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(54) **RECEIVER ASSEMBLY WITH REAR ACOUSTIC PASSAGE FOR AN EAR-WEARABLE DEVICE**

(57) Embodiments herein relate to ear-wearable devices having moving coil receivers. In an embodiment, an ear-wearable device can include a receiver assembly having a receiver housing. The receiver housing can have a front housing portion including a front housing wall and a rear housing portion having a rear housing wall defining a rear acoustic inlet. The ear-wearable device can include a receiver and an insert. The ear-wearable device can include a rear acoustic passage defined between the rear housing wall and the second insert side and extending between the rear acoustic inlet and a receiver inlet. The receiver is configured to fit within the receiver housing between the front housing portion and the first insert side. The receiver housing is configured to permit fluid communication between an external environment and the receiver rear side through the rear acoustic inlet and the rear acoustic passage. Other embodiments are also included herein.

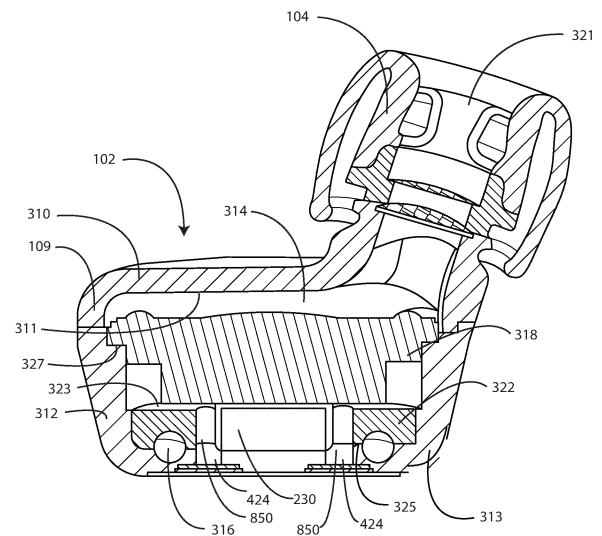


FIG. 3

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Description

Field

[0001] Embodiments herein relate to ear-wearable devices and more particularly to ear-wearable devices having moving coil receivers.

Background

[0002] Ear-wearable devices are electronic instruments worn in or around the ear that compensate for hearing losses by amplifying sound. Many ear-wearable devices include a receiver configured to convert electrical signals into sounds. Some ear-wearable devices include a balanced armature receiver and have a closed fit in which the user's ear canal is sealed to the device. Open fit hearing aids can improve user experience by enhancing comfort and allowing ambient sound to enter and own-voice sounds to exit the ear canal, providing a more natural listening experience. Many ear-wearable devices have less than ideal bass response and can be improved to provide a higher-quality sound for the user.

Summary

[0003] In a first aspect, an ear-wearable device can include a receiver assembly, wherein the receiver assembly includes: a receiver housing having a front housing portion can include a front housing wall, a rear housing portion can include a rear housing wall, wherein the rear housing wall defines a rear acoustic inlet. The ear-wearable device can include a receiver configured to convert electrical signals into sounds. The ear-wearable device can include an insert configured to fit within the receiver housing and defining a first insert opening, the insert can include a first insert side facing the front housing portion and a second insert side facing the rear housing wall. The ear-wearable device can include a rear acoustic passage defined between the rear housing wall and the second insert side, the rear acoustic passage extending between the rear acoustic inlet and a receiver inlet disposed adjacent to the first insert opening. In various embodiments, the receiver can be configured to fit within the receiver housing between the front housing portion and the first insert side. In various embodiments, a front housing volume can be formed between a receiver front side and the front housing wall. In various embodiments, the receiver housing can be configured to permit fluid communication between an external environment and the receiver rear side through the rear acoustic inlet and the rear acoustic passage.

[0004] In a second aspect, in addition to one or more of the preceding or following aspects, or in the alternative to some aspects, the front housing portion further can include a stem protruding from the front housing wall, the stem defining a stem acoustic channel.

[0005] In a third aspect, in addition to one or more of the

preceding or following aspects, or in the alternative to some aspects, further can include an earbud configured to removably attach to the stem of the receiver housing, the earbud can include: an axial wall defining an earbud acoustic channel, wherein the earbud acoustic channel can be in acoustic communication with the stem acoustic channel, and an outer dome connected to the axial wall at a front edge and unconnected to the axial wall at a rear edge.

[0006] In a fourth aspect, in addition to one or more of the preceding or following aspects, or in the alternative to some aspects, the earbud further can include a plurality of vent openings defined in the axial wall.

[0007] In a fifth aspect, in addition to one or more of the preceding or following aspects, or in the alternative to some aspects, the axial wall can include: a first portion can include a first material, the first portion defining retention features configured to removably attach to the stem of the receiver housing, and a second portion can include a second material configured to conform to an ear of a wearer, wherein the second material can be more compliant than the first material.

[0008] In a sixth aspect, in addition to one or more of the preceding or following aspects, or in the alternative to some aspects, the rear housing portion further can include an ambient opening defined in the rear housing wall, wherein the ambient opening can be configured to be in fluid communication with a rear side of the receiver.

[0009] In a seventh aspect, in addition to one or more of the preceding or following aspects, or in the alternative to some aspects, the insert further defines a second insert opening in acoustic communication with the ambient opening.

[0010] In an eighth aspect, in addition to one or more of the preceding or following aspects, or in the alternative to some aspects, the ear-wearable device can further include a first mesh layer having a first set of acoustic properties, wherein the first mesh layer can be configured to cover the ambient opening, and a second mesh layer having a second set of acoustic properties, wherein the second mesh layer can be configured to cover the ambient opening and the rear acoustic inlet. The first mesh layer can be configured to provide more acoustic damping than the second mesh layer.

[0011] In a ninth aspect, in addition to one or more of the preceding or following aspects, or in the alternative to some aspects, the rear acoustic passage includes a curved portion between the rear acoustic inlet and the receiver inlet.

[0012] In a tenth aspect, in addition to one or more of the preceding or following aspects, or in the alternative to some aspects, the curved portion of the rear acoustic passage includes an arc-shaped trajectory in a plane parallel to at least a portion of the rear housing wall.

[0013] In an eleventh aspect, in addition to one or more of the preceding or following aspects, or in the alternative to some aspects, the rear acoustic passage can include: a first axial portion extending away from the rear acoustic

inlet to a first plane, a second axial portion extending from the first plane to the receiver inlet, and a curved portion spanning between the first vertical portion and the second vertical portion, wherein the curved portion makes an arc-shaped trajectory intersecting the first plane.

[0014] In a twelfth aspect, in addition to one or more of the preceding or following aspects, or in the alternative to some aspects, the rear acoustic passage can be tuned to increase a low frequency efficiency of the receiver.

[0015] In a thirteenth aspect, in addition to one or more of the preceding or following aspects, or in the alternative to some aspects, the receiver includes a moving coil receiver.

[0016] In a fourteenth aspect, an ear-wearable device can include a receiver assembly, the receiver assembly can be included having a receiver configured convert electrical signals into sounds, the receiver can include a front side and a receiver rear side. The receiver assembly can include a receiver housing can be included having a front housing portion can include a front housing wall, a rear housing portion can include a rear housing wall, wherein the rear housing wall defines a rear acoustic inlet. The receiver assembly can include a rear acoustic passage defined adjacent to the rear housing wall, the rear acoustic passage extending between the rear acoustic inlet and a receiver inlet. In various embodiments, the receiver can be configured to fit within the receiver housing between the front housing portion and the rear housing portion. In various embodiments, a front housing volume can be formed between the receiver front side and the front housing wall. In various embodiments, the receiver housing can be configured to permit fluid communication between an external environment and the receiver rear side through the rear acoustic inlet and the rear acoustic passage. In various embodiments, the rear acoustic passage includes a curved portion between the rear acoustic inlet and the receiver inlet.

[0017] In a fifteenth aspect, in addition to one or more of the preceding or following aspects, or in the alternative to some aspects, the rear housing portion further can include an ambient opening defined in the rear housing wall, wherein the ambient opening can be configured to be in fluid communication with a rear side of the receiver.

[0018] In a sixteenth aspect, in addition to one or more of the preceding or following aspects, or in the alternative to some aspects, the ear-wearable device can further include a. a first mesh layer having a first set of acoustic properties, wherein the first mesh layer can be configured to cover the ambient opening and a second mesh layer having a second set of acoustic properties, wherein the second mesh layer can be configured to cover the ambient opening and the rear acoustic inlet. The first mesh layer can be configured to provide more acoustic damping than the second mesh layer.

[0019] In a seventeenth aspect, in addition to one or more of the preceding or following aspects, or in the alternative to some aspects, the curved portion of the rear acoustic passage includes an arc-shaped trajectory

in a plane parallel to at least a portion of the rear housing wall.

[0020] In an eighteenth aspect, in addition to one or more of the preceding or following aspects, or in the alternative to some aspects, the rear acoustic passage can include: a first axial portion extending away from the rear acoustic inlet to a first plane, a second axial portion extending from the first plane to the receiver inlet, and the curved portion spanning between the first vertical portion and the second vertical portion, wherein the curved portion makes an arc-shaped trajectory intersecting the first plane.

[0021] In a nineteenth aspect, in addition to one or more of the preceding or following aspects, or in the alternative to some aspects, the rear acoustic passage can be tuned to increase a low frequency efficiency of the receiver.

[0022] In a twentieth aspect, an ear-wearable device can include a receiver assembly, wherein the receiver assembly includes a receiver housing, the receiver housing can include a rear housing wall, wherein the rear housing wall defines a rear acoustic inlet. The ear-wearable device can include a receiver configured to convert electrical signals into sounds and configured to fit within the receiver housing. The ear-wearable device can include a rear acoustic passage at least partially defined between a first housing component and a second housing component. In various embodiments, the first housing component and a second housing component can be separately manufactured and then can be assembled to form at least a portion of the receiver assembly. In various embodiments, the rear acoustic passage extends between the rear acoustic inlet and a rear cavity adjacent to the receiver rear side. In various embodiments, the receiver housing can be configured to permit fluid communication between an external environment and the rear cavity through the rear acoustic inlet and the rear acoustic passage.

[0023] This summary is an overview of some of the teachings of the present application and is not intended to be an exclusive or exhaustive treatment of the present subject matter. Further details are found in the detailed description and appended claims. Other aspects will be apparent to persons skilled in the art upon reading and understanding the following detailed description and viewing the drawings that form a part thereof, each of which is not to be taken in a limiting sense. The scope herein is defined by the appended claims and their legal equivalents.

Brief Description of the Figures

[0024] Aspects may be more completely understood in connection with the following figures (FIGS.), in which:

FIG. 1 is a schematic view of an ear-wearable device in accordance with various embodiments herein.

FIG. 2 is a schematic block diagram shown with

various components of a hearing assistance device in accordance with various embodiments herein.

FIG. 3 is a cross-sectional view of receiver assembly in accordance with various embodiments herein.

FIG. 4 is a bottom perspective view of a portion of the receiver assembly of FIG. 3 in accordance with various embodiments herein.

FIG. 5 is an exploded view of the bottom of receiver assembly in accordance with various embodiments herein.

FIG. 6 is an exploded view of a receiver assembly in accordance with various embodiments herein.

FIG. 7 is a cross sectional view of a receiver assembly through a rear acoustic inlet of a rear acoustic passage in accordance with various embodiments herein.

FIG. 8 is a cross sectional view of a receiver assembly through a receiver inlet of the rear acoustic passage in accordance with various embodiments herein.

FIG. 9 is a cross sectional view of a receiver assembly through the rear acoustic passage plane in accordance with various embodiments herein.

FIG. 10 is a partially exploded view of a receiver assembly showing the second insert side in accordance with various embodiments herein.

FIG. 11 is a cross-sectional view of an earbud in accordance with various embodiments herein.

[0025] While embodiments are susceptible to various modifications and alternative forms, specifics thereof have been shown by way of example and drawings and will be described in detail. It should be understood, however, that the scope herein is not limited to the particular aspects described. On the contrary, the intention is to cover modifications, equivalents, and alternatives falling within the spirit and scope herein.

