This invention relates, in general, to hearing aids and is concerned with the combination of an electronic hearing aid with a custom built ear mold in such a manner that the unit is self-contained and may be worn entirely in the ear.

Otherwise stated, the invention is embodied in a hearing aid particularly characterized as being a self-contained unit whereby the entire electronic circuit and mechanism including a power source are incorporated in an ear mold requiring no wires or other connections running from the ear mold to remote parts of the body of the user.

More specifically stated, it is a general object and accomplishment of the invention to provide a novel hearing aid of unitary design wherein all of the elements of the electronic circuit, the power source and the microphone are placed in an ear mold thereby obviating the necessity of cords, plastic tubes and the like, which serve as connecting devices to units disposed remotely from the earmold on the user's body as may be found in conventional hearing aids.

It is an important object and accomplishment of the invention to provide a hearing aid of unitary design wherein the output transducer or receiver is mounted in the earmold in a unique manner so as to dispose the receiver close to the tympanic membrane (eardrum) providing a tight acoustic seal between the output transducer and the entrance to the ear canal.

The disposition of the output transducer in close proximity to the ear canal provides distinct advantages not found in conventional hearing aids. Because the diaphragm of the receiver must transmit sound pressure waves through the air between the eardrum and the diaphragm, reduction of the volume of air that must be moved drastically reduces the amount of acoustic power necessary from the receiver. Moreover, in accordance with well-known laws of acoustics, the high frequency response of the waves reaching the eardrum are increased almost inversely as the distance, and since the great majority of people with hard-of-hearing difficulties have less acuity in the high frequencies, that is a distinct advantage over former methods, resulting in higher discrimination for speech.

It is another important object and accomplishment of the invention to provide a hearing aid of unitary design and a new and unique circuit approach in the electronic amplifier in order to accomplish the results contemplated and enable all of the necessary circuit components to be placed in the earmold. Most present day hearing aid circuits employing transistors require transformers as impedance matching devices to couple one transistor to the next. Transformers take up room, and limit frequency response in proportion to their physical components. Another method sometimes used in present day hearing aids is known as resistance capacitive coupling. This method also requires relatively large amount of space thereby making it almost impossible to use this method to build a complete useful circuit inside an earmold to provide a

unitary structure as contemplated by the present invention.

It is a further object and accomplishment of the invention to provide an electronic circuit for a hearing aid of unitary design wherein one transistor is directly connected to the next without any electrical components. By employing four transistors with two pair directly coupled, it is possible to produce an amplifier with high electrical gain and an excellent frequency response. The input voltage from the microphone is then capacitively coupled to the amplifier with a single tiny capacitor. The invention further contemplates the simplification of the electronic circuit and simplifies the components thereof with a three transistor circuit whereby producing an amplifier with excellent frequency response, and medium gain, sufficient to provide enough acoustical gain and power for those with mild and medium hearing losses.

Extreme advantages are claimed by the present invention with respect to it being a genuine contribution to better hearing, impossible by former methods of approach. Contemporary hearing aids are made in such a manner that the microphone is worn on some part of the head or body, separate from the actual ear. Studies made by the Bell Telephone Laboratories, the Harvard Acoustical Laboratories, and others, prove conclusively that the sound energy must be collected at the pinna of the ear for best hearing. This is due to buffering effects of the body and head, and dramatic differences in the frequency response. Speech intelligibility, psychological comfort of the user are obtained only when the microphone is placed exactly in the entrance to the ear canal. Moreover, nature constructed the pina of the ear to collect sounds, and unless the hearing aid is worn completely enclosed in the ear of the user, as contemplated by the present invention, the function of the pina is inoperative.

People wearing a single hearing aid or two hearing aids with the microphones placed on some other part of the body, describe a real sensation of unbalance, confusion, and unreality, which completely disappears when two hearing aids, of the nature herein prescribed, are used.

Accordingly, it is another important object and accomplishment of the invention to provide a hearing aid of unitary design and in which true orientation of the direction of sound is possible thereby avoiding sensations of unbalance, confusion and unreality on the part of the user.

While the hearing aid of the present invention contemplates the use of a battery as a power source, it is to be understood, that some other source of power may be used such as, for example, a thermal device, a sun battery, detection of electro-magnetic waves, or some other means of power could be used without changing the basic concept of the present invention.

