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(54) **BATTERY ASSEMBLIES WITH MOLDED POLYMER BATTERY MANAGEMENT UNIT ASSEMBLIES**

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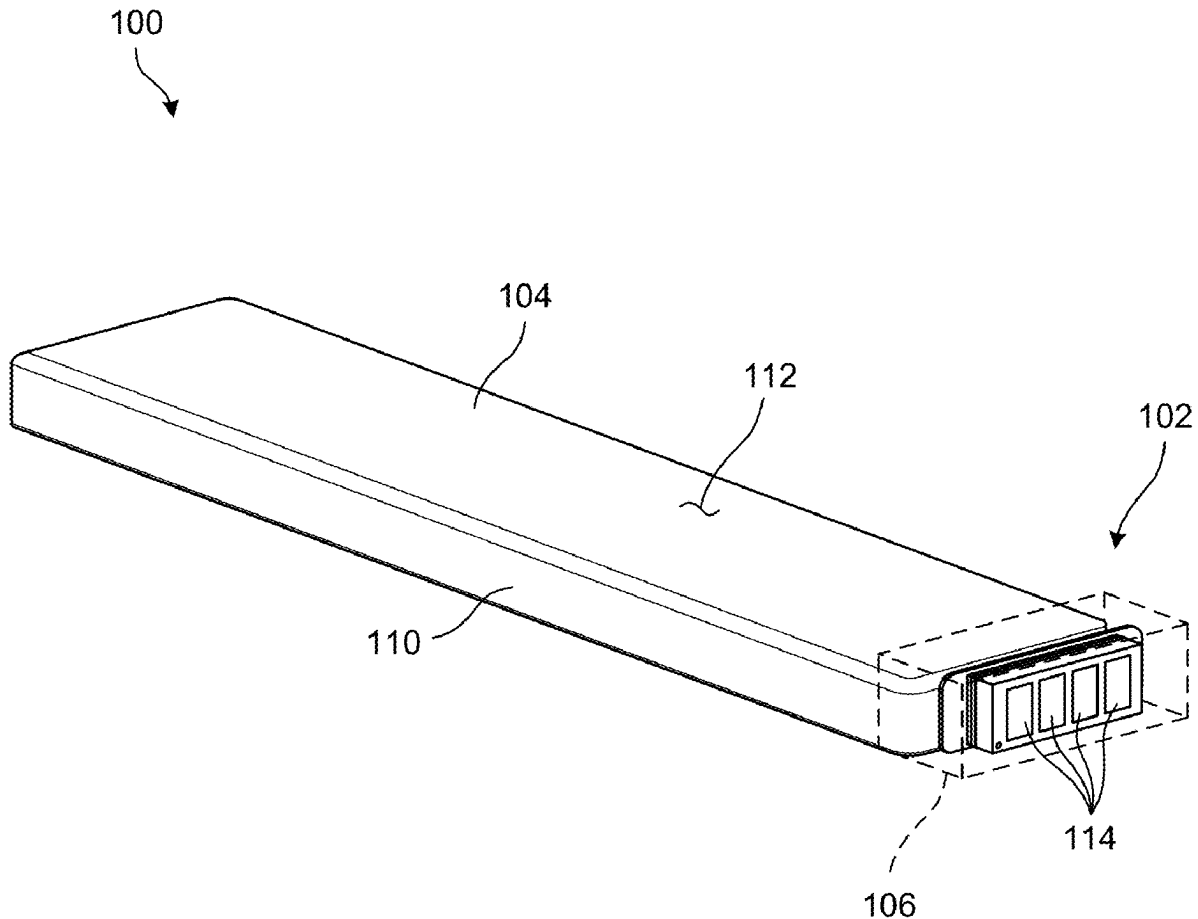
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(57) **ABSTRACT**

Battery assemblies may include a battery cell unit enclosed in a steel can and a battery management unit overmolded to the steel can with an overmold material. Various other devices and systems are also disclosed.