Detailed Description

[0026] Ear-wearable devices include a receiver configured to convert electrical signals into sounds. Certain types of receivers (e.g., balanced armature receivers) perform optimally when the ear-wearable device has a closed fit, meaning that the wearer's ear canal is sealed by the ear-wearable device. Such receivers suffer from poor low-frequency response when configured with an open fit, resulting in negative consequences such as poor sound quality, including tinny sounds and low frequency distortion. By utilizing a moving coil receiver, an ear-wearable device can be designed to have an open fit while providing an acceptable low frequency response.

[0027] Many long-term hearing aid users find an open-fit hearing aid to be more comfortable in the ear than a closed-fit hearing aid. When an ear-wearable device seals the ear canal, it can create a feeling of fullness or discomfort due to the pressure differential. An open fit helps alleviate this pressure by allowing air to flow in and

out of the ear canal, making the ear-wearable device more comfortable to wear.

[0028] Open fit ear-wearable devices can be especially helpful to individuals with high-frequency hearing loss.

5 Examples of high-frequency sounds are speech consonants and birdsong. Instead of completely sealing the ear canal, like in closed-fit ear-wearable devices, open-fit ear-wearable devices leave the ear canal partially open. This allows natural sound to enter the ear, including lower frequency sounds that the user can hear, while amplifying specific frequencies that the user has difficulty hearing.

[0029] An open-fit device can also avoid the occlusion effect, a phenomenon where the sound of the user's own voice sounds strange, hollow, or booming when wearing a closed-fit device. When the ear is plugged, low-frequency sound from the user's voice is trapped in the ear, does not exit the ear, and creates acoustic pressure in the ear while the user is speaking. For all these reasons, an open-fit ear-wearable device is selected by many users. However, it is challenging for open-fit ear-wearable devices to accurately produce lower frequency sounds. Unfortunately, some open-fit ear-wearable devices sound "tinny" instead of rich and full when producing lower frequency sounds. This issue can be mitigated by strategically designing an acoustic volume behind the receiver or speaker of the ear-wearable device.

[0030] In various embodiments, an ear-wearable device can include a rear acoustic passage with characteristics that support the production of high-quality sound by the ear-wearable device. Such a rear acoustic passage can be provided in an open-fit or closed-fit ear-wearable device.

[0031] In various embodiments, an ear wearable device includes receiver assembly with a receiver housing having a front housing portion and a rear housing portion, and the wall of the rear housing portion can define a rear acoustic inlet leading to a rear acoustic passage that provides an acoustic mass or acoustic inertance behind a receiver. The rear acoustic passage permits fluid communication between an external environment and a receiver rear side. In some embodiments, the rear acoustic passage includes a curved portion. In some embodiments, the rear acoustic passage comprises an arch-shaped trajectory in a plane parallel to at least a portion of the rear housing wall.

[0032] In some embodiments, a rear acoustic passage can be defined between two separately manufactured components that are used in a receiver assembly. Because the rear acoustic passage can have a diameter that is quite small, such as in the range of about 0.5 to 2 mm, it is challenging to manufacture a component that defines a precisely shaped passage. In various embodiments, two separately manufactured components can be brought together in the receiver assembly such that the rear acoustic passage is defined between a first housing component and a second housing component.

[0033] In some embodiments, the receiver assembly can include an insert that cooperates with the rear hous-

ing to define the rear acoustic passage between one side of the insert and a rear housing wall of the receiver housing. Embodiments that define the rear acoustic passage between two components, such as between an insert and a rear housing, can enjoy an easier and more efficient manufacturing process and provide more flexibility in tuning the shape of the acoustic passage.

[0034] For embodiments with an open-fit, an earbud can be provided having an axial wall defining an earbud acoustic channel and an outer dome connected to the axial wall at a front edge and unconnected to the axial wall at a rear edge. Vent openings defined in the axial wall can provide fluid communication between the user's ear canal and the ambient environment, allowing pressure to equalize and often allowing natural sounds to be heard by the user.

Ear-Worn Devices (FIGS. 1-2)

[0035] Referring now to FIG. 1, a schematic view of an ear-wearable device is shown in accordance with various embodiments herein. The ear-wearable device 100 can include a receiver assembly 102 adjacent to an earbud 104 configured to fit within the ear canal of the ear-wearable device user. The receiver assembly 102 can include a receiver housing 109 and a receiver (not shown in this view) configured to fit within the receiver housing 109 that converts electrical signals into sound, such as an electroacoustic transducer, speaker, or the like. The ear-wearable device 100 can further include an ear-wearable device housing 106. A cable 108 or connecting wire can include one or more electrical conductors and provide electrical communication between components inside of the ear-wearable device housing 106 and components inside of the receiver assembly 102. The ear-wearable device housing 106 can define a battery compartment into which a battery can be disposed to provide power to the ear-wearable device 100. The ear-wearable device housing 106 can include one or more microphones 107 configured to receive an acoustic input from the surrounding environment and to transmit the acoustic input to the receiver via the cable 108.

[0036] In various embodiments, the ear-wearable device 100 can be an open fit ear-wearable device. Alternatively, a version of the ear-wearable device 100 that has a closed fit is also possible, as features described herein could be beneficial in the closed-fit device environment.

[0037] In the example of FIG. 1, the receiver of an open-fit ear-wearable device is configured to be positioned in the ear canal, near the eardrum, delivering sound directly into the ear canal.

[0038] The ear-wearable device 100 shown in FIG. 1 is a receiver assembly-in-canal type device and thus the receiver assembly 102 is designed to be placed within the ear canal. However, it will be appreciated that many different form factors for hearing assistance devices are contemplated herein. As such, hearing assistance

devices herein can include, but are not limited to, behind-the-ear (BTE), in-the ear (ITE), in-the-canal (ITC), invisible-in-canal (IIC), receiver assembly-in-canal (RIC), receiver assembly in-the-ear (RITE) and completely-in-the-canal (CIC) type hearing assistance devices. Aspects of hearing assistance devices and functions thereof are described in U.S. Pat. No. 9,848,273; U.S. Publ. Pat. Appl. No. 20180317837; and U.S. Publ. Pat. Appl. No. 20180343527, the content of all of which is herein incorporated by reference in their entirety.

[0039] Referring now to FIG. 2, a schematic block diagram is shown with various components of a hearing assistance device in accordance with various embodiments. The block diagram of FIG. 2 represents a hearing assistance device for purposes of illustration. The ear-wearable device 100 shown in FIG. 2 includes several components electrically connected to a printed circuit board 218 (e.g., flexible printed circuit board) (e.g., flexible mother board) which is disposed within ear-wearable device housing 106. A power supply circuit 204 can include a battery and can be electrically connected to the printed circuit board 218 and provides power to the various components of the ear-wearable device 100. One or more microphones 206 are electrically connected to the printed circuit board 218, which provides electrical communication between the microphones 206 and a digital signal processor (DSP) 212. Among other components, the DSP 212 incorporates or is coupled to audio signal processing circuitry configured to implement various functions described herein. A sensor package 214 can be coupled to the DSP 212 via the printed circuit board 218. The sensor package 214 can include one or more different specific types of sensors such as those described in greater detail below. One or more user switches 210 (e.g., on/off, volume, mic directional settings, memory change) are electrically coupled to the DSP 212 via the printed circuit board 218.

[0040] An audio output device 216 is operatively connected to the DSP 212 via the printed circuit board 218. In some embodiments, the audio output device 216 comprises a speaker (coupled to an amplifier). In other embodiments, the audio output device 216 comprises an amplifier coupled to a receiver 226 adapted for positioning within an ear of a wearer. The receiver 226 can include a transducer (e.g., a speaker).

[0041] An electrical filter component 230 may also be included, either within the ear-wearable device housing 106, in a receiver assembly 102, or in a different housing. An electrical filter 230 can help to reduce power consumption of the receiver 226. One example of a filter is an electrical inductor, which includes a coil in some embodiments. In some examples, the electrical inductor may have a value of between about 1-20 microhenry. The electrical filter component can be electrically connected to a signal output of the audio output device and to the positive input of the receiver. Alternatively, the electrical filter component can be electrically connected to a negative terminal of the audio output device and to the

negative terminal of the receiver. In some embodiments, the electrical filter component is electrically connected to both a positive and negative terminal of the receiver and the audio output device.

[0042] The ear-wearable device 100 may incorporate a communication device 208 coupled to the printed circuit board 218 and to an antenna 202 directly or indirectly via the printed circuit board 218. The communication device 208 can be a Bluetooth® transceiver, such as conforms to a Bluetooth® specification, for example, including but not limited to Bluetooth® low energy (BLE), Bluetooth® 4.2 or 5.0, and Bluetooth® Long Range). Hearing assistance devices of the present disclosure can incorporate an antenna arrangement coupled to a high-frequency radio, such as a 2.4 GHz radio. The radio can conform to an IEEE 802.11 compliant device (e.g., WiFi®). It is understood that hearing assistance devices of the present disclosure can employ other radios, such as a 900 MHz radio.

[0043] Hearing assistance devices of the present disclosure can be configured to receive streaming audio (e.g., digital audio data or files) from an electronic or digital source. Hearing assistance devices herein can also be configured to switch communication schemes to a long-range mode of operation, wherein, for example, one or more signal power outputs may be increased, and data packet transmissions may be slowed or repeated to allow communication to occur over longer distances than that during typical modes of operation. Representative electronic/digital sources (also serving as examples of accessory devices herein) include an assistive listening system, a TV streamer, a radio, a smartphone, a cell phone/entertainment device (CPED), a pendant, wrist-worn device, or other electronic device that serves as a source of digital audio data or files.

[0044] The communication device 208 can be configured to communicate with one or more external devices, such as those discussed previously, in accordance with various embodiments. In various embodiments, the communication device 208 can be configured to communicate with an external visual display device such as a smart phone, a video display screen, a tablet, a computer, or the like.

[0045] In various embodiments, the ear-wearable device 100 can also include a control circuit 222 and a memory storage device 224. The control circuit 222 can be in electrical communication with other components of the device. The control circuit 222 can execute various operations, such as those described herein. The control circuit 222 can include various components including, but not limited to, a microprocessor, a microcontroller, an FPGA (field-programmable gate array) processing device, an ASIC (application specific integrated circuit), or the like. The memory storage device 224 can include both volatile and non-volatile memory. The memory storage device 224 can include ROM, RAM, flash memory, EEPROM, SSD devices, NAND chips, and the like. The memory storage device 224 can be

used to store data from sensors as described herein and/or processed data generated using data from sensors as described herein, including, but not limited to, information regarding exercise regimens, performance of the same, visual feedback regarding exercises, and the like.

Receiver Assembly (FIG. 3)

[0046] Referring now to FIG. 3, a cross-sectional view of receiver assembly is shown in accordance with various embodiments herein. In various embodiments, the ear-wearable device can include a receiver assembly 102 connected to an earbud 104. In various embodiments, the receiver assembly 102 can include a receiver housing 109 having a front housing portion 310 and a rear housing portion 312. The front housing portion 310 and rear housing portion 312 can each be formed from any suitable material or materials including, but not limited to silicone, urethane, acrylates, flexible epoxy, acrylate urethane, and combinations thereof. In some embodiments, the front housing portion 310 and the rear housing portion 312 are formed from the same material. Alternatively, the front housing portion 310 and rear housing portion 312 may be formed from different materials from each other. In some embodiments, the front housing portion 310 is manufactured to be removably attachable to the rear housing portion 312 by any combination of means including, but not limited to adhesives, snap fits, press fits, pin connections, or the like. Alternatively, the front housing portion 310 can be permanently attached to the rear housing portion 312 by any means including, but not limited to welding, ultrasonic welding, heat welding, soldering, adhesives, press-fit connections, snap-fit connections, heat staking, threading the components together, or the like. In various embodiments, the front housing portion 310 can include a front housing wall 311 and can define a front housing volume 314. In various embodiments, the rear housing portion 312 can include a rear housing wall 313 and can define a rear housing volume and/or a rear acoustic passage 316.

