# United States Patent [19]

**Kishikawa et al.**

[11] **3,922,504**

[45] **Nov. 25, 1975**


[54] **ELECTROACOUSTIC TRANSDUCER**


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[52] **U.S. Cl.** ..... **179/115.5 PV**

[51] **Int. Cl.²** ..... **H04R 9/02**

[58] **Field of Search** ..... 179/115.5 PV, 111 R, 117, 179/119 R



[56] **References Cited**

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[57] **ABSTRACT**

An electroacoustic transducer wherein a diaphragm of a nonmagnetic and insulative material having thereon a series of conductors is disposed between a pair of magnetic circuits opposing one another through a slight clearance so that the conductors will lie in magnetic flux flowing between opposite polarity ends of at least a pair of permanent magnets in each magnetic circuit and will move in directions transverse the flux when the diaphragm is vibrated. The magnets in one of the magnetic circuits on sound passing side of the diaphragm are made smaller than those of the other circuit in their size in opposing direction of the respective circuits.


**5 Claims, 5 Drawing Figures**

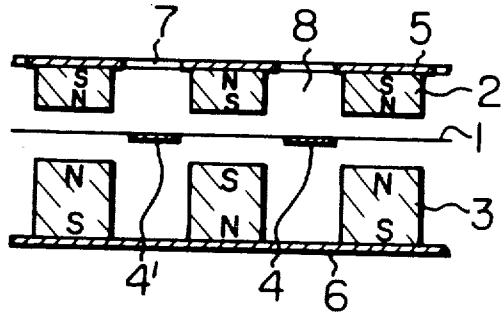


Fig. 1 PRIOR ART

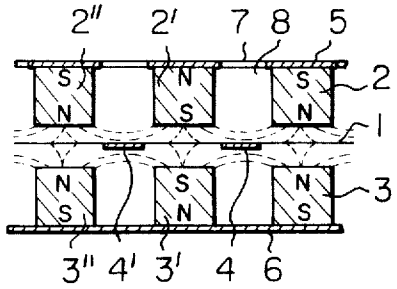



Fig. 2 PRIOR ART

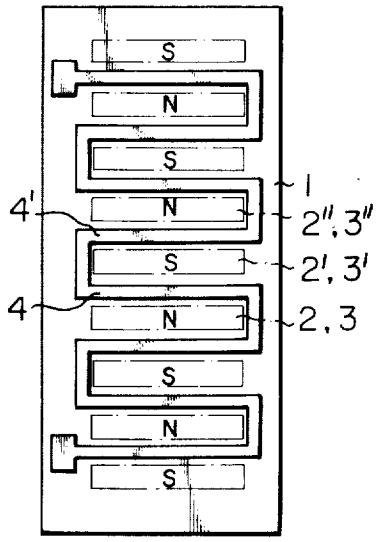



Fig. 3

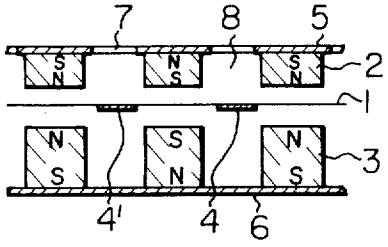



Fig. 4

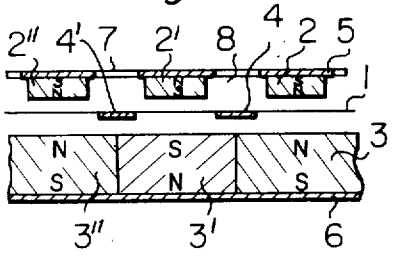
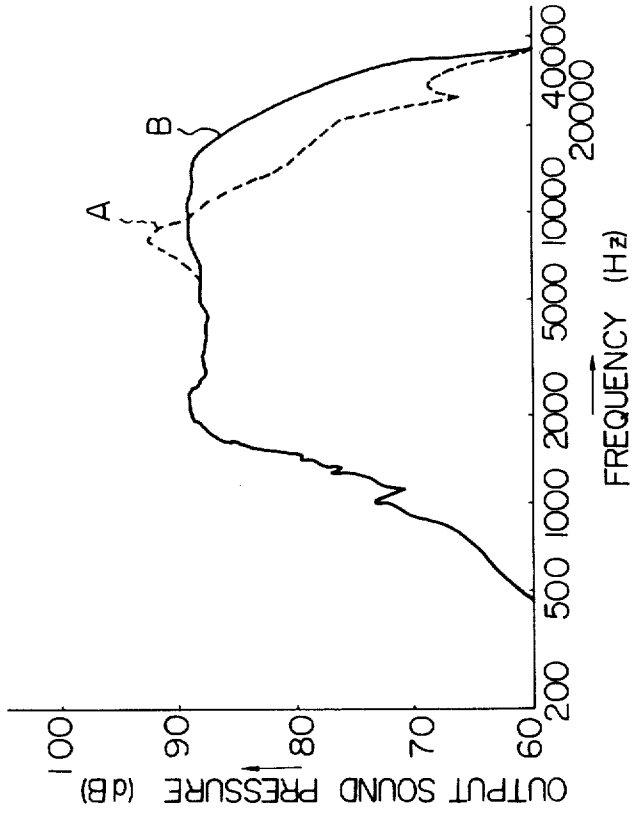


