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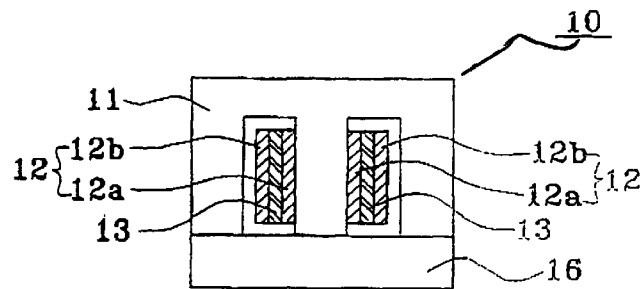
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(54) **Transformer for piezoelectric speaker and piezoelectric speaker operative with said transformer**

(57) The transformer (10) for a piezoelectric speaker includes an E-shaped magnetic core (11). An inner secondary winding (12a) having a number of turns corresponding to approximately one-half of the number of turns of a secondary winding (12) is wound around a shaft portion of the magnetic core (11). A primary winding (13) is wound around the shaft portion of the magnetic core (11) over the inner secondary winding (12a). Further, an outer secondary winding (12b) having a number of turns corresponding to the another half of the number of turns of the secondary winding (12) is wound around the shaft portion of the magnetic core (11) over the primary winding (13). An I-shaped core (16) is provided at the open side of the E-shaped magnetic core (11).

Fig. 1



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a transformer for a piezoelectric speaker which is optimum for driving a piezoelectric speaker, and to a piezoelectric speaker operative with the transformer.

2. Description of the Related Art

Conventional transformers for piezoelectric speakers include, for example, that disclosed in Unexamined Published Japanese Utility Model Application No. 64-29986 which will be described with reference to Fig. 4.

A transformer 1 comprises a toroidal magnetic core 2 in the form of a square frame, a primary winding 3 wound around the lower part of the magnetic core in the drawing and a secondary winding 4 wound around the upper part of the magnetic core 2 in the drawing apart from the primary winding 3.

The primary winding 3 is connected to an input terminal 5 that connects to an amplifier (not shown) for driving a speaker, and the secondary winding 4 is connected to a sounding body 6 constituted by a piezoelectric body to form a piezoelectric speaker 7.

When an audio signal amplified by the amplifier is input from the input terminal 5 to the primary winding 3, a magnetic field is produced at the primary winding 3. This magnetic field induces electric power at the secondary winding 4, and an electrical signal produced by the electric power is applied to the sounding body 6 for audio generation.

In general, output impedance of an amplifier is substantially 0 ohm, and the frequency characteristics of the transformer connected to the amplifier and the sounding body constituted by a piezoelectric body are not determined simply by the inductance of the secondary winding of the transformer but determined by the inductance of the secondary winding when the primary winding is short-circuited, which is referred to as leakage inductance.

Let us assume that f represents the resonance frequency of the speaker device. Then, f is expressed as follows.

$$f = (2\pi(LC))^{-1/2}$$

where L represents leakage inductance, and C represents the capacity of the piezoelectric body.

The leakage inductance depends on the degree of coupling between the primary and secondary windings. For example, the leakage inductance tends to decrease as the degree of coupling between the primary and secondary windings increases.

The frequency characteristics of the transformer

connected to the sounding body are expressed by the curves shown in Fig. 5. The frequency at which response represented by the ordinate tends to decrease is referred to as "high frequency cut-off". The curve indicated by the broken line represents leakage inductance higher than that represented by the curve indicated by the solid line. Let us assume that f_1 and f_2 represent high frequency cut-off for the curves indicated by the solid line and broken line respectively. Then, $f_2 < f_1$ is satisfied, i.e., the higher the leakage inductance, the lower the frequency cut-off. The term "response" as referred to herein means the efficiency of a signal input to the sounding body.

