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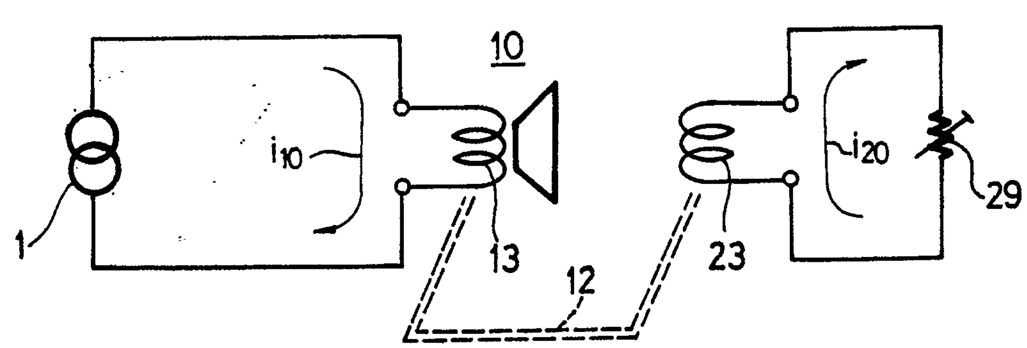
(54) **Loudspeaker drive unit.**

(57) The invention relates to a constant current drive speaker system in which a dynamic speaker is driven by a constant current amplifier. Generally, when the dynamic speaker is driven by a constant current, it is frequently observed that the vibrational system thereof cannot be damped satisfactorily near the low band resonance frequency. To remove this disadvantage, a damping coil (23) provided bodily with the vibrational system is terminated by a predetermined impedance and is provided within a magnetic gap of a magnetic circuit (25) provided independently of the magnetic circuit (15) of the vibrational system, thereby damping the vibration system. Alternatively, a voice coil bobbin is formed of a conductive material to form a short-circuited ring on which there is wound a voice coil. This speaker system is driven by a low frequency, whereby the vibrational system thereof is damped without electromagnetic coupling.

FIG. 3



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LOUDSPEAKER DRIVE UNIT

The present invention relates generally to loudspeaker drive units for loudspeaker systems, particularly but not exclusively ones in which a loudspeaker is driven by constant current. More particularly the invention relates to such drive units in which the vibrational system of the drive unit can be damped satisfactorily in an electromagnetic fashion.

In the prior art, most loudspeakers are driven by amplifiers which act as a constant voltage source.

In the case of a standard direct radiation-type speaker, its electrical impedance has a maximum value at a bass resonance frequency f_0 and increases monotonically in the high frequency band as shown by the full line Z in figure 1B of the accompanying drawings. Accordingly, when such a direct radiation-type speaker is driven by a constant voltage, the resulting drive current i has a minimum value at the bass resonance frequency f_0 and gradually decreases in the high band region as shown by the dashed line i in figure 1B. This drive current i typically provides an output acoustic pressure frequency characteristic shown in figure 1A.

When a speaker system intended to driven by a constant voltage source, the output impedance of the signal source is designed to be substantially zero so that the braking or damping factor becomes substantially zero so that the braking or damping factor becomes substantially infinite. Therefore, the vibrating system of the speaker is damped fairly satisfactorily.

As is well known, the vibrating system of the dynamic speaker is applied with a force proportional to the current flowing to its voice coil in accordance with Fleming's left hand rule. For this reason, the dynamic speaker is preferably driven by a constant current system. When the aforenoted speaker system is driven by a constant current signal source whose output impedance is infinite, current distortion is cancelled out by a non-linear reaction of a magnetic circuit, and it is possible to prevent the speaker system from being affected by the marked rise of electrical resistance brought about by heat generation in the voice coil.

The increase of output acoustic pressure level corresponding to the increased electrical impedance occurs near the bass resonance frequency f_0 and in the high band. The problem thus arises that a flat reproduced acoustic pressure response is difficult to achieve. Further, the damping factor approaches zero so that the vibrating system is not adequately damped.

In order to solve the above described problems, it has been proposed to construct a speaker system driven by a constant current by adding a suitable braking or damping resistor to its mechanical system or to its acoustic system. This proposal, however, causes the mechanical arrangement of the speaker system to become complicated.

