June 6, 1961 M. E. WEBBER ET AL 2,987,584

IN-EAR HEARING AID

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FIG. 1

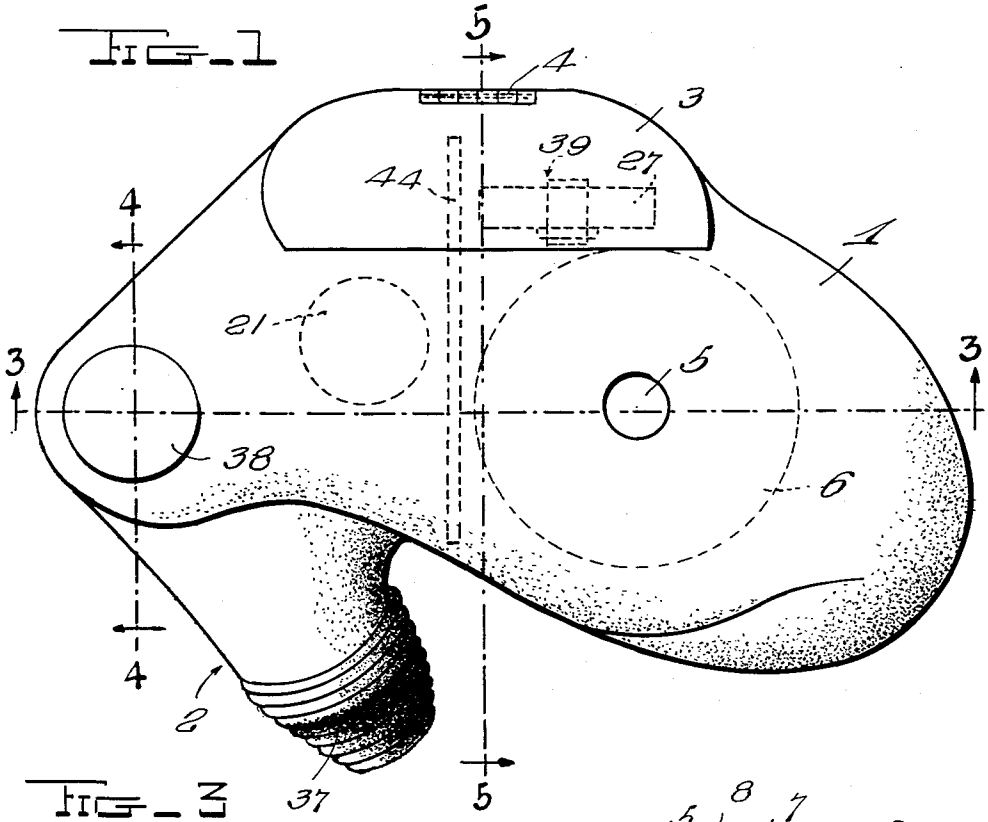

FIG. 3

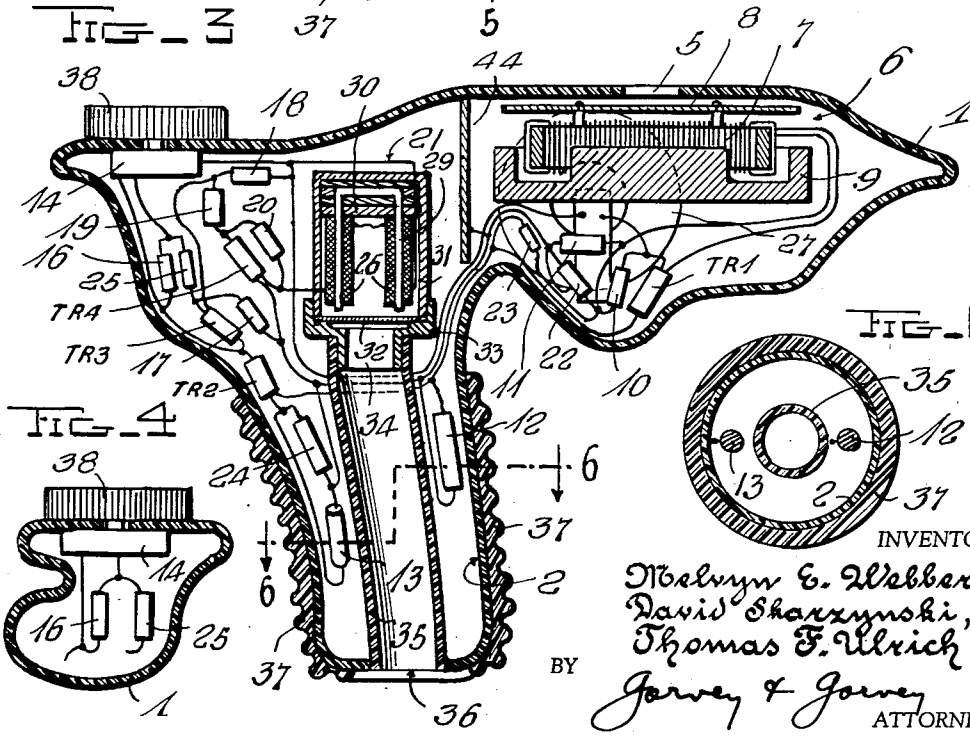

FIG. 4

FIG. 6

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FIG. 2

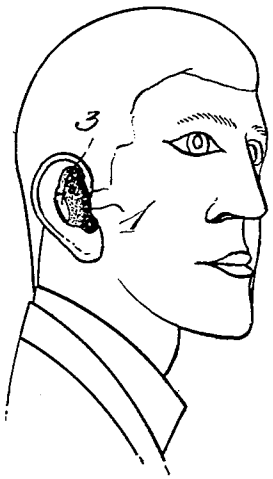


FIG. 8

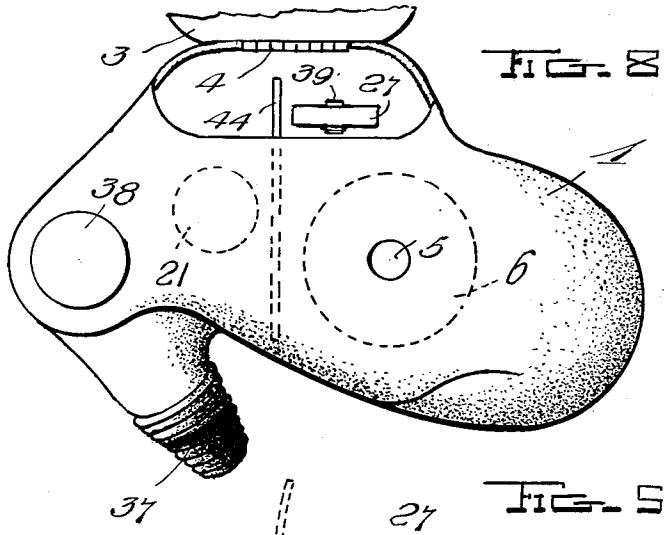


FIG. 5

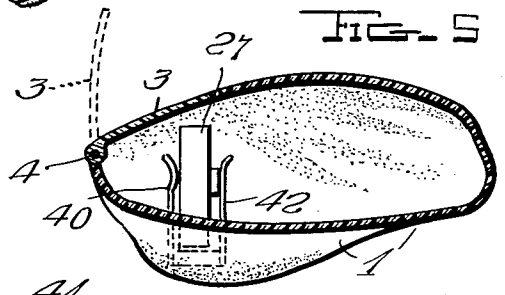


FIG. 9

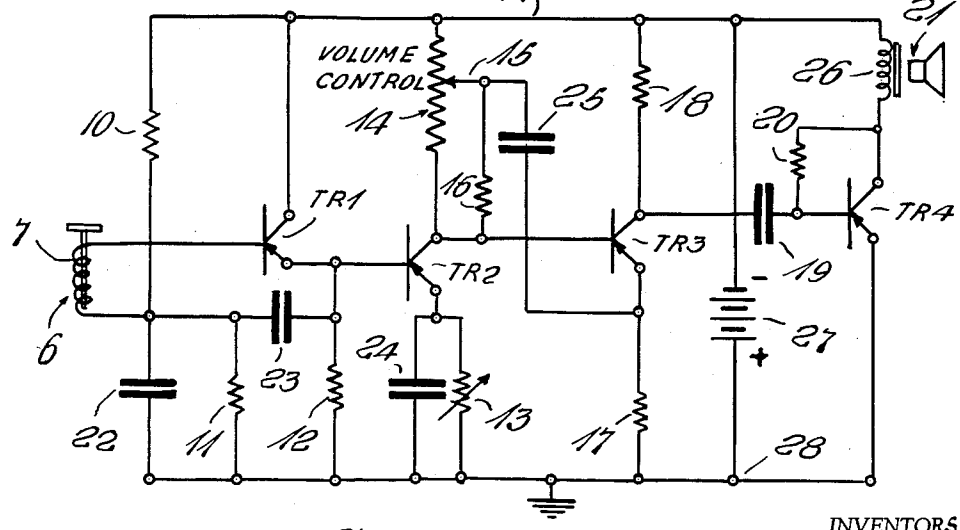
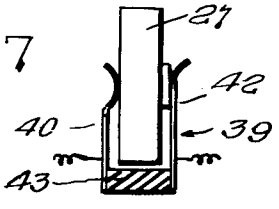


FIG. 7



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2,987,584

IN-EAR HEARING AID

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2 Claims. (Cl. 179—107)

Our invention relates broadly to hearing aid devices and more particularly to a hearing aid unit which fits wholly within the ear of the user without connection to other external units.

One of the objects of our invention is to provide a compact transistorized circuit arrangement for single unit hearing aids in which feedback from the receiver to the microphone is eliminated.

Another object of our invention is to provide a construction of hearing aid unit which fits wholly within the ear of the user and does not protrude outwardly beyond the high line of the ear.

Still another object of our invention is to provide a construction of hearing aid unit, fitting wholly within the user's ear, having an adjustable volume control disposed thereon conveniently adjustable from the exterior of the unit.