It is further pointed out that while the microphone is used to collect sound energy, it might be easily replaced and changed by some other detection device, such as, for example, a tuned circuit to pick up radio programs, or detection devices for other types of stimuli. The transducer shown and contemplated by this invention is for the purpose of giving a sound stimulus to the eardrum. It could be replaced by a device to give other types of response, such as an electrical stimulus to page a doctor in a hospital paging system, or to transmit orders and information to military forces, to stagehands and cameramen on television programs thereby eliminating wire connection which usually restricts the movement of the workmen.

The invention further contemplates the provision of an earmold for the hearing aid of the present invention, said
em earmold being capable of being conveniently molded of a plastic composition to provide economies of manufacture, and more important, to appeal to the aesthetic senses of the user from the design standpoint.

An ancillary object and accomplishment of the invention is to provide a hearing aid of unitary design and which is adapted to be economically manufactured and which is designed to permit the manufacture and assembly thereof in accordance with present-day large scale mass production methods of construction and assembly.

Additional objects, features and advantages of the invention disclosed herein will be apparent to persons skilled in the art after the construction and operation are understood from the description. It is preferred to accomplish the various objects of this invention and to practice the same in substantially the manner as more fully described herein and as more particularly pointed out in the appended claims.

A preferred embodiment of the invention is illustrated in the accompanying drawings which form a part hereof and wherein:

- Fig. 1 is a perspective view of the hearing aid embodying the features of the present invention, this view showing the complete hearing aid and including all of its component parts and which hearing aid may be disposed completely over the ear of the user.
- Fig. 2 is a side sectional view of the hearing aid contemplated in Fig. 1, this view being taken substantially on the plane of the line 2—2 in Fig. 1 and showing the relative disposition of the component parts inside the earmold.
- Fig. 3 is a top elevational view of the hearing aid illustrated in Figs. 1 and 2 and being taken substantially on the plane of the line 3—3 in Fig. 2;
- Fig. 4 is a wiring diagram of a three transistor circuit producing an amplifier with an excellent frequency response, and medium gain, sufficient to produce enough acoustical gain and power for those of mild and medium hearing losses;
- Fig. 5 is a wiring diagram illustrating a four transistor circuit with two transistors directly coupled to make two pairs and each pair coupled by a single capacitor to produce an amplifier with high electrical gain, and excellent frequency response without the use of a capacitor for each transistor and is sufficient to produce acoustical gain and power for those with very high hearing losses;
- Fig. 6 is a wiring circuit showing a tuned circuit for the detection of electro-magnetic waves, this circuit being a substitute for the battery illustrated in Figs. 4 and 5 thereby providing another means as a source of power and
- Fig. 7 illustrates a wiring circuit employing a thermal couple which may be used as a substitute for the battery illustrated in the diagram in Figs. 4 and 5 thereby providing another means as a source of power; and
- Fig. 8 is a wiring diagram incorporating in the wiring circuit shown in Figs. 4 and 5 a tuning circuit whereby the hearing aid contemplated by this invention will pick up radio programs thereby to provide in an earmold not only a hearing aid but a small radio adapted to be completely inserted in the ear of the user.

The drawings are to be understood to be more or less of a schematic character for the purpose of illustrating or disclosing a typical or preferred form of the improvements contemplated herein, and in the drawings like reference characters identify the same parts in the several views.

In the exemplary embodiment of the invention depicted in Figs. 1, 2 and 3, the hearing aid with which this invention is particularly concerned is designated in its entirety by the numeral 21, and comprises, in general, an earmold 21 formed of rubber and plastic according to the ear contour of the user, an electronic circuit 22, disposed within the confines of the earmold 21, and a cover cap 23 containing the additional components of said electronic circuit 22.

Particular attention is invited to Figs. 1 and 2 wherein it can be seen that the earmold 21 is formed of an im-

pression (not shown) of the ear of the user to define the shape and contour substantially as shown and to define a canal 20 projecting from a body portion 31 which is hollow and defining a chamber 32 adapted to receive the component parts of the electronic circuit 22 to be hereinafter described in detail, said body defining a cup-like shape with the upper regions thereof terminating in a flanged rim 33 surrounding the periphery of the body, and said canal 20 having a through bore 35 defining a sound channel.

It is important to note that the earmold shell can be made of hard plastic or rubber or may be a combination of soft plastic or soft rubber with hard plastic or hard rubber. When the shell 21 is formed of soft plastic or rubber, a hard rubber or plastic inner liner is used to prevent collapsing of the earmold. It is to be understood that any material which has the characteristics of the materials hereinbefore mentioned could be used. The important requirement of the material is that it must create a complete seal of the ear to prevent feed back.

