May 24, 1960 F. A. HERRMANN 2,938,083

TRANSISTOR AMPLIFIER HEARING AID UNIT WITH RECEIVER VIBRATION FEEDBACK SUPPRESSION

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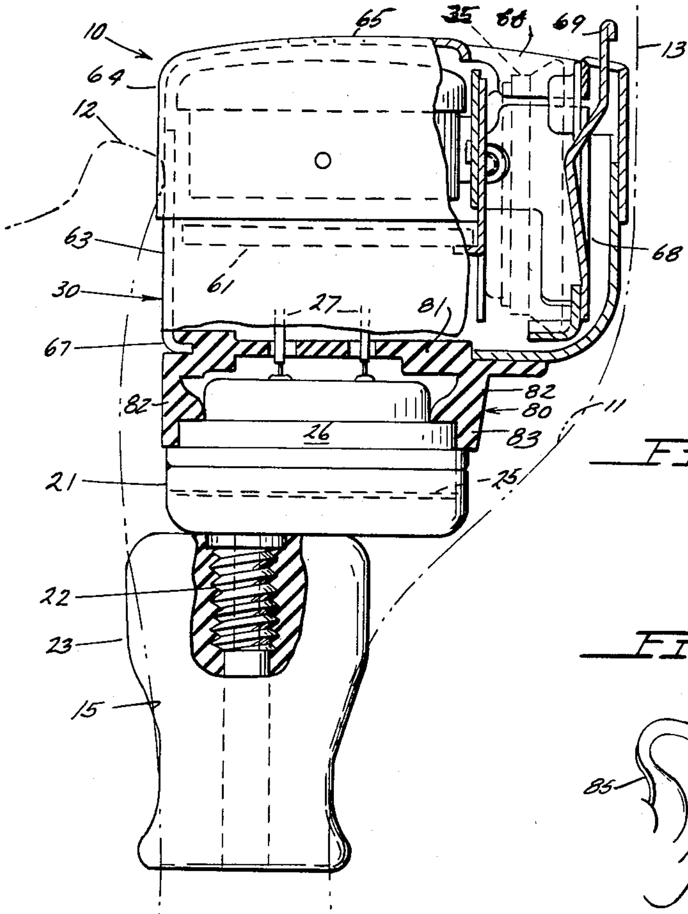
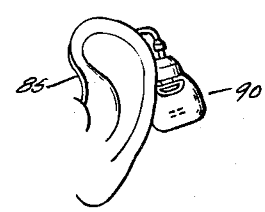