[0047] In various embodiments, the receiver assembly 102 may further include a receiver 318 configured to fit within the receiver housing 109. A receiver, as defined herein, is any device that is configured to convert electrical signals into sounds. In the context of ear-wearable devices, one or more microphones (such as microphone 107 included in the in the ear-wearable device housing 106 of FIG. 1) gather acoustic energy (sound) from the surrounding environment and convert the acoustic energy into electrical signals. In some embodiments, the electrical signals are then transmitted to an amplifier which performs various signal processing steps such as increasing the amplitude of the electric signals. In some cases, the amplifier may perform further processing on the electrical signals such as filtering, compression, or the like. The amplified electric signals are then transmitted to the receiver 318, which converts the re-

ceived electric signals into sounds (e.g., pressure waves configured to propagate through the acoustic environment). The sounds are then transmitted to a user's ear via an acoustic outlet 321 defined in the earbud 104. Any suitable type or types of receivers can be used in the ear-worn device including, but not limited to armature receivers, moving coil receivers, micro-electromechanical system (MEMS) speakers, or the like.

[0048] In the example of FIG. 3, the receiver 318 is a moving coil receiver. A moving coil receiver, also known as a dynamic receiver, as defined herein is a type of electroacoustic transducer used in various audio devices, including ear-wearable devices. Moving coil receivers typically contain a thin, lightweight coil of wire that is suspended within a magnetic field and attached to a diaphragm. The coil can be positioned within a permanent magnet, or an electromagnetic field created by a magnet. Electrical signals received from the ear-wearable device's amplifier are passed through the coil. These electrical signals create a varying electromagnetic field around the coil. As the electrical signals flow through the coil, the interaction between the electromagnetic field and the coil causes the coil and the attached diaphragm to vibrate. The vibration of the diaphragm produces sound waves that correspond to the electrical signals. The sound waves are emitted from the receiver. For instance, sounds can be emitted from the ear-wearable device 100 at acoustic outlet 321 and directed into the user's ear canal.

[0049] In various embodiments, a moving coil receiver includes a diaphragm with a diameter of at least 2, 4, 8, 9, 10, 11, 12, 13 or 14 millimeters (mm), or ranges between these values. In one example, the moving coil receiver has a diaphragm having a diameter of 13 mm.

[0050] In various embodiments, the receiver assembly 102 can include an insert 322 configured to fit within the receiver housing 109. The insert 322 can be placed within the receiver housing 109, such as to separate the front housing volume 314 from the rear acoustic passage 316. The insert 322 can have a first insert side 323 facing the front housing portion 310 and a second insert side 325 facing the rear housing wall 313. In the example of FIG. 3, the receiver 318 is configured to fit within the receiver housing 109 between the front housing portion 310 and the first insert side 323. In some embodiments, a portion of receiver 318 is supported by the insert 322. In some embodiments, a portion of receiver 318 is supported by one or more ledges 327 defined within the rear housing wall 313.

[0051] In various embodiments, the receiver assembly 102 may further include one or more filters 230. Filter 230 can be configured to modify and enhance the incoming acoustic input by selectively amplifying or attenuating specific frequencies or sound characteristics. In the example of FIG. 3, the filter 230 is configured to fit within the receiver housing 109 within a space defined by the insert 322.

Acoustic Openings (FIG. 4)

[0052] Referring now to FIG. 4, a bottom perspective view of a portion of the receiver assembly of FIG. 3 is shown in accordance with various embodiments herein. The receiver assembly 102 can include a receiver housing 109 having a front housing portion 310 and a rear housing portion 312. In various embodiments, the receiver assembly can include one or more acoustic openings. In the example of FIG. 4, the receiver assembly can include a rear acoustic inlet 422 defined in the rear housing wall 313 of the rear housing portion 312. The rear acoustic inlet 422 is in acoustic communication with the rear acoustic passage 316, which is in acoustic communication with the receiver 318.

[0053] The rear housing wall 313 can further define one or more ambient openings 424. In some embodiments, the receiver assembly 102 can include greater than or equal to one, two, three, or four ambient openings of any suitable size, shape, and configuration. In various embodiments, the ambient openings 424 are in acoustic communication with the receiver 318. FIG. 4 shows the bottom view without any mesh layers against the rear housing wall 313, so that the rear acoustic inlet 422 and ambient openings 424 are visible.

Mesh Layer Configuration (FIG. 5)

[0054] Referring now to FIG. 5, an exploded view of the receiver assembly of FIG. 4 is shown in accordance with various embodiments herein. In various embodiments, the receiver assembly 102 can include a first mesh layer 528 and a second mesh layer 530. The first mesh layer 528 and the second mesh layer 530 can be formed from any suitable type of mesh (or other material having similar acoustic properties) such as acoustic mesh. Acoustic mesh as defined herein is a particular type of wire mesh used to achieve sound attenuation objectives.

[0055] The first mesh layer 528 can have a first set of acoustic properties and the second mesh layer can have a second set of acoustic properties. In some embodiments, the first mesh layer 528 and second mesh layer can have the same acoustic properties. Alternatively, the first mesh layer 528 and second mesh layer 530 and the second mesh layer can have different acoustic properties. For instance, the first mesh layer 528 can be formed from a denser weave than the second mesh layer 530 such that the first mesh layer is configured to provide greater sound attenuation and/or acoustic damping than the second mesh layer. Alternatively, the first mesh layer 528 can be formed from a less dense weave than the second mesh layer 530.

[0056] In various embodiments, the first mesh layer 528 is configured to cover the ambient openings 424 on the rear housing wall 313. In various embodiments, the first mesh layer 528 can be held by place by one or more features (e.g., protrusions and indentations) on the rear housing wall 313. For instance, the first mesh layer 528

includes a mesh aperture 529 configured to interface with a protrusion 531 defined by the rear housing wall 313 and the first mesh layer 528 can sit within a first indentation 532 of the rear housing wall 313. In the example of FIG. 5, the first mesh layer does not cover the rear acoustic inlet 422. However, in alternative embodiments, the first mesh layer can cover the rear acoustic inlet 422.

[0057] In various embodiments, the second mesh layer 530 is configured to cover the ambient openings 424 and the rear acoustic inlet 422 on the rear housing wall 313. In the example of FIG. 5, the second mesh layer 530 is stacked on top of the first mesh layer 528, but in alternative embodiments, the first mesh layer 528 may be stacked on top of the second mesh layer 530. In various embodiments, the second mesh layer 530 can be held by place by one or more features (e.g., protrusions and indentations) defined on the rear housing wall 313. For instance, the second mesh layer 530 can sit within a second indentation 534 of the rear housing wall 313.

[0058] In various embodiments, the first mesh layer 528 and the second mesh layer 530 are distributed over the various openings of the rear housing wall 313 to optimize their acoustic damping effects. In some embodiments, such as the device shown in the FIGS., it can be advantageous to have more damping on the ambient openings 424 than on the rear acoustic inlet 422, because the ambient openings lead to shorter axially-oriented rear vent passages while the rear acoustic inlet leads to a curved rear acoustic passage, oriented to span a larger portion of the receiver rear wall area and with more acoustic resistance than the vent passages. The mesh densities can be selected to provide the best acoustic properties for a particular ear-worn device configuration. The mesh layers 528, 530 can also provide ingress protection to the rear acoustic volume.

[0059] The example of FIG. 3 shows a receiver assembly having two mesh layers. Alternatively, the receiver assembly 102 may have any suitable number of mesh layers such as one, two, three, four, or more mesh layer distributed in any suitable configuration over the rear acoustic inlet 422 and the ambient openings 424.

Receiver Assembly Exploded View (FIG. 6)

[0060] Referring now to FIG. 6, an exploded view of a receiver assembly is shown in accordance with various embodiments herein. In various embodiments, the receiver assembly 102 can include an earbud 104, a first mesh layer 528, a second mesh layer 530, and a receiver housing formed from a front housing portion 310 and a rear housing portion 312. The receiver housing can include at least a receiver 318, a filter component 230, and an insert 322.

[0061] In various embodiments, the earbud 104 can be removably attachable to the front housing portion 310 of the receiver assembly 102. The earbud 104 can include one or more layers of mesh. In the example of FIG. 6, the receiver assembly can include a first earbud mesh layer

632 and a second earbud mesh layer 633. The first earbud mesh layer 632 and the second earbud mesh layer 633 are configured to prevent foreign matter from entering the receiver housing 109 through the earbud 104 and can be designed with any suitable acoustic properties to optimize sound quality. The first earbud mesh layer 632 and the second earbud mesh layer 633 can be separated from each other within the receiver assembly 102 by a fixed axial distance. In various embodiments, the first earbud mesh layer 632 can be disposed within the earbud 104 and the second earbud mesh layer 633 can be disposed on the top of the stem 842 (best seen in FIG. 8) of the receiver housing 109. Alternatively, the receiver assembly 102 may include only one of mesh layers 632, 633 or may not include any mesh layers in the earbud 104 or stem 842.

[0062] In various embodiments, the receiver assembly 102 can include an insert 322 configured to fit within the receiver housing 109. The insert 322 can be placed within the receiver housing 109, such as to separate the front housing volume 314 from the rear acoustic passage 316. The insert 322 can partially define the rear acoustic passage 316. In various embodiments, the insert 322 can have one or more openings spanning from the first insert side 323 to the second insert side 325. In the example of FIG. 6, the insert can have a first insert opening 638 configured to form a portion of the rear acoustic passage 316. The insert can further include a second insert opening 639 configured to hold the filter 230 within the receiver housing 109. In some examples, the second insert opening 639 is configured to be slightly larger than the filter 230, in at least one dimension. For instance, the second insert opening 639 can have a protruding portion on either side. In some embodiments, the second insert opening 639 is in acoustic communication with the ambient openings 424 defined in the rear housing wall 313. As best seen in the cross-sectional view of FIG. 8, the second inset opening leaves a gap in the receiver housing such that the ambient openings 424 are in fluid communication with the receiver 318.

Acoustic Passages (FIGS. 7-8)

[0063] FIG. 7 is a cross sectional view of a receiver assembly through the rear acoustic inlet 422, shown in accordance with various embodiments herein. FIG. 8 is a cross sectional view of a receiver assembly through a receiver inlet 840, shown in accordance with various embodiments herein. The receiver assembly 102 can include a rear acoustic passage 316 defined between the rear housing wall 313 and the second insert side 325. In addition, or alternatively, the receiver assembly can define venting passages leading to the rear side of the receiver. The receiver assembly can also device a front acoustic passage leading to an earbud.

[0064] In various embodiments, the rear acoustic passage 316 begins at the rear acoustic inlet 422 (best seen in FIG. 7). The rear acoustic passage 316 extends

through the space defined between the rear housing wall 313 and the second insert side 325. The rear acoustic passage 316 extends up through the first insert opening 638 and terminates at the receiver inlet 840 (best seen in FIG. 8). In various embodiments, the receiver housing 109 is configured to permit fluid communication between an external environment and the receiver rear side 636 through the rear acoustic inlet 422 and the rear acoustic passage 316. This fluid communication facilitates the easier movement of the receiver, compared to if the housing was closed to fluid communication. The air in the rear acoustic passage 316 provides a suspension effect to the receiver, allowing smoother movement and facilitating high-quality sound production particularly at lower frequencies.

[0065] In various embodiments, the rear acoustic passage 316 can have an annular cross section and can be partially defined by the rear housing wall 313 and partially defined by the second insert side 325. In the example of FIGS. 7-8, approximately half of the cross-sectional area of the rear acoustic passage 316 is defined by the rear housing wall 313, approximately half of the cross-sectional area of the rear acoustic passage 316 is defined by the second insert side 325, and the two halves are combined to form a rear acoustic passage having a substantially circular cross section. In most conventional manufacturing processes (e.g., injection molding, 3D printing), such a configuration is simpler than forming an acoustic passage in a singular piece of material. However, in alternate configurations, the rear acoustic passage 316 may be defined entirely by the rear housing wall 313 or the rear acoustic passage 316 may be defined entirely by second insert side 325. While the rear acoustic passage 316 is depicted as having a substantially circular cross-sectional area in FIGS. 7-8, it is possible for the rear acoustic passage to have any other suitable cross-sectional shape such as oval, square, or the like. The rear housing and insert may be formed using injection molding, 3D printing, compression molding, or other manufacturing processes.