The sound channel 35 conveys and directs sound into the ear canal (not shown) and toward the eardrum (not shown) of the user, said sound canal being molded at the same time as the body 31 of the earmold 21 or drilled after the earmold is made. The earmold should be made as thin as possible to accommodate the component electronic parts of the electronic circuit 22. The unit should also be as light in weight as possible to prevent ear fatigue.

It is of particular note in some cases that the body portion 31 of the earmold 21 may be formed of hard plastic or rubber while the canal 20 may be formed of soft plastic thereby providing rigidity to the body portion and yet affording a certain amount of resiliency to the canal 30.

Thus, it can be seen that by a combination of the intricate skills of the plastics industry, the dental arts, the earmold laboratories, and the chemist, it is possible to control the colors of the finished device so that the skin is matched, thus allowing the device to blend inconspicuously into the color of the individual user.

Having thus described the earmold 21, attention is invited to Figs. 2 and 5 wherein there is illustrated the relative disposition of the component parts of the electronic circuit 22.

It is important to note that this invention contemplates a new and unique circuit approach in the electronic amplifier in order to accomplish the results and enable all the necessary circuit components to be placed in the earmold 21 as illustrated in the Fig. 2 and illustrated in the Fig. 4 for the purpose of placing them directly coupled to the amplifier. By employing four transistors with two pairs directly coupled, it is possible to produce an amplifier with high electrical gain, and excellent frequency response. As clearly shown in Fig. 5, the input voltage from the microphone is then directly coupled to the amplifier.

It is possible to further simplify the number of components with the three transistor circuit illustrated in Fig. 4 and produce an amplifier with excellent frequency response and medium gain, sufficient to provide enough acoustical gain and power for those with mild and medium hearing losses. It is obvious that it would be possible to house two transistor beads in a single housing having them directly coupled internally.

In the electronic circuit 22 as illustrated in Fig. 2,
all of the circuit elements are mounted on a sheet of melamine which makes the device practical from a mass production point of view, and permits repairs to be made, if necessary, and gives structural strength to the device. Melamine has been chosen because of its excellent dielectric, mechanical, electrical and low moisture absorption properties. It is obvious that other materials could be used for this purpose.

The four transistor electronic circuit comprises transistors 41, 42, 43 and 44 suitably mounted on the sheet melamine 40, an output transistor (receiver) 45, a microphone 46 disposed in the cap 23, resistors 47, 48, 49, 50 and 51 also suitably mounted on said melamine sheet 40, a condenser 52, a volume control 55 disposed in said cap 23, a power source or battery 56 mounted in a movable segment 57 of the cap 23, and suitable circuit wiring as at 58 electrically connecting said components according to the diagram illustrated in Fig. 5. Interposed in said circuit is an off-on switch 60 which will be hereinafter further described in detail.

As illustrated in Fig. 4, the three transistor electronic circuit comprises transistors 70, 71 and 72, an output transistor (receiver) 73, a microphone 74, resistors 75, 76, 77, 78, and a condenser 79, a volume control 84, a power source or battery 81, and suitable circuit wiring as at 82, electrically connecting said components according to the diagram illustrated in Fig. 4. Interposed in said circuit is an off-on switch 83, which will be hereinafter further described in detail.

In audio-amplifiers such as described herein, a limiting factor in the amount of gain possible without acoustic feedback (or whistle) is the proximity of the microphone 46 to the receiver 45. It has been found in these devices that part of the feed back is caused by magnetic coupling resulting in transformer action. The relatively high current in the coil of the receiver 45 sets up magnetic lines of force which cut across the coil turns in the microphone 46, and induce voltages which are then amplified by the gain of the system. A mu-metal shield is used around the coil of the receiver 45, or the coil of the microphone 46, or between the two coils—or a combination of any or all of these shields. Other materials having magnetic shielding properties could be used and the coils could be oriented in such a manner as to minimize or eliminate coupling. One or both coils could be movable allowing for final adjustment for cancelling this coupling, or a coil wound in opposite direction with the microphone coil 46 could be used to cause the effect of cancellation of induced voltages.

Attention is invited to the output transducer (receiver) 45 illustrated in Fig. 2, which comprises a housing 90 having depending therefrom an ear 91 through which sound waves are transmitted into the sound canal 35 for conveyance to the eardrum (not shown) of the user, said ear being adapted for removable locking engagement in a through bored 94 of a locking ring 95 which is fixedly impregnated into the body 31 of the earmold 21 at the upper regions of the sound canal 35.