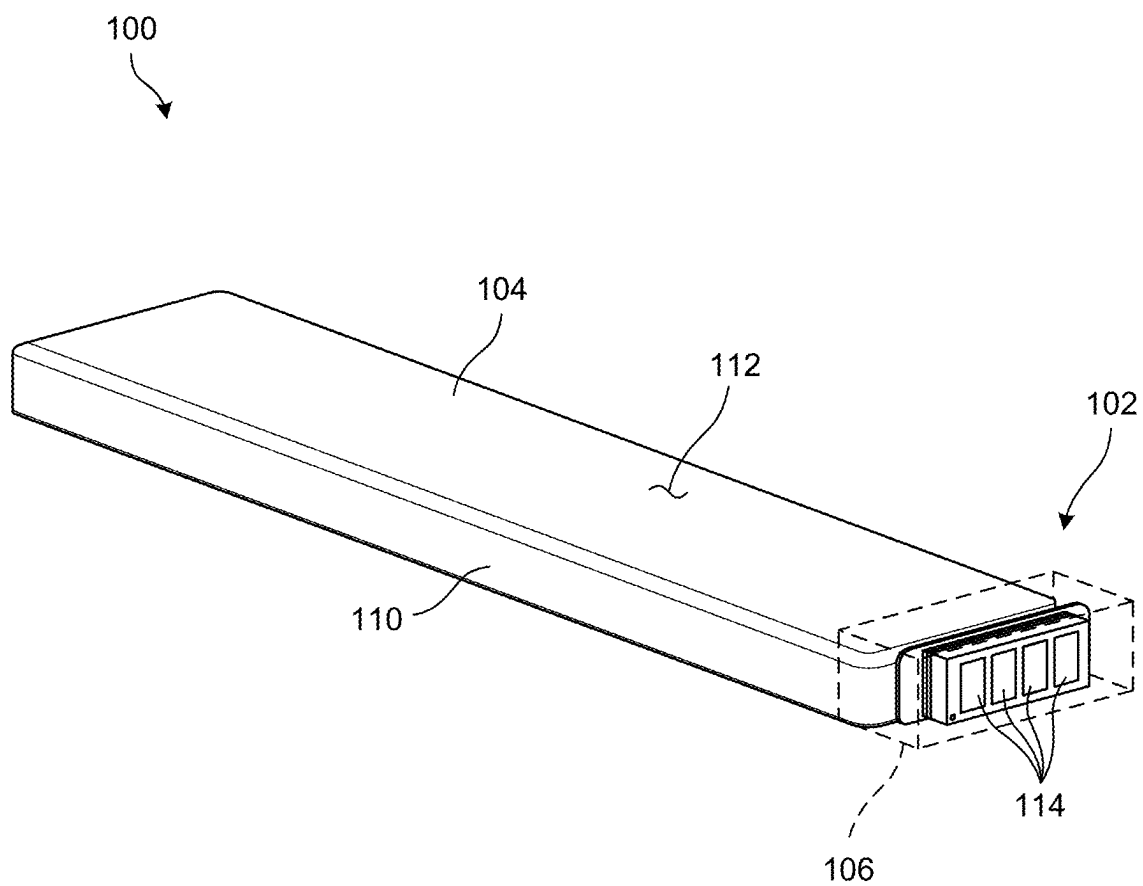


FIG. 1

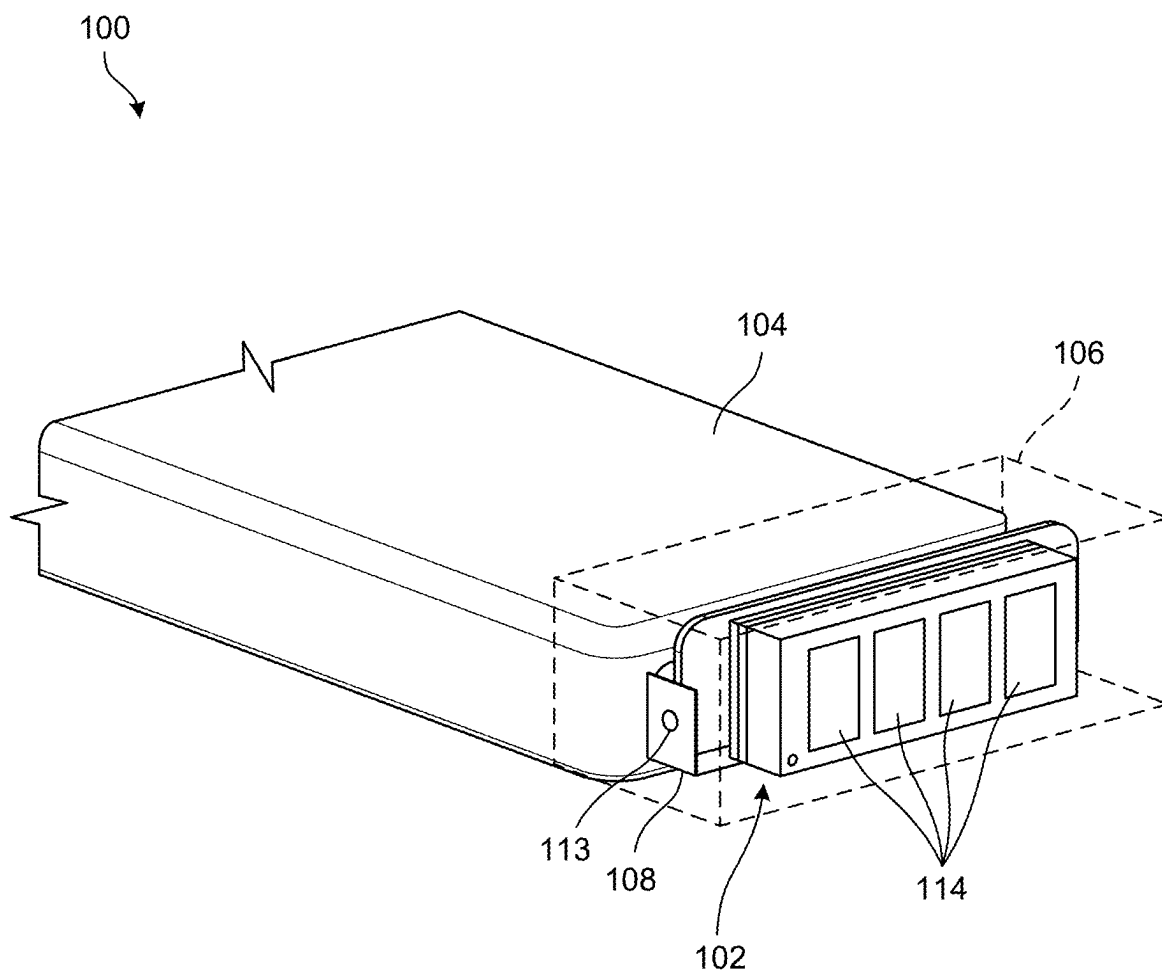


FIG. 2

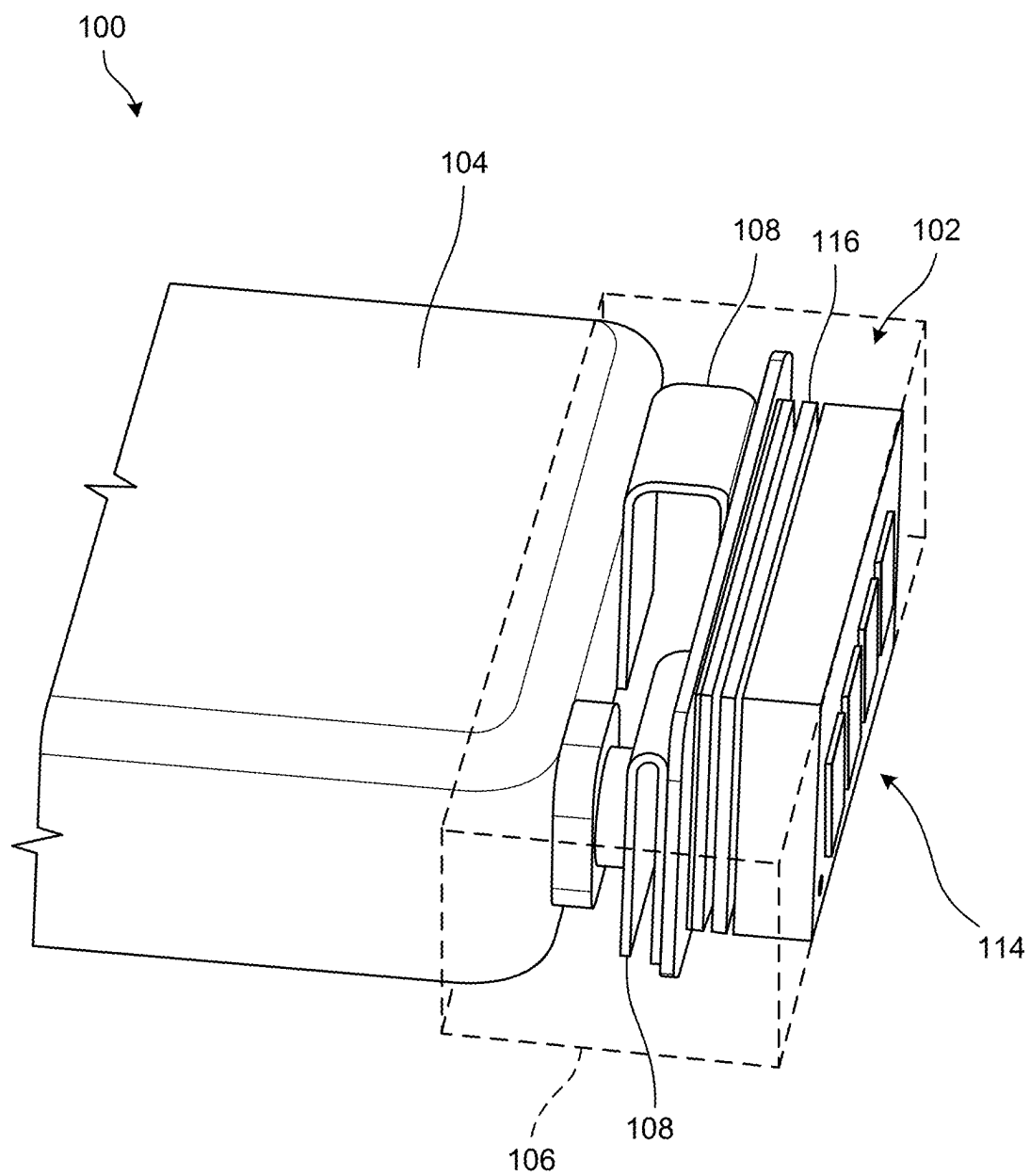


FIG. 3

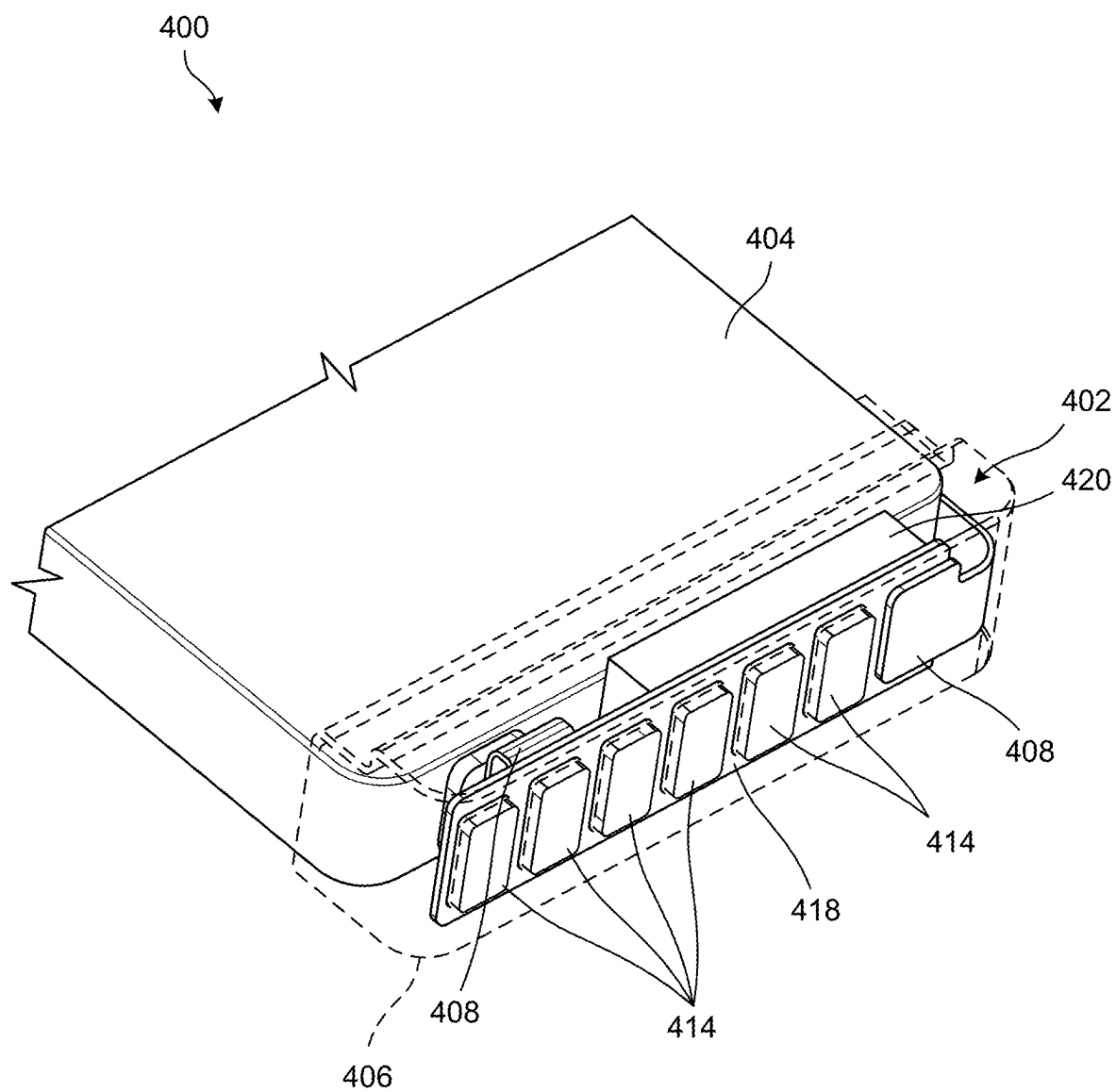


FIG. 4

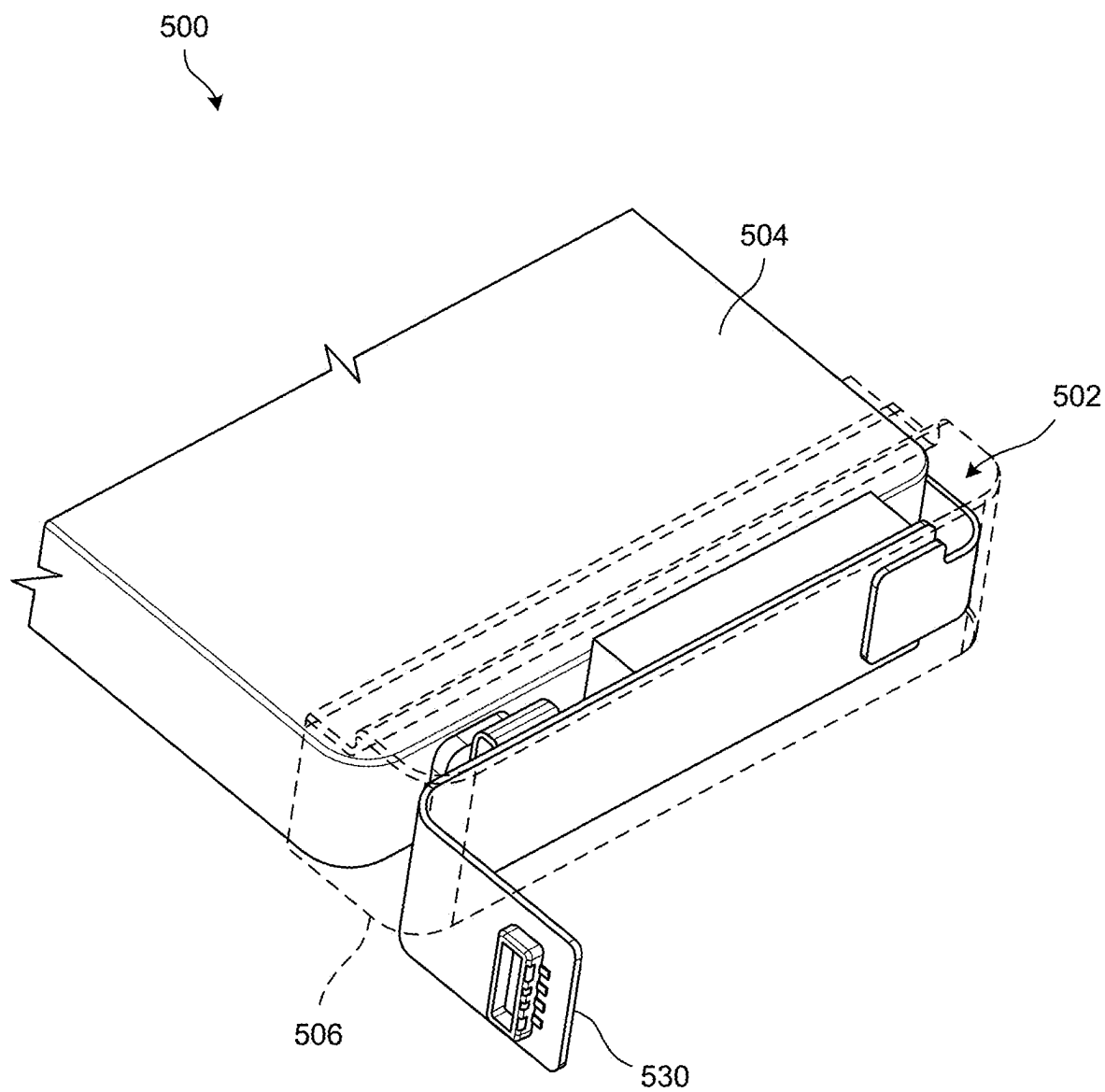


FIG. 5

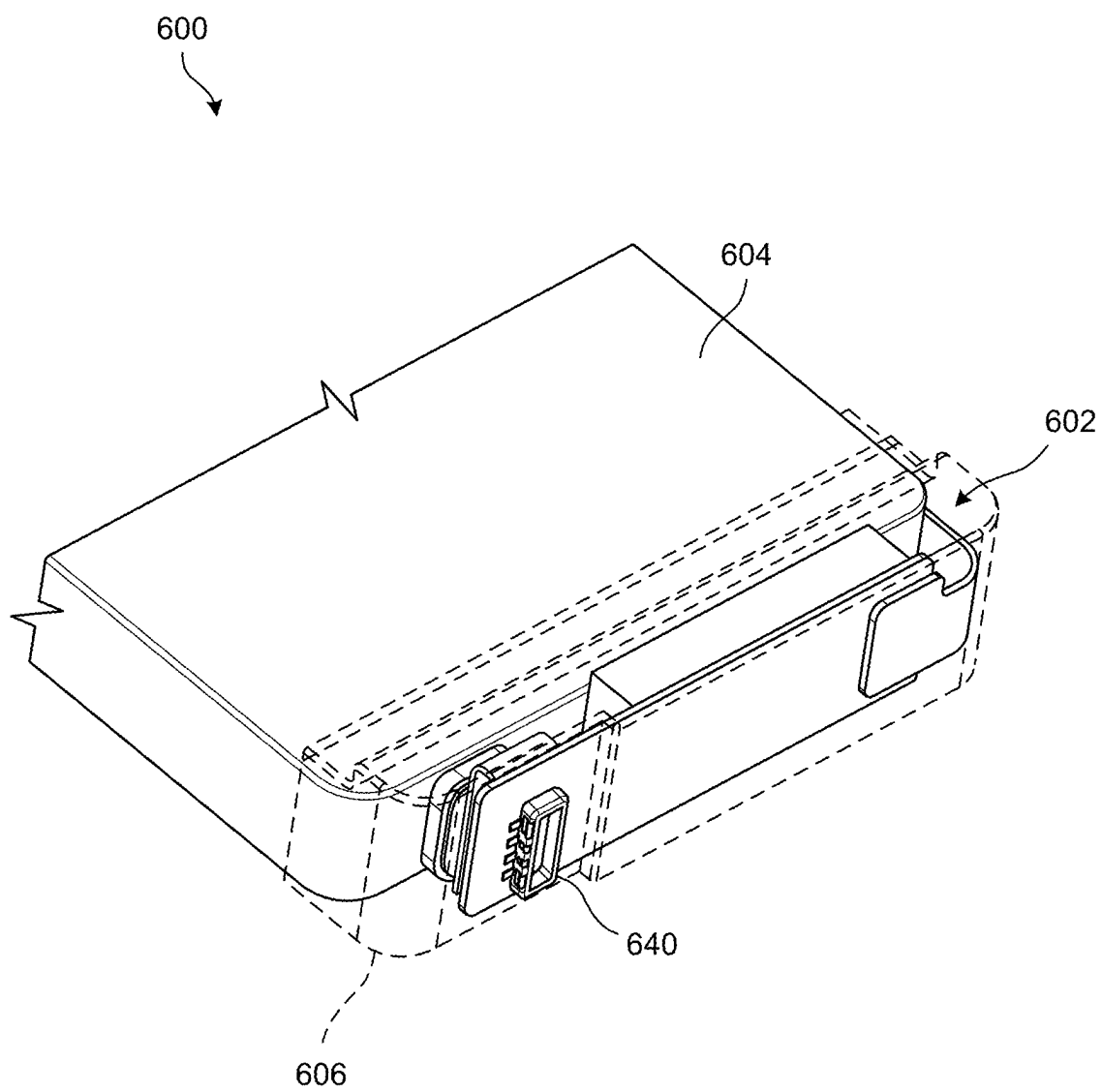


FIG. 6

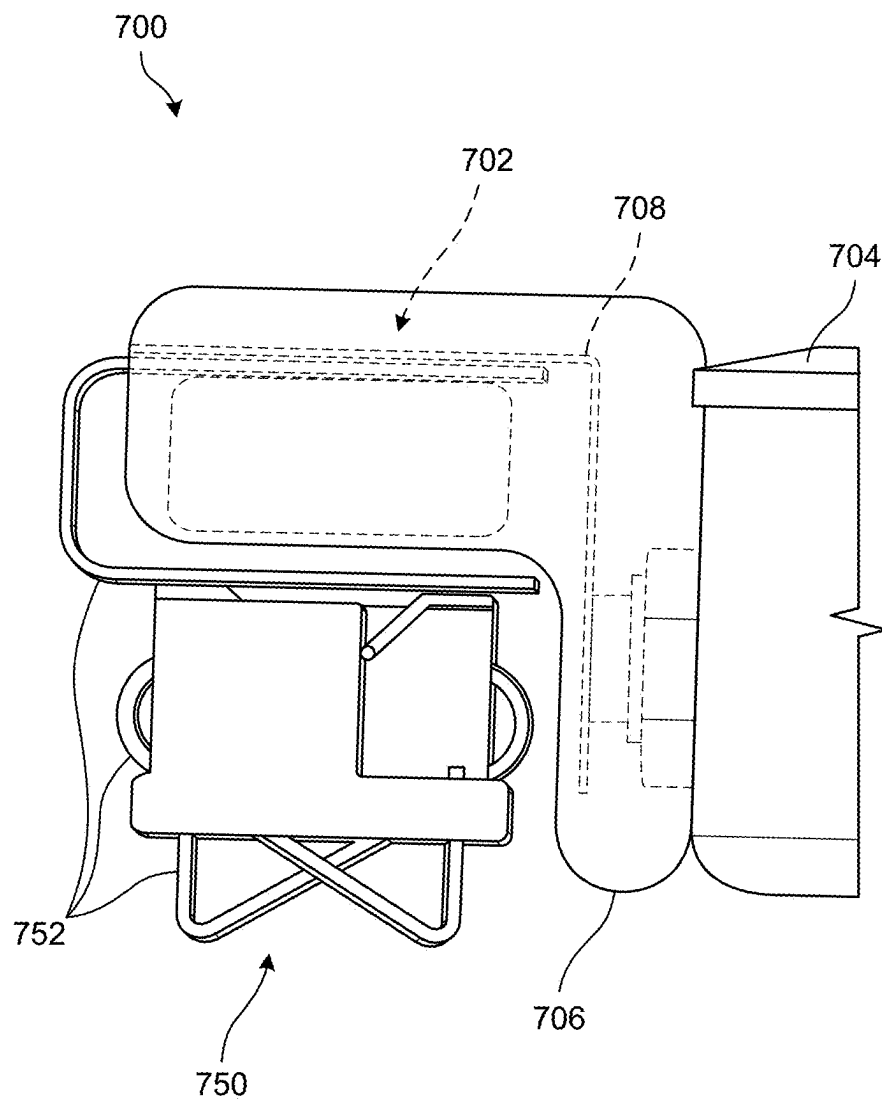
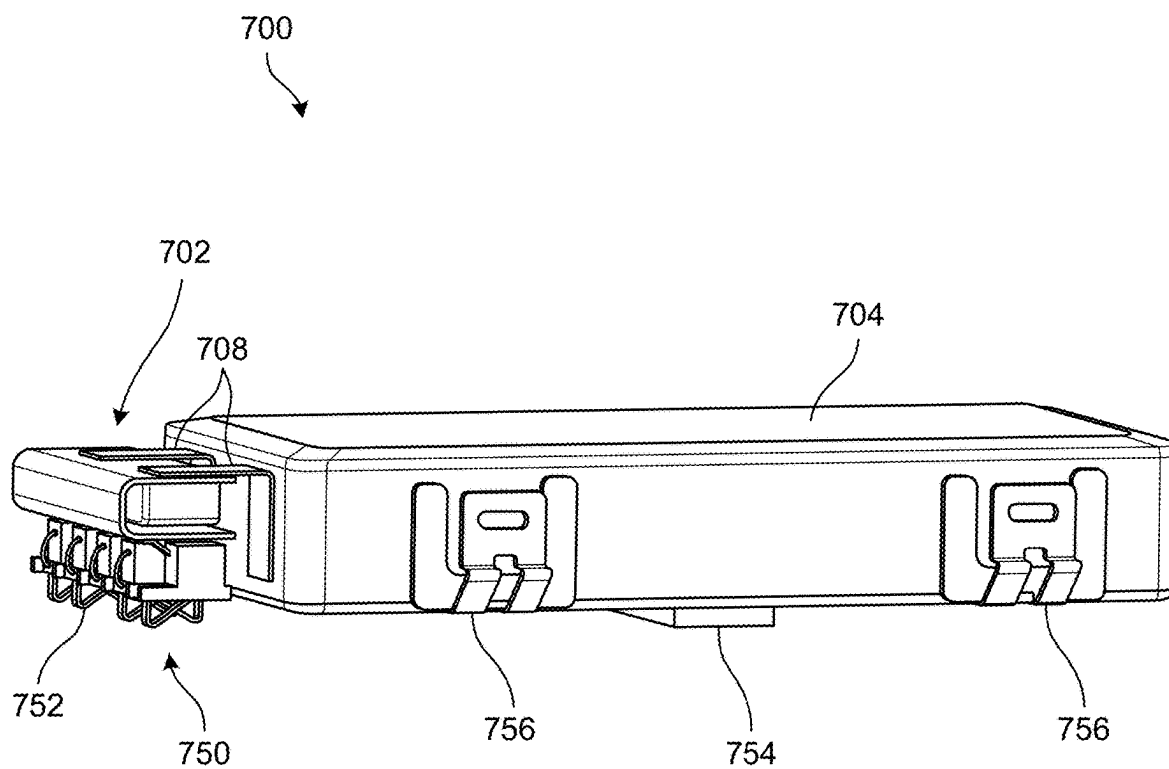


