

"PIEZO-ELECTRIC LOUDSPEAKER"

This invention relates to a piezo-electric loudspeaker.

A piezo-electric loudspeaker is known which has a piezo-electric vibrator which comprises either a piezo-electric element per se or a resilient thin plate at least one of whose opposite surfaces is provided with a piezo-electric element. Such a piezo-electric vibrator has been used as a sound (driving) source. In the known piezo-electric loudspeaker, the said piezo-electric vibrator has been coupled to a vibratory diaphragm, such as a paper cone, at a point or position where the amplitude of vibration of the piezo-electric vibrator is at its maximum when the vibrator vibrates in the main resonance mode. Various coupling structures have been used to couple the piezo-electric vibrator and the vibratory diaphragm directly or through a rod or wire, but in all cases the parts have been coupled together at one point only. Where such coupling structures have previously been used, the piezo-electric vibrator has been able to produce sounds only when vibrated at or near its main resonance frequency, and the impedance has been high at low frequencies. It has therefore been very difficult to produce low frequency sound. Consequently the piezo-electric loudspeaker previously used has been employed only as a tweeter.

The object of the present invention is to provide a piezo-electric loudspeaker which can produce a satisfactory sound

pressure extending over a wide frequency range.

According therefore to the present invention, there is provided a piezo-electric loudspeaker comprising a circular piezo-electric vibrator whose peripheral portion is supported by a frame, and a vibratable diaphragm whose peripheral portion is supported by the said frame, the said vibratable diaphragm being coupled to the piezo-electric vibrator at a circular region which is concentric with the piezo-electric vibrator.

The vibratable diaphragm and the piezo-electric vibrator are preferably coupled together by a cylindrical coupling member.

The piezo-electric vibrator may comprise a resilient plate at least one of whose surfaces has a piezo-electric element fixed thereto.

Preferably the ratio d/D is in the range 0.65 to 0.8, where d is the diameter of the or each piezo-electric element, and D is the diameter of the portion of the piezo-electric vibrator which is not directly supported by the frame.

Preferably also the ratio ϕ/d is in the range 0.65 to 0.8, where ϕ and d are the respective diameters of the circular region and of the or each piezo-electric element.

The piezo-electric vibrator may be provided adjacent its centre with an adjusting mass for reducing the frequencies of the main and secondary resonance modes of the piezo-electric vibrator.

Moreover, the vibratable diaphragm may be provided centrally with a dome portion.

The invention enables an ultra-thin piezo-electric loudspeaker to be produced which can be employed in a portable miniature radio.

The invention is illustrated, merely by way of example, in the accompanying drawings, in which:-

Figure 1 is a cross-sectional view of a first embodiment of a piezo-electric loudspeaker according to the present invention,

Figure 2 is a frequency-sound pressure characteristic diagram relating to the loudspeaker of Figure 1, and

Figure 3 is a cross-sectional view of a second embodiment of a piezo-electric loudspeaker according to the present invention.

Referring to Figure 1, a piezo-electric loudspeaker comprises a discoid frame 10 which is bored to provide at its central portion a circular opening 11. The frame 10 is provided with a projecting portion or flange 12 which projects from the front surface of its peripheral portion. A circular piezo-electric vibrator 20, which acts as a driving (sound) source, is mounted in the circular opening 11, the peripheral portion of the piezo-electric vibrator 20 being secured to a shoulder of the opening 11 by means of a ring member 30.

The piezo-electric vibrator 20 has a bimorph structure and comprises a thin circular resilient metal plate 21 and circular piezo-electric elements 22, 23 which are fixed by means of adhesive

(not shown) on opposite surfaces respectively of the plate

21. The piezo-electric elements 22, 23 may be formed from an inorganic material having a large mechanical coupling coefficient.

Thus for example they may be formed of a Rochelle salt, a

5 barium titanate, a lead titanate zirconate, a lead cobalt niobate, or a lead bismuth niobate. The plate 21 may be made of phosphor bronze or stainless steel.