The output transducer 45 can be easily removed from its operative position as shown in Fig. 2 by merely applying a slight force against the housing 90 which will cause the ear 91 to be removed from its locking engagement in the through bored 94 and, thereafter, the output transducer may be removed from the body 31 of the earmold 21 for repair or replacement. In assembly, the transducer 45 is inserted by exerting a slight downward force thereon to force the ear 91 into the through bored 94 whereupon the transducer will be removably locked into its proper operative position as shown in Fig. 2.

It is important to note the manner in which the output transducer 45 is permanently mounted 21 to the earmold 31 and the permanent mounting of the locking ring 95 which may be made of metal or plastic and is permanently mounted in the earmold in close proximity to the ear canal 35. This permits the receiver 45 to be snapped and held rigidly in position as hereinbefore described and enables tight acoustic seal between the receiver 45 and the entrance to the ear canal 35. Certain advantages are provided when the output transducer is positioned closer to the tympanic membrane (eardrum).

Among these advantages are:

1. Because the diaphragm of the receiver must transmit sound pressure waves through the air between the eardrum and the diaphragm, the reduction of the volume of air that must be moved drastically reduces the amount of acoustic power necessary from the receiver.

2. In accordance with the well-known laws of acoustics, the high frequency response of the waves reaching the eardrum is increased almost inversely as the distance because the great majority of people with hard of hearing difficulty have less acuity in the high frequencies; this is a distinct advantage over former methods, resulting in higher discrimination for speech.

It is to be understood that the shape and mechanical configuration of the receiver 45 as shown could vary in almost any manner. For example, the receiver might be made in the shape of a cylinder of very small diameter, and relatively long length so that it could be recessed even further into the ear canal 35 and occupy less space in the earmold cavity 32.

The microphone 46 is a self-contained unit disposed in a housing 98 which is press fitted into a hollow cavity 99 disposed in the cap 23, said microphone 46 being adapted to receive sound waves through an aperture 100 in the cap 23, said sound waves being picked up by the microphone 46 and conveyed via the electronic circuit 22 and amplified thereby to the output transducer (receiver) 45 whereupon the sound waves are transmitted into the sound canal 35 for conveyance to the eardrum (not shown) of the user.

The resistors 47-50 as illustrated in the wiring diagram depicted in Figs. 5, and the resistors 75-79 as depicted in Fig. 4 are of conventional design and are as respectively marked in these diagrams. Accordingly, these resistors will not be further described herein.

As may thus be seen in Fig. 2, the volume control 55 is press fitted into a through bored 105 in the cap 23 and comprises an adjustment screw which may be located by inserting a conventional screwdriver in the slot 107 disposed in the upper end portions of the adjustment screw 106.

It is preferred to use the battery 56 as a source of power to operate the electronic circuit 22. The battery cell is disposed in a housing 110, disposed in a cavity 111 in the movable segment 57 of the cap 23. One electrical side of the battery is in frictional contact with a metallic plate 112 disposed on a cover plate 113 upon which the cap 23 is disposed. The other electrical side of the battery is connected by suitable wiring as at 114 to the switch 60.

A feature of the invention resides in the movable segment 57 which comprises a pair of pins 115, 116 which project from the movable segment into the body of the cap 23 and act as guides for the movable segment 57 when moved outwardly from the cap to the position shown in dotted lines in Figs. 2 and 3. Movement of the movable segment 57 to its outer position permits the battery to be conveniently removed from its normal operative position in the cavity 111.

Attention is invited to the Figures 2 and 3 wherein the off-on switch 60 is disclosed and which comprises a spring plate 120 carried by the cap 23 and sandwiched between the said cap and the movable segment 57. The extreme outer ends 121, 122 of which are arranged respectively to frictionally engage the guide pins 115, 116 which are provided with slots (not shown) into which the ends 121 and 122 may fall to provide a locking arrangement to hold the movable segment 57 in its operative position as shown in full lines in Figs. 2 and 3. The guide pins 115,
116 may be also provided with additional slots (not shown) wherein the ends 121, 122 will fall to hold said movable segment 57 in its outer position illustrated by dotted lines in Figs. 2 and 3.