FIG. 7

**FIG. 8**

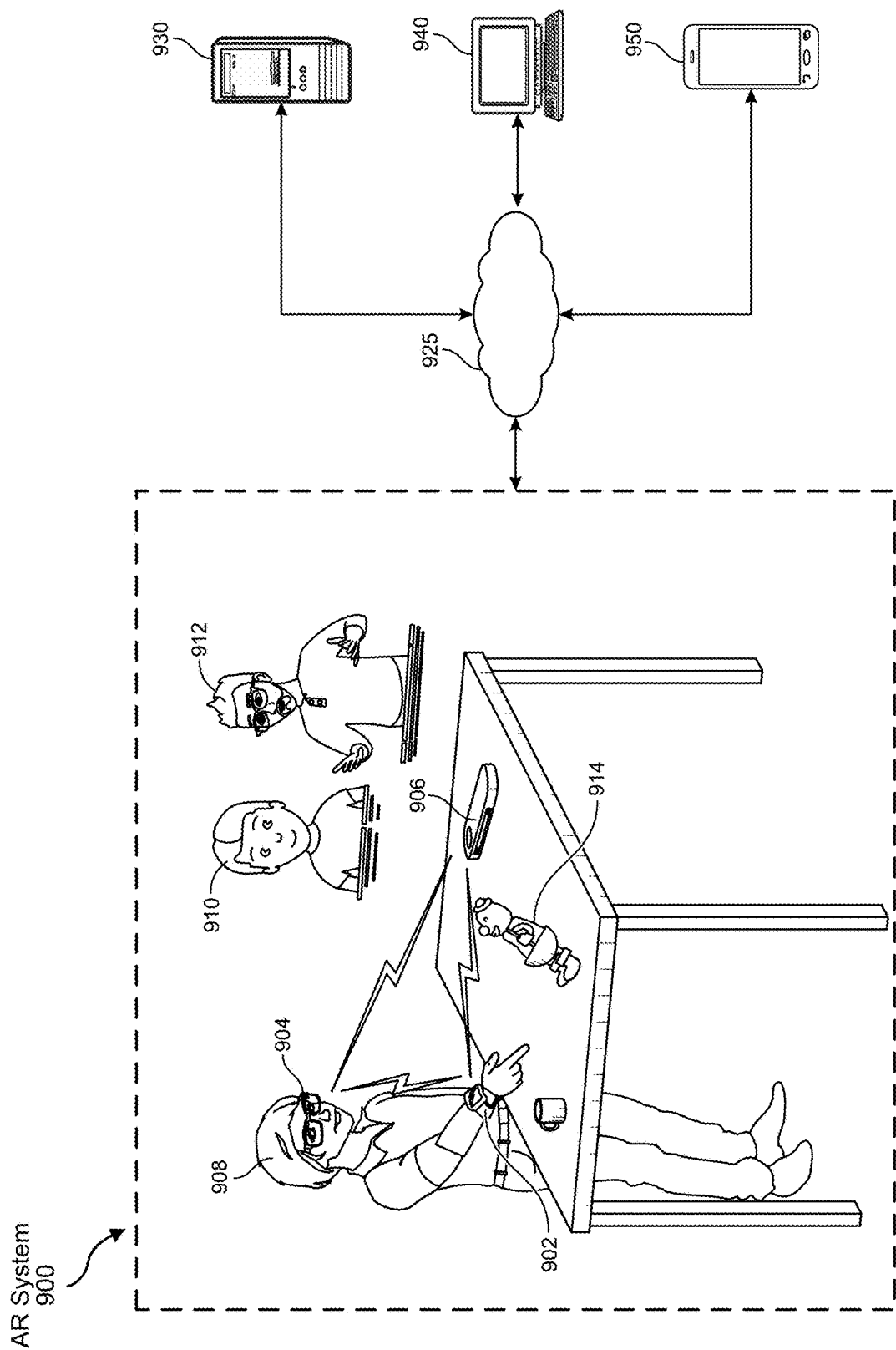


FIG. 9

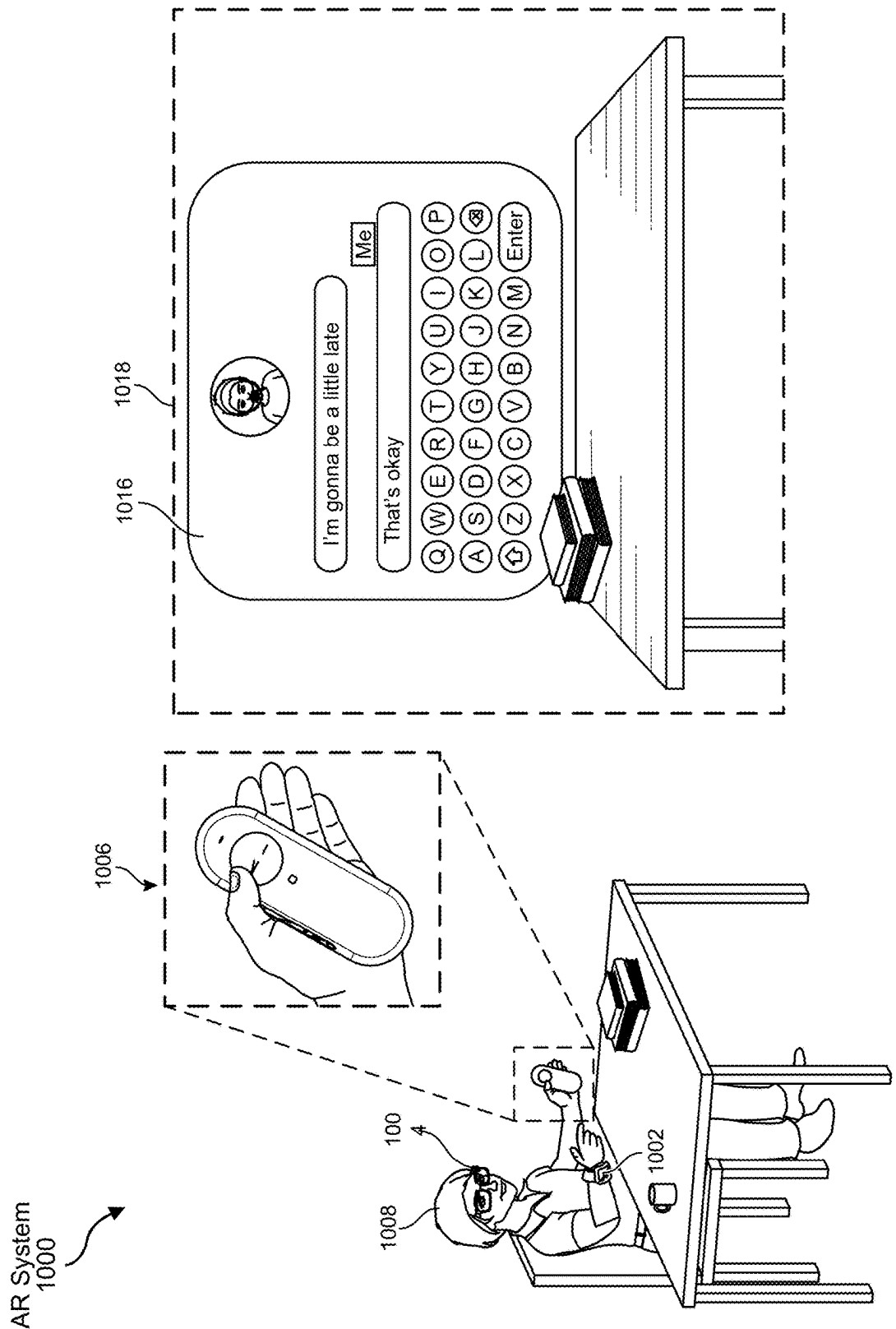


FIG. 10

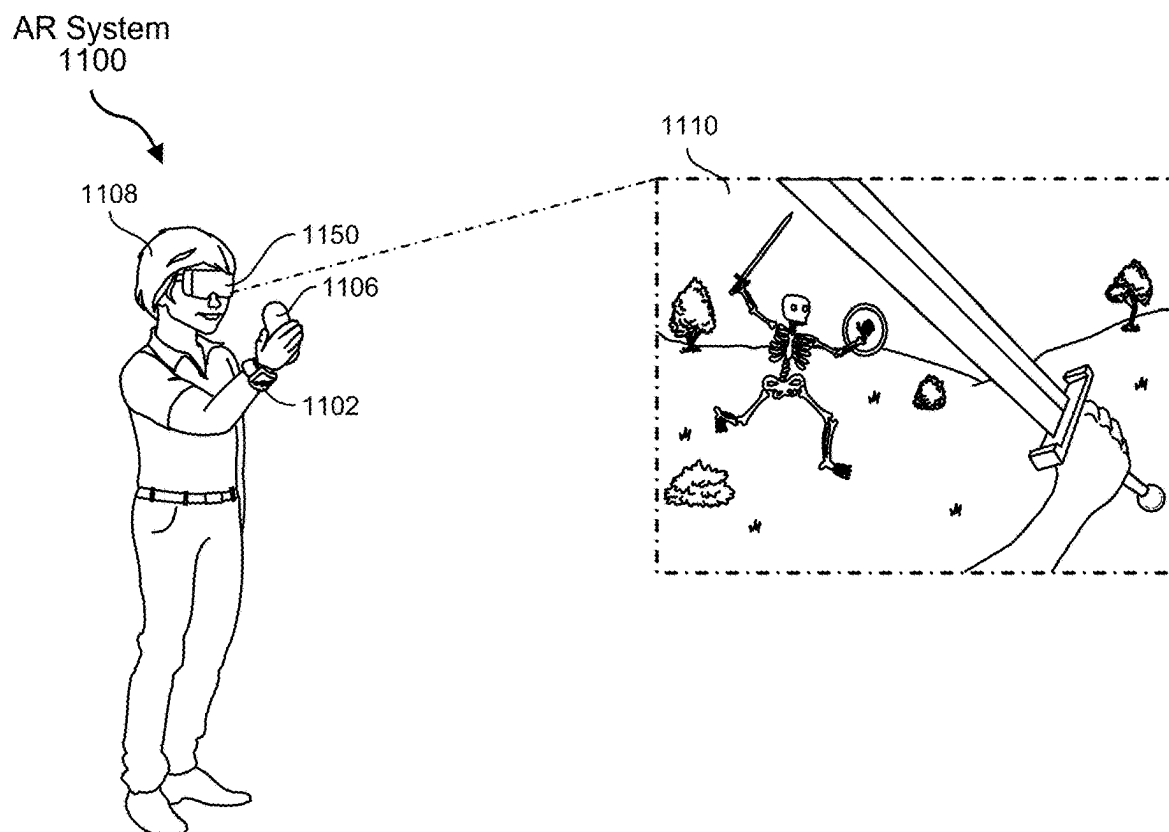


FIG. 11A

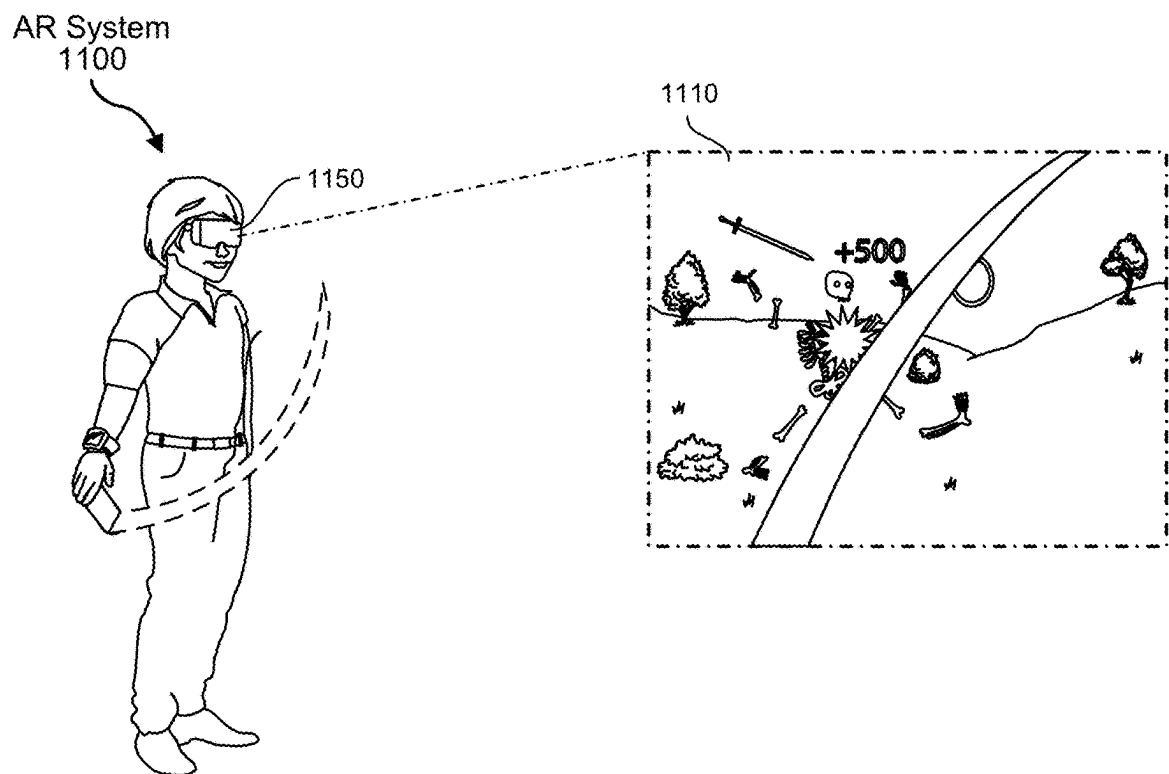


FIG. 11B

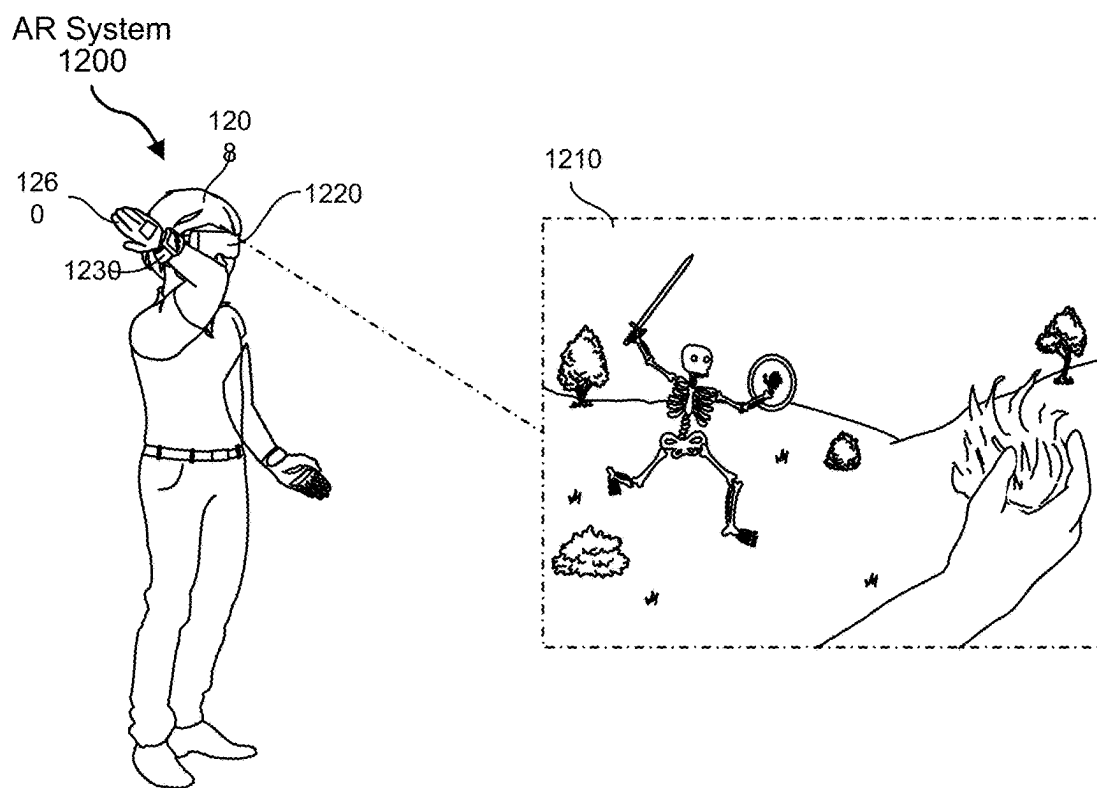


FIG. 12A

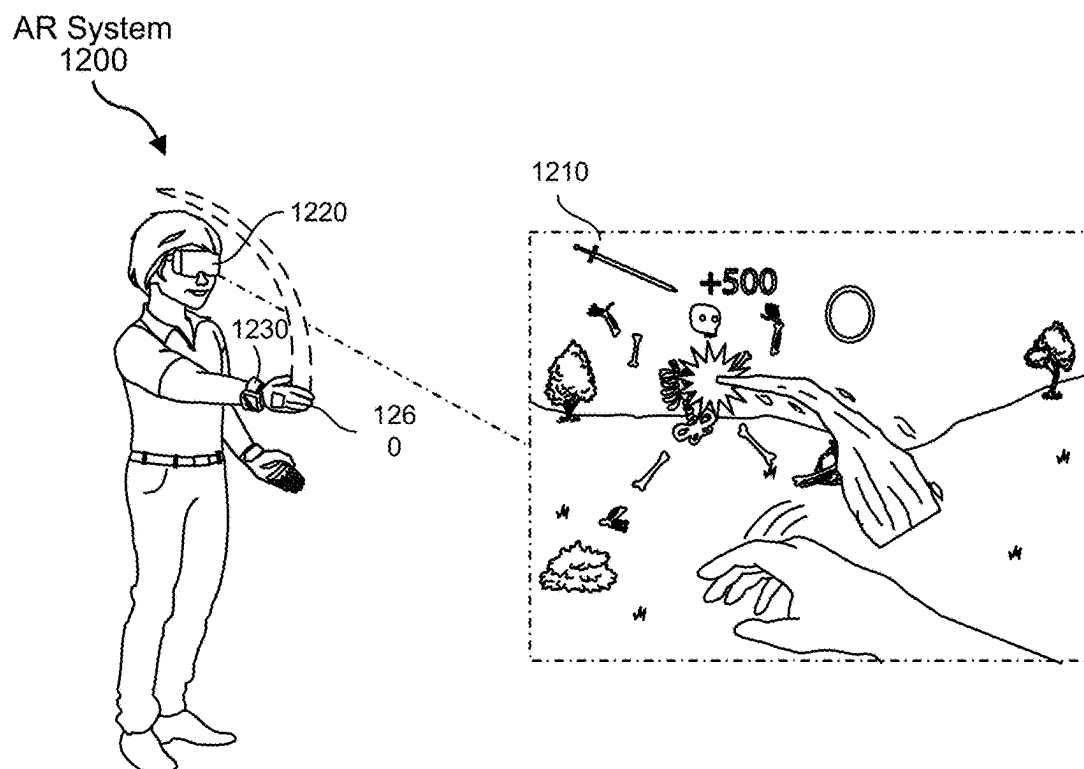
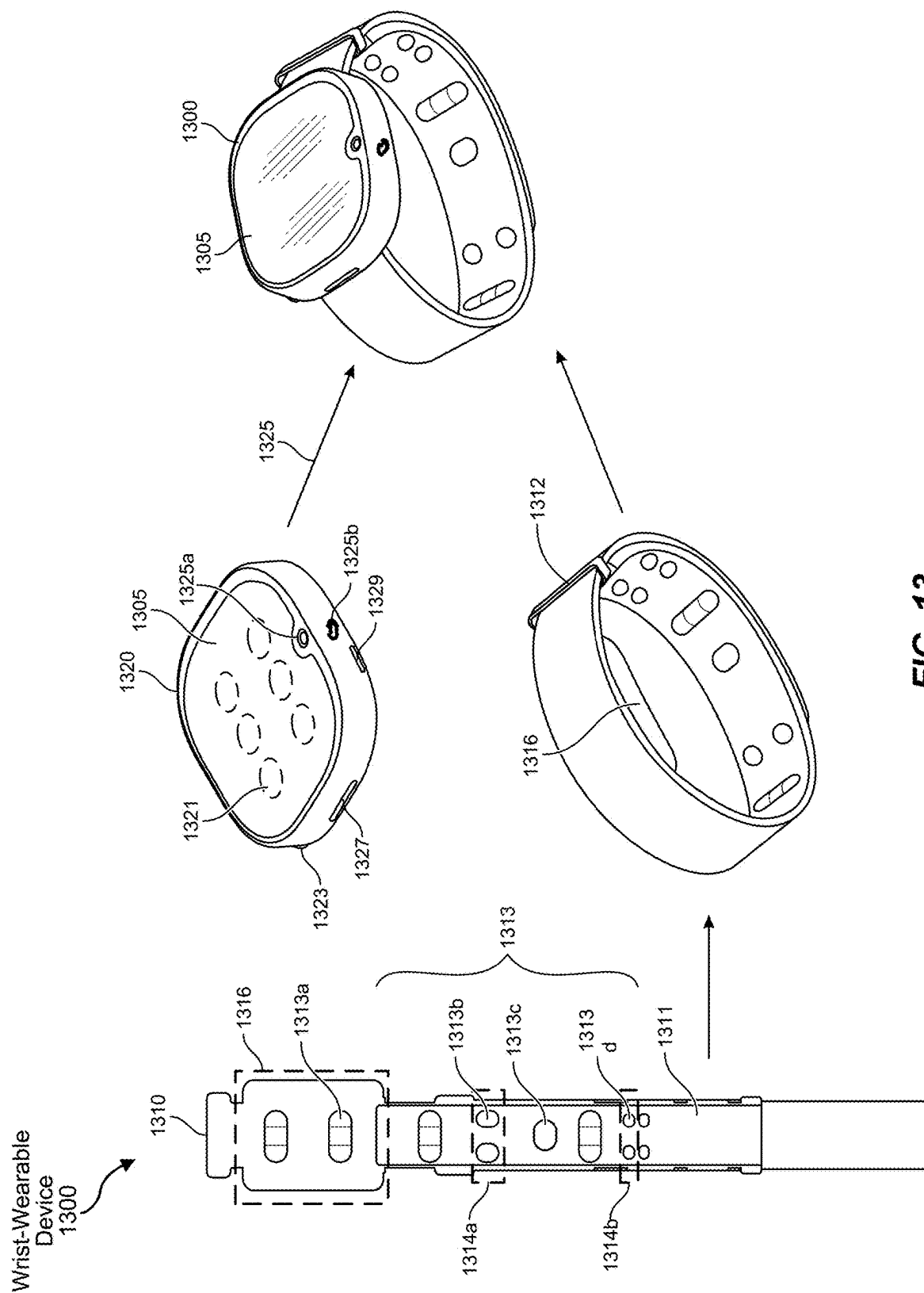