According to a first aspect of the invention, there is provided a dynamic loudspeaker drive unit having a vibrational system which, in use, is driven by an electrical signal to produce sound, the vibrational system including an element which forms part of a first magnetic circuit in which magnetic flux is produced by the electrical signal, comprising

a) a damping coil provided bodily with the vibrational system of said drive unit so as to be vibrated therewith; and

b) a damping magnetic circuit independent of the first magnetic circuit, wherein said damping coil is provided in a magnetic gap of said damping magnetic circuit and two ends of said damping coil are terminated by a predetermined impedance.

A second aspect of the invention provides a dynamic loudspeaker drive unit having a magnetic circuit in which, in use, magnetic flux is produced by application of an electrical signal, a voice coil bobbin formed of or comprises an electrically conductive material forming a short-circuited ring and a voice coil wound around said voice coil bobbin, the voice coil and voice coil being located in a magnetic gap of said magnetic circuit.

The invention will be further described by way of non-limitative example with reference to the accompanying drawings, in which:-

Figure 1A is a graphical representation of an output sound pressure frequency characteristic generated by a prior art speaker driven by constant current;

Figure 1B is a graphical representation of frequency versus impedance for a drive current which drives a prior art speaker;

Figure 2 is a fragmentary, sectional view showing a main portion of a first embodiment of a speaker system according to the present invention;

Figure 3 is a schematic diagram showing another main portion of the speaker system shown in figure 2;

Figure 4 is a fragmentary, sectional view showing a main portion of a second embodiment of the speaker system according to the present invention;

Figure 5 is a schematic diagram showing another main portion of the speaker system shown in figure 4;

Figure 6 is a fragmentary, sectional view showing a main portion of a third embodiment of the speaker system according to the present invention; and

Figure 7 is a schematic diagram showing another main portion of the speaker system shown in figure 6.

The present invention will now be described with reference to the attached drawings.

Figure 2 is a sectional view of one main portion of a first embodiment of the speaker system according to the present invention, and figure 3 is a schematic diagram showing another main portion of the first embodiment of the speaker system according to the present invention.

Referring initially to figure 2, there is provided a dynamic speaker 10, wherein a central portion of a cone-type diaphragm 11 is bonded to a bobbin 12. A voice coil 13 is wound around one end portion 12a of the bobbin 12, and a peripheral edge portion of the diaphragm 11 is bonded to one end portion of a frame 14. A magnetic circuit 15 is comprised of a magnet 16, a pole 17 and a plate 18. The magnetic circuit 15 is secured to the other end of the frame 14, and the voice coil 13 is coaxially provided in the air gap between the pole 17 and the plate 18.

An electromagnetic braking or damping system 20 is provided, in which a braking or damping coil 23 is wound around the other end portion 12b of the bobbin 12 which is extended forwardly of the speaker in its axial direction. A damping magnetic circuit 25, which comprises a magnet 26, is provided so as to surround the damping coil 23. This damping coil 23 is provided in the air gap between a pole 27 and a plate 28 of the magnetic circuit 25. In figure 2, reference numeral 24 designates a supporting member.

As shown in figure 3, the voice coil 13 is connected to a drive amplifier that operates as a constant current source 1. The damping coil 23 is connected with a semi-fixed variable resistor 29. In that case, the resistor 29 may be replaced with a proper impedance having a suitable frequency characteristic.

When a drive current i_{10} is supplied to the voice coil 13 of the speaker 10, the diaphragm 11, the bobbin 12 and the voice coil 13 are bodily vibrated, whereby the coil 23 provided at the other end portion 12b of the bobbin 12 is vibrated within the magnetic circuit 25. Thus, an electromotive force $\underline{e}$ occurs in the coil 23 in proportion to the length $\bar{\ }$ of the coil 23 and the vibrational speed of the coil 23 and the magnetic flux density in the magnetic circuit 25 according to Fleming's right hand rule, and a current i_{20} depending on the electromotive force e and a resistance value R_{29} of the resistor 29 flows through the damping coil 23. An interaction between this current izo and the magnetic circuit 25 produces a force acting in the opposite direction of the vibrating direction of the bobbin 12. This force is transmitted through the bobbin 12 to the diaphragm 11, so that the diaphragm 11 is properly damped.