FIG. 1

FIG. 8



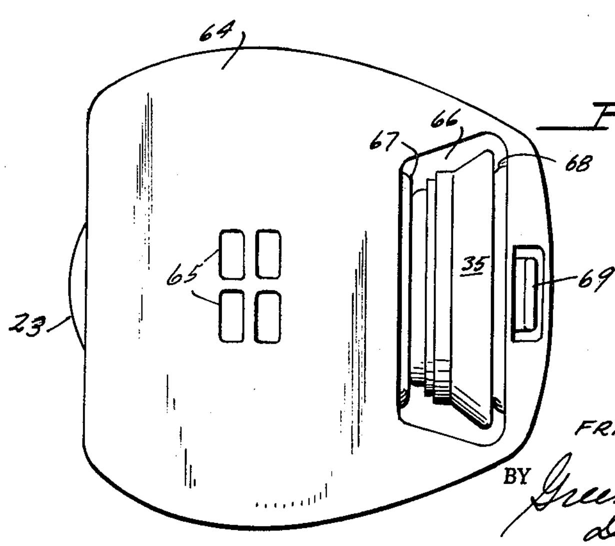


FIG. 2

INVENTOR.
FRANK A. HERRMANN

BY Greene, Pineles & Durr

ATTORNEYS

FIG. 3

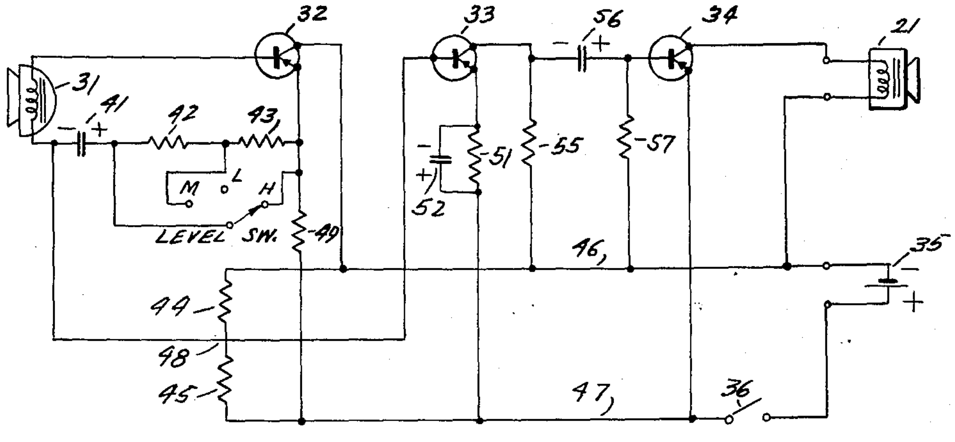


FIG. 4

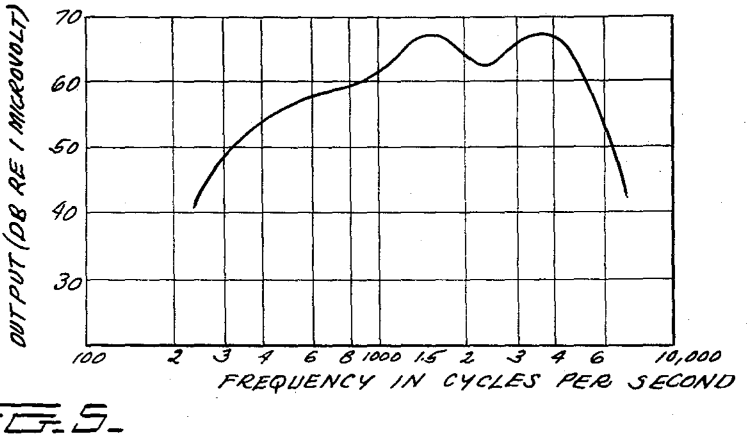
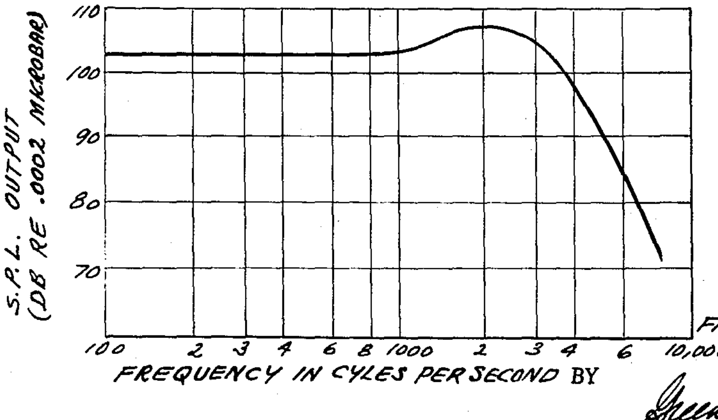


FIG. 5



INVENTOR.
FRANK A. HERRMANN

BY Greene, Pineles & Durr
ATTORNEYS

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TRANSISTOR AMPLIFIER HEARING AID UNIT WITH RECEIVER VIBRATION FEEDBACK SUPPRESSION

Frank A. Herrmann, White Plains, N.Y., assignor to Sonotone Corporation, Elmsford, N.Y., a corporation of New York

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5 Claims. (Cl. 179—107)

This invention relates to all-in-one unitary transistor hearing aids wherein all its elements including the microphone, the transistor amplifier, the receiver or earphone, and the battery cell, are combined into a single miniature-size unit of an over-all volume small enough to fit within the outer ear cavity of the user's ear. Since such hearing aids have to operate with a gain of about 30 decibels, plus-minus 5 decibels, it is essential to prevent feedback to the microphone of the sound output of the earphone, as well as of the incident corresponding mechanical reaction vibration of the earphone body or casing, while securing the desired minimum over-all volume of such hearing aid unit.