FIG. 12B



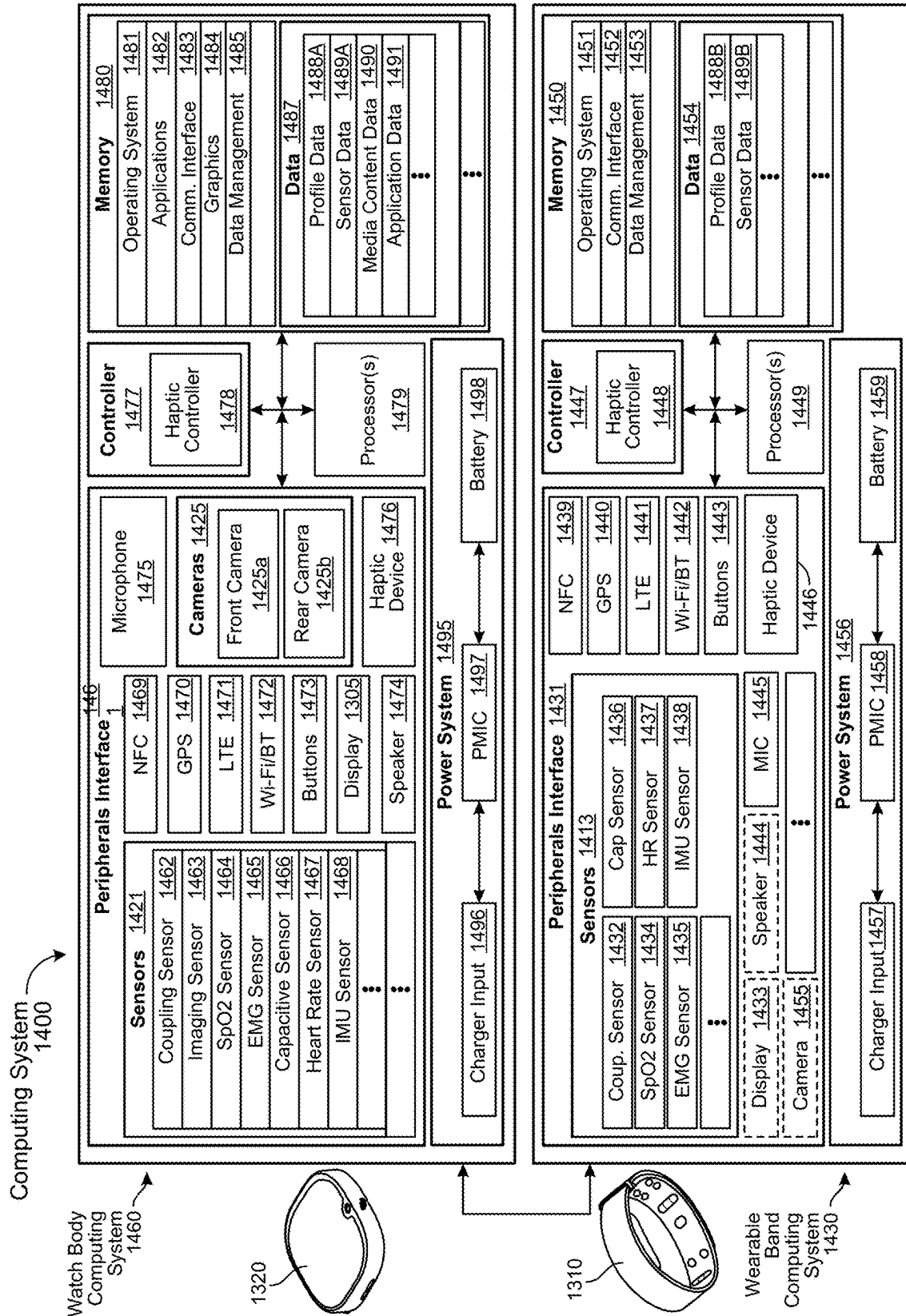


FIG. 14

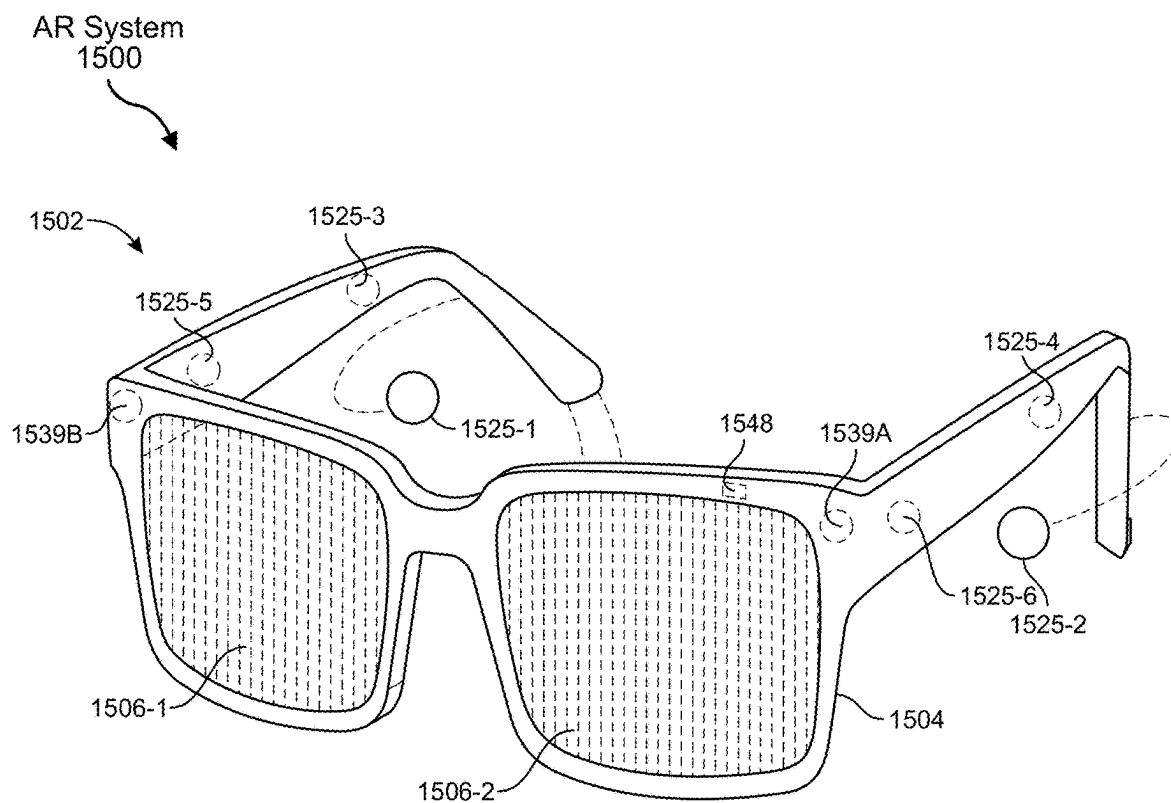


FIG. 15

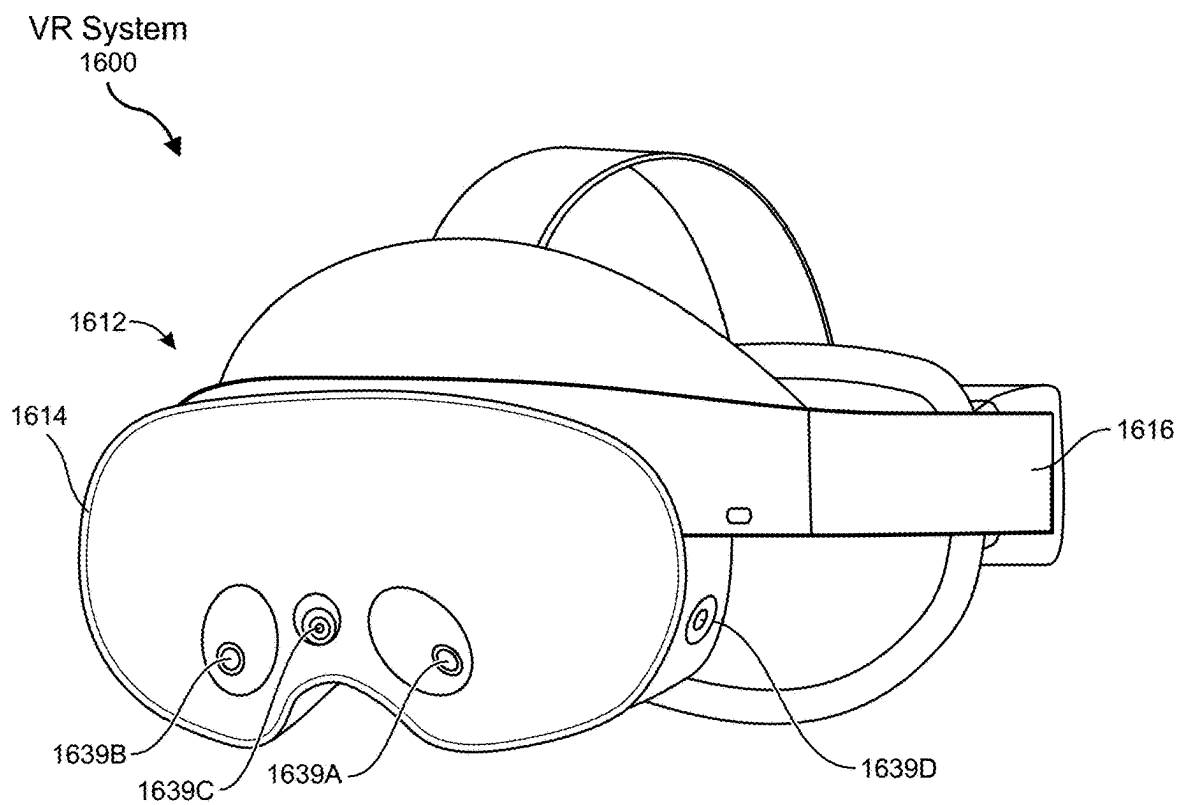


FIG. 16A

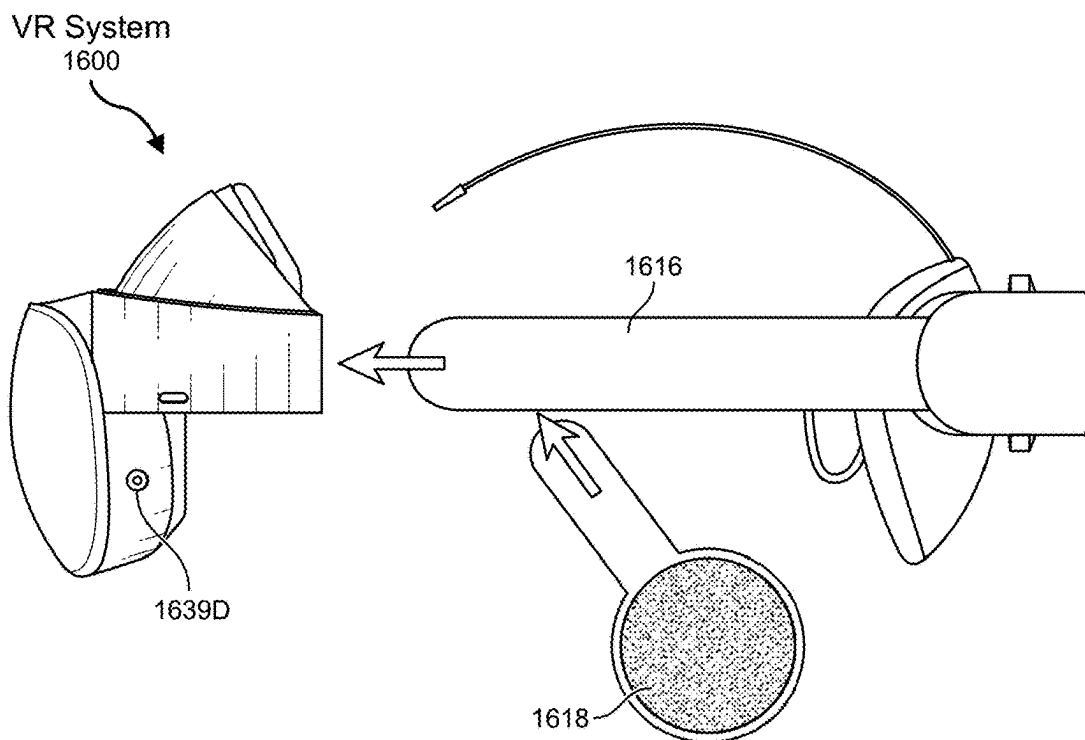


FIG. 16B

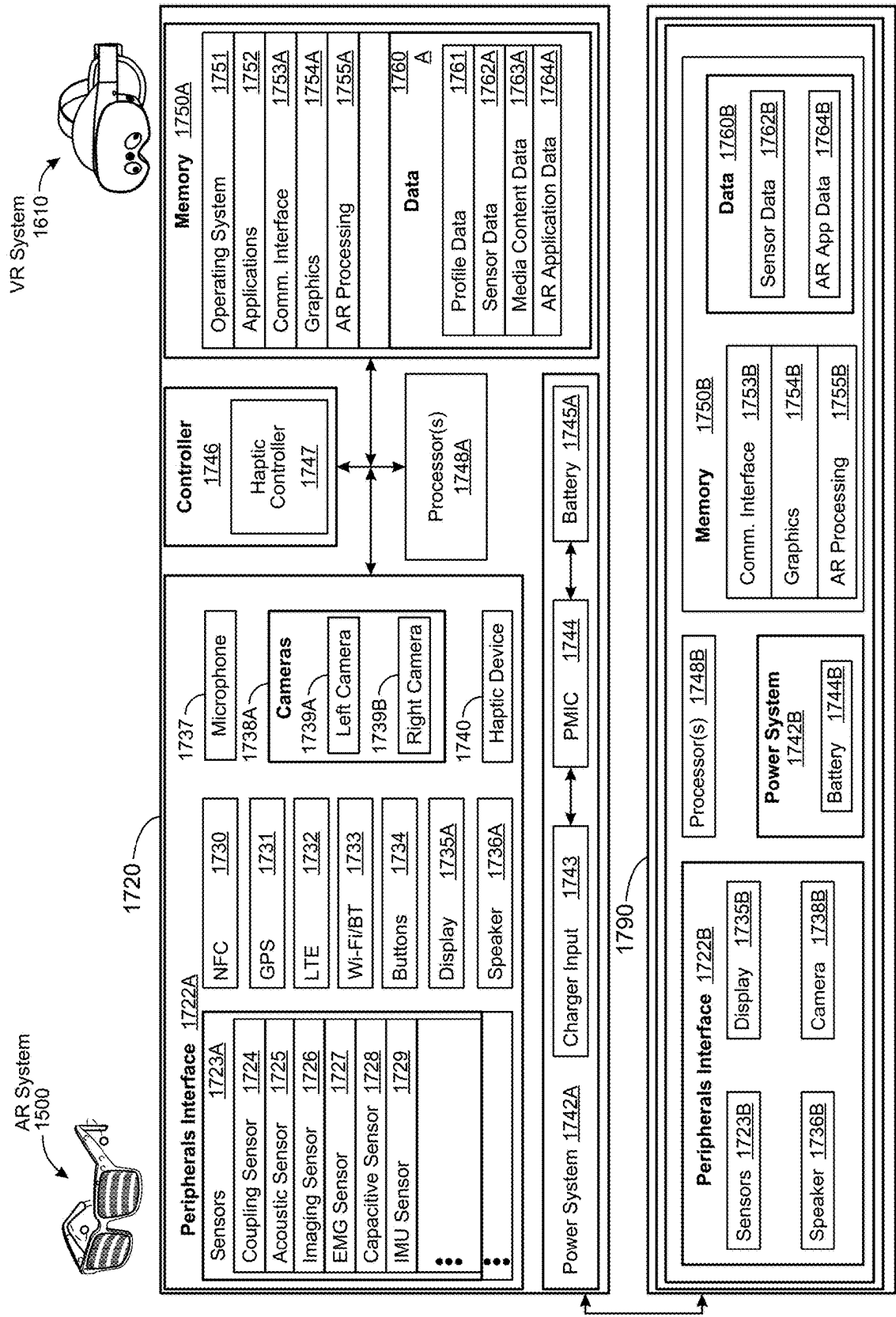


FIG. 17

**BATTERY ASSEMBLIES WITH MOLDED
POLYMER BATTERY MANAGEMENT UNIT
ASSEMBLIES**

**CROSS REFERENCE TO RELATED
APPLICATION**

[0001] This application claims the benefit of U.S. Provisional Application No. 63/553,664, filed 15 Feb. 2024, the disclosure of which is incorporated, in its entirety, by this reference.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] The accompanying drawings illustrate a number of example embodiments and are a part of the specification. Together with the following description, these drawings demonstrate and explain various principles of the present disclosure.