Fig. 5


OUTPUT SOUND PRESSURE (dB)
100
90
80
70
60
200
500
1000
2000
5000
10000
20000
40000
FREQUENCY (Hz)
A
B

# ELECTROACOUSTIC TRANSDUCER

This invention relates to electroacoustic transducers and, more particularly, to an electroacoustic transducer comprising a flexible diaphragm made of a nonmagnetic and insulative material having a series of conductors and a plurality of permanent magnet arranged as opposed to each other with magnetic pole surfaces and through a slight clearance on both surfaces of said diaphragm.

A known electroacoustic transducer of this kind has such structure as is shown, for example, in FIGS. **1** and **2**, in which **1** is a diaphragm made of membrane of a nonmagnetic material, **2**, **2'**, **2''** . . . and **3**, **3'**, **3''** . . . are a plurality pair of elongated permanent magnets, each of the respective pairs **2** and **3**, **2'** and **3'**, **2''** and **3''** . . . of which is arranged as opposed to each other with magnetic pole surfaces through a slight clearance on both sides of the diaphragm **1** and in parallel relation to adjacent pairs so that, while the magnetic poles of the respective pairs adjacent one another in expanding direction of the membrane **1** will be alternately of different polarities, the poles of each pair opposing will be of the same polarity. **4**, **4'** . . . are parallel strip conductors formed on the diaphragm **1** by such a means as a printing or the like so as to be respectively positioned intermediate between the adjacent magnets **2** and **2'**, **2'** and **2''** . . . or **3** or **3'**, **3'** and **3''** . . . , which conductors are connected at the respective ends with one another so as to be at least one zigzag shaped continuous conductor, as shown in FIG. **2**. **5** and **6** are soft iron plates bonded respectively on outside surfaces of the respective groups of the magnets **2**, **2'**, **2''** . . . and **3**, **3'**, **3''** . . . on each side of the diaphragm **1** and one of them, for example, the iron plate **5**, is provided with perforations **7** for allowing sounds to pass therethrough, between the adjacent magnets **2** and **2'**, **2'** and **2''** and so on. Dotted lines shown in FIG. **1** in spaces between the opposing and adjacent magnetic pole surfaces represent magnetic flux distribution.

The operation of the electroacoustic transducer shown in FIGS. **1** and **2** shall be explained next.

Referring to FIG. **1**, the opposing surfaces of, for example, the pair of magnets **2'** and **3'** are of S-pole and those of adjacent pairs of the magnets **2** and **3**, **2''** and **3''** are N-pole, so that the magnetic flux will be caused to flow from the respective opposing N-poles to the respective adjacent S-poles so as to be substantially in parallel with the plane of the diaphram **1**. The parallel sections **4**, **4'** . . . of the continuous conductor are disposed thus in such magnetic flux at right angles with respect to the flowing direction of the flux.

In case an electric current is passed through the continuous conductor in the above arrangement, the diaphragm **1** on which the conductor is provided is subjected to an electromagnetic force effective in a direction perpendicular to the plane of the diaphragm. While the direction of the electric current flowing each of the parallel sections **4**, **4'** . . . of the conductor is opposite to one another, the direction of the magnetic flux traversing each of such sections **4**, **4'** . . . is also opposite to one another. Consequently, the diaphragm **1** is subjected to a driving force effective in a fixed direction, so that the electroacoustic transducer will be utilized as a speaker operated in response to the direction and magnitude of the current passed through the strip conductor.



It is obvious that in case the diaphragm **1** is caused to be vibrated by a sound contrarily to the above, there is produced an electromotive force in the conductor on the diaphragm **1** vibrated, so that the electroacoustic transducer will be able to be utilized as a microphone.

In the above described known electroacoustic transducer, it is necessary to balance the magnetic forces of the permanent magnets opposed to each other and, therefore, bar-shaped ferrite magnets of the same dimensions or volume have been used but, in order to elevate the acoustic reproduction effeciency, it is desirable that the volume of the permanent magnets is made as large as possible.

On the other hand, it is also necessary to provide the perforations **7** between the adjacent magnets and, therefore, in order to make the volume of the opposing permanent magnets large enough, their dimension in the direction in which they are opposing, that is the height must be necessarily made larger. In such case, however, the adjacent ones of the permanent magnets **2**, **2'** . . . and the perforations **7** therebetween will act on each other to produce a resonance phenomenon within cavities **8** inside the respective perforations **7**. Therefore, as shown by a curve A of dotted line in FIG. **5**, certain peak and dip will appear in the reproduction frequency characteristic in the high acoustic range and any good quality acoustic reproduction or transducing cannot be expected.

