(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 414 479 A2**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: **90309125.4**

(51) Int. Cl.5: **H04R 1/10**, G10K 11/16

(22) Date of filing: **21.08.90**

(30) Priority: **23.08.89 US 398133**

(43) Date of publication of application:
27.02.91 Bulletin 91/09

(84) Designated Contracting States:
AT BE CH DE DK ES FR GB GR IT LI LU NL SE

(71) Applicant: **BOSE CORPORATION**
100 The Mountain Road
Framingham, Massachusetts 01701(US)

(72) Inventor: **Sapiejewski, Roman**
122 Chandler Street
Boston, Massachusetts 02116(US)
Inventor: **Breen, John J.**
The Mountain
Framingham, Massachusetts 01701(US)

(74) Representative: **Brunner, Michael John et al**
GILL JENNINGS & EVERY 53-64 Chancery Lane
London WC2A 1HN(GB)

(54) **High compliance headphone driving.**

(57) An active noise reducing headset has a high compliance driver (13) having a diaphragm (14). A structure (15) limits the maximum excursion of the diaphragm (14) so that the voice coil does not escape the air gap. Indentations (17) in the diaphragm (14) may be provided to prevent unrecoverable diaphragm collapse.

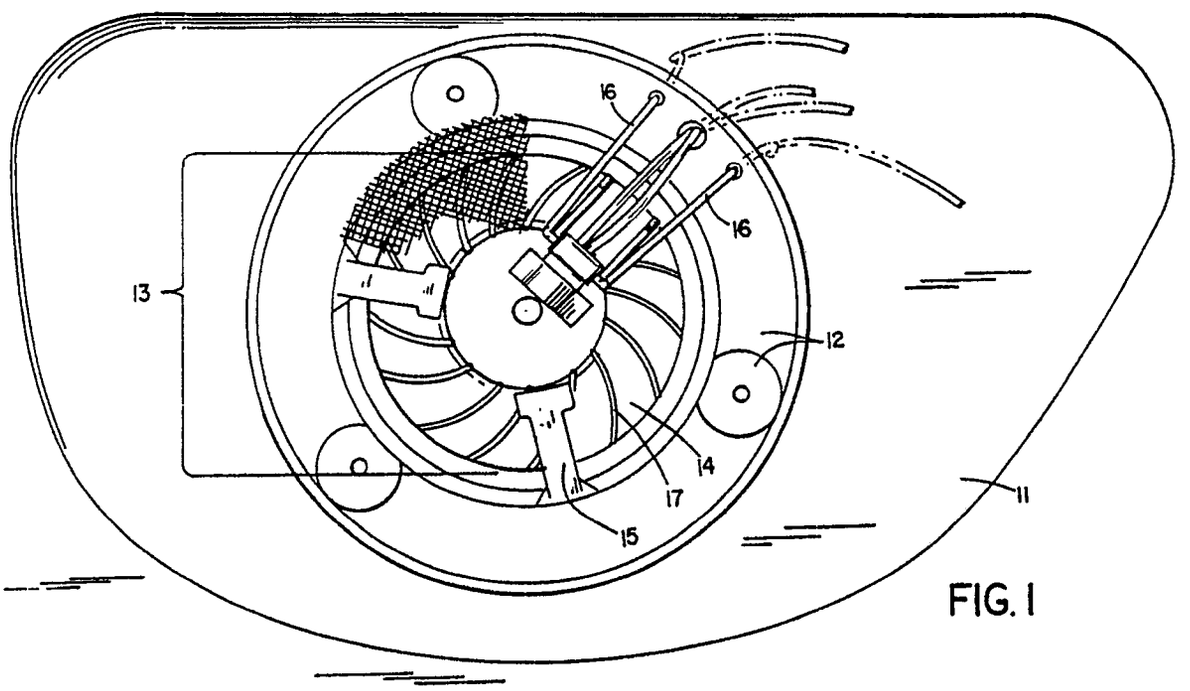


FIG. 1

EP 0 414 479 A2

HIGH COMPLIANCE HEADPHONE DRIVING

The present invention relates to high compliance drivers in active noise reducing headsets. Particularly. it relates to an apparatus for protecting the driver diaphragm.

In active noise reducing headphones it is known to use a headphone having front (inside) and rear (outside) cavities separated by a baffle carrying a small driver.

According to the present invention, a headset comprises at least one earcup having a front and rear cavity, a baffle separating the front and rear cavities, a high compliance driver having a diaphragm joined to a voice coil normally residing in a gap mounted on the baffle, and an active noise reduction system.

Preferably, a limiting structure limits the maximum excursion of the diaphragm.