The damping current i_{20} also serves as a detecting current relative to the motion of the vibrating system in the speaker 10. Accordingly, by feeding this damping current i_{20} back to the signal source 1 to thereby carry out the motional feedback, the motion of the vibrating system can be controlled so as to provide a predetermined acoustic reproducing characteristic.

A second embodiment of the speaker system according to the present invention will be described with reference to figures 4 and 5.

The arrangement of the second embodiment of this invention is represented in figures 4 and 5, wherein like parts corresponding to those of figures 2 and 3 are marked with the same references.

It will be seen in figure 4 that a stationary coil 22 is opposed to the damping coil 23 in the damping system 20A. The coil 22 may be wound around the outer periphery of the pole 27 of the magnetic circuit 25 as shown in figure 4. Alternatively, the coil 22 may be provided in the inner peripheral surface of the plate 28.

In this embodiment, the damping coil 23 is short circuited as shown in figure 5, and other portions are formed similarly to those of figures 2 and 3.

In accordance with the second embodiment, a damping current i_{20s} of relatively large current value results from dividing the electromotive force $\underline{e}$ in the coil 23 by the resistance value r_{23} of the $\bar{\ }$coil 23, thereby satisfactorily damping the diaphragm.

Further, the above described motional feedback can be easily carried out by using an electromotive force electromagnetically induced in the stationary coil 22.

As described above, since the damping coil bodily provided with the vibrating system of the dynamic speaker is provided in the air gap of the damping magnetic circuit which is independent of the magnetic circuit of the speaker and the two ends of the damping coil are terminated by predetermined impedance, it is possible to obtain the speaker system of relatively simple arrangement in which the vibrating system of the speaker driven by a constant current can be properly damped in an electromagnetic fashion.

A third embodiment of the speaker system according to the present invention will be described with reference to figures 6 and 7. In this embodiment, the arrangement of the speaker system is further simplified, and in figures 6 and 7, like parts corresponding to those of figures 2 and 3 are marked with the same references.

Referring to figure 6, there is shown a dynamic speaker 10S, wherein a cone-type diaphragm 11 is bonded at a central portion thereof to a conductive coil bobbin 12S and a voice coil 13 is wound around the bobbin 12S. The diaphragm 11 is also bonded at a peripheral edge portion thereof to one end portion of the frame 14. The magnetic circuit 15 is comprised of the magnet 16, the pole 17 and the plate 18 and is secured to the other end portion of the frame 14. The voice coil 13 is coaxially provided in the air gap between the pole 17 and the plate 18.

The bobbin 12S is a copper thin plate shaped, for example, as a cylinder and is served as a short circuit ring from an electrical standpoint.

As shown in figure 7, the voice coil 13 is connected to the drive amplifier provided as the constant current source 1 via a low-pass filter 2 used to separate the frequency band, whereby the speaker 10S functions as a woofer.

Further, the cut-off (ie, crossover) frequency of the low-pass filter 2 is determined, for example, as fco = 1 kHz, and the bobbin 12S is represented as a short circuited coil.

When the drive current i_{10} is supplied to the voice coil 13 of speaker 10S, the diaphragm 11, the bobbin 12S and the voice coil 13 are vibrated within the magnetic circuit 15 altogether so that, according to Fleming's right hand rule, the electromotive force $\underline{e}$ occurs in the bobbin 12S in proportion to the length and the vibrational speed of the bobbin 12S and the magnetic flux density of the magnetic circuit 15, thereby permitting a large current i_{12s}, dependent on the electromotive force $\underline{e}$ and a resistance value r_{12s} of the bobbin 12S in the circumferential direction thereof, to flow. This current i_{12s} produces a force acting in the opposite direction to the vibrational direction of the bobbin 12S to occur, due to the interaction between it and the magnetic circuit 15. The resultant force is transmitted to the diaphragm 11, sufficiently damping the diaphragm 11 whose vibration amplitude increases in the low band region.

In this embodiment, since the voice coil 13 is wound around the conductive bobbin 12S and is provided within the common magnetic circuit 15, the conductive bobbin 12S and the voice coil 13 are electromagnetically coupled to each other.