[0066] The acoustic output from the receiver 318 is propagated through the front housing volume 314. In various embodiments, the front housing volume 314 is formed between a receiver front side 634 and the front housing wall 311. In various embodiments, the front housing portion 310 includes a stem 842 protruding from the front housing wall 311. In various embodiments, the stem 842 can define a front acoustic passage 844. The front acoustic passage 844 is in fluid communication with the front housing volume 314. The acoustic output passes through the front housing volume 314 and front acoustic passage 844 into the ear canal of the ear-wearable device user through the acoustic outlet 321 defined in the earbud 104.

[0067] The rear housing wall 313 can further define one or more ambient openings 424. As best seen in FIG. 8, the ambient openings 424 are in acoustic communication with the receiver rear side 636 via rear vent passages

850. In various embodiments, the ambient openings 424 are configured to provide venting to the receiver rear side 636 of the receiver 318. Venting can improve the sound quality of the amplified sounds, by allowing the receiver rear side 636 to move as it generates sound. The benefits of the venting provided by the ambient openings 424 and the rear vent passages 850 can be optimized using one or more mesh layers with acoustic properties, as discussed in the context of FIG. 5.

Rear Acoustic Passage Shape (FIGS. 9-10)

[0068] FIG. 9 is a cross sectional view of a receiver assembly through the rear acoustic passage plane shown in accordance with various embodiments herein, looking towards the rear housing wall of the receiver housing. FIG. 10 is a partially exploded view of a receiver assembly, where the rear housing portion 312 is removed from the receiver assembly to reveal the second insert side 325, in accordance with various embodiments herein.

[0069] In various embodiments, the rear acoustic passage 316 can include a curved portion 944 between the rear acoustic inlet 422 and the receiver inlet 840. The curved portion 944 can be defined in both the rear housing wall 313 (best seen in FIG. 9) and in the second insert side 325 (best seen in FIG. 10). However, in alternate configurations, the curved portion may be defined only by the rear housing wall 313 or only by an insert component. In the example of FIGS. 9-10, the curved portion 944 of the rear acoustic passage 316 has an arc shape in a plane parallel to at least a portion of the rear housing wall. However, other suitable shapes of acoustic passage can be used such as spiral, circular, oval, ellipse, square, rectangular, triangular, pie-piece shaped, or chevron shaped. In some embodiments, the acoustic passage includes curved surfaces and does not include hard corners or right angles, to reduce the chance of echoes.

[0070] FIG. 9 includes dashed line 3-3 showing the cross-sectional plane of FIG. 3 through the ambient openings 424. FIG. 9 also includes dashed line 7-7 showing the cross-sectional plane of FIG. 7 through the rear acoustic inlet 422. FIG. 9 also includes dashed line 8-8 showing the cross-sectional plane of FIG. 8 through the receiver inlet 840.

[0071] Referring back to FIG. 7, the rear acoustic passage 316 can include a first axial portion 739 extending away from the rear acoustic inlet 422 to the rear acoustic passage plane 741. Referring back to FIG. 8, the rear acoustic passage 316 can include a second axial portion 841 extending from the rear acoustic passage plane 741 through the first insert opening 638 to the receiver inlet 840. Referring back to FIGS. 9-10, the curved portion 944 of the rear acoustic passage 316 can be defined between the first axial portion 739 and the second axial portion 841 and is configured to intersect the rear acoustic passage plane 741.

[0072] It can be challenging for open-fit ear-wearable

devices to produce high-quality sounds in lower frequencies. This issue can be mitigated by tuning the rear acoustic passage 316. The shape of an acoustic passage can significantly affect the receiver's acoustic resonance properties and its efficiency in transmitting various acoustic frequencies. In the examples of FIG. 9-10, the curved shape of the rear acoustic passage 316 allows for more flexibility in acoustic passage tuning. In various embodiments, the rear acoustic passage 316 is tuned to increase a low frequency efficiency of the receiver 318. The rear acoustic passage 316 provides an acoustic mass, also known as an acoustic inertance, to the rear wall of the receiver. Acoustic mass for a cylinder, M, is:

$$M = \rho * L_E / s,$$

Where:

ρ = the density of air,
 L_E = the effective length of the cylinder after an end-correction, which will be a bit longer than a cylinder, and
 s = the cross-sectional area of the cylinder.

[0073] A longer and narrower cylinder will be "heavy" and provide more resistance to the travel of sound when compared to a short and wide cylinder with a "light" effect on the receiver. The acoustic mass together with the rear volume and the receiver's mechanical stiffness determine a resonant frequency. A design for an ear-wearable device can have a desired resonant frequency and these parameters can be adjusted to achieve the desired resonant frequency.

[0074] In some embodiments, the acoustic mass can be greater than or equal to 4000, 7200, 10400, 13600, 16800, or 20000 kg/m⁴. In some embodiments, the acoustic mass can be less than or equal to 100000, 84000, 68000, 52000, 36000, or 20000 kg/m⁴. In some embodiments, the acoustic mass can fall within a range of 4000 to 100000 kg/m⁴, or 7200 to 84000 kg/m⁴, or 10400 to 68000 kg/m⁴, or 13600 to 52000 kg/m⁴, or 16800 to 36000 kg/m⁴, or can be about 20000 kg/m⁴.

[0075] In one example, the length of the rear acoustic passage 316 as defined herein is the distance between the rear acoustic inlet 422 and the receiver inlet 840 and can include the first axial portion 739, second axial portion 841, and the curved portion 944. In some embodiments, the length of the rear acoustic passage can be greater than or equal to 9 mm, 11 mm, 12 mm, 14 mm, 16 mm, 17 mm, or 19 mm. In some embodiments, the length of the rear acoustic passage can be less than or equal to 29 mm, 27 mm, 26 mm, 24 mm, 22 mm, 21 mm, or 19 mm. In some embodiments, the length of the rear acoustic passage can fall within a range of 9 mm to 29 mm, or 11 mm to 27 mm, or 12 mm to 26 mm, or 14 mm to 24 mm, or 16 mm to 22 mm, or 17 mm to 21 mm, or can be about 19 mm.

[0076] In the context of the present application, the cross-sectional area of the rear acoustic passage 316 is determined by its diameter, which is labeled D_{AP} in FIG. 9. In some embodiments, the diameter can be greater than or equal to 0.3 mm, 0.4 mm, 0.6 mm, 0.8 mm, 0.9 mm, 1.0 mm, or 1.2 mm. In some embodiments, the diameter can be less than or equal to 5.0 mm, 4.4 mm, 3.7 mm, 3.1 mm, 2.5 mm, 1.8 mm, or 1.2 mm. In some embodiments, the diameter can fall within a range of 0.3 mm to 5.0 mm, or 0.4 mm to 4.4 mm, or 0.6 mm to 3.7 mm, or 0.8 mm to 3.1 mm, or 0.9 mm to 2.5 mm, or 1.0 mm to 1.8 mm, or can be about 1.2 mm.

[0077] In various embodiments, the ratio of length to diameter can play a key role in the resonance properties of the rear acoustic passage 316. In some embodiments, the ratio of length to diameter can be greater than or equal to 6, 8, 10, 12, 14, or 16. In some embodiments, the ratio of length to diameter can be less than or equal to 26, 24, 22, 20, 18, or 16. In some embodiments, the ratio of length to diameter can fall within a range of 6 to 26, or 8 to 24, or 10 to 22, or 12 to 20, or 14 to 18, or can be about 16.

Earbud Configuration (FIG. 11)

[0078] Referring now to FIG. 11, a cross-sectional view of an earbud is shown in accordance with various embodiments herein. In various embodiments, the earbud 104 can have a first earbud portion 1141 and a second earbud portion 1143. In various embodiments, the earbud 104 is configured to be removably attachable to the stem 842 of the receiver housing 109 at the first earbud portion 1141. The removable attachability of the earbud 104 from the receiver housing 109 facilitates easy cleaning and replacement of the earbud 104. In various embodiments, the first earbud portion 1141 can include one or more retention features 1148 such that the earbud stays securely attached to the stem of the receiver housing 109. For instance, the first earbud portion 1141 can include a flange configured to snap onto a corresponding groove on the stem 842 of the receiver housing 109. In some embodiments, the retention features 1148 are further configured to hold the first earbud mesh layer 632 in place within the earbud 104. In various embodiments the first earbud portion 1141 can be constructed from any suitable material or materials with sufficient ductility to snap onto the receiver housing, but sufficient rigidity to maintain its shape including, but not limited to silicone, urethane, acrylates, flexible epoxy, acrylate urethane, and combinations thereof.

[0079] In various embodiments, the earbud 104 can include a second earbud portion 1143. The second earbud portion 1143 can be permanently attached to the first earbud portion 1141 by any suitable means such as welding, adhesives, or the like. In various embodiments, the second earbud portion 1143 can be constructed from a less rigid material than the first earbud portion 1141. In various embodiments, the second earbud portion 1143 is

made from a material and constructed so that it uniformly conforms to the ear canal and maintains a constant and comfortable radial pressure on the ear canal. In various examples, the second earbud portion 1143 is made of resilient material, such as silicone. In various examples, the second earbud portion 1143 is made of a flexible material. By flexible material, it is meant that a material is capable of bending easily without breaking. In various examples, the second earbud portion 1143 is made of an elastomeric material. By elastomeric material, it is meant a material with viscoelasticity that is soft and deformable at ambient temperatures, such as rubber, silicone, and amorphous polymers. In alternative embodiments, the second earbud portion 1143 can be constructed from the same material as the first earbud portion 1141.

[0080] In various embodiments, the earbud 104 can include an axial wall 1150 defining an earbud acoustic channel 1152. The earbud acoustic channel 1152 can be in acoustic communication with the front acoustic passage 844. The earbud acoustic channel 1152 terminates at acoustic outlet 321. In various embodiments, the axial wall 1150 is formed partially from the first earbud portion 1141 and partially from the second earbud portion 1143.

[0081] In various embodiments, the second earbud portion 1143 can form an outer dome 1138. The outer dome can be connected to the axial wall 1150 at flexible tip portion 1146 of the earbud. The outer dome can be unconnected to the axial wall at a rear edge 1154 of the earbud to further enhance the complaint fit of the earbud.

[0082] In various embodiments, the earbud can include a plurality of vent openings 1142 defined in the axial wall 1150. The earbud can include any suitable number, shape, and configuration of vent openings 1142 defined in the axial wall 1150 such as one, two, three, four, or more vent openings. In various embodiments, the plurality of vent openings 1142 are configured to give the earbud 104 an open fit. Unlike traditional in-ear earphones, which create a seal inside the ear canal to isolate the ear canal from external sounds, open-fit earbuds allow some ambient noise to pass through. Open fit devices can be prone to "tinny" audio (e.g., attenuation of low frequency sound). This problem is remedied in part by the tuned rear acoustic passage 316 and in part by providing an open-fit ear bud so that the wearer can hear ambient noise (e.g., a natural version of their own voice). In various embodiments ambient sounds can follow an acoustic path such as exemplary path 1156. For instance, ambient sounds can enter the earbud 104 through the open end of the outer dome 1138 at the rear edge 1154, pass through the earbud acoustic channel 1152 through one of the vent openings 1142, and then enter the wearer's ear through the acoustic outlet 321. In alternate configurations, the earbud 104 can be devoid of vent openings 1142 and provide a closed fit.

[0083] In the example of FIG. 11, the earbud 104 is devoid of vent openings 1142 on the outer dome 1138. Accordingly, when viewing the earbud 104 from the outside, it will appear to have a closed fit. Such a configura-

tion is advantageous because vent openings 1142 on an outer surface of the earbud 104 would be occluded by the user's ear canal and could provide an inlet for foreign matter to the earbud 104.