In accordance with the invention, the required essential reduction of the vibration feedback from the earphone body to the microphone is obtained by joining the amplifier-microphone section thereof to its tiny earphone by a body of vibration-attenuating elastomer material of sufficient volume and sound dissipating characteristics to secure the required suppression of feedback of mechanical vibrations from the earphone body to the amplifier-microphone section.

The foregoing and other objects of the invention will be best understood from the following description of exemplifications thereof, reference being had to the accompanying drawings wherein:

Fig. 1 is an elevational view, with parts in section, of one form of a unitary hearing aid unit exemplifying the invention, as it is held in its operative position within the outer ear cavity of the user;

Fig. 2 is a top view of the hearing aid unit of Fig. 1;

Fig. 3 is a circuit diagram of the hearing aid of Figs. 1 and 2;

Figs. 4 and 5 are typical frequency response curves of a microphone and earphone, respectively; and

Fig. 6 is an elevational view showing how a hearing aid unit similar to that of Figs. 1 to 3,, is worn behind the ear at its junction to the adjacent head body portions.

Referring to Figs. 1 and 2, the hearing aid unit generally designated 10 has such small lateral dimensions that its outer wider amplifier section 30 fits within the concha cavity 11 of the user's outer ear between the tragus 12 and anti-helix 13 thereof. The receiver or earphone 21 has a sound outlet duct 22 connected through a flexible ear tip 23 of elastomer material, such as rubber, fitting within and acoustically sealing the ear canal 15 of the user. For the sake of clarity, the parts of the user's ear including its tragus 12, anti-helix 13 and the walls of its ear canal 15, are indicated in dash-double-dot lines.

The hearing aid of Figs. 1 and 2 embodies and combines the elements and components shown in the circuit diagram, Fig. 3. It comprises a microphone 31 the output of which is impressed on an amplifier operating with three transistors 32, 33, 34, which deliver the amplified microphone output to the receiver or earphone 21. The circuits of all three transistor amplifier stages are energized from the same energy source consisting of a single, tiny battery cell 35 which may be connected or disconnected

from the transistor amplifier stage by a switch 36. The microphone 31 and the receiver 21 have electromagnetic sound energy transducers. For instance, the microphone 31 may have a transducer of the type shown in Egerton Patent 1,385,898, and the earphone may be of the type shown in Pearson Patent 2,493,734. The output of the microphone is delivered to the base and emitter of the first transistor 32 through a circuit including a by-pass capacitor 41 and resistances 42, 43. Direct-current bias for transistor 32 and for the other transistors is provided by voltage-dividing resistances 44, 45 which are connected through energy supply leads 46, 47 to the opposite terminals of the supply cell 35. The two resistances 44, 45 have an intermediate tap 48 from which the proper bias current is impressed between the base and emitter of transistor 32, through a bias circuit including resistance 49 connected between the emitter of transistor 32 and supply lead 47.

The output developed between the collector and emitter of the first transistor 32 is impressed between the base and emitter of the second transistor 33. The emitter of transistor 33 is connected to its supply lead 47 by a resistance element 51 which is by-passed by a capacitor 52. The collector of the second transistor 33 is connected through load resistance 55 to supply lead 46. The base and emitter of these transistors have applied thereto proper bias by the voltage-dividing resistance elements 44, 45 and intermediate tap 48. The output developed between the collector and emitter of transistor 33 is delivered through a circuit including by-pass capacitor 56 to the base and emitter of the third transistor 34. Proper bias is applied by the voltage-dividing resistance elements 44, 45 to the base and emitter of transistor 34 through a circuit including resistance 57. The output developed between the collector and emitter of the third transistor 34 is delivered to the winding of the receiver 21 for energizing it with amplified current sufficient to cause its diaphragm to deliver to the ear canal of the user the required amplifier sound output corresponding to the desired amplification of 25 to 35 db.