When the sounding body constituted by a piezoelectric body is driven at a predetermined voltage, the sounding body constituted by a piezoelectric body has high impedance at low frequencies and conversely has low impedance at high frequencies because it has capacitive properties. Therefore, the sound pressure characteristics of the sounding body are expressed by the curve shown in Fig. 6. It is assumed here that no transformer is connected to the sounding body.

When leakage inductance from a transformer is taken into account for the sounding body constituted by a piezoelectric body, the graphs in Figs. 5 and 6 overlap with each other to result in sound pressure characteristics as shown in Fig. 7 wherein the frequency is flat in the region higher than the high frequency cut-offs f_1 and f_2 .

The piezoelectric speaker device described as an example of the related art exhibits extreme distortion in its characteristics in a low frequency band because of core loss when the transformer is used from a frequency band as low as 20 Hz. A possible means for improving this is to increase the number of turns of the transformer significantly to reduce the influence of the core loss. In this case, however, leakage inductance as described above will increase.

When leakage inductance is thus increased, the high frequency cut-off decreases as described with reference to Fig. 5. That is, since frequency band cut-off works at a lower frequency, sound pressure during audio generation is reduced as indicated by the curve in the broken line in Fig. 7, which makes sounds in a high frequency band less penetrating.

Although sound pressure characteristics in a low frequency band can be improved by increasing the cross sectional area of the core of the transformer without increasing the number of turns, the size of the transformer itself is increased in this case.

Further, sounds in a high frequency band can be made more penetrating by decreasing the capacity of the piezoelectric body. In this case, however, a shortage of sounds occurs in a low frequency band and signals input to the piezoelectric body will be converted into sounds at reduced efficiency.

SUMMARY OF THE INVENTION

It is therefore an object of the invention to solve the above-described problems and to provide a transformer for a piezoelectric speaker in which the degree of coupling between the primary and secondary windings can be sufficiently improved even if the number of windings of the transformer is increased, with a consequent increase in leakage inductance, and which provides sufficient sound pressure characteristics in both the low and the high frequency bands without decreasing the capacity of a piezoelectric body when used in a piezoelectric speaker.

In order to achieve the above-described object, according to the present invention, there is provided a transformer for a piezoelectric speaker having a sounding body constituted by a piezoelectric body, comprising a magnetic core, a primary winding, and a secondary winding, wherein the primary winding is connectable to an input terminal for receiving a drive signal for driving the sounding body; the secondary winding is connectable to the sounding body; characterised in that the secondary winding is divided into two parts; and one of the divided secondary windings, primary winding, and the other divided secondary winding are wound around the magnetic core in an overlapping relationship in the order designated.

The overlapping relationship can increase the contact area between the primary and secondary windings to a value twice or more than the contact area in a conventional transformer, whereupon the degree of coupling between the primary and secondary windings is also increased.

Further, when the transformer is used in a piezoelectric speaker, a sufficient degree of coupling is achieved between the primary and secondary windings even if the number of windings of the transformer is increased, with a consequent increase in leakage inductance. Moreover, by virtue of the invention, the leakage inductance of the piezoelectric speaker is lower than that in conventional speakers. As a result, sufficient sound pressure characteristics can be achieved in both low and high frequency bands.

Preferred embodiments of the invention are recited in the dependent claims.

The invention also relates to a piezoelectric speaker device comprising :

a piezoelectric speaker,
a transformer having a magnetic core, a primary winding adapted to receive a drive signal, and a secondary winding connected to said piezoelectric speaker for transmitting said drive signal thereto, characterised in that said secondary winding is divided into two parts, whereby one of the divided secondary windings, said primary winding and the other divided secondary winding are wound around the magnetic core in an overlapping relationship in

the order designated.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional view showing a structure of a transformer for a piezoelectric speaker according to an embodiment of the present invention.

Fig. 2 is a schematic diagram illustrating the connection of a piezoelectric speaker with a transformer to form a piezoelectric speaker system according to the present invention.

Fig. 3 illustrates frequency characteristics of a transformer for a piezoelectric speaker according to the present invention in conjunction with a sounding body.

Fig. 4 illustrates a conventional transformer for a piezoelectric speaker.