[0003] FIG. 1 is a perspective view of a battery assembly, according to at least one embodiment of the present disclosure.

[0004] FIG. 2 is a detailed perspective view of a battery management unit (BMU) of the battery assembly of FIG. 1.

[0005] FIG. 3 is another detailed perspective view of the BMU of the battery assembly of FIG. 1.

[0006] FIG. 4 is a detailed perspective view of a battery management unit of a battery assembly, according to at least one embodiment of the present disclosure.

[0007] FIG. 5 is a detailed perspective view of a battery management unit of a battery assembly, according to at least one additional embodiment of the present disclosure.

[0008] FIG. 6 is a detailed perspective view of a battery management unit of a battery assembly, according to at least one other embodiment of the present disclosure.

[0009] FIG. 7 is a detailed side view of a battery management unit of a battery assembly, according to at least one embodiment of the present disclosure.

[0010] FIG. 8 is a perspective view of a battery assembly, according to at least one additional embodiment of the present disclosure.

[0011] FIG. 9 is an illustration of an example artificial-reality system according to some embodiments of this disclosure.

[0012] FIG. 10 is an illustration of an example artificial-reality system with a handheld device according to some embodiments of this disclosure.

[0013] FIG. 11A is an illustration of example user interactions within an artificial-reality system according to some embodiments of this disclosure.

[0014] FIG. 11B is an illustration of example user interactions within an artificial-reality system according to some embodiments of this disclosure.

[0015] FIG. 12A is an illustration of example user interactions within an artificial-reality system according to some embodiments of this disclosure.

[0016] FIG. 12B is an illustration of example user interactions within an artificial-reality system according to some embodiments of this disclosure.

[0017] FIG. 13 is an illustration of an example wrist-wearable device of an artificial-reality system according to some embodiments of this disclosure.

[0018] FIG. 14 is an illustration of an example wearable artificial-reality system according to some embodiments of this disclosure.

[0019] FIG. 15 is an illustration of an example augmented-reality system according to some embodiments of this disclosure.

[0020] FIG. 16A is an illustration of an example virtual-reality system according to some embodiments of this disclosure.

[0021] FIG. 16B is an illustration of another perspective of the virtual-reality systems shown in FIG. 16A.

[0022] FIG. 17 is a block diagram showing system components of example artificial- and virtual-reality systems.

[0023] Throughout the drawings, identical reference characters and descriptions indicate similar, but not necessarily identical, elements. While the example embodiments described herein are susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and will be described in detail herein. However, the example embodiments described herein are not intended to be limited to the particular forms disclosed. Rather, the present disclosure covers all modifications, equivalents, and alternatives falling within the scope of the appended claims.

**DETAILED DESCRIPTION OF EXAMPLE
EMBODIMENTS**

[0024] Many electronic devices, such as smartwatches, fitness bands, augmented-reality glasses, virtual-reality devices, mobile phones, etc., include batteries for providing electrical power to the device. The batteries of some electrical devices may be difficult to replace, such as due to difficult access, mechanical and/or electrical connections that are challenging to engage, etc.

[0025] The present disclosure is generally directed to battery assemblies with overmolded battery management units (e.g., at least partially covered in a molded polymer material), which may facilitate user replacement of the battery assemblies. In some embodiments, the battery assemblies of the present disclosure may include a battery cell unit enclosed in a steel can. A battery management unit (BMU) may be positioned adjacent to (e.g., at an end of, along a side of, etc.) the steel can and overmolded to the steel can. Electrical contacts of the BMU may be exposed through the overmold material to enable connection to one or more electrical components to be powered by the battery assembly.

[0026] Features from any of the embodiments described herein may be used in combination with one another in accordance with the general principles described herein. These and other embodiments, features, and advantages will be more fully understood upon reading the following detailed description in conjunction with the accompanying drawings and claims.

[0027] The following will provide, with reference to FIGS. 1-8, detailed descriptions of battery assemblies and components thereof, according to various embodiments of the present disclosure. With reference to FIGS. 9-17, the following will provide detailed descriptions of electronic devices and systems that may be used in conjunction with embodiments of the present disclosure.

[0028] FIG. 1 is a perspective view of a battery assembly 100, according to at least one embodiment of the present disclosure. FIG. 2 is a detailed perspective view of a battery management unit (BMU) 102 of battery assembly 100. FIG. 3 is another detailed perspective view of BMU 102 of battery assembly 100.

[0029] Battery assembly 100 may include BMU 102 operably coupled to a steel can 104, which may contain one or more battery cell units. As illustrated in FIGS. 1-3, at least a portion of BMU 102 may be overmolded to steel can 104 of battery assembly 100 with an overmold material 106, illustrated in dashed lines in FIGS. 1-3 and as transparent to better show underlying components of BMU 102.

[0030] Steel can 104 is illustrated in FIG. 1 as generally having an elongated rectangular prism shape with rounded edges. However, the present disclosure is not so limited, and steel can 104 may have any other suitable shape, such as to be installed within a receptacle of an electronic device intended to receive power from battery assembly 100. For example, steel can 104 may generally have a shape of a cylinder, a cube, a wider (relative to FIG. 1) rectangular prism, a flatter (relative to FIG. 1) rectangular prism, a longer (relative to FIG. 1) rectangular prism, an L-shape, a curved shape, etc.

[0031] BMU 102 may be mechanically secured to steel can 104. In some embodiments, BMU 102 may be secured to steel can 104 with overmold material 106 bonding to steel can 104, with one or more rigid connectors 108 (FIG. 3), with one or more fasteners (e.g., screws, bolts, pins, etc.), with a weld, with an adhesive material, or a combination thereof. In one example, if overmold material 106 is selected to bond well with a steel material of steel can 104, overmold material 106 may be directly bonded to steel can 104. In some cases, a portion of steel can 104 underlying overmold material 106 may be surface-treated, such as by being etched, roughened, sand-blasted, wire brushed, anodized, pre-coated with a resin, plasma treated, corona treated, cleaned, etc., to improve bonding between overmold material 106 and steel can 104.

[0032] In additional examples, an adhesive material may be used between overmold material 106 and steel can 104. The adhesive material may be selected to improve a bond between overmold material 106 and steel can 104. For example, an epoxy adhesive, an acrylic adhesive, a cyanoacrylate adhesive, etc., may be used to bond overmold material 106 to steel can 104. In some embodiments, a sealant may be used between and/or along an interface between overmold material 106 and steel can 104 to reduce a risk of water or other fluid ingress. In other embodiments, overmold material 106 itself may form a sufficient watertight barrier.

[0033] Overmold material 106 may be formed from a variety of materials. In some examples, overmold material 106 may include a polymer material, such as one or more of: thermoplastic polyurethane, polycarbonate, acrylonitrile butadiene styrene, a combination thereof, etc.

[0034] BMU 102 may be positioned on steel can 104 in a variety of locations. By way of example, as illustrated in FIGS. 1-3, BMU 102 may be positioned at a longitudinal end of steel can 104. In additional examples, BMU 102 may be positioned in other locations relative to steel can 104, such as along a side edge 110 (FIG. 1) of steel can 104 or along a face 112 (FIG. 1) of steel can 104.

[0035] As illustrated in FIG. 3, one or more rigid connectors 108 (e.g., brackets) may be used to initially secure BMU 102 to steel can 104, after which overmold material 106 may be formed around BMU 102 and rigid connectors 108. Rigid connectors 108 may be or include a rigid polymer, a rigid metallic material, and/or a composite material. In some examples, a fastener (e.g., screw, bolt, clip, pin, etc.), a weld,

and/or an adhesive may be used to couple rigid connectors 108 to steel can 104 and/or to BMU 102 (e.g., to a printed circuit board (PCB) of BMU 102). In some embodiments, one or more of rigid connectors 108 may also act as an electrical connection between BMU 102 and one or more battery cell units within steel can 104. In some examples, rigid connectors 108 may include one or more through-holes 113, notches, and/or other geometric features. For example, overmold material 106 may be formed to fill such features to mechanically strengthen a connection between rigid connectors 108 and overmold material 106. In some examples, as shown in FIG. 3, rigid connectors 108 may be U-shaped. Additionally or alternatively, various other configurations and shapes of rigid connectors 108 could be used.

[0036] Electrical contacts 114 of BMU 102 may be exposed (e.g., not covered by overmold material 106) to enable electrical coupling of battery assembly 100 to an electrical device intended to draw power from battery cell units within steel can 104 and/or to enable electrical coupling of battery assembly 100 to a charger to recharge such battery cell units. Accordingly, overmold material 106 may not be formed over and/or may be removed from over electrical contacts 114. For example, a mold used in forming overmold material 106 may be configured to leave electrical contacts 114 exposed. In additional examples, an extension (e.g., cord, protrusion, connector, etc.) may support electrical contacts 114 away from remaining components of BMU 102 to facilitate overmolding BMU 102 with overmold material 106. Examples of various configurations for electrical contacts and associated connectors are described below with reference to FIGS. 4-7.

[0037] Returning again to FIGS. 1-3, the BMU 102 may include a system in a package (SiP) 116, which may include a processor for managing charge and discharge of the battery cell unit. For example, the SiP of BMU 102 may include one or more integrated circuits, passive components, and/or sensors, etc., combined into a single package for managing operation of the battery cell unit within steel can 104.

[0038] FIGS. 4-6 illustrate three respective examples of battery assemblies 400, 500, 600, including respective BMUs 402, 502, 602 that are overmolded.

[0039] In a first example shown in FIG. 4, battery assembly 400 may include BMU 402 coupled to at least one battery cell unit within a steel can 404. In this example, contact pads 414 may be operatively coupled to an underlying support structure 418, such as a PCB. Support structure 418 and, consequently, components thereon may be coupled to steel can 404 of battery assembly 400 via rigid connectors 408. In some embodiments, support structure 418 may be a dual-sided support structure 418, with contact pads 414 on one face and BMU circuitry 420 on an opposing face of support structure 418. For example, BMU circuitry 420 may include one or more processors, diodes, amplifiers, cutoff transistors, temperature monitors, voltage sensors, current sensors, fuses, etc.

[0040] Contact pads 414 of BMU 402 may be exposed through overmold material 406 otherwise surrounding BMU 402. For example, contact pads 414 may protrude from support structure 418 of BMU 402. Overmold material 406 may be formed to cover portions of BMU 402 not including contact pads 414, such as up to an around a base portion of individual contact pads 414 (as illustrated in FIG. 4). In additional embodiments, overmold material 406 may be formed to include a single window that exposes each of

contact pads 414. In additional embodiments, individual windows in overmold material 406 may expose respective contact pads 414 and/or a portion of support structure 414 adjacent to contact pads 414.

[0041] In a second example shown in FIG. 5, battery assembly 500 may include a BMU 502 coupled to at least one battery cell unit within a steel can 504. In this example, a flexible connector 530 may extend from (e.g., out of) overmold material 506 that at least partially surrounds BMU 502. The flexible connector 530 may be configured to connect BMU 502, and ultimately the battery cell unit within the steel can, to an electronic device and/or a charger in a variety of ways (e.g., using electrical connectors of a variety of styles and designs). By way of example, during use, the steel can 504 of the battery assembly 500 may be positioned and installed within a receptacle of the electronic device either before or after connecting the flexible connector 530.

[0042] In a third example shown in FIG. 6, battery assembly 600 may include a BMU 602 coupled to at least one battery cell unit within a steel can 604. In this example, a board-to-board connector 640, or other similar type of connector, may be rigidly connected to overmold material 606. In use, the battery assembly 600 may be positioned within a receptacle of an electronic device and pressed into place to make an electrical connection with a complementary connector of the electronic device.

[0043] FIGS. 7 and 8 illustrate an example of a battery assembly 700 including a BMU 702 coupled to a steel can 704 that contains one or more battery cell units. FIG. 7 shows a detailed view of a portion of battery assembly 700 including BMU 702 and overmold material 706 covering at least a portion of BMU 702. FIG. 8 shows a perspective view of battery assembly 700 with overmold material 706 omitted to better view underlying components of BMU 702.

[0044] In this example, BMU 702 includes spring contacts 750 for connecting to an electronic device and/or charger. BMU 702 may be overmolded in a way that provides space for spring contacts 750 to flex and function properly. For example, spring contacts 750 may be exposed outside of overmold material 706 to allow for movement of springs 752 of spring contacts 750.

[0045] BMU 702 may be coupled to steel can 704 via one or more brackets 708, which may be bolted, welded, and/or bonded (e.g., with an adhesive) to steel can 704. For example, as shown in FIG. 8, in some examples, two brackets 708 may couple BMU 702 to steel can 704. In this example, the two brackets 708 may include a conductive material (e.g., a metal material). A first one of the brackets 708 may function as an anode connector between an anode of the battery unit within steel can 704 and the BMU 702. A second one of the brackets 708 may function as a cathode connector between a cathode of the battery unit within steel can 704 and the BMU 702. In additional embodiments, an anode connector and a cathode connector may be separate from brackets 708, such as in the form of a wire, trace, plug and corresponding receptacle, conductive post, or the like.

[0046] As illustrated in FIG. 8, additional features may also be included in battery assembly 700, such as a resilient pad 754 (e.g., a foam pad) on one or more sides of the steel can 704, which may allow battery assembly 700 to be biased within a receptacle of a corresponding electronic device, which may reduce and/or dampen movement of battery assembly 700 within the receptacle and/or may eliminate or reduce rattling of battery assembly 700 within the recep-

tacle. Additionally or alternatively, one or more retention clips 756 may be provided to retain battery assembly 700 within a receptacle of the electronic device. In some embodiments that include one or more retention clips 756, one or more undercuts in a housing of the electronic device may be provided and configured for engagement with retention clips 756. Such resilient pad 754 and retention clips 756 may be used in conjunction with any of the battery assemblies described in this disclosure, such as any of battery assemblies 100, 400, 500, 600, and/or 700.

[0047] In some embodiments, overmold material 106, 406, 506, 606, and/or 706 of respective battery assemblies 100, 400, 500, 600, and/or 700 according to the present disclosure may be configured to facilitate aligning and/or securing of battery assemblies 100, 400, 500, 600, and/or 700 and/or electrical contacts thereof with corresponding features of an electronic device intended to draw power from and/or to charge battery assemblies 100, 400, 500, 600, and/or 700. For example, one or more notches, protrusions, etc., may be included in overmold material 106, 406, 506, 606, and/or 706 for mating with a complementary feature in the electronic device.

[0048] In some examples, battery assemblies of the present disclosure may be interchangeable in various different electronic devices (e.g., both a mobile device and a wearable device). Alternatively, the battery assemblies may be customized for a specific electronic device (e.g., a smartwatch).

[0049] The overmolded BMUs of the present disclosure may facilitate user replacement of batteries in electronic devices (e.g., wearable devices, mobile devices, etc.) by providing a single, cohesive unit that can easily be attached to and/or detached from the electronic devices.

[Inventor(S): The Following Section is Boilerplate]

[0050] Embodiments of the present disclosure may include or be implemented in conjunction with various types of Artificial-Reality (AR) systems. AR may be any superimposed functionality and/or sensory-detectable content presented by an artificial-reality system within a user's physical surroundings. In other words, AR is a form of reality that has been adjusted in some manner before presentation to a user. AR can include and/or represent virtual reality (VR), augmented reality, mixed AR (MAR), or some combination and/or variation of these types of realities. Similarly, AR environments may include VR environments (including non-immersive, semi-immersive, and fully immersive VR environments), augmented-reality environments (including marker-based augmented-reality environments, markerless augmented-reality environments, location-based augmented-reality environments, and projection-based augmented-reality environments), hybrid-reality environments, and/or any other type or form of mixed- or alternative-reality environments.

[0051] AR content may include completely computer-generated content or computer-generated content combined with captured (e.g., real-world) content. Such AR content may include video, audio, haptic feedback, or some combination thereof, any of which may be presented in a single channel or in multiple channels (such as stereo video that produces a three-dimensional (3D) effect to the viewer). Additionally, in some embodiments, AR may also be associated with applications, products, accessories, services, or some combination thereof, that are used to, for example,

create content in an artificial reality and/or are otherwise used in (e.g., to perform activities in) an artificial reality.

[0052] AR systems may be implemented in a variety of different form factors and configurations. Some AR systems may be designed to work without near-eye displays (NEDs). Other AR systems may include a NED that also provides visibility into the real world (such as, e.g., augmented-reality system 1500 in FIG. 15) or that visually immerses a user in an artificial reality (such as, e.g., virtual-reality system 1600 in FIGS. 16A and 16B). While some AR devices may be self-contained systems, other AR devices may communicate and/or coordinate with external devices to provide an AR experience to a user. Examples of such external devices include handheld controllers, mobile devices, desktop computers, devices worn by a user, devices worn by one or more other users, and/or any other suitable external system.