Indentations may be provided on the diaphragm. The indentations may have a component transverse to the circular grooves or corrugations near the diaphragm periphery.

Other features and advantages of the invention will become apparent from the following detailed description when read in connection with the accompanying drawing, the single figure of which is a plan view of a high compliance driver with the headphone cup generally illustrated to show the environment of the invention.

With reference now to the drawing, there is shown an embodiment of the invention. The invention includes a baffle 11 that separates a front or inside cavity from a rear or outside cavity and carries a high compliance driver 13 having a diaphragm 14. Plastics fingers 15 are equiangularly spaced about the driver axis, extend radially inward and are positioned along the driver axial direction of motion so as to limit displacement of the diaphragm 14 from its centre or rest position to a plane sufficiently close to the rest plane with the diaphragm 14 centred so that a portion of the voice coil is always in the air gap and sufficiently far from the central plane so that the diaphragm 14 is free to translate axially without obstruction when normally reproducing sound with the headphones properly mounted on the head of the user. An active noise reduction system mounting structure 16 carries a microphone (not shown) near the diaphragm 14 used with associated electronic circuitry comprising a system corresponding substantially to the active noise reducing system disclosed in US-A-4644581 and US-A-4455675, incorporated herein by reference.

Having described the physical arrangement of an exemplary embodiment, it is appropriate to consider certain principles. It is convenient to refer to the cavity nearer the user and encompassing his ear with headphones properly positioned as the front or inside cavity and the cavity further from the user as the rear or outside cavity. It is desirable to keep the front cavity volume as small as practical to maximise the sound pressure that the small driver produces at the ear canal to cancel low frequency noise. However, to increase passive transmission attenuation for ambient noise penetrating an ear cup sealed around the ear by a cushion, it is desirable to make the front cavity volume large.

It has been discovered that the effective air volume which determines this transmission attenuation is not simply the volume of the front cavity but also a function of the driver compliance (below its free air resonance frequency) and the volume of the rear cavity. If C_f is the compliance of the front cavity air volume, C_r is the compliance of the rear cavity air volume and C_d is the compliance of the driver, then the effective compliance C_{eff} determining passive transmission attenuation is the front cavity compliance in series with the parallel combination of the driver compliance and the rear cavity compliance, i.e.

$$C_{eff} = C_f + \left(\frac{C_r C_d}{C_r + C_d} \right)$$

below the free air resonance of the driver.

Since compliance of an enclosed quantity of air is proportional to the volume, for a given ear cup volume divided into front and rear cavities, it can be shown that the effective compliance C_{eff} is maximised by maximising the driver compliance. Thus, a driver with very high compliance (low stiffness) and low mass (so as to resonate with the high compliance at as high a frequency as practical) effects significant improvements in passive transmission attenuation below driver free air resonance without audibly affecting sound reproduction. In the limit, if the compliance of the driver is much greater than the compliance of the air in the rear cavity, the effective compliance is equal to the sum of the rear cavity and front cavity compliances, $C_f + C_r$.

High compliance herein means the driver compliance is greater than the rear cavity compliance.

Another advantage of high compliance drivers is that at very low frequencies (below the rear cavity port resonance when the rear cavity is ported), higher driver compliance results in higher system efficiency. This increase in efficiency reduces the electrical power required to generate

sound pressures needed to cancel high levels of low frequency noise. This feature is particularly advantageous in battery-powered active noise reduction headsets and hearing protectors.

When the ear opening in the headset is sealed against the head or any other surface, motion of the earcup relative to that surface changes the volume of the front cavity. Slight changes in volume result in tremendous subsonic pressures. If the volume is increased, such as when the earcup is removed from the head after the cushion was sealed tightly to the head, the under-pressure generated tends to pull the driver diaphragm 14 toward the opened end of the earcup. Since high compliance, low mass drivers move very freely, this pressure can very easily pull the voice coil outside of the gap beyond its normal maximum range of excursion, with the risk that it may catch on the driver basket or magnet and not return to its nominal rest position upon release of the under-pressure. If the volume is decreased, such as when the earcup is pushed suddenly against the head, the over-pressure generated can cause the thin, flexible diaphragm to collapse from its normal shape. Drivers with diaphragms formed from thin plastics films usually are formed with angled grooves or corrugations in the outer annulus between the voice coil and the edge of the diaphragm. These grooves expand and contract as the voice coil moves and help ensure linear, piston-like motion. Under the over-pressure conditions described above, these grooves may irreversibly change shape, and prevent the driver diaphragm from returning to its normal shape and position.