5 **[0084]** It should be noted that, as used in this specification and the appended claims, the singular forms "a," "an," and "the" include plural referents unless the content clearly dictates otherwise. It should also be noted that the term "or" is generally employed in its sense including
10 "and/or" unless the content clearly dictates otherwise.

[0085] It should also be noted that, as used in this specification and the appended claims, the phrase "configured" describes a system, apparatus, or other structure that is constructed or configured to perform a particular task or adopt a particular configuration. The phrase "configured" can be used interchangeably with other similar phrases such as arranged and configured, constructed and arranged, constructed, manufactured and arranged, and the like.

20 **[0086]** All publications and patent applications in this specification are indicative of the level of ordinary skill in the art to which this invention pertains. All publications and patent applications are herein incorporated by reference to the same extent as if each individual publica-
25 tion or patent application was specifically and individually indicated by reference.

[0087] As used herein, the recitation of numerical ranges by endpoints shall include all numbers subsumed within that range (e.g., 2 to 8 includes 2.1, 2.8, 5.3, 7,
30 etc.).

[0088] The headings used herein are provided for consistency with suggestions under 37 CFR 1.77 or otherwise to provide organizational cues. These headings shall not be viewed to limit or characterize the invention(s) set out in any claims that may issue from this disclosure. As an example, although the headings refer to a "Field," such claims should not be limited by the language chosen under this heading to describe the so-called technical field. Further, a description of a technology in the "Background" is not an admission that technology is prior art to any invention(s) in this disclosure. Neither is the "Summary" to be considered as a characterization of the invention(s) set forth in issued claims.

[0089] The embodiments described herein are not intended to be exhaustive or to limit the invention to the precise forms disclosed in the following detailed description. Rather, the embodiments are chosen and described so that others skilled in the art can appreciate and understand the principles and practices. As such, aspects have
40 been described with reference to various specific and preferred embodiments and techniques. However, it should be understood that many variations and modifications may be made while remaining within the spirit and scope herein.

55 **[0090]** The invention relates, inter alia, to the following aspects:

1. An ear-wearable device comprising a receiver

assembly, wherein the receiver assembly comprises:

a. a receiver housing, the receiver housing comprising:

a front housing portion comprising a front housing wall;

a rear housing portion comprising a rear housing wall, wherein the rear housing wall defines a rear acoustic inlet;

b. a receiver configured to convert electrical signals into sounds;

c. an insert configured to fit within the receiver housing and defining a first insert opening, the insert comprising a first insert side facing the front housing portion and a second insert side facing the rear housing wall; and

d. a rear acoustic passage defined between the rear housing wall and the second insert side, the rear acoustic passage extending between the rear acoustic inlet and a receiver inlet disposed adjacent to the first insert opening;

wherein the receiver is configured to fit within the receiver housing between the front housing portion and the first insert side;

wherein a front housing volume is formed between a receiver front side and the front housing wall; and

wherein the receiver housing is configured to permit fluid communication between an external environment and the receiver rear side through the rear acoustic inlet and the rear acoustic passage.

2. The ear-wearable device of any of claim 1, the front housing portion further comprising a stem protruding from the front housing wall, the stem defining a stem acoustic channel.

3. The ear-wearable device of any of claims 1-2, further comprising an earbud configured to removably attach to the stem of the receiver housing, the earbud comprising:

an axial wall defining an earbud acoustic channel; wherein the earbud acoustic channel is in acoustic communication with the stem acoustic channel; and

an outer dome connected to the axial wall at a front edge and unconnected to the axial wall at a rear edge.

4. The ear-wearable device of any of the preceding claims, the earbud further comprising a plurality of vent openings defined in the axial wall.

5. The ear-wearable device of any of the preceding claims, the axial wall comprising:

a first portion comprising a first material, the first portion defining retention features configured to removably attach to the stem of the receiver housing; and

a second portion comprising a second material configured to conform to an ear of a wearer, wherein the second material is more compliant than the first material.

6. The ear-wearable device of any of the preceding claims, the rear housing portion further comprising an ambient opening defined in the rear housing wall, wherein the ambient opening is configured to be in fluid communication with a rear side of the receiver.

7. The ear-wearable device of any of the preceding claims, wherein the insert further defines a second insert opening in acoustic communication with the ambient opening.

8. The ear-wearable device of any of the preceding claims, further comprising:

a. a first mesh layer having a first set of acoustic properties, wherein the first mesh layer is configured to cover the ambient opening; and

b. a second mesh layer having a second set of acoustic properties, wherein the second mesh layer is configured to cover the ambient opening and the rear acoustic inlet; and

c. wherein the first mesh layer is configured to provide more acoustic damping than the second mesh layer.

9. The ear-wearable device of any of the preceding claims, wherein the rear acoustic passage comprises a curved portion between the rear acoustic inlet and the receiver inlet.

10. The ear-wearable device of any of the preceding claims, wherein the curved portion of the rear acoustic passage comprises an arc-shaped trajectory in a plane parallel to at least a portion of the rear housing wall.

11. The ear-wearable device of any of the preceding claims, the rear acoustic passage comprising:

a first axial portion extending away from the rear acoustic inlet to a first plane;

a second axial portion extending from the first plane to the receiver inlet; and

a curved portion spanning between the first vertical portion and the second vertical portion, wherein the curved portion makes an arc-

shaped trajectory intersecting the first plane.

12. The ear-wearable device of any of the preceding claims, wherein the rear acoustic passage is tuned to increase a low frequency efficiency of the receiver. 5

13. The ear-wearable device of any of the preceding claims, wherein the receiver comprises a moving coil receiver. 10

14. An ear-wearable device comprising a receiver assembly, the receiver assembly comprising:

- a) a receiver configured convert electrical signals into sounds, the receiver comprising a front side and a receiver rear side, 15
- b) a receiver housing comprising:

- a front housing portion comprising a front housing wall; 20

- a rear housing portion comprising a rear housing wall, wherein the rear housing wall defines a rear acoustic inlet;

- a rear acoustic passage defined adjacent to the rear housing wall, the rear acoustic passage extending between the rear acoustic inlet and a receiver inlet; 25

- wherein the receiver is configured to fit within the receiver housing between the front housing portion and the rear housing portion; 30

- wherein a front housing volume is formed between the receiver front side and the front housing wall;

- wherein the receiver housing is configured to permit fluid communication between an external environment and the receiver rear side through the rear acoustic inlet and the rear acoustic passage; and 35

- wherein the rear acoustic passage comprises a curved portion between the rear acoustic inlet and the receiver inlet. 40

15. The ear-wearable device of any of claim 14, the rear housing portion further comprising an ambient opening defined in the rear housing wall, wherein the ambient opening is configured to be in fluid communication with a rear side of the receiver. 45

16. The ear-wearable device of any of claims 14-15, further comprising: 50

- a. a first mesh layer having a first set of acoustic properties, wherein the first mesh layer is configured to cover the ambient opening; and 55
- b. a second mesh layer having a second set of acoustic properties, wherein the second mesh layer is configured to cover the ambient opening

and the rear acoustic inlet; and

c. wherein the first mesh layer is configured to provide more acoustic damping than the second mesh layer.

17. The ear-wearable device of any of claims 14-16, wherein the curved portion of the rear acoustic passage comprises an arc-shaped trajectory in a plane parallel to at least a portion of the rear housing wall.

18. The ear-wearable device of any of claims 14-17, the rear acoustic passage comprising:

- a first axial portion extending away from the rear acoustic inlet to a first plane;

- a second axial portion extending from the first plane to the receiver inlet; and

- the curved portion spanning between the first vertical portion and the second vertical portion, wherein the curved portion makes an arc-shaped trajectory intersecting the first plane.

19. The ear-wearable device of any of claims 14-18, wherein the rear acoustic passage is tuned to increase a low frequency efficiency of the receiver.

20. An ear-wearable device comprising a receiver assembly, wherein the receiver assembly comprises:

- a. a receiver housing, the receiver housing comprising a rear housing wall, wherein the rear housing wall defines a rear acoustic inlet,

- b. a receiver configured convert electrical signals into sounds and configured to fit within the receiver housing;

- c. a rear acoustic passage at least partially defined between a first housing component and a second housing component, wherein the first housing component and a second housing component are separately manufactured and then are assembled to form at least a portion of the receiver assembly, wherein the rear acoustic passage extends between the rear acoustic inlet and a rear cavity adjacent to a receiver rear side;

wherein the receiver housing is configured to permit fluid communication between an external environment and the rear cavity through the rear acoustic inlet and the rear acoustic passage.

Claims

1. An ear-wearable device comprising a receiver assembly, wherein the receiver assembly comprises:

- a. a receiver housing, the receiver housing comprising:
- a front housing portion comprising a front housing wall;
 - a rear housing portion comprising a rear housing wall, wherein the rear housing wall defines a rear acoustic inlet;
- b. a receiver configured to convert electrical signals into sounds;
- c. an insert configured to fit within the receiver housing and defining a first insert opening, the insert comprising a first insert side facing the front housing portion and a second insert side facing the rear housing wall; and
- d. a rear acoustic passage defined between the rear housing wall and the second insert side, the rear acoustic passage extending between the rear acoustic inlet and a receiver inlet disposed adjacent to the first insert opening; wherein the receiver is configured to fit within the receiver housing between the front housing portion and the first insert side; wherein a front housing volume is formed between a receiver front side and the front housing wall; and wherein the receiver housing is configured to permit fluid communication between an external environment and the receiver rear side through the rear acoustic inlet and the rear acoustic passage.
2. The ear-wearable device of any of claim 1, the front housing portion further comprising a stem protruding from the front housing wall, the stem defining a stem acoustic channel.
3. The ear-wearable device of any of claims 1-2, further comprising an earbud configured to removably attach to the stem of the receiver housing, the earbud comprising:
- an axial wall defining an earbud acoustic channel; wherein the earbud acoustic channel is in acoustic communication with the stem acoustic channel; and
 - an outer dome connected to the axial wall at a front edge and unconnected to the axial wall at a rear edge.
4. The ear-wearable device of any of the preceding claims, the earbud further comprising a plurality of vent openings defined in the axial wall.
5. The ear-wearable device of any of the preceding claims, the axial wall comprising:
- a first portion comprising a first material, the first portion defining retention features configured to removably attach to the stem of the receiver housing; and
 - a second portion comprising a second material configured to conform to an ear of a wearer, wherein the second material is more compliant than the first material.
6. The ear-wearable device of any of the preceding claims, the rear housing portion further comprising an ambient opening defined in the rear housing wall, wherein the ambient opening is configured to be in fluid communication with a rear side of the receiver.
7. The ear-wearable device of any of the preceding claims, wherein the insert further defines a second insert opening in acoustic communication with the ambient opening.
8. The ear-wearable device of any of the preceding claims, further comprising:
- a. a first mesh layer having a first set of acoustic properties, wherein the first mesh layer is configured to cover the ambient opening; and
 - b. a second mesh layer having a second set of acoustic properties, wherein the second mesh layer is configured to cover the ambient opening and the rear acoustic inlet; and
 - c. wherein the first mesh layer is configured to provide more acoustic damping than the second mesh layer.
9. The ear-wearable device of any of the preceding claims, wherein the rear acoustic passage comprises a curved portion between the rear acoustic inlet and the receiver inlet.
10. The ear-wearable device of any of the preceding claims, wherein the curved portion of the rear acoustic passage comprises an arc-shaped trajectory in a plane parallel to at least a portion of the rear housing wall.
11. The ear-wearable device of any of the preceding claims, the rear acoustic passage comprising:
- a first axial portion extending away from the rear acoustic inlet to a first plane;
 - a second axial portion extending from the first plane to the receiver inlet; and
 - a curved portion spanning between the first vertical portion and the second vertical portion, wherein the curved portion makes an arc-shaped trajectory intersecting the first plane.
12. The ear-wearable device of any of the preceding

claims, wherein the rear acoustic passage is tuned to increase a low frequency efficiency of the receiver.