Assuming that the above described coupling is a transformer of which the voice coil 13 serves as the primary side and the bobbin 12S serves as the secondary side, then its transmission characteristic provides a band-pass type, as shown in a well-known equivalent circuit. Generally, since the inductance of the voice coil 13 is small, the coupling coefficient between the primary and secondary sides decreases greatly in the low frequency band so that the influence of the coupling between the voice coil 13 and the conductive bobbin 12S is negligible.

The speaker 10S is driven by the constant current in the above described embodiments. If the speaker 10S is driven by a constant voltage, then without being affected by the band-separating network, the vibration system of the speaker 10S can be damped well electromagnetically, similarly as described above.

As set out above, according to the third embodiment of the present invention, since the bobbin around which the voice coil of the conductive-type speaker is wound is made of the conductive material to form the short-circuited ring and is provided in the air gap of the magnetic circuit while the drive signal is supplied to the voice coil via the low-pass filter, it is possible to obtain the speaker system of very simple arrangement in which the vibration system of the speaker can be damped well electromagnetically.

It will be appreciated that the invention is not limited to speaker systems with a single drive unit, but is equally applicable to systems with multiple drive units such as woofer/tweeter systems and woofer/mid-range/tweeter systems in which at least one of the loudspeaker drive units in accordance with the invention.

Claims

1. A dynamic loudspeaker drive unit having a vibrational system which, in use, is driven by an electrical signal to produce sound, the vibrational system including an element which forms part of a first magnetic circuit in which magnetic flux is produced by the electrical signal, comprising

a) a damping coil provided bodily with the vibrational system of said drive unit so as to be vibrated therewith; and

b) a damping magnetic circuit independent of the first magnetic circuit, wherein said damping coil is provided in a magnetic gap of said damping magnetic circuit and two ends of said damping coil are terminated by a predetermined impedance.

2. A drive unit according to claim 1, wherein said damping coil is connected with a semi-fixed resistor.

3. A drive unit according to claim 1, wherein said damping coil is connected with a true impedance having a frequency dependent impedance characteristic.

4. A drive unit according to claim 1, 2 or 3, wherein and including means for feeding back a current generated in said damping coil to an amplifier used to drive the drive unit.

5. A drive unit according to any one of the preced-

ing claims, further comprising a fixed pickup coil provided within said damping magnetic circuit, whereby an electromotive force generated in said fixed pickup can be fed back to an amplifier used to drive said drive unit.

6. A dynamic loudspeaker drive unit having a magnetic circuit in which, in use, magnetic flux is produced by application of an electrical signal, a voice coil bobbin formed of or comprises an electrically conductive material forming a short-circuited ring and a voice coil wound around said voice coil bobbin, the voice coil and voice coil being located in a magnetic gap of said magnetic circuit.

7. A drive unit according to claim 6 in which the voice coil is connected to receive a drive signal via a low pass filter.

8. A loudspeaker incorporating at least one drive unit according to any one of the preceding claims.

9. A loudspeaker incorporating at least one drive unit according to any one of claims 1 to 7 in combination with an amplifier adapted to apply a constant current drive signal thereto.