Referring to Figs. 1 and 2, all of the foregoing circuit components and elements described above in connection with Fig. 3, except the earphone, are combined into the wider amplifier section 30 having an over-all volume to permit insertion thereof into the outer cavity of the user's ear, with lateral dimensions fitting between the anti-helix, tragus and anti-tragus. The amplifier unit 30 has a chassis plate 61 along which are assembled all the circuit elements of the amplifier shown diagrammatically in Fig. 3, except for the receiver 21. The chassis plate 61 consists of a printed circuit member of insulating material provided on its surface with printed circuit elements through which the various components of the hearing aid are connected in the operating circuit of Fig. 3. The microphone 31 is mounted above the chassis plate 61, as shown in Fig. 1, and is enclosed in a metallic casing of magnetic shield material so as to suppress magnetic interlinkage thereof with the electromagnetic transducer element of the receiver 21. Most of the other amplifier components and elements are carried along the underside of the chassis plate 61, as shown in Fig. 1. The amplifier chassis plate 61 with the amplifier elements and microphone mounted along it, are housed in a metallic casing 63 having an outer casing wall 64 overlying the microphone 31 and provided with openings 65 through which sound from the outer space is transmitted to the microphone for causing it to generate corresponding electric output impressed on the transistor amplifier. In general, the amplifier arrangement is of the type described in co-pending applications Serial Nos. 615,189, filed October 10, 1956, and 634,368, filed January 15, 1957, both assigned to the assignee of the present application.

The upper amplifier casing wall **65** has an opening **66** through which the battery cell **35** may be inserted between a fixed terminal member **67** carried by the chassis plate **61** and a flexible terminal member **68** having a grip finger **69** which may be gripped on the exterior of the casing cover **65** for releasing the battery from its operative position in the amplifier section **30**. Upon gripping the projecting finger **69** of the battery holding spring **68** and flexing it to the right, as seen in Figs. 1 and 2, the battery cell **35** is free to drop out from the battery compartment of the amplifier casing **63** for replacing it by another cell.

The receiver **21** has a light vibratory diaphragm **25** which is vibrated by a receiver body **26** for generating the required sound output which is transmitted through the receiver sound outlet duct **22** and its flexible rubber ear tip **23** to the ear canal of the user. These vibrations of diaphragm **25** cause it to exert opposite inertia reaction forces on the receiver body **26**, which as a result, undergoes similar vibrations of much smaller amplitude, corresponding to its larger mass. These inertia reaction vibrations of the receiver body **26** are transmitted to any other body which is mechanically joined thereto. Thus, when the receiver or earphone **21** is directly attached to the body of the amplifier-microphone section, the minute mechanical vibrations of the receiver body **26** will be transmitted to the casing **63** of the microphone-amplifier section **30** and these casing vibrations will in turn be transmitted mechanically to the microphone **31**. In addition to the mechanical receiver-body vibrations so transmitted to the microphone **31** by the amplifier-microphone casing **63**, the large area of the so-vibrating casing **63** excites the surrounding air into corresponding vibrations which will be acoustically transmitted to the microphone. In the past, difficulties have been encountered in finding a way for suppressing mechanical and acoustic feedback of the minute mechanical vibrations from the earphone body **26** to the adjoining amplifier-microphone casing of such unitary hearing aid when it is operated at the desired full gain of 25 to 35 db.

The present inention overcomes the difficulties connected with suppression of acoustic and mechanical vibration feedback from the earphone body to the adjoining microphone-amplifier section of such hearing aid unit. In accordance with the invention, excessive feedback action of the minute mechanical vibrations of the earphone body **26** are suppressed by connecting the earphone **21** to the amplifier-microphone section **30** through a relatively large barrier body **80** of sound-absorbing and sound-attenuating elastomer material, such as rubber. In the form shown, the elastomer barrier body **80** has a body portion affixed to the adjoining wall portion **67** of the amplifier-microphone casing **63**, which is separated by a relatively thick intermediate barrier body portion **82** from a relatively remote barrier body part **83**, which is secured to the vibrating earphone body **26**, so that the elastomer material of the substantially thick intermediate barrier portion **82** is interposed between the earphone body **26** and the amplifier casing portion **66**, for suppression of mechanical vibration feedback to casing **63** and the microphone **31** held therein.

In the form shown, the barrier elastomer body portion **81** is suitably joined to the metallic casing wall portion **66** of the amplifier-microphone unit **30** as by cement. The remote barrier elastomer portion **83** forms an elastomer body projecting a distance away from the amplifier casing **63** and separating therewith the earphone body **26**, with the intermediate elastomer body portion **82** having sufficient volume and vibration-dissipating characteristics for keeping feedback of mechanical earphone body vibrations below a level that would set up generation of sustained electrical and mechanical oscillations and continuous earphone whistling.