- 13. The ear-wearable device of any of the preceding claims, wherein the receiver comprises a moving coil receiver. 5

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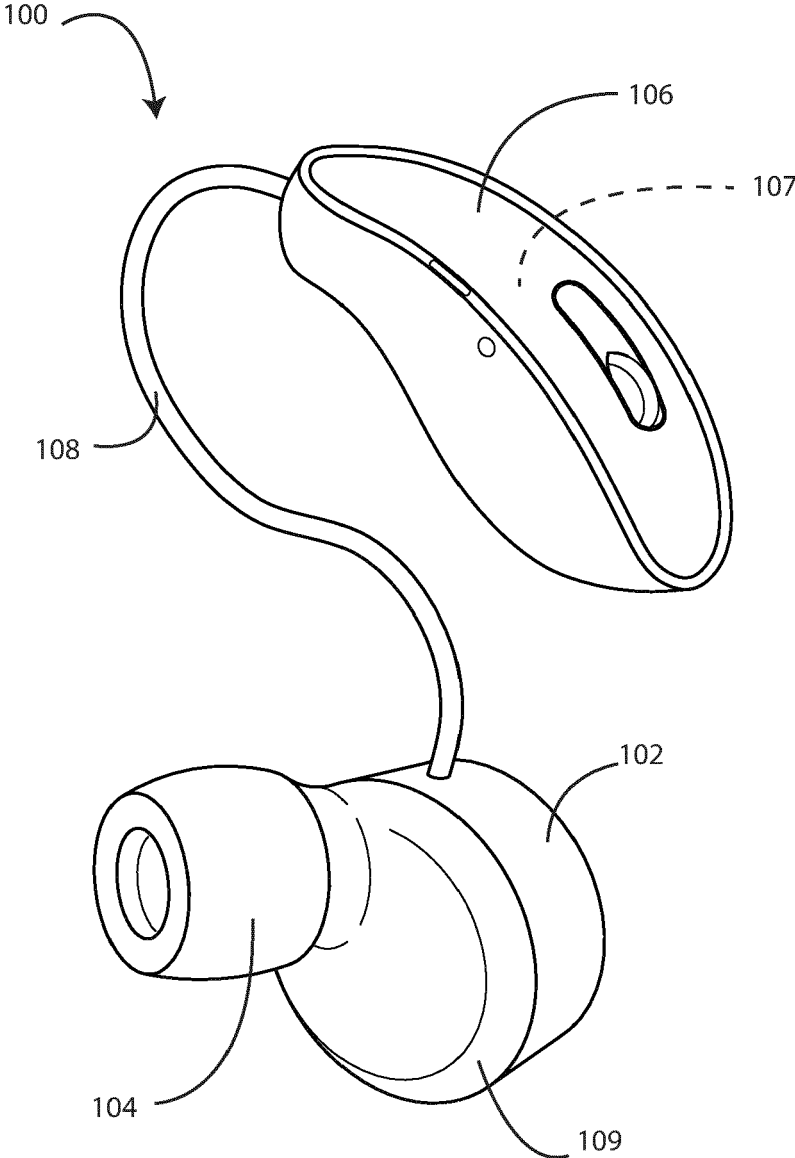