FIG. 1A

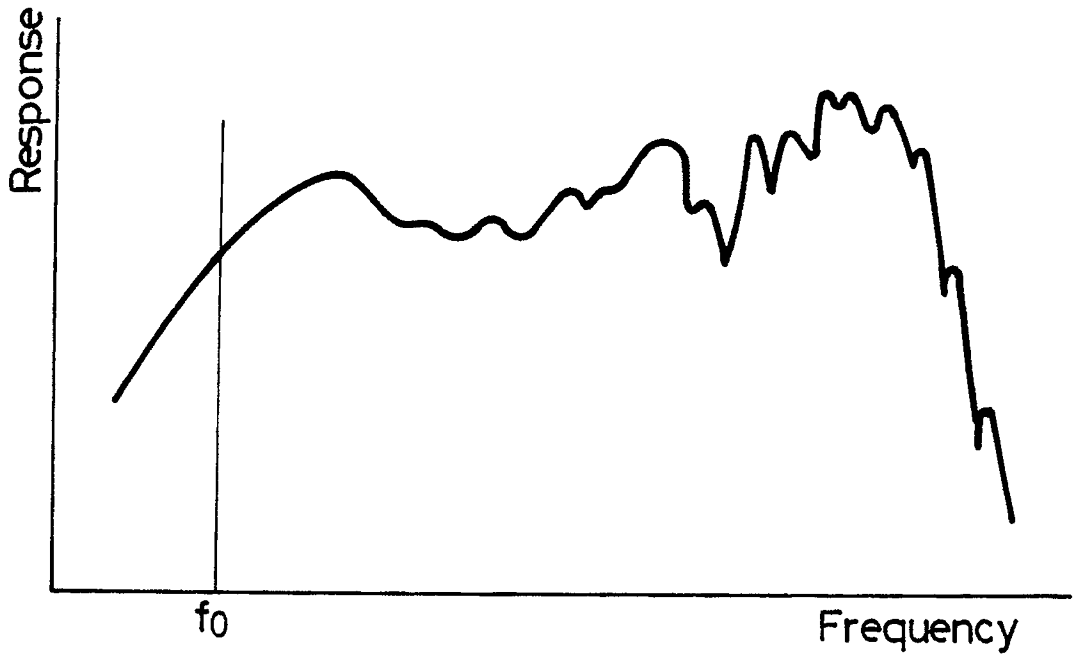
Response
f0
Frequency

FIG. 1B

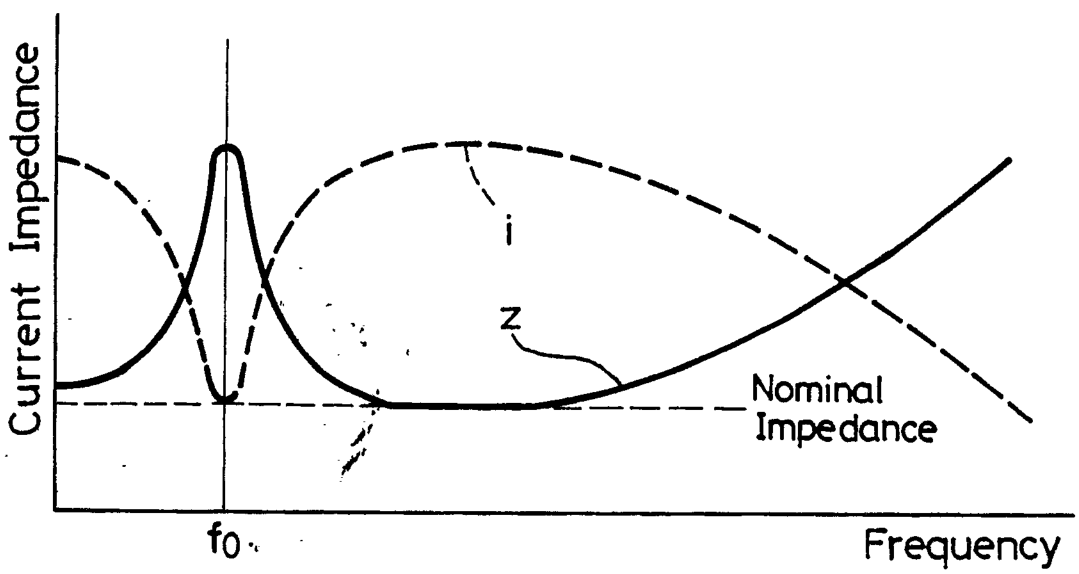
Current Impedance
i
Z
Nominal
Impedance
f0
Frequency