A further object of our invention is to provide a construction of hearing aid unit totally contained within the user's ear and having a compartment therein with a hinged section thereon for access to the interior thereof, for insertion and renewal of a battery unit.

Still a further object of our invention is to provide a hearing aid unit totally contained within an ear-piece adapted to be constructed of a plastic resin from a mold of the individual user's ear.

Other and further objects of our invention reside in the means for reducing electrical feedback through the ear-piece hearing aid as set forth in more detail in the specification hereinafter following by reference to the accompanying drawings, in which:

FIG. 1 is a front elevational view of the in-ear hearing aid of our invention, showing the battery compartment closed and the device ready for insertion into the ear;

FIG. 2 is a schematic view illustrating the manner in which the hearing aid is worn in the ear by an individual;

FIG. 3 is a longitudinal sectional view taken substantially on line 3—3 of FIG. 1;

FIG. 4 is a transverse sectional view taken substantially on line 4—4 of FIG. 1;

FIG. 5 is a transverse sectional view taken substantially on line 5—5 of FIG. 1;

FIG. 6 is a transverse sectional view taken substantially on line 6—6 of FIG. 3 and illustrating particularly the manner in which the circuit components are installed in the space between the exterior of the end tube and the interior of the shell of the in-ear hearing aid;

FIG. 7 is a detail schematic view showing the manner of detachably mounting the battery in position for energization of the transistorized amplifier and the microphone circuit thereof;

FIG. 8 is a view similar to the view illustrated in FIG. 1 showing the in-ear hearing aid on a reduced scale and illustrating particularly the hinged door of the battery compartment moved to open position for permitting insertion or removal of the battery from the battery compartment; and

FIG. 9 is a diagrammatic view of the transistorized circuit employed in the in-ear hearing aid of our invention.

Our invention is directed to the construction of a hearing aid unit which is totally contained within the user's ear with no cords, glasses or other article associated therewith. It consists of a hollow plastic case molded to the interior contour of the ear and contains thereon a hinged compartment for access to the interior thereof for replacement of the battery power supply, etc. The exterior of the case also provides an opening for the microphone pick-up and a volume control knob for increasing or decreasing the amplification of the four-stage transistor amplifier circuit, contained therein, according to the user's desire.