FIG. 1

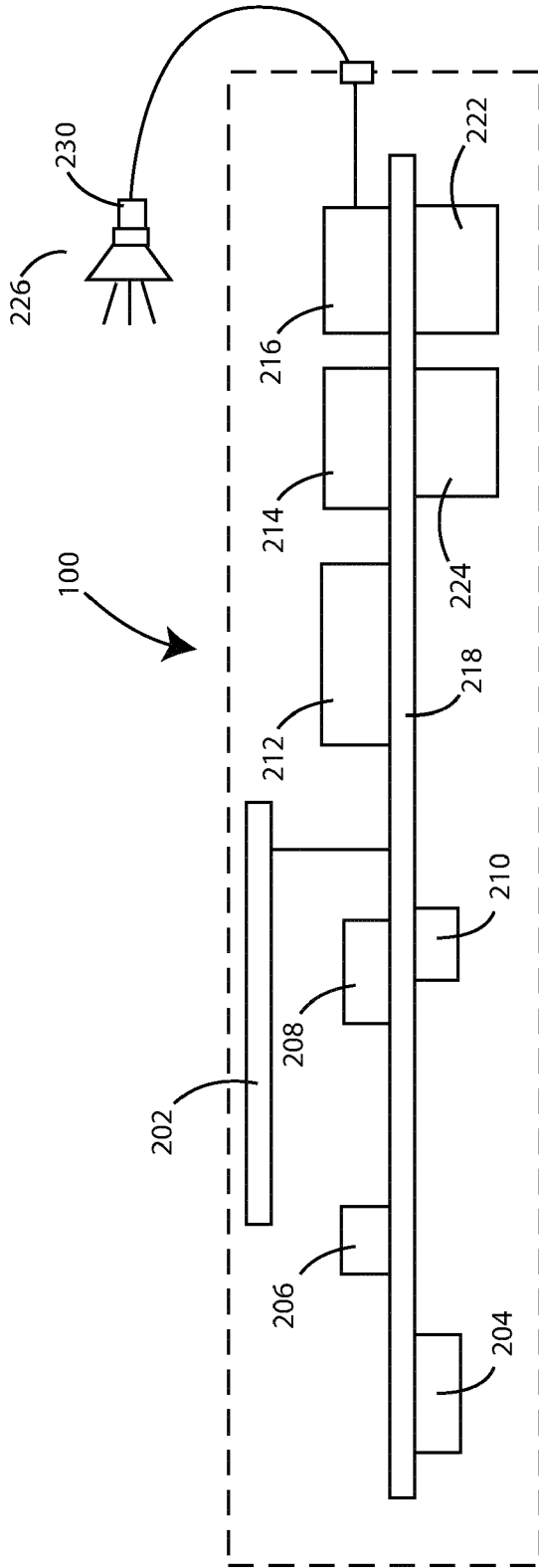


FIG. 2

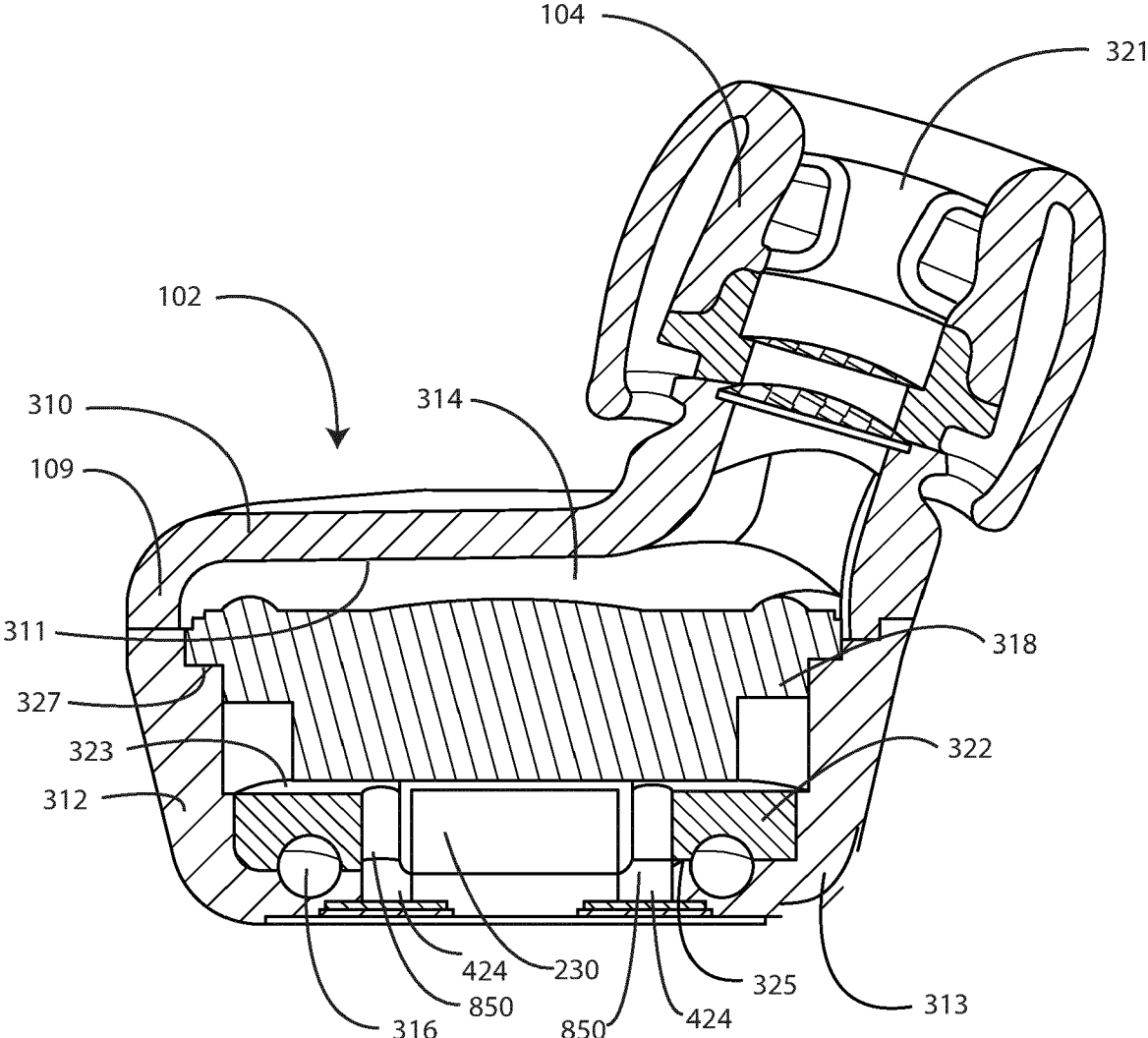


FIG. 3

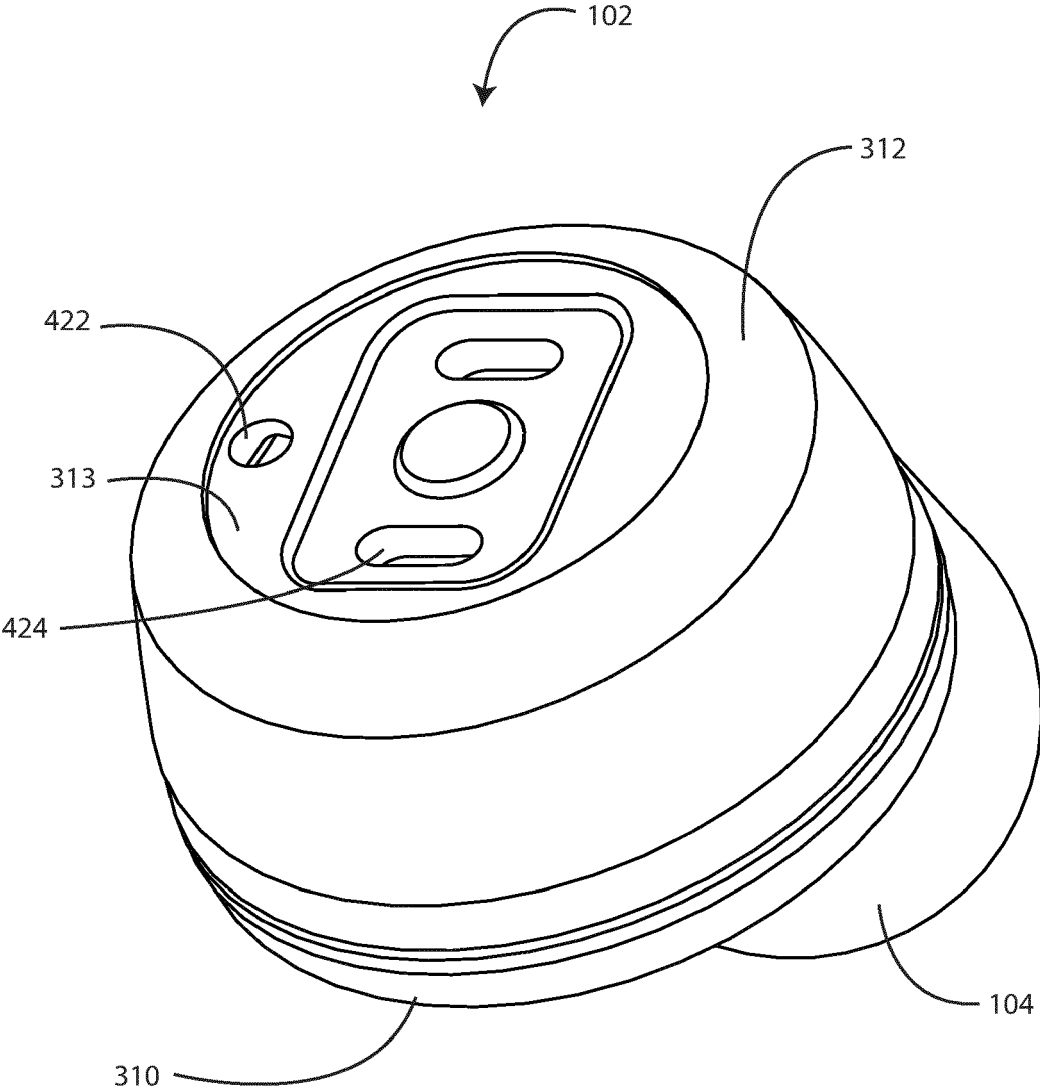


FIG. 4

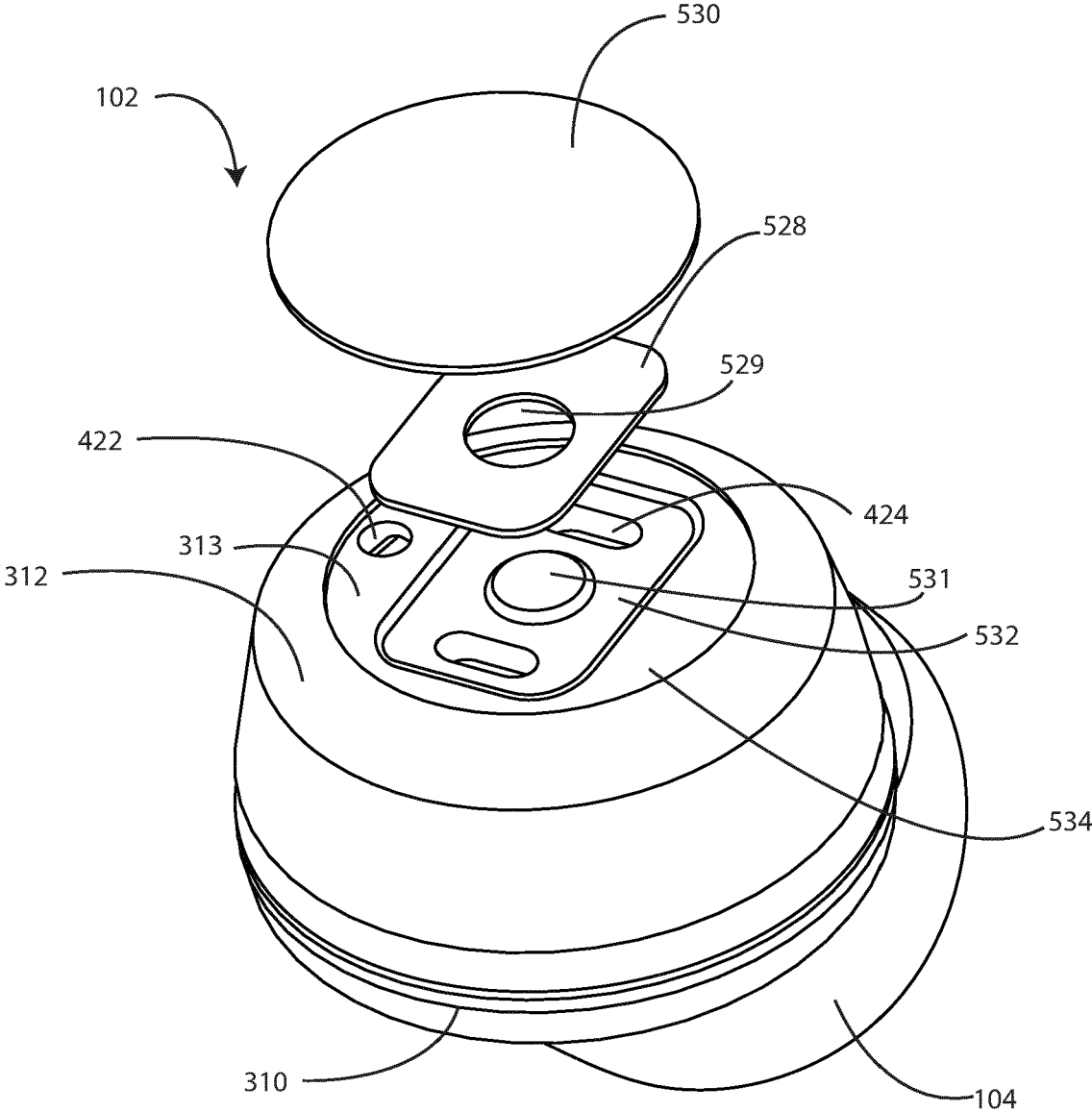


FIG. 5

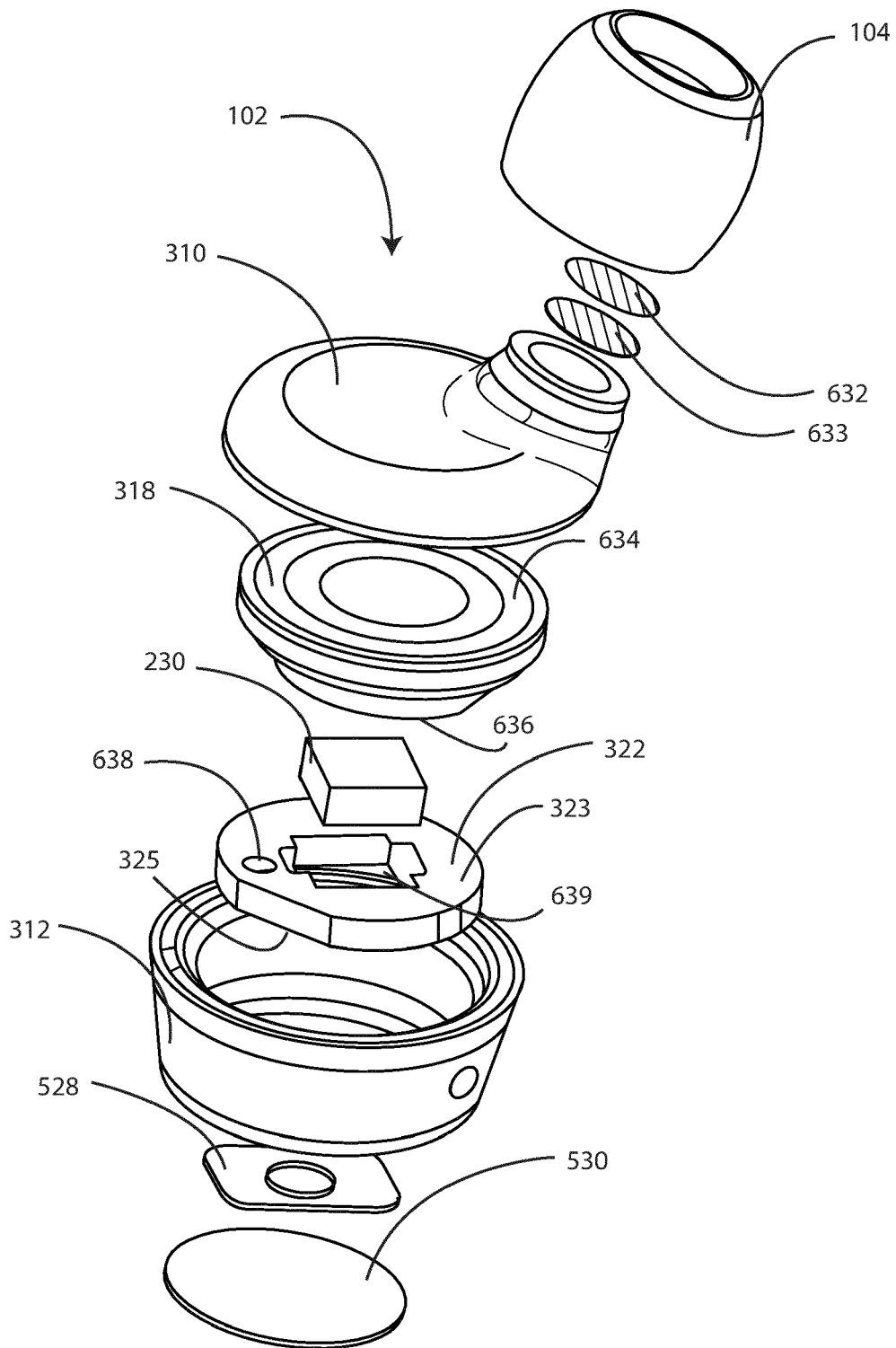


FIG. 6