FIG. 2

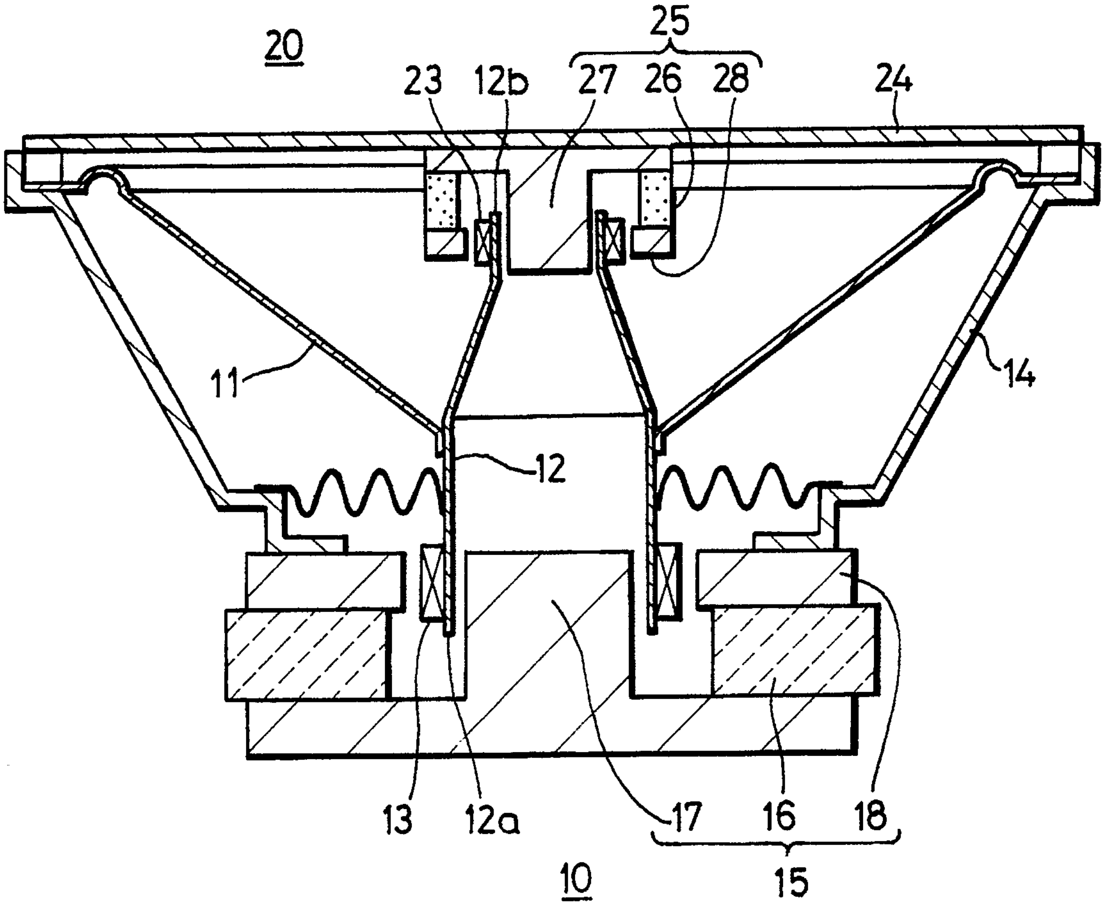
20
25
23
12b
27
26
28
24
11
14
12
13
12a
17
16
18
10
15

