 Referring to Figure 5, another example is shown, which utilises a modification of the structure of the vibrator housing. A magnetic plate 36' is provided at its outer periphery with a plurality of supporting tabs 361' connected with the outer peripheral surface of the spring plate 35'. Therefore, if the outer
10 peripheral portion of the magnetic plate 36' is attached on a vibration plate 34' or other stationary portion which is to be vibrated by the vibrator, an enclosing outer housing of the vibrator is omitted, and the vibration of the yoke 33 is directly
15 transmitted to the stationary portion through the magnetic plate 36'.

The above mentioned vibrator is arranged to be used, for example, with a chair, i.e., the vibrator is mounted in a back 40a of a chair 40 by being
20 securing to a cushion spring 41, and the audio signal is applied to the vibrator. Furthermore, as shown in Figure 6, if the chair 40 has a lumber support mechanism, a lumber plate 42 may be used as the magnetic plate 36 or vibration plate 37. This form
25 of vibrator comprises minimum parts and is easily produced.

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CLAIMS

1. An audio frequency electromechanical vibrator comprising a flat plate shaped permanent magnet; an electromagnetic coil wound around the permanent magnet; a yoke in which the permanent magnet and coil are disposed; and a housing element, to which the yoke is resiliently mounted, and which at least partly consists of a plate of magnetic material to form a magnetic flux circuit together with the yoke; the arrangement being such that when the coil is energized with an audio frequency signal, the yoke vibrates relatively to the housing element.
2. A vibrator according to claim 1, wherein the yoke is resiliently supported by the plate of magnetic material.
3. A vibrator according to claim 1 or claim 2, wherein the yoke is resiliently mounted to the housing element by an annular spring plate surrounding the yoke.
4. A vibrator according to claims 2 and 3, wherein the plate of magnetic material is provided at its periphery with a plurality of tabs to which the spring plate is connected.
5. A vibrator, substantially as described with reference to Figures 2 to 4, or to Figures 2 to 4 when modified in accordance with Figure 5 and/or Figure 6, of the accompanying drawings.