Each of the piezo-electric elements 22, 23, at its respective external surface, is provided with a driving electrode

10 (not shown). The driving electrodes are electrically connected to each other by a lead wire 24 which passes through a small hole 25 which is bored in the plate 21. Lead wires 26, 27, for establishing external connections, are connected to the plate 21 and to the driving electrode of the piezo-electric element 15 22 respectively, and a driving signal is applied in operation to the lead wires 26, 27.

The peripheral portion of a vibratable diaphragm 40 is secured to the projecting portion 12 of the frame 10 by means of a ring member 50. The vibratable diaphragm 40 has an annular shape 20 in plan and a gentle cone shape in cross section. The vibratable diaphragm 40 is coupled to the piezo-electric vibrator 20 by means of a cylindrical coupling member 60.

The cylindrical coupling member 60 is positioned concentrically of the piezo-electric vibrator 20 so that the 25 vibratable diaphragm 40 and piezo-electric vibrator 20 are coupled together at a circular region which is concentric with the piezo-electric vibrator 20.

If desired, the vibratable diaphragm 40, instead of being coupled to the piezo-electric vibrator 20 by means of a cylindrical coupling member 60, may be directly coupled to the piezo-electric vibrator 20 at the said circular region.

5 The vibratable diaphragm 40 may be made from paper, a plastics diaphragm, a plastics diaphragm onto which metal has been evaporated, or a thin metal plate.

 The cylindrical coupling member 60 may be made of any material, but it is preferable to make it from a light and
10 stiff material.

 In the construction described above, the vibration of the piezo-electric vibrator 20 is transmitted to the vibratable film 40 through the cylindrical coupling member 60 and thus the sound is produced by virtue of the vibration of the
15 vibratable diaphragm 40.

 A comparison will now be made between the loudspeaker described above, in which the vibratable diaphragm 40 is coupled to the piezo-electric vibrator 20 through the cylindrical coupling member 60, and the conventional device in which the
20 vibratable diaphragm 40 was coupled to the centre of the piezo-electric vibrator 20. In the conventional case, the vibration of the piezo-electric vibrator can be effectively transmitted to the vibratable diaphragm only when the piezo-electric vibrator is operated at its main resonance frequency, so that the vibration
25 of the piezo-electric vibrator is no longer transmitted to

the vibratable diaphragm once the piezo-electric vibrator is operated in any of its secondary resonance modes. In contrast to this, in the case of the loudspeaker according to the present invention which is described above, even when the piezo-electric vibrator 20 is operated in a secondary resonance mode, the vibration of the piezo-electric vibrator 20 can be transmitted far more effectively to the vibratable diaphragm 40 than was possible in the construction of the prior art. In other words, in the piezo-electric loudspeaker of the present invention, the sound pressure characteristic of the loudspeaker is improved by comparison with that of the prior art so that, as shown in Figure 2, it extends over a wide range from low frequency to high frequency.

In the loudspeaker of the present invention, the sound pressure characteristic is influenced by the ratios d/D and ϕ/d in which d is the diameter of each of the piezo-electric elements 22, 23, D is the diameter of the portion of the piezo-electric vibrator 20 which is not directly supported by the frame 10, and ϕ is the diameter of the cylindrical coupling member 60. It has been found by experiment that, when the ratio d/D is in the range of 0.65 to 0.8, there are many secondary resonances having a comparatively high level in the low frequency range, and the main resonance frequency is comparatively reduced. Moreover, when the ratio ϕ/d is in the range 0.65 to 0.8, the vibration of the piezo-electric

vibrator 20 can be transmitted evenly and over a wide frequency range to the vibratable diaphragm 40.