[0053] FIGS. 9-12B illustrate example artificial-reality (AR) systems in accordance with some embodiments. FIG. 9 shows a first AR system 900 and first example user interactions using a wrist-wearable device 902, a head-wearable device (e.g., AR glasses 1500), and/or a handheld intermediary processing device (HIPD) 906. FIG. 10 shows a second AR system 1000 and second example user interactions using a wrist-wearable device 1002, AR glasses 1004, and/or an HIPD 1006. FIGS. 11A and 11B show a third AR system 1100 and third example user interactions using a wrist-wearable device 1102, a head-wearable device (e.g., VR headset 1150), and/or an HIPD 1106. FIGS. 12A and 12B show a fourth AR system 1200 and fourth example user interactions using a wrist-wearable device 1230, VR headset 1220, and/or a haptic device 1260 (e.g., wearable gloves).

[0054] A wrist-wearable device 1300, which can be used for wrist-wearable device 902, 1002, 1102, 1230, and one or more of its components, are described below in reference to FIGS. 13 and 14; head-wearable devices 1500 and 1600, which can respectively be used for AR glasses 904, 1004 or VR headset 1150, 1220, and their one or more components are described below in reference to FIGS. 15-17.

[0055] Referring to FIG. 9, wrist-wearable device 902, AR glasses 904, and/or HIPD 906 can communicatively couple via a network 925 (e.g., cellular, near field, Wi-Fi, personal area network, wireless LAN, etc.). Additionally, wrist-wearable device 902, AR glasses 904, and/or HIPD 906 can also communicatively couple with one or more servers 930, computers 940 (e.g., laptops, computers, etc.), mobile devices 950 (e.g., smartphones, tablets, etc.), and/or other electronic devices via network 925 (e.g., cellular, near field, Wi-Fi, personal area network, wireless LAN, etc.).

[0056] In FIG. 9, a user 908 is shown wearing wrist-wearable device 902 and AR glasses 904 and having HIPD 906 on their desk. The wrist-wearable device 902, AR glasses 904, and HIPD 906 facilitate user interaction with an AR environment. In particular, as shown by first AR system 900, wrist-wearable device 902, AR glasses 904, and/or HIPD 906 cause presentation of one or more avatars 910, digital representations of contacts 912, and virtual objects 914. As discussed below, user 908 can interact with one or more avatars 910, digital representations of contacts 912, and virtual objects 914 via wrist-wearable device 902, AR glasses 904, and/or HIPD 906.

[0057] User 908 can use any of wrist-wearable device 902, AR glasses 904, and/or HIPD 906 to provide user inputs. For example, user 908 can perform one or more hand gestures

that are detected by wrist-wearable device 902 (e.g., using one or more EMG sensors and/or IMUs, described below in reference to FIGS. 13 and 14) and/or AR glasses 904 (e.g., using one or more image sensor or camera, described below in reference to FIGS. 15-17) to provide a user input. Alternatively, or additionally, user 908 can provide a user input via one or more touch surfaces of wrist-wearable device 902, AR glasses 904, HIPD 906, and/or voice commands captured by a microphone of wrist-wearable device 902, AR glasses 904, and/or HIPD 906. In some embodiments, wrist-wearable device 902, AR glasses 904, and/or HIPD 906 include a digital assistant to help user 908 in providing a user input (e.g., completing a sequence of operations, suggesting different operations or commands, providing reminders, confirming a command, etc.). In some embodiments, user 908 can provide a user input via one or more facial gestures and/or facial expressions. For example, cameras of wrist-wearable device 902, AR glasses 904, and/or HIPD 906 can track eyes of user 908 for navigating a user interface.

[0058] Wrist-wearable device 902, AR glasses 904, and/or HIPD 906 can operate alone or in conjunction to allow user 908 to interact with the AR environment. In some embodiments, HIPD 906 is configured to operate as a central hub or control center for the wrist-wearable device 902, AR glasses 904, and/or another communicatively coupled device. For example, user 908 can provide an input to interact with the AR environment at any of wrist-wearable device 902, AR glasses 904, and/or HIPD 906, and HIPD 906 can identify one or more back-end and front-end tasks to cause the performance of the requested interaction and distribute instructions to cause the performance of the one or more back-end and front-end tasks at wrist-wearable device 902, AR glasses 904, and/or HIPD 906. In some embodiments, a back-end task is a background processing task that is not perceptible by the user (e.g., rendering content, decompression, compression, etc.), and a front-end task is a user-facing task that is perceptible to the user (e.g., presenting information to the user, providing feedback to the user, etc.). HIPD 906 can perform the back-end tasks and provide wrist-wearable device 902 and/or AR glasses 904 operational data corresponding to the performed back-end tasks such that wrist-wearable device 902 and/or AR glasses 904 can perform the front-end tasks. In this way, HIPD 906, which has more computational resources and greater thermal headroom than wrist-wearable device 902 and/or AR glasses 904, performs computationally intensive tasks and reduces the computer resource utilization and/or power usage of wrist-wearable device 902 and/or AR glasses 904.

[0059] In the example shown by first AR system 900, HIPD 906 identifies one or more back-end tasks and front-end tasks associated with a user request to initiate an AR video call with one or more other users (represented by avatar 910 and the digital representation of contact 912) and distributes instructions to cause the performance of the one or more back-end tasks and front-end tasks. In particular, HIPD 906 performs back-end tasks for processing and/or rendering image data (and other data) associated with the AR video call and provides operational data associated with the performed back-end tasks to AR glasses 904 such that the AR glasses 904 perform front-end tasks for presenting the AR video call (e.g., presenting avatar 910 and digital representation of contact 912).

[0060] In some embodiments, HIPD 906 can operate as a focal or anchor point for causing the presentation of infor-

mation. This allows user 908 to be generally aware of where information is presented. For example, as shown in first AR system 900, avatar 910 and the digital representation of contact 912 are presented above HIPD 906. In particular, HIPD 906 and AR glasses 904 operate in conjunction to determine a location for presenting avatar 910 and the digital representation of contact 912. In some embodiments, information can be presented a predetermined distance from HIPD 906 (e.g., within 5 meters). For example, as shown in first AR system 900, virtual object 914 is presented on the desk some distance from HIPD 906. Similar to the above example, HIPD 906 and AR glasses 904 can operate in conjunction to determine a location for presenting virtual object 914. Alternatively, in some embodiments, presentation of information is not bound by HIPD 906. More specifically, avatar 910, digital representation of contact 912, and virtual object 914 do not have to be presented within a predetermined distance of HIPD 906.

[0061] User inputs provided at wrist-wearable device 902, AR glasses 904, and/or HIPD 906 are coordinated such that the user can use any device to initiate, continue, and/or complete an operation. For example, user 908 can provide a user input to AR glasses 904 to cause AR glasses 904 to present virtual object 914 and, while virtual object 914 is presented by AR glasses 904, user 908 can provide one or more hand gestures via wrist-wearable device 902 to interact and/or manipulate virtual object 914.

[0062] FIG. 10 shows a user 1008 wearing a wrist-wearable device 1002 and AR glasses 1004, and holding an HIPD 1006. In second AR system 1000, the wrist-wearable device 1002, AR glasses 1004, and/or HIPD 1006 are used to receive and/or provide one or more messages to a contact of user 1008. In particular, wrist-wearable device 1002, AR glasses 1004, and/or HIPD 1006 detect and coordinate one or more user inputs to initiate a messaging application and prepare a response to a received message via the messaging application.

[0063] In some embodiments, user 1008 initiates, via a user input, an application on wrist-wearable device 1002, AR glasses 1004, and/or HIPD 1006 that causes the application to initiate on at least one device. For example, in second AR system 1000, user 1008 performs a hand gesture associated with a command for initiating a messaging application (represented by messaging user interface 1016), wrist-wearable device 1002 detects the hand gesture and, based on a determination that user 1008 is wearing AR glasses 1004, causes AR glasses 1004 to present a messaging user interface 1016 of the messaging application. AR glasses 1004 can present messaging user interface 1016 to user 1008 via its display (e.g., as shown by a field of view 1018 of user 1008). In some embodiments, the application is initiated and executed on the device (e.g., wrist-wearable device 1002, AR glasses 1004, and/or HIPD 1006) that detects the user input to initiate the application, and the device provides another device operational data to cause the presentation of the messaging application. For example, wrist-wearable device 1002 can detect the user input to initiate a messaging application, initiate and run the messaging application, and provide operational data to AR glasses 1004 and/or HIPD 1006 to cause presentation of the messaging application. Alternatively, the application can be initiated and executed at a device other than the device that detected the user input. For example, wrist-wearable device 1002 can detect the hand gesture associated with initiating the messaging appli-

cation and cause HIPD 1006 to run the messaging application and coordinate the presentation of the messaging application.

[0064] Further, user 1008 can provide a user input provided at wrist-wearable device 1002, AR glasses 1004, and/or HIPD 1006 to continue and/or complete an operation initiated at another device. For example, after initiating the messaging application via wrist-wearable device 1002 and while AR glasses 1004 present messaging user interface 1016, user 1008 can provide an input at HIPD 1006 to prepare a response (e.g., shown by the swipe gesture performed on HIPD 1006). Gestures performed by user 1008 on HIPD 1006 can be provided and/or displayed on another device. For example, a swipe gestured performed on HIPD 1006 is displayed on a virtual keyboard of messaging user interface 1016 displayed by glasses 1004.

[0065] In some embodiments, wrist-wearable device 1002, AR glasses 1004, HIPD 1006, and/or any other communicatively coupled device can present one or more notifications to user 1008. The notification can be an indication of a new message, an incoming call, an application update, a status update, etc. User 1008 can select the notification via wrist-wearable device 1002, AR glasses 1004, and/or HIPD 1006 and can cause presentation of an application or operation associated with the notification on at least one device. For example, user 1008 can receive a notification that a message was received at wrist-wearable device 1002, AR glasses 1004, HIPD 1006, and/or any other communicatively coupled device and can then provide a user input at wrist-wearable device 1002, AR glasses 1004, and/or HIPD 1006 to review the notification, and the device detecting the user input can cause an application associated with the notification to be initiated and/or presented at wrist-wearable device 1002, AR glasses 1004, and/or HIPD 1006.

[0066] While the above example describes coordinated inputs used to interact with a messaging application, user inputs can be coordinated to interact with any number of applications including, but not limited to, gaming applications, social media applications, camera applications, web-based applications, financial applications, etc. For example, AR glasses 1004 can present to user 1008 game application data, and HIPD 1006 can be used as a controller to provide inputs to the game. Similarly, user 1008 can use wrist-wearable device 1002 to initiate a camera of AR glasses 1004, and user 1008 can use wrist-wearable device 1002, AR glasses 1004, and/or HIPD 1006 to manipulate the image capture (e.g., zoom in or out, apply filters, etc.) and capture image data.

[0067] Users may interact with the devices disclosed herein in a variety of ways. For example, as shown in FIGS. 11A and 11B, a user 1108 may interact with an AR system 1100 by donning a VR headset 1150 while holding HIPD 1106 and wearing wrist-wearable device 1102. In this example, AR system 1100 may enable a user to interact with a game 1110 by swiping their arm. One or more of VR headset 1150, HIPD 1106, and wrist-wearable device 1102 may detect this gesture and, in response, may display a sword strike in game 1110. Similarly, in FIGS. 12A and 12B, a user 1208 may interact with an AR system 1200 by donning a VR headset 1220 while wearing haptic device 1260 and wrist-wearable device 1230. In this example, AR system 1200 may enable a user to interact with a game 1210 by swiping their arm. One or more of VR headset 1220,

haptic device **1260**, and wrist-wearable device **1230** may detect this gesture and, in response, may display a spell being cast in game **1110**.

[0068] Having discussed example AR systems, devices for interacting with such AR systems and other computing systems more generally will now be discussed in greater detail. Some explanations of devices and components that can be included in some or all of the example devices discussed below are explained herein for ease of reference. Certain types of the components described below may be more suitable for a particular set of devices, and less suitable for a different set of devices. But subsequent reference to the components explained here should be considered to be encompassed by the descriptions provided.

[0069] In some embodiments discussed below, example devices and systems, including electronic devices and systems, will be addressed. Such example devices and systems are not intended to be limiting, and one of skill in the art will understand that alternative devices and systems to the example devices and systems described herein may be used to perform the operations and construct the systems and devices that are described herein.

[0070] An electronic device may be a device that uses electrical energy to perform a specific function. An electronic device can be any physical object that contains electronic components such as transistors, resistors, capacitors, diodes, and integrated circuits. Examples of electronic devices include smartphones, laptops, digital cameras, televisions, gaming consoles, and music players, as well as the example electronic devices discussed herein. As described herein, an intermediary electronic device may be a device that sits between two other electronic devices and/or a subset of components of one or more electronic devices and facilitates communication, data processing, and/or data transfer between the respective electronic devices and/or electronic components.

[0071] An integrated circuit may be an electronic device made up of multiple interconnected electronic components such as transistors, resistors, and capacitors. These components may be etched onto a small piece of semiconductor material, such as silicon. Integrated circuits may include analog integrated circuits, digital integrated circuits, mixed signal integrated circuits, and/or any other suitable type or form of integrated circuit. Examples of integrated circuits include application-specific integrated circuits (ASICs), processing units, central processing units (CPUs), co-processors, and accelerators.

[0072] Analog integrated circuits, such as sensors, power management circuits, and operational amplifiers, may process continuous signals and perform analog functions such as amplification, active filtering, demodulation, and mixing. Examples of analog integrated circuits include linear integrated circuits and radio frequency circuits.

[0073] Digital integrated circuits, which may be referred to as logic integrated circuits, may include microprocessors, microcontrollers, memory chips, interfaces, power management circuits, programmable devices, and/or any other suitable type or form of integrated circuit. In some embodiments, examples of integrated circuits include central processing units (CPUs),

[0074] Processing units, such as CPUs, may be electronic components that are responsible for executing instructions and controlling the operation of an electronic device (e.g., a computer). There are various types of processors that may be

used interchangeably, or may be specifically required, by embodiments described herein. For example, a processor may be: (i) a general processor designed to perform a wide range of tasks, such as running software applications, managing operating systems, and performing arithmetic and logical operations; (ii) a microcontroller designed for specific tasks such as controlling electronic devices, sensors, and motors; (iii) an accelerator, such as a graphics processing unit (GPU), designed to accelerate the creation and rendering of images, videos, and animations (e.g., virtual-reality animations, such as three-dimensional modeling); (iv) a field-programmable gate array (FPGA) that can be programmed and reconfigured after manufacturing and/or can be customized to perform specific tasks, such as signal processing, cryptography, and machine learning; and/or (v) a digital signal processor (DSP) designed to perform mathematical operations on signals such as audio, video, and radio waves. One or more processors of one or more electronic devices may be used in various embodiments described herein.

[0075] Memory generally refers to electronic components in a computer or electronic device that store data and instructions for the processor to access and manipulate. Examples of memory can include: (i) random access memory (RAM) configured to store data and instructions temporarily; (ii) read-only memory (ROM) configured to store data and instructions permanently (e.g., one or more portions of system firmware, and/or boot loaders) and/or semi-permanently; (iii) flash memory, which can be configured to store data in electronic devices (e.g., USB drives, memory cards, and/or solid-state drives (SSDs)); and/or (iv) cache memory configured to temporarily store frequently accessed data and instructions. Memory, as described herein, can store structured data (e.g., SQL databases, MongoDB databases, GraphQL data, JSON data, etc.). Other examples of data stored in memory can include (i) profile data, including user account data, user settings, and/or other user data stored by the user, (ii) sensor data detected and/or otherwise obtained by one or more sensors, (iii) media content data including stored image data, audio data, documents, and the like, (iv) application data, which can include data collected and/or otherwise obtained and stored during use of an application, and/or any other types of data described herein.

[0076] Controllers may be electronic components that manage and coordinate the operation of other components within an electronic device (e.g., controlling inputs, processing data, and/or generating outputs). Examples of controllers can include: (i) microcontrollers, including small, low-power controllers that are commonly used in embedded systems and Internet of Things (IoT) devices; (ii) programmable logic controllers (PLCs) that may be configured to be used in industrial automation systems to control and monitor manufacturing processes; (iii) system-on-a-chip (SoC) controllers that integrate multiple components such as processors, memory, I/O interfaces, and other peripherals into a single chip; and/or (iv) DSPs.

[0077] A power system of an electronic device may be configured to convert incoming electrical power into a form that can be used to operate the device. A power system can include various components, such as (i) a power source, which can be an alternating current (AC) adapter or a direct current (DC) adapter power supply, (ii) a charger input, which can be configured to use a wired and/or wireless

connection (which may be part of a peripheral interface, such as a USB, micro-USB interface, near-field magnetic coupling, magnetic inductive and magnetic resonance charging, and/or radio frequency (RF) charging), (iii) a power-management integrated circuit, configured to distribute power to various components of the device and to ensure that the device operates within safe limits (e.g., regulating voltage, controlling current flow, and/or managing heat dissipation), and/or (iv) a battery configured to store power to provide usable power to components of one or more electronic devices.

[0078] Peripheral interfaces may be electronic components (e.g., of electronic devices) that allow electronic devices to communicate with other devices or peripherals and can provide the ability to input and output data and signals. Examples of peripheral interfaces can include (i) universal serial bus (USB) and/or micro-USB interfaces configured for connecting devices to an electronic device, (ii) Bluetooth interfaces configured to allow devices to communicate with each other, including Bluetooth low energy (BLE), (iii) near field communication (NFC) interfaces configured to be short-range wireless interfaces for operations such as access control, (iv) POGO pins, which may be small, spring-loaded pins configured to provide a charging interface, (v) wireless charging interfaces, (vi) GPS interfaces, (vii) Wi-Fi interfaces for providing a connection between a device and a wireless network, and/or (viii) sensor interfaces.