The case carries a hollow protrusion thereon which extends into the user's ear and contains interiorly thereof a sound tube connecting the receiver output to the bottom surface of the protrusion and components of the electrical circuit disposed about the sound tube to conserve space. The exterior surface of the protrusion is covered with a ribbed flexible material to aid in holding the unit in the user's ear and to eliminate mechanical noise feedback to the microphone through the case due to movement between the protrusion and the ear.

Interior of the case electrical feedback from the receiver to the microphone is eliminated by placement of a shield element between the microphone and the receiver which also isolates the first stage transistor circuitry from the other transistor circuitry stages.

The result of our invention is a very inconspicuous hearing aid unit which protrudes no further from the ear than the highest line thereof and which is extremely light in weight. Our hearing aid also enables the user to hear from the location from which nature intended the user to hear and by placement in the ear all clothing noise or muffling of sound due to clothing is eliminated.

Referring to the drawings in more detail, the hollow case 1 is constructed from a mold of the individual user's ear. Thus the shape of the case is subject to a certain amount of variation since the shape of each person's ear is individual to that person. The case 1, resulting from the molding process, is a shell constructed of a plastic resin material, having an irregular contour, as shown, to perfectly fit the interior contour of the user's ear, and having the protrusion shown at 2 thereon for extending into the auditory canal of the user's ear. The case is provided with a hinged portion on the front surface thereof as shown at 3 which pivots about hinge member 4 to provide access to the interior of the case.

The front surface of case 1 contains opening 5 beneath which is located microphone 6 connected to the input of a four-stage transistor amplifier circuit as shown in FIGS. 3 and 9. Microphone 6 is of the dynamic type such as shown in FIG. 3 consisting of a toroid winding 7 carried by diaphragm 8 acting in the field of the permanent magnet member 9. The microphone 6 is positioned so that diaphragm 8 is centered beneath the opening 5 provided for the admission of sound waves to the microphone.

Resistors 10 and 11 together form a voltage bleeder circuit and when taken in conjunction with resistor 12, connected between the emitter of transistor TR1 and ground, this circuit establishes the D.C. operating bias level of transistor TR1. This circuit also partially establishes the D.C. bias of transistors TR2 and TR3 since their outputs are connected in series. These three resistors also provide D.C. stabilization and temperature compensation for transistor TR1 and to a lesser degree for transistors TR2 and TR3. Capacitor 22 in conjunction with the proper microphone input impedance by-passes to ground those frequencies which most cause several of the different unwanted feedback problems from the receiver 21 to the microphone 6. The output of microphone 6 is coupled directly to the base of transistor TR1 and to the base of the second stage transistor TR2 through coupling capacitor 23, which also couples the microphone to ground through resistor 12.

Resistor 13 in the emitter circuit of transistor TR2 partially establishes the D.C. operating bias level for transistors TR2 and TR3 and also aids in maintaining D.C.

stabilization in these transistors. By changing the value of this bias resistor the overall gain of the amplifier is changed; therefore, the overall gain of the circuit is adjusted for the individual's degree of deafness by varying the value of resistor **13**. By-pass capacitor **24** connected in parallel with resistor **13** between the emitter and ground of transistor TR2 by-passes substantially all frequencies to ground across resistor **13**.

The volume control potentiometer **14** in the collector circuit of transistor TR2 forms the collector load for transistor TR2 thus controlling the output of transistor TR2. The adjustable tap **15** and the transistor connection end of volume control **14** are shunted by resistor **16** to enable variation of the collector load with the volume output level to further stabilize the circuit at high output levels. This shunt also serves to provide less noise at the lower volume output levels. The collector of TR2 is connected directly to the base of TR3, while capacitor **25**, depending upon volume control settings, couples out of phase signals to the collector of transistor TR2, thus, lowering volume and maintaining faithful reproduction or by-passing resistor **17** to achieve maximum gain.