Fig. 5 illustrates frequency characteristics of a transformer for a piezoelectric speaker connected to a sounding body.

Fig. 6 illustrates sound pressure characteristics of a sounding body constituted by a piezoelectric body which is not connected to a transformer for a piezoelectric speaker.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

A preferred embodiment of the present invention will now be described with reference to the accompanying drawings.

Fig. 1 shows a transformer for a piezoelectric speaker according to an embodiment of the present invention. A transformer 10 for a piezoelectric speaker includes an E-shaped magnetic core 11. An inner secondary winding 12a having a number of turns corresponding to approximately one-half of the number of turns of a secondary winding 12 is wound around a shaft portion of the magnetic core 11. A primary winding 13 is wound around the shaft portion of the magnetic core 11 over the inner secondary winding 12a. Further, an outer secondary winding 12b having a number of turns corresponding to the other half of the number of turns of the secondary winding 12 is wound around the shaft portion of the magnetic core 11 over the primary winding 13. An I-shaped core 16 is provided at the open side of the E-shaped magnetic core 11 to complete the transformer 10 as an EI core type transformer.

As described above, the transformer 10 for a piezoelectric speaker has a structure wherein the primary winding 13 is sandwiched by the secondary winding 12. Thus, the primary winding 13 and secondary winding 12 contact with each other in an area larger than that in a conventional transformer for a piezoelectric speaker and, therefore, the degree of coupling between the primary and secondary windings is also improved.

Fig. 2 illustrates an implementation of this transformer 10 in a piezoelectric speaker to form a piezoelectric speaker device. The piezoelectric speaker device

can be made as a self-contained unit comprising the piezoelectric speaker 20 itself and the transformer so connected thereto. The unit may also optionally incorporate an audio amplifier for driving the piezoelectric speaker 20 from a signal source, such as a pre-amplifier, tuner or disc player, etc. A piezoelectric speaker 20 includes a sounding body 15 constituted by a piezoelectric body. The primary winding 13 of the transformer 10 for a piezoelectric speaker is connected to an input terminal 14 that receives the output signal of an amplifier (not shown) for driving the sounding body 15 of the piezoelectric speaker 20. The secondary winding 12 is connected to the sounding body 15 of the piezoelectric speaker 20.

When an audio signal amplified by the amplifier is fed into the input terminal 14 to the primary winding 13, a magnetic field is produced at the primary winding 13. This magnetic field induces electric power at the secondary winding 12, and an electrical signal produced by the electric power is applied to the sounding body 15 for audio generation.

Fig. 2 schematically shows the secondary winding 12 divided into two parts (12a and 12b). Although the inner secondary winding 12a, the primary winding 13 and the outer secondary winding 12b are shown adjacent to each other around the magnetic core 11 in Fig. 2, in practice, the inner secondary winding 12a is wound around the magnetic core 11; the primary winding 13 is wound thereon; and the outer secondary winding 12b is further wound thereon as shown in Fig. 1.

Although not shown, the sounding body 15 constituted by a piezoelectric body may be, for example, a sounding body including vibrator made piezoelectric ceramic in the form of a hemispherical or spherical shell or a sounding body including a plate vibrator made of piezoelectric ceramic. There is no special limit for the shape and the like of the sounding body as long as it is constituted by a piezoelectric body.

In a piezoelectric speaker utilising this transformer 10 for a piezoelectric speaker having a sandwich type winding structure, a high degree of coupling is achieved between the primary and secondary windings of the transformer 10 for a piezoelectric speaker to reduce leakage inductance as compared with that in a conventional piezoelectric speaker.

As a result, even if the number of turns of the transformer 10 for a piezoelectric speaker is increased significantly to reduce the influence of core loss as a means for mitigating deterioration of sound pressure characteristics in a low frequency band due to core loss of the magnetic core 11 when the transformer is used in a frequency band as low as about 20 Hz, increase in leakage inductance is sufficiently suppressed as compared with that in a conventional piezoelectric speaker because a sufficient degree of coupling is achieved between the primary and secondary windings. Thus, the piezoelectric speaker 20 has a high frequency cut-off at a high value and can therefore generate sounds

over a wide range including low and high frequency bands with a sufficient sound pressure.