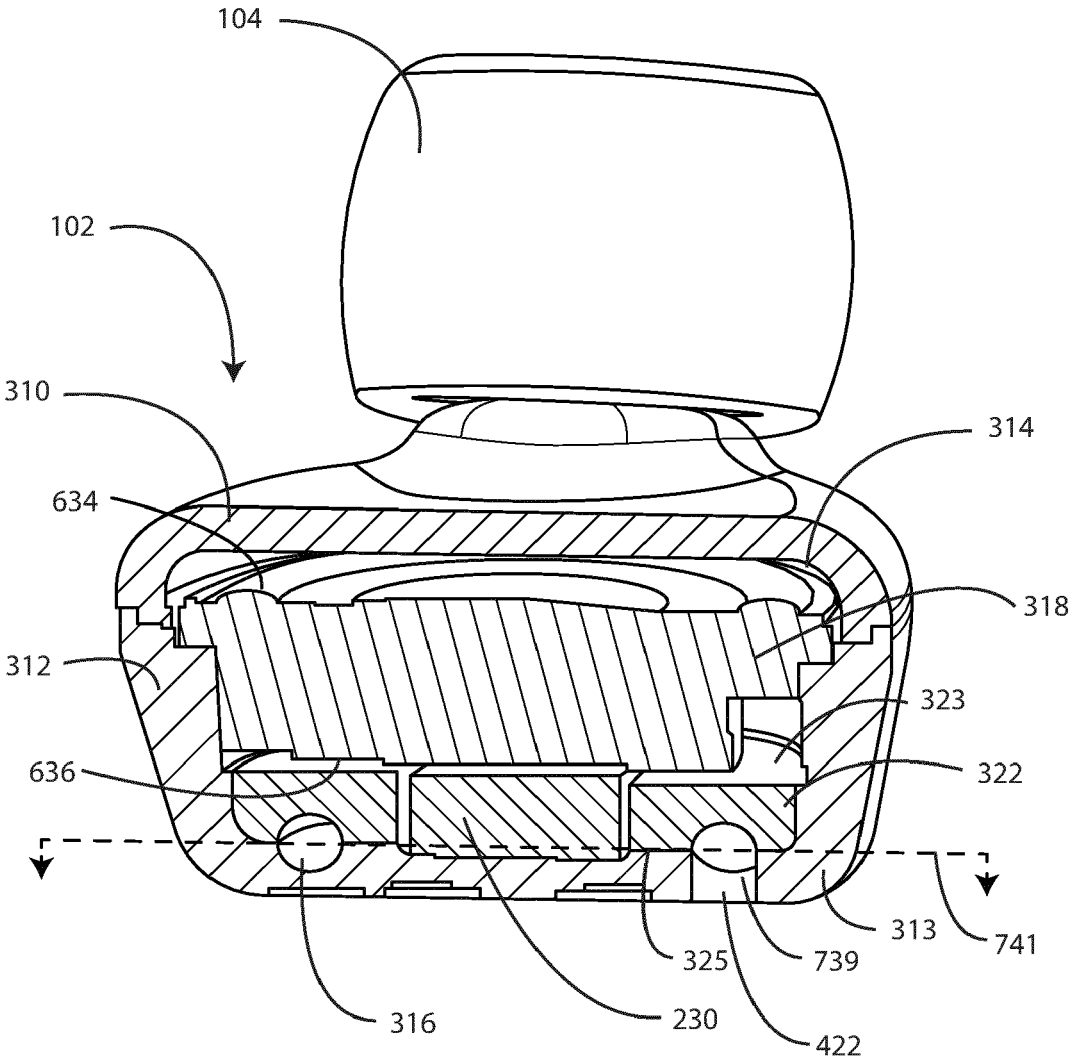


FIG. 7

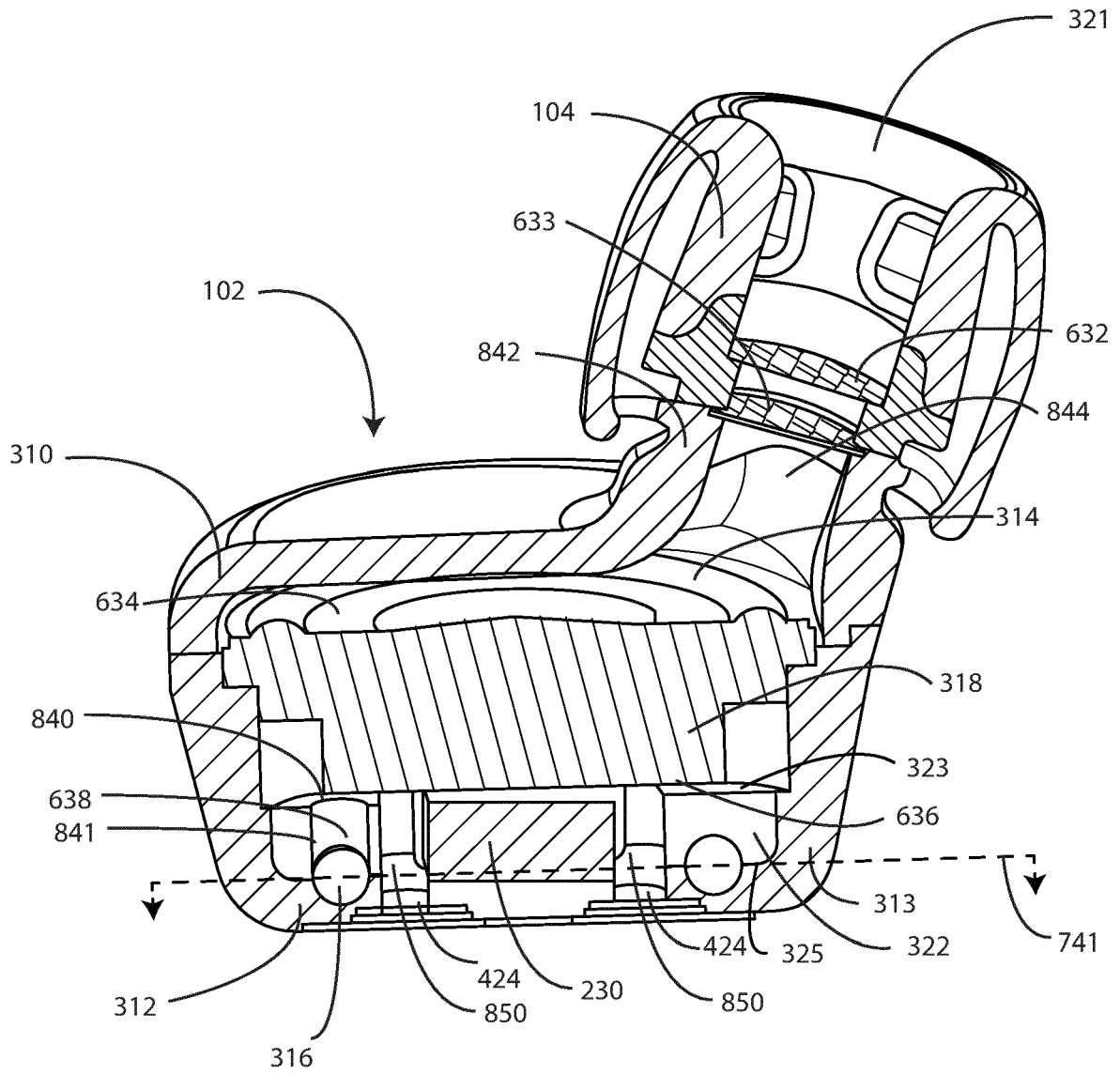


FIG. 8

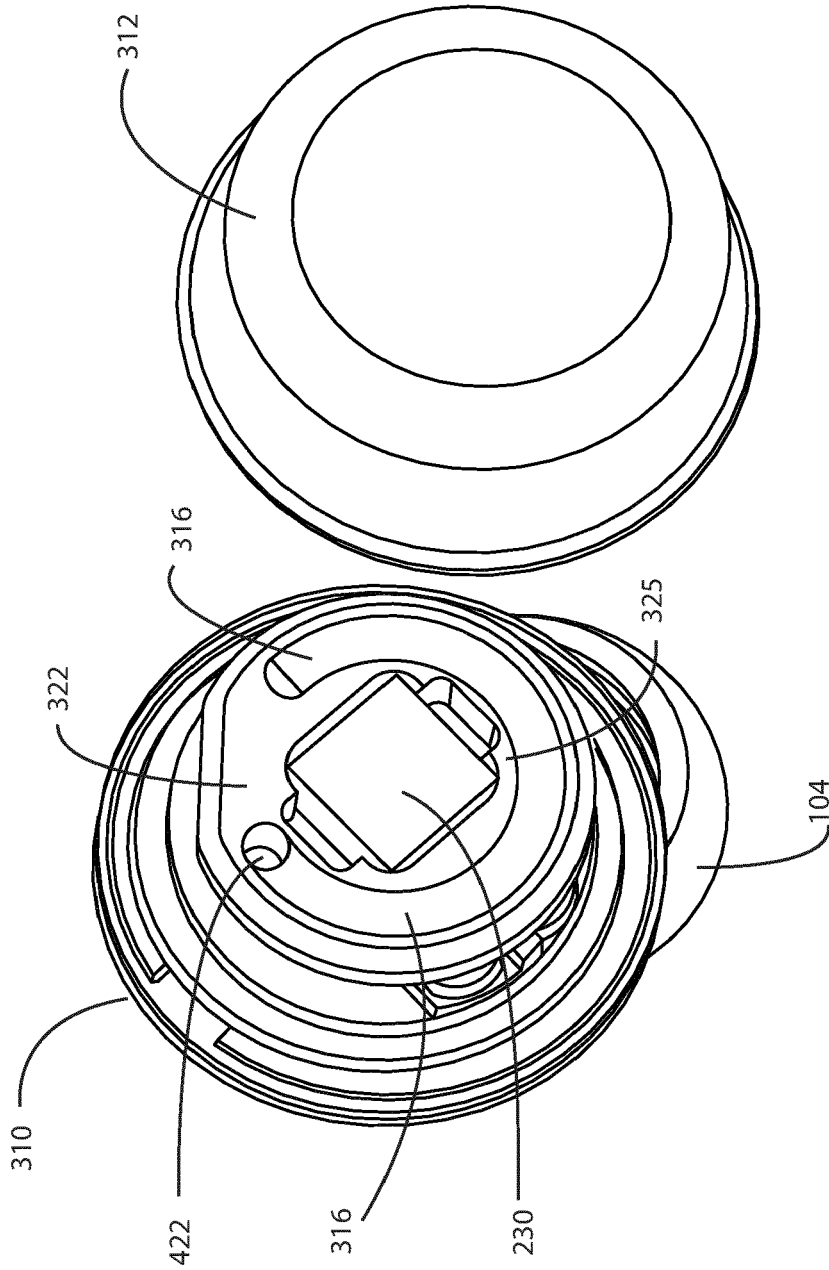


FIG. 10

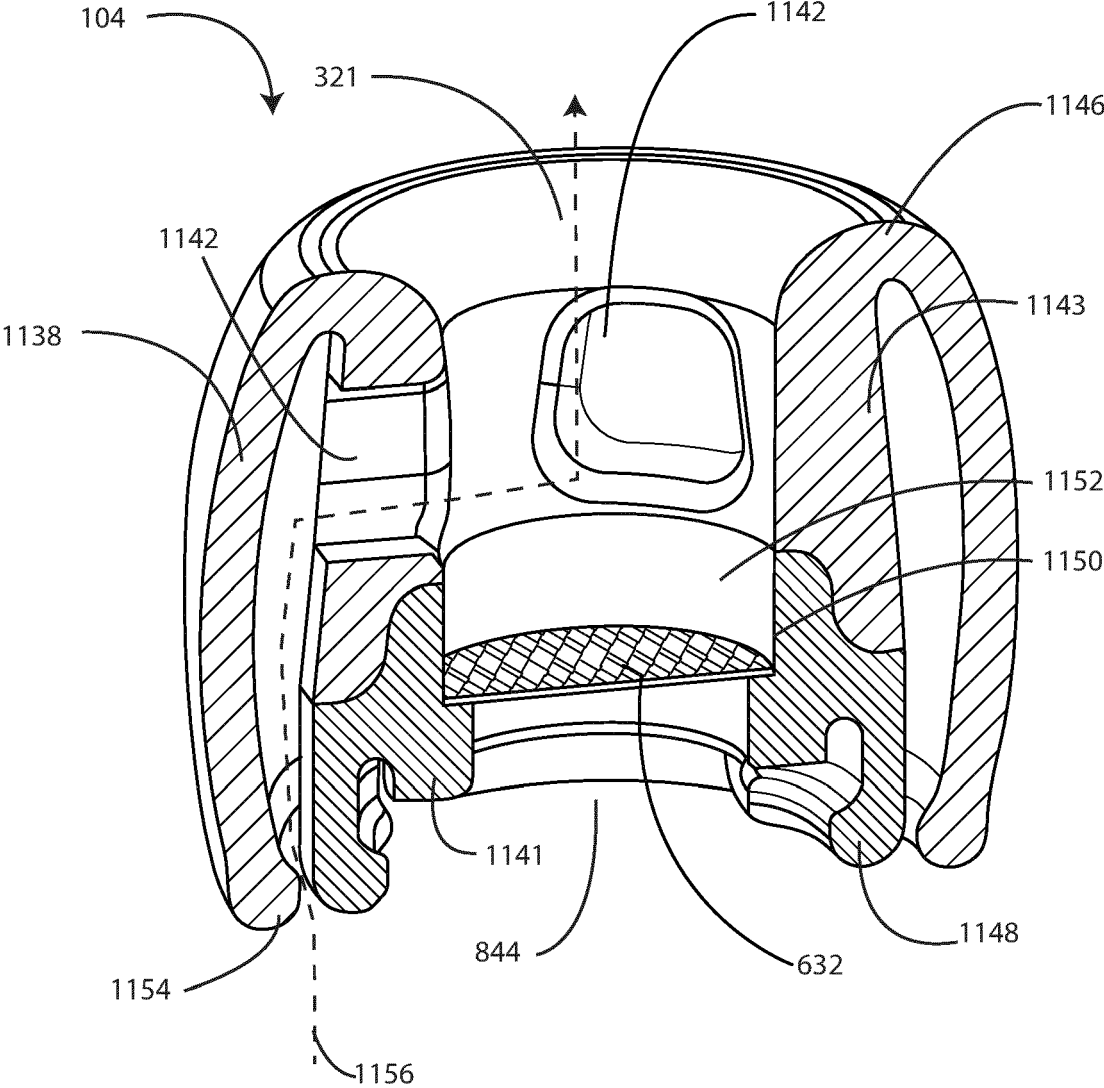


FIG. 11



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