Resistor **17** in the emitter circuit of transistor TR3 performs essentially the same function as resistor **13**, that is, it partially establishes the operating bias level of the transistor and aids in D.C. stabilization for the transistor. In addition, resistor **17**, depending on the setting of volume control **14**, provides degenerative feedback, thus maintaining a more faithful reproduction of sound. Resistor **18** in the output circuit of transistor TR3 forms the collector load for this transistor and this resistor is adjusted in value to give higher or lower amplification so that the circuit output is tailored to the proper output amplification to meet the requirements of the individual user's degree of deafness.

At low volume setting of control **14** the collector load is almost full value. Thils tends to reduce noise and gain in the output circuit and at the same time degeneration is introduced into transistor TR3 because capacitor **25**, which is the by-pass capacitor to bias resistor **17**, offers a high resistance to ground, thus further lowering the gain. Capacitor **25** also couples degeneration from the emitter of transistor TR3 to the adjustable tap **15** of the volume control **14** which thus acts as a bleeder circuit for the degeneration signal, and, since it is at a low setting, the degeneration signal is a low resistance from the collector of TR2 and a high resistance from being by-passed, so the volume level or output gain is further reduced.

When the volume control **14** is at a medium volume setting the results are medium feedback (degeneration signal) and a medium value of plate load; while, when the volume control is set at a high volume level the results are a low value of degenerative feedback and a lower collector load which thus increases amplification from the transistor stage.

Capacitor **19** connected between the collector of transistor TR3 and the base of transistor TR4 serves to couple the output signal of transistor TR3 into transistor TR4. The D.C. bias level of transistor TR4 is established by resistor **20** connected between the base and the collector of the transistor since the transistor's emitter is connected to ground, and this resistor also serves to provide D.C. stabilization and temperature compensation for the transistor. The collector load of TR4 is provided by the windings **26** of receiver **21** connected between the output of TR4 and one terminal of battery **27**. The other terminal of battery **27** is connected into the ground circuit as shown at **28**.

The receiver **21** is of the dynamic type such as shown by way of illustration in FIG. 3 where receiver **21** is shown consisting of a horseshoe magnet **29**, associated with permanent magnet rings **30** contained within case **31**. The pole pieces of horseshoe magnet **29** carry electrical windings **26** thereon which control the movement of diaphragm **32** to produce an audio reproduction of the sound waves received at the microphone. The diaphragm **32** is secured in position by cap **33** carrying a collar **34** thereon for the attachment of plastic sound tube **35** which extends substantially through the center of protrusion **2** of hollow case **1** and opens as shown at **36** on the far protruding end thereof. The purpose of this sound tube **35** is to directly carry the audio reproduction from the receiver **21** as deep into the auditory canal of the user's ear as possible, thus associating as closely as possible the diaphragm of the receiver and the ear drum.

The protrusion **2** is covered by a sleeve **37** constructed of a flexible plastic or rubber material. This sleeve provides ridges therein to allow for movement of the ear without excessive noise feedback through the hearing aid case and also to aid in maintaining the hearing aid in position in the ear without slippage or without the aid of exterior clamps holding the unit to the ear.

The volume control potentiometer **14** is provided with a variable top arm adjusting knob **38** disposed on the exterior of the case **1** to provide convenient volume adjustment, of the hearing aid circuitry, for the user's varying needs.

The battery **27** is positioned in a compartment in the case so as to be beneath the movable hinged portion **3** of the case to provide for convenient removal and replacement thereof. The battery is held in position in the hollow case **1** by means of battery-holding clip **39**. Clip **39** consists of clip member **40**, electrically connected to the circuit power supply line **41**, and clip member **42**, connected to the hearing aid ground circuit, carried by insulation block **43** and resiliently biased toward each other so as to maintain battery **27** firmly in position between them by compressive force. The unit is designed to accommodate a standard type battery, such as a 675 type mercury battery.

The circuit components are disposed in hollow case **1** substantially as shown in FIG. 3, but their location is dependent to some degree upon the shape of the individual user's ear. The general parts location layout will remain substantially as shown in FIG. 3, that is, the microphone **6** and circuit components associated with transistor TR1 separated from the receiver **21** and remaining circuit components by magnetic shield member **44** disposed across the width of the case and effectively dividing it into two sections magnetically shielded from each other. By means of this shield **44** we have been able to eliminate the feedback problem of the receiver feeding back sound in the form of radiated electrical energy to the closely spaced microphone which causes the circuit to go into an oscillating conditon audible to the user as a whistle.