[0079] Sensors may be electronic components (e.g., in and/or otherwise in electronic communication with electronic devices, such as wearable devices) configured to detect physical and environmental changes and generate electrical signals. Examples of sensors can include (i) imaging sensors for collecting imaging data (e.g., including one or more cameras disposed on a respective electronic device), (ii) biopotential-signal sensors, (iii) inertial measurement units (e.g., IMUs) for detecting, for example, angular rate, force, magnetic field, and/or changes in acceleration, (iv) heart rate sensors for measuring a user's heart rate, (v) SpO2 sensors for measuring blood oxygen saturation and/or other biometric data of a user, (vi) capacitive sensors for detecting changes in potential at a portion of a user's body (e.g., a sensor-skin interface), and/or (vii) light sensors (e.g., time-of-flight sensors, infrared light sensors, visible light sensors, etc.).

[0080] Biopotential-signal-sensing components may be devices used to measure electrical activity within the body (e.g., biopotential-signal sensors). Some types of biopotential-signal sensors include (i) electroencephalography (EEG) sensors configured to measure electrical activity in the brain to diagnose neurological disorders, (ii) electrocardiogram (ECG) sensors configured to measure electrical activity of the heart to diagnose heart problems, (iii) electromyography (EMG) sensors configured to measure the electrical activity of muscles and to diagnose neuromuscular disorders, and (iv) electrooculography (EOG) sensors configured to measure the electrical activity of eye muscles to detect eye movement and diagnose eye disorders.

[0081] An application stored in memory of an electronic device (e.g., software) may include instructions stored in the memory. Examples of such applications include (i) games, (ii) word processors, (iii) messaging applications, (iv) media-streaming applications, (v) financial applications, (vi) calendars, (vii) clocks, and (viii) communication interface

modules for enabling wired and/or wireless connections between different respective electronic devices (e.g., IEEE 1502.15.4, Wi-Fi, ZigBee, 6LoWPAN, Thread, Z-Wave, Bluetooth Smart, ISA100.11a, WirelessHART, or MiWi), custom or standard wired protocols (e.g., Ethernet or HomePlug), and/or any other suitable communication protocols).

[0082] A communication interface may be a mechanism that enables different systems or devices to exchange information and data with each other, including hardware, software, or a combination of both hardware and software. For example, a communication interface can refer to a physical connector and/or port on a device that enables communication with other devices (e.g., USB, Ethernet, HDMI, Bluetooth). In some embodiments, a communication interface can refer to a software layer that enables different software programs to communicate with each other (e.g., application programming interfaces (APIs), protocols like HTTP and TCP/IP, etc.).

[0083] A graphics module may be a component or software module that is designed to handle graphical operations and/or processes and can include a hardware module and/or a software module.

[0084] Non-transitory computer-readable storage media may be physical devices or storage media that can be used to store electronic data in a non-transitory form (e.g., such that the data is stored permanently until it is intentionally deleted or modified).

[0085] FIGS. 13 and 14 illustrate an example wrist-wearable device 1300 and an example computer system 1400, in accordance with some embodiments. Wrist-wearable device 1300 is an instance of wearable device 902 described in FIG. 9 herein, such that the wearable device 902 should be understood to have the features of the wrist-wearable device 1300 and vice versa. FIG. 14 illustrates components of the wrist-wearable device 1300, which can be used individually or in combination, including combinations that include other electronic devices and/or electronic components.

[0086] FIG. 13 shows a wearable band 1310 and a watch body 1320 (or capsule) being coupled, as discussed below, to form wrist-wearable device 1300. Wrist-wearable device 1300 can perform various functions and/or operations associated with navigating through user interfaces and selectively opening applications as well as the functions and/or operations described above with reference to FIGS. 9-12B.

[0087] As will be described in more detail below, operations executed by wrist-wearable device 1300 can include (i) presenting content to a user (e.g., displaying visual content via a display 1305), (ii) detecting (e.g., sensing) user input (e.g., sensing a touch on peripheral button 1323 and/or at a touch screen of the display 1305, a hand gesture detected by sensors (e.g., biopotential sensors)), (iii) sensing biometric data (e.g., neuromuscular signals, heart rate, temperature, sleep, etc.) via one or more sensors 1313, messaging (e.g., text, speech, video, etc.); image capture via one or more imaging devices or cameras 1325, wireless communications (e.g., cellular, near field, Wi-Fi, personal area network, etc.), location determination, financial transactions, providing haptic feedback, providing alarms, providing notifications, providing biometric authentication, providing health monitoring, providing sleep monitoring, etc.

[0088] The above-example functions can be executed independently in watch body 1320, independently in wearable band 1310, and/or via an electronic communication between watch body 1320 and wearable band 1310. In some

embodiments, functions can be executed on wrist-wearable device **1300** while an AR environment is being presented (e.g., via one of AR systems **900** to **1200**). The wearable devices described herein can also be used with other types of AR environments.

[0089] Wearable band **1310** can be configured to be worn by a user such that an inner surface of a wearable structure **1311** of wearable band **1310** is in contact with the user's skin. In this example, when worn by a user, sensors **1313** may contact the user's skin. In some examples, one or more of sensors **1313** can sense biometric data such as a user's heart rate, a saturated oxygen level, temperature, sweat level, neuromuscular signals, or a combination thereof. One or more of sensors **1313** can also sense data about a user's environment including a user's motion, altitude, location, orientation, gait, acceleration, position, or a combination thereof. In some embodiment, one or more of sensors **1313** can be configured to track a position and/or motion of wearable band **1310**. One or more of sensors **1313** can include any of the sensors defined above and/or discussed below with respect to FIG. **13**.

[0090] One or more of sensors **1313** can be distributed on an inside and/or an outside surface of wearable band **1310**. In some embodiments, one or more of sensors **1313** are uniformly spaced along wearable band **1310**. Alternatively, in some embodiments, one or more of sensors **1313** are positioned at distinct points along wearable band **1310**. As shown in FIG. **13**, one or more of sensors **1313** can be the same or distinct. For example, in some embodiments, one or more of sensors **1313** can be shaped as a pill (e.g., sensor **1313a**), an oval, a circle a square, an oblong (e.g., sensor **1313c**) and/or any other shape that maintains contact with the user's skin (e.g., such that neuromuscular signal and/or other biometric data can be accurately measured at the user's skin). In some embodiments, one or more sensors of **1313** are aligned to form pairs of sensors (e.g., for sensing neuromuscular signals based on differential sensing within each respective sensor). For example, sensor **1313b** may be aligned with an adjacent sensor to form sensor pair **1314a** and sensor **1313d** may be aligned with an adjacent sensor to form sensor pair **1314b**. In some embodiments, wearable band **1310** does not have a sensor pair. Alternatively, in some embodiments, wearable band **1310** has a predetermined number of sensor pairs (one pair of sensors, three pairs of sensors, four pairs of sensors, six pairs of sensors, sixteen pairs of sensors, etc.).

[0091] Wearable band **1310** can include any suitable number of sensors **1313**. In some embodiments, the number and arrangement of sensors **1313** depends on the particular application for which wearable band **1310** is used. For instance, wearable band **1310** can be configured as an armband, wristband, or chest-band that include a plurality of sensors **1313** with different number of sensors **1313**, a variety of types of individual sensors with the plurality of sensors **1313**, and different arrangements for each use case, such as medical use cases as compared to gaming or general day-to-day use cases.

[0092] In accordance with some embodiments, wearable band **1310** further includes an electrical ground electrode and a shielding electrode. The electrical ground and shielding electrodes, like the sensors **1313**, can be distributed on the inside surface of the wearable band **1310** such that they contact a portion of the user's skin. For example, the electrical ground and shielding electrodes can be at an inside

surface of a coupling mechanism **1316** or an inside surface of a wearable structure **1311**. The electrical ground and shielding electrodes can be formed and/or use the same components as sensors **1313**. In some embodiments, wearable band **1310** includes more than one electrical ground electrode and more than one shielding electrode.

[0093] Sensors **1313** can be formed as part of wearable structure **1311** of wearable band **1310**. In some embodiments, sensors **1313** are flush or substantially flush with wearable structure **1311** such that they do not extend beyond the surface of wearable structure **1311**. While flush with wearable structure **1311**, sensors **1313** are still configured to contact the user's skin (e.g., via a skin-contacting surface). Alternatively, in some embodiments, sensors **1313** extend beyond wearable structure **1311** a predetermined distance (e.g., 0.1-2 mm) to make contact and depress into the user's skin. In some embodiment, sensors **1313** are coupled to an actuator (not shown) configured to adjust an extension height (e.g., a distance from the surface of wearable structure **1311**) of sensors **1313** such that sensors **1313** make contact and depress into the user's skin. In some embodiments, the actuators adjust the extension height between 0.01 mm-1.2 mm. This may allow a the user to customize the positioning of sensors **1313** to improve the overall comfort of the wearable band **1310** when worn while still allowing sensors **1313** to contact the user's skin. In some embodiments, sensors **1313** are indistinguishable from wearable structure **1311** when worn by the user.

[0094] Wearable structure **1311** can be formed of an elastic material, elastomers, etc., configured to be stretched and fitted to be worn by the user. In some embodiments, wearable structure **1311** is a textile or woven fabric. As described above, sensors **1313** can be formed as part of a wearable structure **1311**. For example, sensors **1313** can be molded into the wearable structure **1311**, be integrated into a woven fabric (e.g., sensors **1313** can be sewn into the fabric and mimic the pliability of fabric and can and/or be constructed from a series woven strands of fabric).

[0095] Wearable structure **1311** can include flexible electronic connectors that interconnect sensors **1313**, the electronic circuitry, and/or other electronic components (described below in reference to FIG. **14**) that are enclosed in wearable band **1310**. In some embodiments, the flexible electronic connectors are configured to interconnect sensors **1313**, the electronic circuitry, and/or other electronic components of wearable band **1310** with respective sensors and/or other electronic components of another electronic device (e.g., watch body **1320**). The flexible electronic connectors are configured to move with wearable structure **1311** such that the user adjustment to wearable structure **1311** (e.g., resizing, pulling, folding, etc.) does not stress or strain the electrical coupling of components of wearable band **1310**.

[0096] As described above, wearable band **1310** is configured to be worn by a user. In particular, wearable band **1310** can be shaped or otherwise manipulated to be worn by a user. For example, wearable band **1310** can be shaped to have a substantially circular shape such that it can be configured to be worn on the user's lower arm or wrist. Alternatively, wearable band **1310** can be shaped to be worn on another body part of the user, such as the user's upper arm (e.g., around a bicep), forearm, chest, legs, etc. Wearable band **1310** can include a retaining mechanism **1312** (e.g., a buckle, a hook and loop fastener, etc.) for securing wearable

band **1310** to the user's wrist or other body part. While wearable band **1310** is worn by the user, sensors **1313** sense data (referred to as sensor data) from the user's skin. In some examples, sensors **1313** of wearable band **1310** obtain (e.g., sense and record) neuromuscular signals.

[0097] The sensed data (e.g., sensed neuromuscular signals) can be used to detect and/or determine the user's intention to perform certain motor actions. In some examples, sensors **1313** may sense and record neuromuscular signals from the user as the user performs muscular activations (e.g., movements, gestures, etc.). The detected and/or determined motor actions (e.g., phalange (or digit) movements, wrist movements, hand movements, and/or other muscle intentions) can be used to determine control commands or control information (instructions to perform certain commands after the data is sensed) for causing a computing device to perform one or more input commands. For example, the sensed neuromuscular signals can be used to control certain user interfaces displayed on display **1305** of wrist-wearable device **1300** and/or can be transmitted to a device responsible for rendering an artificial-reality environment (e.g., a head-mounted display) to perform an action in an associated artificial-reality environment, such as to control the motion of a virtual device displayed to the user. The muscular activations performed by the user can include static gestures, such as placing the user's hand palm down on a table, dynamic gestures, such as grasping a physical or virtual object, and covert gestures that are imperceptible to another person, such as slightly tensing a joint by co-contracting opposing muscles or using sub-muscular activations. The muscular activations performed by the user can include symbolic gestures (e.g., gestures mapped to other gestures, interactions, or commands, for example, based on a gesture vocabulary that specifies the mapping of gestures to commands).

[0098] The sensor data sensed by sensors **1313** can be used to provide a user with an enhanced interaction with a physical object (e.g., devices communicatively coupled with wearable band **1310**) and/or a virtual object in an artificial-reality application generated by an artificial-reality system (e.g., user interface objects presented on the display **1305**, or another computing device (e.g., a smartphone)).

[0099] In some embodiments, wearable band **1310** includes one or more haptic devices **1446** (e.g., a vibratory haptic actuator) that are configured to provide haptic feedback (e.g., a cutaneous and/or kinesthetic sensation, etc.) to the user's skin. Sensors **1313** and/or haptic devices **1446** (shown in FIG. 14) can be configured to operate in conjunction with multiple applications including, without limitation, health monitoring, social media, games, and artificial reality (e.g., the applications associated with artificial reality).

[0100] Wearable band **1310** can also include coupling mechanism **1316** for detachably coupling a capsule (e.g., a computing unit) or watch body **1320** (via a coupling surface of the watch body **1320**) to wearable band **1310**. For example, a cradle or a shape of coupling mechanism **1316** can correspond to shape of watch body **1320** of wrist-wearable device **1300**. In particular, coupling mechanism **1316** can be configured to receive a coupling surface proximate to the bottom side of watch body **1320** (e.g., a side opposite to a front side of watch body **1320** where display **1305** is located), such that a user can push watch body **1320** downward into coupling mechanism **1316** to attach watch body **1320** to coupling mechanism **1316**. In some embodi-

ments, coupling mechanism **1316** can be configured to receive a top side of the watch body **1320** (e.g., a side proximate to the front side of watch body **1320** where display **1305** is located) that is pushed upward into the cradle, as opposed to being pushed downward into coupling mechanism **1316**. In some embodiments, coupling mechanism **1316** is an integrated component of wearable band **1310** such that wearable band **1310** and coupling mechanism **1316** are a single unitary structure. In some embodiments, coupling mechanism **1316** is a type of frame or shell that allows watch body **1320** coupling surface to be retained within or on wearable band **1310** coupling mechanism **1316** (e.g., a cradle, a tracker band, a support base, a clasp, etc.).

[0101] Coupling mechanism **1316** can allow for watch body **1320** to be detachably coupled to the wearable band **1310** through a friction fit, magnetic coupling, a rotation-based connector, a shear-pin coupler, a retention spring, one or more magnets, a clip, a pin shaft, a hook and loop fastener, or a combination thereof. A user can perform any type of motion to couple the watch body **1320** to wearable band **1310** and to decouple the watch body **1320** from the wearable band **1310**. For example, a user can twist, slide, turn, push, pull, or rotate watch body **1320** relative to wearable band **1310**, or a combination thereof, to attach watch body **1320** to wearable band **1310** and to detach watch body **1320** from wearable band **1310**. Alternatively, as discussed below, in some embodiments, the watch body **1320** can be decoupled from the wearable band **1310** by actuation of a release mechanism **1329**.

[0102] Wearable band **1310** can be coupled with watch body **1320** to increase the functionality of wearable band **1310** (e.g., converting wearable band **1310** into wrist-wearable device **1300**, adding an additional computing unit and/or battery to increase computational resources and/or a battery life of wearable band **1310**, adding additional sensors to improve sensed data, etc.). As described above, wearable band **1310** and coupling mechanism **1316** are configured to operate independently (e.g., execute functions independently) from watch body **1320**. For example, coupling mechanism **1316** can include one or more sensors **1313** that contact a user's skin when wearable band **1310** is worn by the user, with or without watch body **1320** and can provide sensor data for determining control commands.

[0103] A user can detach watch body **1320** from wearable band **1310** to reduce the encumbrance of wrist-wearable device **1300** to the user. For embodiments in which watch body **1320** is removable, watch body **1320** can be referred to as a removable structure, such that in these embodiments wrist-wearable device **1300** includes a wearable portion (e.g., wearable band **1310**) and a removable structure (e.g., watch body **1320**).

[0104] Turning to watch body **1320**, in some examples watch body **1320** can have a substantially rectangular or circular shape. Watch body **1320** is configured to be worn by the user on their wrist or on another body part. More specifically, watch body **1320** is sized to be easily carried by the user, attached on a portion of the user's clothing, and/or coupled to wearable band **1310** (forming the wrist-wearable device **1300**). As described above, watch body **1320** can have a shape corresponding to coupling mechanism **1316** of wearable band **1310**. In some embodiments, watch body **1320** includes a single release mechanism **1329** or multiple release mechanisms (e.g., two release mechanisms **1329** positioned on opposing sides of watch body **1320**, such as

spring-loaded buttons) for decoupling watch body 1320 from wearable band 1310. Release mechanism 1329 can include, without limitation, a button, a knob, a plunger, a handle, a lever, a fastener, a clasp, a dial, a latch, or a combination thereof.

[0105] A user can actuate release mechanism 1329 by pushing, turning, lifting, depressing, shifting, or performing other actions on release mechanism 1329. Actuation of release mechanism 1329 can release (e.g., decouple) watch body 1320 from coupling mechanism 1316 of wearable band 1310, allowing the user to use watch body 1320 independently from wearable band 1310 and vice versa. For example, decoupling watch body 1320 from wearable band 1310 can allow a user to capture images using rear-facing camera 1325b. Although release mechanism 1329 is shown positioned at a corner of watch body 1320, release mechanism 1329 can be positioned anywhere on watch body 1320 that is convenient for the user to actuate. In addition, in some embodiments, wearable band 1310 can also include a respective release mechanism for decoupling watch body 1320 from coupling mechanism 1316. In some embodiments, release mechanism 1329 is optional and watch body 1320 can be decoupled from coupling mechanism 1316 as described above (e.g., via twisting, rotating, etc.).