The present invention is suggested to remove the above mentioned problems in the electroacoustic transducers referred to, successfully improving the frequency characteristic by making the height of each one of the opposing pairs of the permanent magnets on the side disposed adjacent the perforations to be smaller than that of the other so that the volume of cavities in which the before described resonance phenomenon occurs will be made smaller as much as possible.

The present invention shall be explained in detail in the following with reference to certain preferred embodiments shown in accompanying drawings, in which:

FIG. **1** is a fragmentary sectioned view of a known electroacoustic transducer showing essential parts thereof;

FIG. **2** is a plan view of a diaphragm used in the transducer of FIG. **1**;

FIG. **3** is a similar view to FIG. **1** showing an embodiment of the present invention;

FIG. **4** is also a similar view to FIG. **1** showing another embodiment of the present invention; and

FIG. **5** shows output sound pressure-to-frequency characteristics of the electroacoustic transducer of the structure shown in FIG. **3**.

Referring to FIG. **3** showing an embodiment of the electroacoustic transducer of the present invention, a plurality pair of elongated permanent magnets **2** and **3** are arranged as opposed respectively through a slight clearance on both sides of a diaphragm **1** which is made of such nonmagnetic and insulative material as a plastic film and provided on a surface with such conductors **4** as are shown in FIG. **2**. The magnetic pole surfaces of the respective pairs of the permanent magnets parallelly adjacent in expanding direction of said diaphragm will have alternately different polarities and the magnetic pole surfaces opposed to each other through said diaphragm will have polarities identical with each other. The conductor **4** provided by such means as, for example, printing on the diaphragm is formed to be of a zigzag shape having parallel conductor parts arranged

so as to be intermediate between the adjacent ones of the permanent magnet. Further, soft iron plates **5** and **6** are bonded respectively on the outside surfaces of the magnet on the opposite sides of the diaphragm **1.** Only the soft iron plate **5** on one side of them is provided with perforations **7** for radiating or passing sounds therethrough between the magnets **2.** In this formation, the present invention has a feature that the height of the permanent magnets **2** arranged on the sound radiating side of the diaphragm is formed to be smaller than the height of the magnets **3** arranged on the nonsound radiating side.

As a result of experimentally making an electroacoustic transducer of this structure, it has been confirmed that the before described cavity resonance phenomenon shifts out of the audible frequency band and that, as shown by a curve B of solid line in FIG. **5,** the acoustic reproduction frequency characteristic reaches a flat and sufficiently high frequency. Further, in such case, the opposite magnetic forces will be unbalanced. However, if such permanent magnet having a high holding force and energy product as a rare earth cobalt magnet is used for the permanent magnet **2,** on the sound radiating side, even if the height, that is, the volume of the permanent magnet **2** is reduced, it will be possible to balance the opposed magnetic force.

Referring next to FIG. **4** showing another embodiment according to the present invention, the energy product is increased by enlarging the width of the permanent magnets **3** arranged on the non-sound radiating side of the diaphragm **1** until, for example, they mutually engage, while the volumes of the permanent magnets **2** arranged on the sound radiating side of the diaphragm are reduced to make the hollows **8** inside the perforations **7** small without changing the density of the magnetic flux intersecting the conductor **4.**

As described above, according to the electroacoustic transducer of the present invention, the acoustic reproduction frequency characteristic can be effectively improved by shifting the cavity resonance phenomenon out of the audible frequency band by making the height of the permanent magnets positioned on the sound radiating or passing side of the diaphragm in the respective pairs of the permanent magnets **2** and **3** opposing are made smaller than that of the other magnets on the non-sound radiating or passing side.



The present invention can be utilized extensively for speakers, headphones, microphones and the like electroacoustic transducers.

What is claimed is:

**1.** An electroacoustic transducer comprising

a pair of magnetic circuits respectively including at least a pair of permanent magnets and a soft iron plate bridged between opposite polarity ends of said magnets and opposing one another through a clearance so that magnetic flux flowing between the other ends of the magnets will be superposed on another as oriented in the same direction and along said clearance, said soft iron plate in one of said magnetic circuits having perforations for allowing sounds to pass therethrough, and

a diaphragm made of a non-magnetic and insulative material and extended within said clearance between the pair of magnetic circuits, said diaphragm having at least on one surface a series of conductors substantially extending in a direction transverse said magnetic flux direction,

said permanent magnets in said magnetic circuit of the side having said perforations being smaller than those in the other magnetic circuit in the dimension in opposing direction of the magnetic circuits.

**2.** The transducer according to claim **1** wherein said permanent magnets having the smaller dimension are of a material which is high in the coercive force and energy product.

**3.** The transducer according to claim **2** wherein said material for the permanent magnet is rare earth cobalt magnet.

**4.** The transducer according to claim **1** wherein said series of conductors is in zigzag shape.

**5.** The transducer according to claim **1** wherein said series of conductors is disposed intermediate between the respective permanent magnets of the respective magnetic circuits which are adjacent in the magnetic flux direction.

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