Since there is obviously no need for reducing the capacity of the piezoelectric body that constitutes the sounding body 15, no reduction occurs in sounds in low frequency bands, and no reduction occurs in the efficiency of conversion of a signal input to the sounding body into a sound (response).

Although the secondary winding is wound with its number of turns divided into approximately two halves in the above-described embodiment, the division of the number of turns is not limited in this way. The number of turns of the secondary winding that form the respective inner and outer windings 12a and 12b can be set to any arbitrary ratio a:b, where a and b respectively designate the number of turns in secondary winding layers 12a and 12b.

As shown in Fig. 3, the frequency characteristics of a transformer for a piezoelectric speaker and a sounding body may result in a curve having a convex peak around a high frequency cut-off f_0 or a curve that tends to gradually decrease just before the high frequency cut-off f_0 . This is attributable to resonance between leakage inductance and the capacity of the piezoelectric body. In this case, an idealised curve as indicated by the solid line can be approximated by changing the diameters of the primary and secondary windings so as to change the winding resistance.

As described above, a transformer for a piezoelectric speaker according to the present invention has a structure wherein the primary winding is sandwiched by the secondary winding to increase the contact area between the primary and secondary windings as compared with a conventional transformer for a piezoelectric speaker, and to improve the degree of coupling between the primary and secondary windings. Further, even if leakage inductance of the transformer for a piezoelectric speaker is increased by increasing the number of turns of the windings thereof, sufficient sound pressure characteristics can be achieved in both low and high frequency bands because a sufficient degree of coupling is achieved between the primary and secondary windings, and the leakage inductance of the piezoelectric speaker is smaller than that in the conventional ones.

Although the foregoing has been a description and illustration of a specific embodiment of the invention, various modifications and changes thereto can be made by persons skilled in the art without departing from the scope of the invention as defined by the following claims.

Claims

1. A transformer (10) for a piezoelectric speaker (20) having a sounding body (15) constituted by a piezoelectric body, comprising:

a magnetic core (11),

a primary winding (13), and
a secondary winding (12),

wherein

said primary winding is connectable to an input
terminal for receiving a drive signal for driving
said sounding body, and
said secondary winding is connectable to said
sounding body,

characterised in that
said secondary winding (12) is divided into two
parts (12a, 12b), whereby

one of the divided secondary windings,
said primary winding (13), and the other
divided secondary winding are wound around
said magnetic core in an overlapping relation-
ship in the order designated.

2. The transformer of claim 1, wherein the parts (12a, 12b) forming the secondary winding (12) have substantially the same number of turns.
3. The transformer of claim 1 or 2, wherein the core comprises an E-shaped core (11), said primary and secondary windings (13, 12) being wound around a central shaft portion of said E-shaped core.
4. The transformer of any one of claims 1 to 3, wherein the primary winding (13) and each of the parts (12a, 12b) forming the secondary winding (12) have substantially the same axial length.
5. A piezoelectric speaker device comprising :
 - a piezoelectric speaker (15, 20),
 - a transformer (10) according to any one of the preceding claims, said transformer having a magnetic core (11), a primary winding (13) adapted to receive a drive signal, and a secondary winding (12) connected to said piezoelectric speaker for transmitting said drive signal thereto,
 - characterised in that said secondary winding (12) is divided into two parts (12a, 12b), whereby one of the divided secondary windings, said primary winding (13) and the other divided secondary winding are wound around the magnetic core in an overlapping relationship in the order designated.
6. The speaker device of claim 5 formed as a self-contained unit.
7. The speaker device of claim 5 or 6 further incorporating an audio amplifier for driving said piezoelectric speaker (15, 20).