The relatively large mass of intermediate rubber barrier body portion **83** forms a collar holding the earphone body **26** spaced from the adjoining amplifier casing portions **36, 56**. The rubber barrier body portion **80**, which is secured to the amplifier casing portion **67**, has openings through which insulating conducting leads **27** of the earphone are connected to the outward side of the amplifier housed in the amplifier casing. With the arrangement of the type shown and described, the earphone body portion **26** to which the remote rubber body portion **83** is secured, is of smaller lateral dimension and is surrounded by the rubber barrier body **80**, thus exposing only a small area of the vibrating earphone body to the surrounding air and thereby reducing acoustic air feedback of the minute mechanical vibrations of the earphone body to the microphone.

Fig. 4 shows a curve diagram typical of the frequency response of the microphone **31** of the hearing aid unit of the type described above in connection with Figs. 1–3, and Fig. 5 shows a curve diagram typical of the response of an earphone of such hearing aid unit. Fig. 4 shows that the response of the microphone rises from about 300 c.p.s. (cycles per second) at a rate of about 6 decibels per octave to 1500 c.p.s., the response thereafter continuing at about the same raised level with an anti-resonant peak at about 2200 c.p.s. and a resonant peak at about 3500 c.p.s., with the response dropping sharply at about 4000 c.p.s. Fig. 5 shows that the response of the earphone is substantially level from 100 c.p.s. to 1000 c.p.s., rising thereafter at a rate of 5 decibels per octave to 2000 c.p.s., and dropping thereafter back to about the same level, as around 100 to 1000 c.p.s., and dropping sharply at 3500 c.p.s. The earphones of the type used in connection with the hearing aid of Fig. 6 have a frequency response similar to that shown in Fig. 5, except that it remains at about the same level between 100 and 3500 c.p.s., with 12 db peak at 2000 c.p.s.

The vibration-dissipating barrier body **80** dissipates only very little of the low-frequency vibrations below 1000 c.p.s. which are transmitted from the body of the earphone **21** to the amplifier casing **30**. However, since the microphone has a relatively low sensitivity in this low-frequency range below 1000 c.p.s., the microphone will not be sufficiently excited by the transmission of these low-frequency earphone body vibrations to cause the hearing aid unit to become self-excited and set up whistling oscillations. On the other hand, earphone body vibrations in the frequency range from about 1500 c.p.s. and higher, if transmitted through the amplifier casing **63** to the microphone **31**, would be sufficient to set up in the hearing aid unit of Figs. 1–3, continuous oscillations and whistling. The vibration-dissipating barrier body **82** of the type described above in connection with Fig. 1, has sufficient vibration-dissipating capacity for vibrations from 1000 c.p.s. and higher to suppress transmission of such vibrations from the body of the earphone **21** to the amplifier casing **30**, and keep their transmission below a level which would set up self-sustaining oscillations and whistling in the hearing aid unit of Fig. 1. Although it has such desired earphone vibration-dissipating characteristics, the barrier body may be designed to provide a relatively positive connection between the microphone amplifier section **30** and the earphone **21** so that they form a self-supporting unit.

Without thereby limiting the scope of the invention, there are given below data of a commercial form of hearing aid exemplifying the invention:

The transistors are of the PNP type.

The casing of the amplifier unit has lateral dimensions ⅝" by ⅝", and a total height of ½", the two complementary parts of the casing being of stainless steel.

The battery cell **35** has a maximum outer diameter of 7/16", and a thickness of ⅛".

The earphone **21** has a circular shape. Its outer portion exposed beyond the rubber barrier body **80** has a diameter of 7/16", and an axial height of 5/32". The inner, narrower, receiver earphone body portion **26** is $\frac{5}{16}$ in diameter, and $\frac{3}{32}''$ high.

The part of the receiver casing adjoining the eartip **23** has a stainless steel exterior.