FIG. 3

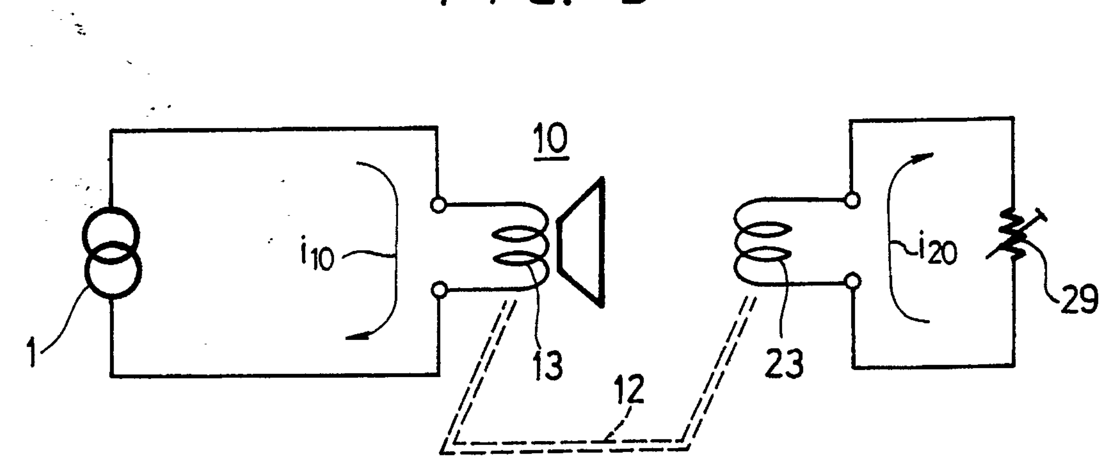
10
i_{10}
i_{20}
1
13
23
29
12

FIG. 4

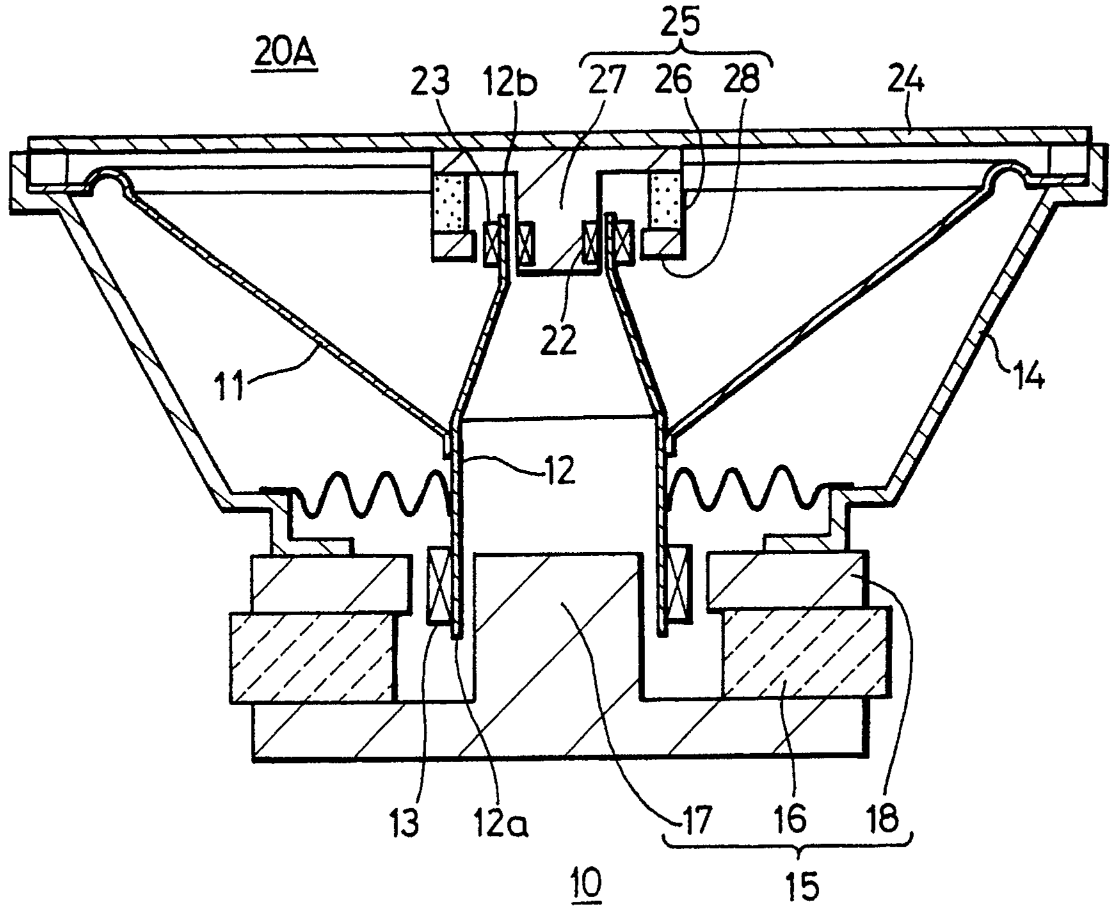
20A
25
23
12b
27
26
28
24
22
11
14
12
13
12a
17
16
18
10
15