For example, if the vibratable diaphragm 40 is a phosphor bronze plate having a diameter of 27mm and a thickness of 0.05mm, and if each of the piezo-electric elements 22, 23 is formed of lead cobalt niobate and has a diameter of 20mm and a thickness of 0.12mm, and if the vibratable diaphragm 40 is a paper cone having an effective diameter of 50mm, then the frequency-sound pressure characteristic of such a loudspeaker will be as shown in Figure 2. This characteristic is obtained by arranging that the input signal is a sine curve wave whose effective voltage is 1 volt, and by arranging that the point from which measurements are taken is 9 centimetres from the front surface of the frame 10 and on the centre line of the latter.

In Figure 3 there is shown a second embodiment of a piezo-electric loudspeaker according to the present invention which is generally similar to that of Figure 1 and which for this reason will not be described in detail, like reference numerals indicating like parts.

In the Figure 3 construction, however, the piezo-electric vibrator 20 is provided centrally with an adjusting mass 28, while the vibratable diaphragm 40 is provided with a dome portion 42 in addition to a conical portion 41. By locating the adjusting mass 28 on the central portion of the piezo-electric vibrator 20, the frequencies of the main and secondary resonance modes of the piezo-electric vibrator 20 are reduced and thus the whole of the

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response frequency of the piezo-electric vibrator 20 can be correspondingly reduced.

The provision of the vibratable diaphragm 40 with a centrally disposed dome portion 42 enables the sound pressure which is produced by the vibratable diaphragm 40 in the high frequency range to be increased.

The vibratable diaphragm 40 shown in Figures 1 and 3 may be circular as shown or may have an oval or other curved shape. Moreover, the piezo-electric vibrator 20 may if desired have an unimorph structure.

Since, in accordance with the present invention, the vibratable diaphragm 40 for producing the acoustic sound is coupled to the piezo-electric vibrator 20, which constitutes the driving source, at a circular region, the vibration of the piezo-electric vibrator 20 can be transmitted more effectively and more evenly to the vibratable diaphragm 40 both in the main resonance mode and also in the secondary resonance modes. Consequently, a satisfactory output sound pressure can be obtained which extends over a wide range from low frequency to high frequency, thus enabling even a piezo-electric loudspeaker to have a characteristic which compares quite well with that of a conventional dynamic loudspeaker and which also has an output sound which is soft. Furthermore, the loudspeaker of the present invention may be manufactured at a low cost in an ultra-thin shape and thus is very suitable for use in a thin portable radio or a miniature cassette recorder.



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C L A I M S

1. A piezo-electric loudspeaker comprising a circular piezo-electric vibrator whose peripheral portion is supported by a frame, and a vibratable diaphragm whose peripheral portion is supported by the said frame, the said vibratable diaphragm being
5 coupled to the piezo-electric vibrator at a circular region which is concentric with the piezo-electric vibrator.
2. A loudspeaker as claimed in claim 1 in which the vibratable diaphragm and the piezo-electric vibrator are coupled together by a cylindrical coupling member.
- 10 3. A loudspeaker as claimed in claim 1 or 2 in which the piezo-electric vibrator comprises a resilient plate at least one of whose surfaces has a piezo-electric element fixed thereto.
4. A loudspeaker as claimed in claim 3 in which the ratio d/D is in the range 0.65 to 0.8, where d is the diameter of the or
15 each piezo-electric element, and D is the diameter of the portion of the piezo-electric vibrator which is not directly supported by the frame.
5. A loudspeaker as claimed in claim 3 or 4 in which the ratio ϕ/d is in the range 0.65 to 0.8, where ϕ and d are the
20 respective diameters of the circular region and of the or each piezo-electric element.



6. A loudspeaker as claimed in any preceding claim in which the piezo-electric vibrator is provided adjacent its centre with an adjusting mass for reducing the frequencies of the main and secondary resonance modes of the piezo-electric vibrator.

7. A loudspeaker as claimed in any preceding claim in which the vibratable diaphragm is provided centrally with a dome portion.

8. A piezo-electric loudspeaker substantially as hereinbefore described with reference to and as shown in Figure 1 or in Figure 3 of the accompanying drawings.

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