It may be seen in Figs. 2 and 3 that electrical connection to one side of the battery 56 is provided by the wire 114 to a stud 131 which makes contact with the spring plate 120 only when the movable segment 57 is in its operative position shown in full lines, thereby making an electrical connection through said spring plate 120 to wiring 132 and through the electronic circuit 22. When the movable segment 57 is moved outwardly from its normal operative position, it is obvious that the stud 131 will not contact the spring plate 120 and therefore the electrical connection between these elements will be broken and the hearing aid will be shut off.

It is obvious that when the hearing aid is not in use, the operator will pull the movable segment 57 out from its normal position a slight distance sufficient to break the contact between the stud 131 and the spring plate 120. When the instrument is to be used, the user will push the movable segment 57 to its proper position whereupon theexterme ends of the spring plate 120 will fall into the slots in the guide pins 115 and 116, thereby to maintain the movable segment in its proper operative position.

It is pointed out that the battery 56 as shown in this device has as its function merely to provide power for the amplifier, and it is to be understood that some other source of power such as thermo device illustrated in Fig. 7, detection of electro-magnetic waves, or some other means of power would not change the basic concept of this invention. It is important to note that only one milliamperere current is necessary as a power source for the hearing aid contemplated herein.

It is further pointed out that while a microphone as at 46 is used to collect sound energy, it might easily be changed and replaced by some other detection device, such as a tuned circuit as illustrated in Fig. 6 to pick up radio programs, or detection devices such as illustrated in Fig. 8 for other types of stimuli. The transducer shown is for the purpose of giving a sound stimulus to the eardrum. It could be replaced by a device to give other types of response such as electrical stimuli to page a doctor in a hospital paging system, or to transmit orders and other nonmilitary information to military forces.

From the foregoing disclosure, it can be seen that we have provided a hearing aid which efficiently fulfills the objects hereinbefore set forth and provides numerous advantages which may be summarized as follows:

1. Structurally simple, efficient and durable;
2. Economical to manufacture and readily adaptable to mass production manufacturing;
3. The provision of a hearing aid particularly characterized as being a self-contained unit whereby the entire electronic circuit and mechanism including a power source are incorporated in an earmold requiring no wires or other connections running from the earmold to remote parts of the body of the user.

While we have illustrated a preferred embodiment of our invention, many modifications may be made without departing from the spirit of the invention, and we do not wish to be limited to the precise details of construction set forth but desire to avail ourselves of all changes within the scope of the appended claims.

We claim:

1. An electronic hearing aid comprising: an earmold having a hollow body portion and a sound canal depending therefrom, and a first cap portion attached to said earmold; an electronic amplifier having an input connection and an output connection and comprising a four transistor circuit with two transistors directly coupled to make two pairs and each pair coupled by a single capacitor, a microphone connected to the input of said electronic circuit, a receiver connected to the output of said circuit, a second cap portion slidably attached to said earmold and comprising a source of power for said circuit and a switch for connecting said source of power to said circuit for energizing it; said microphone being disposed in said first cap portion and said electronic circuit comprising said transistors being disposed in the hollow body portion of said earmold, the complete assembly of which comprises a unitary structure adapted to fit into the ear of the user.

2. An electronic hearing aid comprising an earmold having a hollow body portion and a stem portion defining a sound canal formed integrally therewith, a first cap portion attached to said earmold, a microphone disposed within said cap, a receiver fixedly mounted within said earmold adjacent the inner end of the sound canal, a transistor amplifier circuit mounted within said earmold and interconnecting said microphone with said receiver, a battery for energizing said amplifier circuit, a second cap portion slidably attached to said earmold, said second cap portion comprising one contact of an electrical switch and a housing for said battery means defining a second contact connectible with said first contact for thereby connecting said battery to said amplifier circuit.

3. An electronic hearing aid comprising an earmold having a hollow body portion and a stem portion defining a sound canal formed integrally therewith, said stem portion defining a sound canal, a receiver mounted on the interior of said ear mold and forming an acoustic seal on the inner end of the sound canal, said receiver being adapted to transmit sound vibrations into said sound canal, a microphone, a transistorized amplifier circuit interconnecting said microphone with said receiver, a first cap portion formed with a cylindrical recess for containing said microphone and attached to said earmold, means defining a first contact of an electrical switch on an edge of said cap, a second cap portion formed with a cylindrical recess and slidably attached to said earmold, means defining a second contact of an electrical switch on an edge of said second cap and adapted to make electrical contact with said first contact, and a battery disposed within the cylindrical recess of said second cap and adapted to supply electrical energy to said amplifier circuit upon closing said contacts.

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