Fig. 1

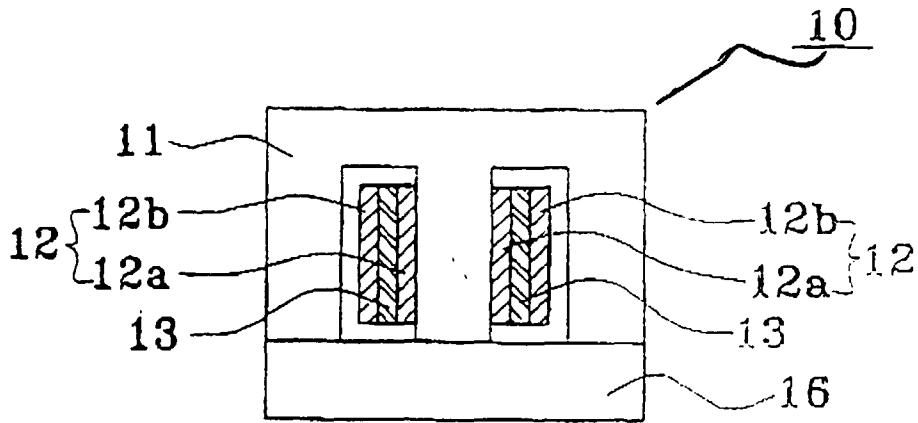


Fig. 2

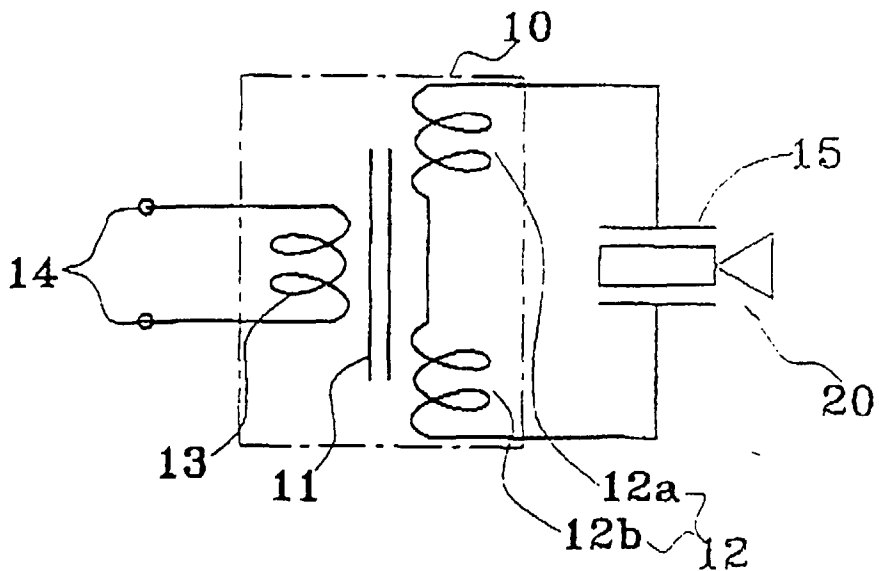


Fig. 3

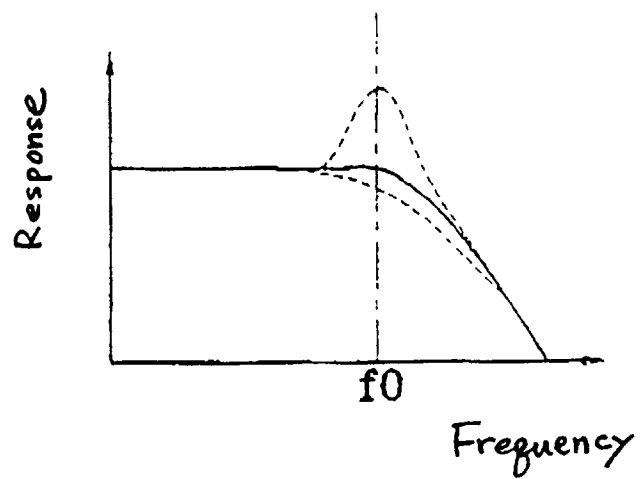