The invention avoids the suction or under-pressure problem by locating a structure in the earcup over the diaphragm 14 to limit voice coil excursion. This structure 15 is positioned such that, during the normal range of excursion of the driver diaphragm, the diaphragm 14 does not touch the structure 15 and its motion is unimpeded. The structure 15 is located close enough to the driver 13 such that it contacts the diaphragm 14 before it is pulled so far that the voice coil is pulled fully from the gap. Since the voice coil is not pulled from the gap, when the suction is released, the coil will return to its normal rest position and not hang up on the basket. The structure 15 is preferably small enough so that it does not cause diffraction or otherwise affect the sound pressure detected by the active noise reduction system's microphone except at high frequencies (above 10KHz). The present invention accomplishes this by using three small fingers of plastics 15 positioned to symmetrically contact the diaphragm 14 along the circle where the voice coil is glued to it. Contacting the diaphragm 14 with small point-like fingers anywhere but along the voice coil might risk possibly puncturing or otherwise damaging the diaphragm. An alternative embodiment for the structure 15 to stop diaphragm motion is a fine wire mesh screen (shown in part in the drawing) shaped so as to contact as much of the surface of the diaphragm 14 as possible at its position of maximum allowed outward excursion. By contacting over a large area, the pressure at any point is small enough so as not to damage the driver.

The present invention avoids the driver collapse or over-pressure problem by using a driver whose diaphragm 14 recovers its shape when collapsed. Changing the shape of the groove or corrugations by including indentations 17, having a radial component in the diaphragm 14 such that the diaphragm 14 recovers its shape if collapsed, prevents unrecoverable collapse. An alternative solution is to change the shape of the metal basket to which the diaphragm 14 is attached or to add a structure to the basket. Commonly the basket surface under the diaphragm 14 is flat. By raising this surface at some points it can be made to support the diaphragm 14 in over-pressure situations, preventing it from collapsing to the point that permanent damage or change in shape occurs.

A preferred form of the invention involves combining the driver mounting structure, active noise reduction system microphone mounting structure, and driver under-pressure excursion stops into a single plastics piece moulded in one shot. This approach reduces the effect of mechanical tolerance build-up and positions all parts accurately so as to provide consistent performance. This structure could be further combined with the baffle separating front and rear cavities.

The specific apparatus functions as follows. When the headset is removed from the head causing an under-pressure situation, the limitation structure or elements 15 limit the excursion of the diaphragm 14 so that the voice coil does not escape the air gap. This structure ensures that the diaphragm 14 will return to its nominal position. These limitation elements 15 do not interfere with the normal range of motion of diaphragm 14.

In an over-pressure situation, such as when the headset is pressed against the head, the grooves 17 in the surface of diaphragm 14 cause the diaphragm 14 to recover its original shape if collapsed by the increase in pressure. Alternatively or additionally, raised points on the basket surface underneath the diaphragm 14 support it during over-pressure situations preventing a collapse.

In a specific embodiment of the invention, the front cavity volume is approximately 100cc (cubic centimetres), and the rear cavity volume is also 100cc. The driver has a free air resonance of 250 Hz and an acoustical compliance of $1x10^{-9}$ m^5N^{-1}. This compliance is equivalent to a volume of 150cc

of air. The effective volume is thus

$$V_{eff}=100+\left(\frac{100x150}{100+150}\right)=160cc$$

The driver diaphragm 14 is formed of mylar which is approximately $25.4x10^{-6}$ m (1 mil) thick. The driver is mounted in a plastics baffle 11 with three under-pressure excursion stops 15 placed to contact the diaphragm 14 at approximately $7.62x10^{-4}$ m (30 mils) excursion. Under maximum operating conditions (high noise and communication levels), driver excursion does not exceed approximately 5.1×10^{-4}m (20 mils). Rear cavity port tuning is set to 90 Hz. Port tuning is chosen based on need for increased driver output for noise cancellation in 50 - 80 Hz range without compromising passive attenuation. A much larger rear cavity would eliminate the need for a port in the rear cavity, but would compromise styling.

Claims

1. A headset comprising at least one earcup having a front and rear cavity, a baffle (11) separating the front and rear cavities, a high compliance driver (13) having a diaphragm (14) joined to a voice coil normally residing in a gap mounted on the baffle (11), and an active noise reduction system.
2. A headset according to claim 1, further comprising a limiting structure (15) for limiting the maximum excursion of the diaphragm (14) so that the voice coil remains at least partially in the gap.
3. A headset according to claim 2, wherein the limiting structure comprises a plurality of elements (15), placed such that the elements (15) contact the diaphragm (14) where the voice coil is joined to the diaphragm (14).
4. A headset according to claim 3, wherein the active noise reduction system mounting structure, the driver mounting structure, the baffle (11) and the limiting elements (15) are combined in a single piece of moulded plastics.
5. A headset according to claim 2, wherein the limiting structure (15) comprises a fine wire mesh screen shaped so as to contact as much of the surface of the diaphragm (14) as practical at its position of maximum allowed outward excursion, preventing further movement.
6. A headset according to any of claims 1 to 5, further comprising means for recovering from collapse of the diaphragm (14) including indentations (17) on the diaphragm (14) such that the diaphragm (14) recovers its shape if collapsed.
7. A headset according to any of claims 1 to 6, further comprising raised portions on the surface underneath the diaphragm (14) preventing unrecoverable collapse of the diaphragm (14).