FIG. 5

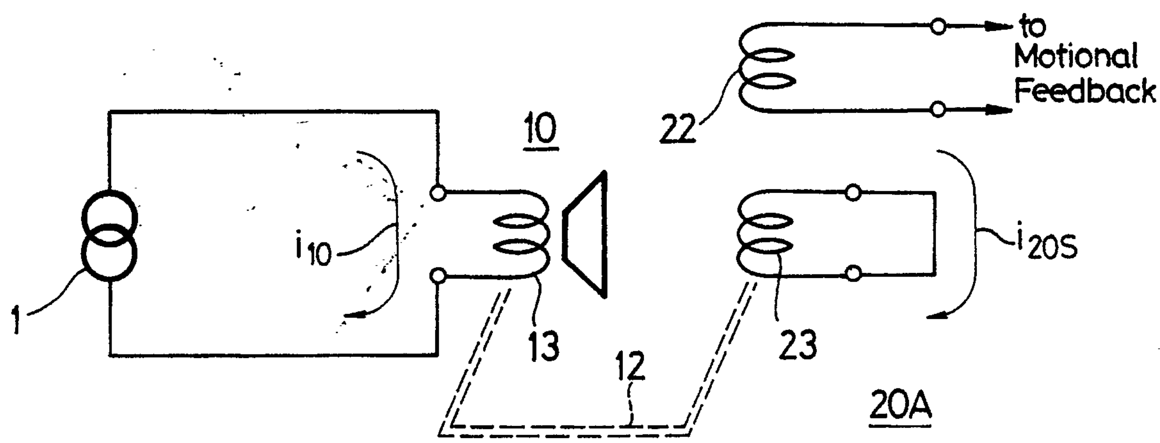
to
Motional
Feedback
22
10
i_{10}
i_{20S}
1
13
23
12
20A

FIG. 6

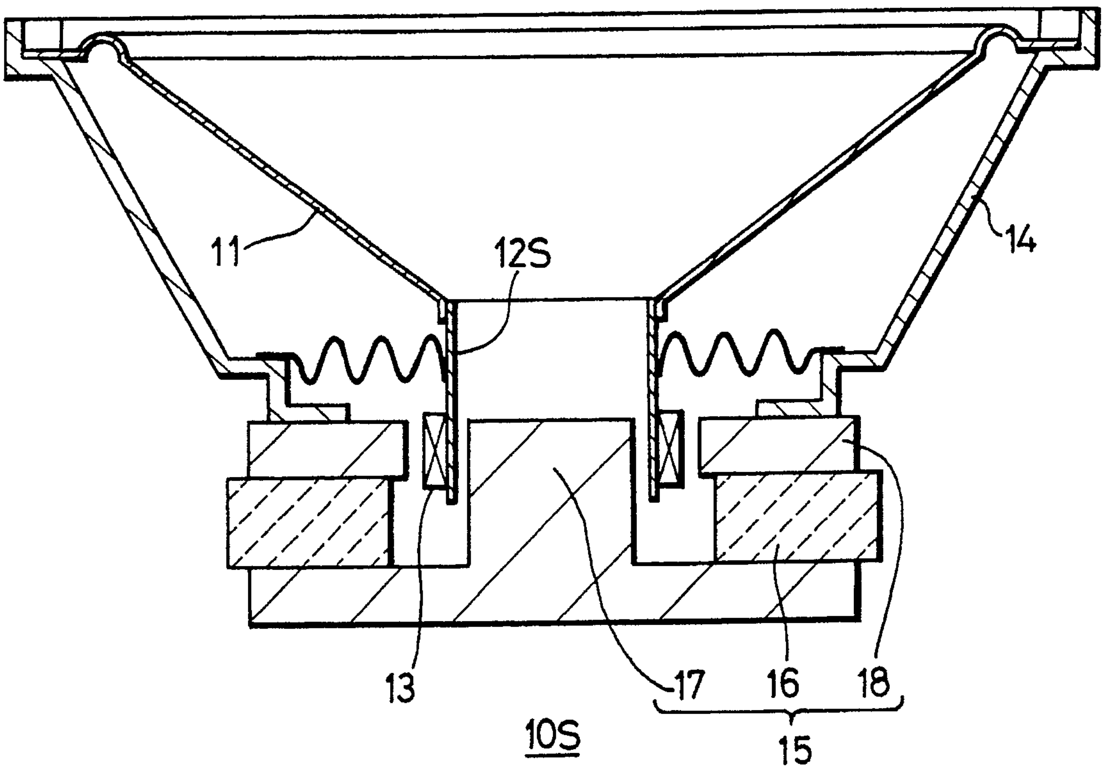

FIG. 7