Other forms of feedback have been eliminated by substantial floatation on the microphone and by proper choice of construction materials and positioning of electrical components and conducted feedback has been eliminated. As mentioned hereinbefore the circuit is constructed so that certain high frequencies are attenuated in the amplifier and this also tends to eliminate some residual types of feedback.

The annular space between the interior wall of the protrusion **2** and the exterior wall of the sound tube **35** serves as a location for mounting various resistive and capacity components, such as shown in FIGS. 3 and 6 at **12**, **13** and **24**. By utilizing this space it has been possible to decrease the overall size of the in-ear hearing aid.

In order to construct the in-ear hearing aid to meet the many different requirements of individuals we first determine the shape of the inside of the ear of the individual being fitted, by inserting a molding material into the ear. When this molding material is shaped, it is removed after approximately fifteen minutes to provide a male impression of the inside of the ear and auditory canal. thereafter coated with a red sealing plastic coating and is

This shaped impression is then permitted to set and is then immersed in a container of gelatin which has the right consistency for setting in about thirty minutes to a pliable female mold from which the original impression is then withdrawn. Now the gelatin mold is poured full of fortified fiberglass and hardener added to it and it is then turned up-side-down and the excess glass drained out, leaving a coating on the gelatin which is an exact replica of the original impression as a shell. This shell is allowed is harden for a period of from one to two hours and then the gelatin removed from the shell and the shell washed. After eighteen to twenty-four hours the shell has set and is ready to serve as a casing for the in-ear hearing aid components. The shell is then painted so that it will blend in color to the flesh of the user. The material of the shell can be worked sufficiently to grind away excess material or to add material for a more precise fit in the ear of the user without the necessity of remolding.

We have found the in-ear hearing aid of our invention to have very desirable frequency response characteristics which are limited only by the construction of available microphones and receivers. We have found the device of our invention to be efficient and economical as the current drain and efficiency of the hearing aid allows for a life of from five days to a week on each battery when using a 675 type mercury battery. This means that operating costs are less than fifty cents per week.

While we have described our invention in certain preferred embodiments, we realize, however, that certain modifications can be made and we desire that it be understood that no limitations upon our invention are intended other than may be imposed by the scope of the appended claims.

What we claim as new and desire to secure by Letters Patent of the United States is as follows:

1. A single unit hearing aid comprising in combination a hollow case constructed of an insulation material and having a top portion and a bottom portion thereon, said bottom portion being shaped to the interior contour of the user's ear to retain said hollow case in the ear, a hollow protrusion having a bottom surface thereon, said hollow protrusion extending from said bottom portion of said hollow case and extending into the auditory canal of the ear, a hinged case portion, a microphone opening and a volume control knob, said hinged case portion, said microphone opening and said volume control knob being carried by said top portion of said hollow case, a microphone disposed within said hollow case beneath said microphone opening, a removable battery disposed beneath said hinged case portion adjacent said microphone, components of a first transistor amplifier stage disposed beneath said microphone, a magnetic shield member separating said microphone, said battery and said components of a first transistor amplifier stage from the remaining interior hollow portion of said hollow case, a volume control potentiometer disposed beneath said volume control knob within said hollow case and adjustably controlled thereby, a sound reproducing device disposed between said volume control potentiometer and said magnetic shield member, a sound tube extending from said sound reproducing device through said hollow protrusion and opening on the bottom surface thereof, and components of other transistor amplifier stages disposed in the remaining interior hollow portion of said hollow case and adjacent said sound tube, and means electrically interconnecting said battery, said microphone, said components of said first transistor amplifier stage, said volume control potentiometer, said components of said other transistor amplifier stages, and said sound reproducing device whereby sound received by said microphone is reproduced by said sound reproducing device.

2. A single unit hearing aid as set forth in claim 1 in which said magnetic shield member substantially traverses the interior width of said hollow case.

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