Fig. 4

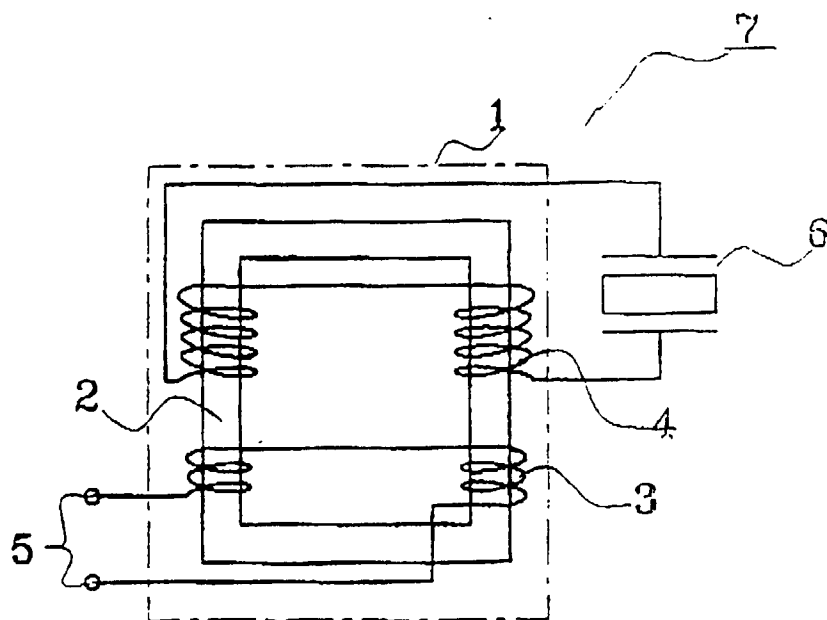


Fig. 5

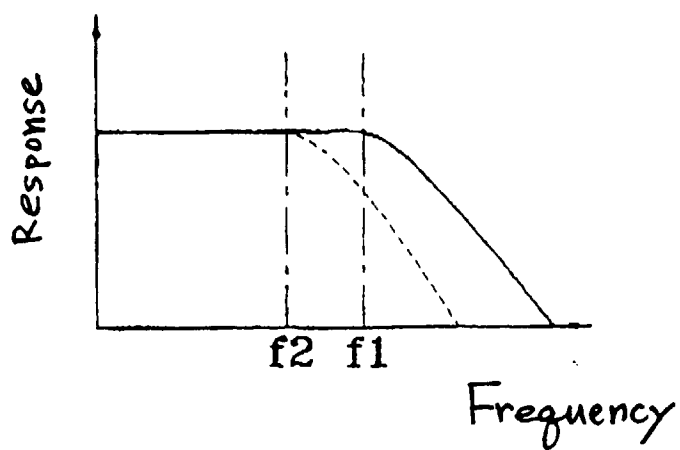


Fig. 6

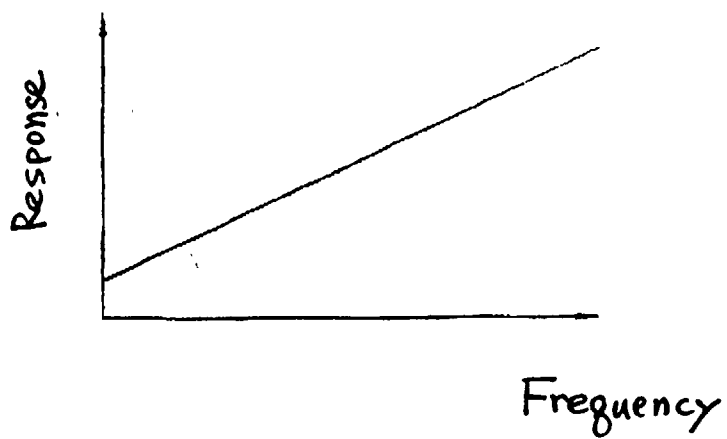


Fig. 7