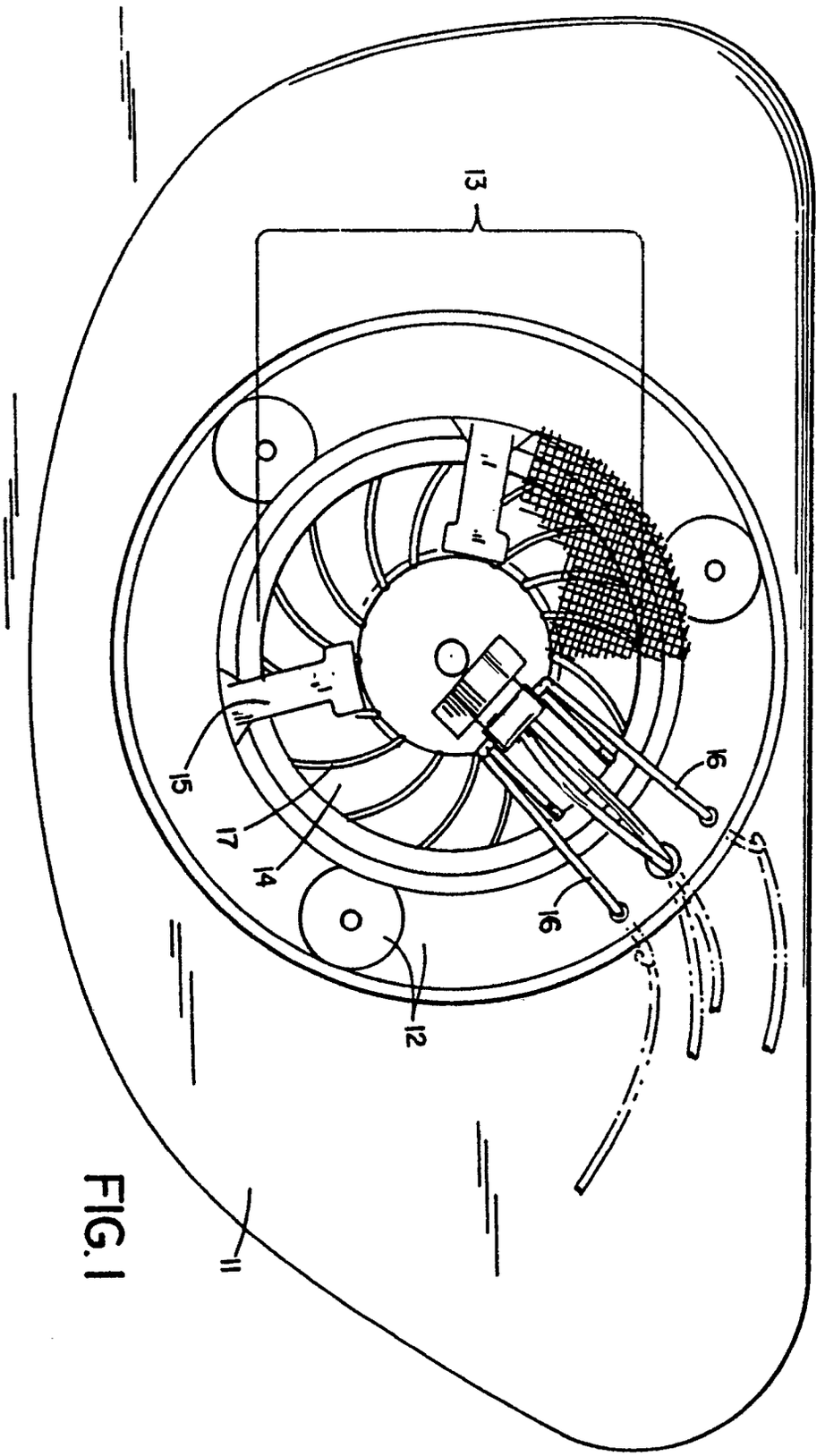


FIG. 1