The elastomer barrier body **30** is of silicon rubber and the weight of its mass is .02 ounce. Its compliance is on the order of .0001 inch displacement by a force of one ounce. The total height is about $\frac{1}{4}''$. Its wall portion **31** has a square shape about $\frac{1}{2}''$ by $\frac{1}{2}''$ in size, with a wall thickness at its outer region of .060". The collar-shaped part of the intermediate elastomer body portion **32** is of circular shape; it has an outer diameter of $\frac{1}{2}''$, and its cross-sectional surface corresponds to an area of $\frac{1}{8}''$ x $\frac{3}{16}''$.

In Fig. 6 is shown a hearing aid unit similar to that of Figs. 1–5, wherein the sound duct **22** of the receiver **21** has connected thereto a small, hollow tubing **85** of flexible material such as neoprene, which extends to an eartip **23** of flexible rubber-like material, such as described above, seated and held in the ear canal of the user for transmitting the earphone sound output to the user's hearing organs. The flexible, sound-conducting tubing **85** which extends from the ear tip in the ear canal of the user is looped in over-lapping engagement over the upper junction portion of the auricle to the head, and extends along the rear of the ear to the sound outlet duct **22** of the earphone **26**, so as to carry and support it together with the other parts of the unitary hearing aid unit **10** similar to that of Figs. 1 and 2, behind the user's ear. The hearing aid unit **90** of Fig. 6 is otherwise similar to that described above in connection with Figs. 1 to 5.

As used in the specification and claims herein, the expression "suppress" is intended to mean attenuation of an undesirable action to a degree sufficient for securing the desired over-all effect.

It will be apparent to those skilled in the art that the novel principles of the invention disclosed herein in connection with specific exemplifications thereof, will suggest various other modifications and applications of the same. It is accordingly desired that in construing the breadth of the appended claims they shall not be limited to the specific exemplifications of the invention described above.

I claim:

1. In a hearing aid, an earphone; an amplifier section including a microphone, a battery cell, and a transistor-amplifier including at least one transistor electrically connected to said cell and between said microphone and earphone for supplying amplified microphone output to said earphone, said amplifier section constituting a unit separated from said earphone; said microphone having a materially lower response at frequencies below 1000 cycles per second than at a frequency between 1500 and 4000 cycles per second; and a barrier body of rubber-like yieldable elastomer material forming the sole mechanical connection joining said earphone and said amplifier section into a self-supporting structure movable as a unit relatively to the ear of the user, which structure has an over-all volume corresponding to an object fitting into the outer cavity of the ear between the anti-helix, tragus and anti-tragus; said barrier body having the property of materially attenuating vibratory energy of frequencies higher than 1000 cycles per second, a body volume of said barrier body which is of substantial thickness separating said earphone and said amplifier section for suppressing feedback of mechanical vibrations of high frequencies of at least about 1000 cycles per second from said earphone to said amplifier section and thereby preventing the setting up of sustained electric oscillations and earphone whistling at such high frequencies.

2. In a hearing aid as claimed in claim 1, said amplifier section having a casing enclosing at least a major part of the spaced occupied thereby, said barrier body forming the sole junction between said casing and said earphone.

3. In a hearing aid as claimed in claim 1, said amplifier section having a metallic casing enclosing at least a major part of the space occupied thereby, said barrier body forming the sole junction between said casing and said earphone.

4. In a hearing aid as claimed in claim 1, said earphone being positioned eccentrically relatively to the nearby portion of said amplifier section and forming therewith a self-supporting structure shaped and of a volume small enough to fit and be held within the outer ear cavity of the user between the anti-helix, tragus and anti-tragus, said amplifier section having a casing enclosing at least a major part of the space occupied thereby, said barrier body forming the sole junction between said casing and said earphone.

5. In a hearing aid as claimed in claim 1, said earphone being positioned eccentrically relatively to the nearby portion of said amplifier section and forming therewith a self-supporting structure shaped and of a volume small enough to fit and be held within the outer ear cavity of the user between the anti-helix, tragus and anti-tragus, said amplifier section having a metallic casing enclosing at least a major part of the space occupied thereby, said barrier body forming the sole junction between said casing and said earphone.

References Cited in the file of this patent

UNITED STATES PATENTS

2,787,670	Rowland	Apr. 2, 1957
2,824,177	Tado	Feb. 18, 1958

FOREIGN PATENTS

922,889	Germany	Jan. 27, 1955