[0106] Watch body 1320 can include one or more peripheral buttons 1323 and 1327 for performing various operations at watch body 1320. For example, peripheral buttons 1323 and 1327 can be used to turn on or wake (e.g., transition from a sleep state to an active state) display 1305, unlock watch body 1320, increase or decrease a volume, increase or decrease a brightness, interact with one or more applications, interact with one or more user interfaces, etc. Additionally or alternatively, in some embodiments, display 1305 operates as a touch screen and allows the user to provide one or more inputs for interacting with watch body 1320.

[0107] In some embodiments, watch body 1320 includes one or more sensors 1321. Sensors 1321 of watch body 1320 can be the same or distinct from sensors 1313 of wearable band 1310. Sensors 1321 of watch body 1320 can be distributed on an inside and/or an outside surface of watch body 1320. In some embodiments, sensors 1321 are configured to contact a user's skin when watch body 1320 is worn by the user. For example, sensors 1321 can be placed on the bottom side of watch body 1320 and coupling mechanism 1316 can be a cradle with an opening that allows the bottom side of watch body 1320 to directly contact the user's skin. Alternatively, in some embodiments, watch body 1320 does not include sensors that are configured to contact the user's skin (e.g., including sensors internal and/or external to the watch body 1320 that are configured to sense data of watch body 1320 and the surrounding environment). In some embodiments, sensors 1321 are configured to track a position and/or motion of watch body 1320.

[0108] Watch body 1320 and wearable band 1310 can share data using a wired communication method (e.g., a Universal Asynchronous Receiver/Transmitter (UART), a USB transceiver, etc.) and/or a wireless communication method (e.g., near field communication, Bluetooth, etc.). For example, watch body 1320 and wearable band 1310 can share data sensed by sensors 1313 and 1321, as well as application and device specific information (e.g., active and/or available applications, output devices (e.g., displays,

speakers, etc.), input devices (e.g., touch screens, microphones, imaging sensors, etc.).

[0109] In some embodiments, watch body 1320 can include, without limitation, a front-facing camera 1325a and/or a rear-facing camera 1325b, sensors 1321 (e.g., a biometric sensor, an IMU, a heart rate sensor, a saturated oxygen sensor, a neuromuscular signal sensor, an altimeter sensor, a temperature sensor, a bioimpedance sensor, a pedometer sensor, an optical sensor (e.g., imaging sensor 1463), a touch sensor, a sweat sensor, etc.). In some embodiments, watch body 1320 can include one or more haptic devices 1476 (e.g., a vibratory haptic actuator) that is configured to provide haptic feedback (e.g., a cutaneous and/or kinesthetic sensation, etc.) to the user. Sensors 1421 and/or haptic device 1476 can also be configured to operate in conjunction with multiple applications including, without limitation, health monitoring applications, social media applications, game applications, and artificial reality applications (e.g., the applications associated with artificial reality).

[0110] As described above, watch body 1320 and wearable band 1310, when coupled, can form wrist-wearable device 1300. When coupled, watch body 1320 and wearable band 1310 may operate as a single device to execute functions (operations, detections, communications, etc.) described herein. In some embodiments, each device may be provided with particular instructions for performing the one or more operations of wrist-wearable device 1300. For example, in accordance with a determination that watch body 1320 does not include neuromuscular signal sensors, wearable band 1310 can include alternative instructions for performing associated instructions (e.g., providing sensed neuromuscular signal data to watch body 1320 via a different electronic device). Operations of wrist-wearable device 1300 can be performed by watch body 1320 alone or in conjunction with wearable band 1310 (e.g., via respective processors and/or hardware components) and vice versa. In some embodiments, operations of wrist-wearable device 1300, watch body 1320, and/or wearable band 1310 can be performed in conjunction with one or more processors and/or hardware components.

[0111] As described below with reference to the block diagram of FIG. 14, wearable band 1310 and/or watch body 1320 can each include independent resources required to independently execute functions. For example, wearable band 1310 and/or watch body 1320 can each include a power source (e.g., a battery), a memory, data storage, a processor (e.g., a central processing unit (CPU)), communications, a light source, and/or input/output devices.

[0112] FIG. 14 shows block diagrams of a computing system 1430 corresponding to wearable band 1310 and a computing system 1460 corresponding to watch body 1320 according to some embodiments. Computing system 1400 of wrist-wearable device 1300 may include a combination of components of wearable band computing system 1430 and watch body computing system 1460, in accordance with some embodiments.

[0113] Watch body 1320 and/or wearable band 1310 can include one or more components shown in watch body computing system 1460. In some embodiments, a single integrated circuit may include all or a substantial portion of the components of watch body computing system 1460 included in a single integrated circuit. Alternatively, in some embodiments, components of the watch body computing

system **1460** may be included in a plurality of integrated circuits that are communicatively coupled. In some embodiments, watch body computing system **1460** may be configured to couple (e.g., via a wired or wireless connection) with wearable band computing system **1430**, which may allow the computing systems to share components, distribute tasks, and/or perform other operations described herein (individually or as a single device).

[0114] Watch body computing system **1460** can include one or more processors **1479**, a controller **1477**, a peripherals interface **1461**, a power system **1495**, and memory (e.g., a memory **1480**).

[0115] Power system **1495** can include a charger input **1496**, a power-management integrated circuit (PMIC) **1497**, and a battery **1498**. In some embodiments, a watch body **1320** and a wearable band **1310** can have respective batteries (e.g., battery **1498** and **1459**) and can share power with each other. Watch body **1320** and wearable band **1310** can receive a charge using a variety of techniques. In some embodiments, watch body **1320** and wearable band **1310** can use a wired charging assembly (e.g., power cords) to receive the charge. Alternatively, or in addition, watch body **1320** and/or wearable band **1310** can be configured for wireless charging. For example, a portable charging device can be designed to mate with a portion of watch body **1320** and/or wearable band **1310** and wirelessly deliver usable power to battery **1498** of watch body **1320** and/or battery **1459** of wearable band **1310**. Watch body **1320** and wearable band **1310** can have independent power systems (e.g., power system **1495** and **1456**, respectively) to enable each to operate independently. Watch body **1320** and wearable band **1310** can also share power (e.g., one can charge the other) via respective PMICs (e.g., PMICs **1497** and **1458**) and charger inputs (e.g., **1457** and **1496**) that can share power over power and ground conductors and/or over wireless charging antennas.

[0116] In some embodiments, peripherals interface **1461** can include one or more sensors **1421**. Sensors **1421** can include one or more coupling sensors **1462** for detecting when watch body **1320** is coupled with another electronic device (e.g., a wearable band **1310**). Sensors **1421** can include one or more imaging sensors **1463** (e.g., one or more of cameras **1425**, and/or separate imaging sensors **1463** (e.g., thermal-imaging sensors)). In some embodiments, sensors **1421** can include one or more SpO₂ sensors **1464**. In some embodiments, sensors **1421** can include one or more biopotential-signal sensors (e.g., EMG sensors **1465**, which may be disposed on an interior, user-facing portion of watch body **1320** and/or wearable band **1310**). In some embodiments, sensors **1421** may include one or more capacitive sensors **1466**. In some embodiments, sensors **1421** may include one or more heart rate sensors **1467**. In some embodiments, sensors **1421** may include one or more IMU sensors **1468**. In some embodiments, one or more IMU sensors **1468** can be configured to detect movement of a user's hand or other location where watch body **1320** is placed or held.

[0117] In some embodiments, one or more of sensors **1421** may provide an example human-machine interface. For example, a set of neuromuscular sensors, such as EMG sensors **1465**, may be arranged circumferentially around wearable band **1310** with an interior surface of EMG sensors **1465** being configured to contact a user's skin. Any suitable number of neuromuscular sensors may be used (e.g., between 2 and 20 sensors). The number and arrangement of

neuromuscular sensors may depend on the particular application for which the wearable device is used. For example, wearable band **1310** can be used to generate control information for controlling an augmented reality system, a robot, controlling a vehicle, scrolling through text, controlling a virtual avatar, or any other suitable control task.

[0118] In some embodiments, neuromuscular sensors may be coupled together using flexible electronics incorporated into the wireless device, and the output of one or more of the sensing components can be optionally processed using hardware signal processing circuitry (e.g., to perform amplification, filtering, and/or rectification). In other embodiments, at least some signal processing of the output of the sensing components can be performed in software such as processors **1479**. Thus, signal processing of signals sampled by the sensors can be performed in hardware, software, or by any suitable combination of hardware and software, as aspects of the technology described herein are not limited in this respect.

[0119] Neuromuscular signals may be processed in a variety of ways. For example, the output of EMG sensors **1465** may be provided to an analog front end, which may be configured to perform analog processing (e.g., amplification, noise reduction, filtering, etc.) on the recorded signals. The processed analog signals may then be provided to an analog-to-digital converter, which may convert the analog signals to digital signals that can be processed by one or more computer processors. Furthermore, although this example is as discussed in the context of interfaces with EMG sensors, the embodiments described herein can also be implemented in wearable interfaces with other types of sensors including, but not limited to, mechanomyography (MMG) sensors, sonomyography (SMG) sensors, and electrical impedance tomography (EIT) sensors.

[0120] In some embodiments, peripherals interface **1461** includes a near-field communication (NFC) component **1469**, a global-position system (GPS) component **1470**, a long-term evolution (LTE) component **1471**, and/or a Wi-Fi and/or Bluetooth communication component **1472**. In some embodiments, peripherals interface **1461** includes one or more buttons **1473** (e.g., peripheral buttons **1323** and **1327** in FIG. 13), which, when selected by a user, cause operation to be performed at watch body **1320**. In some embodiments, the peripherals interface **1461** includes one or more indicators, such as a light emitting diode (LED), to provide a user with visual indicators (e.g., message received, low battery, active microphone and/or camera, etc.).

[0121] Watch body **1320** can include at least one display **1305** for displaying visual representations of information or data to a user, including user-interface elements and/or three-dimensional virtual objects. The display can also include a touch screen for inputting user inputs, such as touch gestures, swipe gestures, and the like. Watch body **1320** can include at least one speaker **1474** and at least one microphone **1475** for providing audio signals to the user and receiving audio input from the user. The user can provide user inputs through microphone **1475** and can also receive audio output from speaker **1474** as part of a haptic event provided by haptic controller **1478**. Watch body **1320** can include at least one camera **1425**, including a front camera **1425a** and a rear camera **1425b**. Cameras **1425** can include ultra-wide-angle cameras, wide angle cameras, fish-eye cameras, spherical cameras, telephoto cameras, depth-sensing cameras, or other types of cameras.

[0122] Watch body computing system 1460 can include one or more haptic controllers 1478 and associated componentry (e.g., haptic devices 1476) for providing haptic events at watch body 1320 (e.g., a vibrating sensation or audio output in response to an event at the watch body 1320). Haptic controllers 1478 can communicate with one or more haptic devices 1476, such as electroacoustic devices, including a speaker of the one or more speakers 1474 and/or other audio components and/or electromechanical devices that convert energy into linear motion such as a motor, solenoid, electroactive polymer, piezoelectric actuator, electrostatic actuator, or other tactile output generating components (e.g., a component that converts electrical signals into tactile outputs on the device). Haptic controller 1478 can provide haptic events to that are capable of being sensed by a user of watch body 1320. In some embodiments, one or more haptic controllers 1478 can receive input signals from an application of applications 1482.

[0123] In some embodiments, wearable band computing system 1430 and/or watch body computing system 1460 can include memory 1480, which can be controlled by one or more memory controllers of controllers 1477. In some embodiments, software components stored in memory 1480 include one or more applications 1482 configured to perform operations at the watch body 1320. In some embodiments, one or more applications 1482 may include games, word processors, messaging applications, calling applications, web browsers, social media applications, media streaming applications, financial applications, calendars, clocks, etc. In some embodiments, software components stored in memory 1480 include one or more communication interface modules 1483 as defined above. In some embodiments, software components stored in memory 1480 include one or more graphics modules 1484 for rendering, encoding, and/or decoding audio and/or visual data and one or more data management modules 1485 for collecting, organizing, and/or providing access to data 1487 stored in memory 1480. In some embodiments, one or more of applications 1482 and/or one or more modules can work in conjunction with one another to perform various tasks at the watch body 1320.

[0124] In some embodiments, software components stored in memory 1480 can include one or more operating systems 1481 (e.g., a Linux-based operating system, an Android operating system, etc.). Memory 1480 can also include data 1487. Data 1487 can include profile data 1488A, sensor data 1489A, media content data 1490, and application data 1491.

[0125] It should be appreciated that watch body computing system 1460 is an example of a computing system within watch body 1320, and that watch body 1320 can have more or fewer components than shown in watch body computing system 1460, can combine two or more components, and/or can have a different configuration and/or arrangement of the components. The various components shown in watch body computing system 1460 are implemented in hardware, software, firmware, or a combination thereof, including one or more signal processing and/or application-specific integrated circuits.

[0126] Turning to the wearable band computing system 1430, one or more components that can be included in wearable band 1310 are shown. Wearable band computing system 1430 can include more or fewer components than shown in watch body computing system 1460, can combine two or more components, and/or can have a different configuration and/or arrangement of some or all of the compo-

nents. In some embodiments, all, or a substantial portion of the components of wearable band computing system 1430 are included in a single integrated circuit. Alternatively, in some embodiments, components of wearable band computing system 1430 are included in a plurality of integrated circuits that are communicatively coupled. As described above, in some embodiments, wearable band computing system 1430 is configured to couple (e.g., via a wired or wireless connection) with watch body computing system 1460, which allows the computing systems to share components, distribute tasks, and/or perform other operations described herein (individually or as a single device).

[0127] Wearable band computing system 1430, similar to watch body computing system 1460, can include one or more processors 1449, one or more controllers 1447 (including one or more haptics controllers 1448), a peripherals interface 1431 that can include one or more sensors 1413 and other peripheral devices, a power source (e.g., a power system 1456), and memory (e.g., a memory 1450) that includes an operating system (e.g., an operating system 1451), data (e.g., data 1454 including profile data 1488B, sensor data 1489B, etc.), and one or more modules (e.g., a communications interface module 1452, a data management module 1453, etc.).

[0128] One or more of sensors 1413 can be analogous to sensors 1421 of watch body computing system 1460. For example, sensors 1413 can include one or more coupling sensors 1432, one or more SpO2 sensors 1434, one or more EMG sensors 1435, one or more capacitive sensors 1436, one or more heart rate sensors 1437, and one or more IMU sensors 1438.

[0129] Peripherals interface 1431 can also include other components analogous to those included in peripherals interface 1461 of watch body computing system 1460, including an NFC component 1439, a GPS component 1440, an LTE component 1441, a Wi-Fi and/or Bluetooth communication component 1442, and/or one or more haptic devices 1446 as described above in reference to peripherals interface 1461. In some embodiments, peripherals interface 1431 includes one or more buttons 1443, a display 1433, a speaker 1444, a microphone 1445, and a camera 1455. In some embodiments, peripherals interface 1431 includes one or more indicators, such as an LED.

[0130] It should be appreciated that wearable band computing system 1430 is an example of a computing system within wearable band 1310, and that wearable band 1310 can have more or fewer components than shown in wearable band computing system 1430, combine two or more components, and/or have a different configuration and/or arrangement of the components. The various components shown in wearable band computing system 1430 can be implemented in one or more of a combination of hardware, software, or firmware, including one or more signal processing and/or application-specific integrated circuits.

[0131] Wrist-wearable device 1300 with respect to FIG. 13 is an example of wearable band 1310 and watch body 1320 coupled together, so wrist-wearable device 1300 will be understood to include the components shown and described for wearable band computing system 1430 and watch body computing system 1460. In some embodiments, wrist-wearable device 1300 has a split architecture (e.g., a split mechanical architecture, a split electrical architecture, etc.) between watch body 1320 and wearable band 1310. In other words, all of the components shown in wearable band

computing system **1430** and watch body computing system **1460** can be housed or otherwise disposed in a combined wrist-wearable device **1300** or within individual components of watch body **1320**, wearable band **1310**, and/or portions thereof (e.g., a coupling mechanism **1316** of wearable band **1310**).

[0132] The techniques described above can be used with any device for sensing neuromuscular signals but could also be used with other types of wearable devices for sensing neuromuscular signals (such as body-wearable or head-wearable devices that might have neuromuscular sensors closer to the brain or spinal column).

[0133] In some embodiments, wrist-wearable device **1300** can be used in conjunction with a head-wearable device (e.g., AR glasses **1500** and VR system **1610**) and/or an HIPD, and wrist-wearable device **1300** can also be configured to be used to allow a user to control any aspect of the artificial reality (e.g., by using EMG-based gestures to control user interface objects in the artificial reality and/or by allowing a user to interact with the touchscreen on the wrist-wearable device to also control aspects of the artificial reality). Having thus described example wrist-wearable devices, attention will now be turned to example head-wearable devices, such as AR glasses **1500** and VR headset **1610**.

[0134] FIGS. **15** to **17** show example artificial-reality systems, which can be used as or in connection with wrist-wearable device **1300**. In some embodiments, AR system **1500** includes an eyewear device **1502**, as shown in FIG. **15**. In some embodiments, VR system **1610** includes a head-mounted display (HMD) **1612**, as shown in FIGS. **16A** and **16B**. In some embodiments, AR system **1500** and VR system **1610** can include one or more analogous components (e.g., components for presenting interactive artificial-reality environments, such as processors, memory, and/or presentation devices, including one or more displays and/or one or more waveguides), some of which are described in more detail with respect to FIG. **17**. As described herein, a head-wearable device can include components of eyewear device **1502** and/or head-mounted display **1612**. Some embodiments of head-wearable devices do not include any displays, including any of the displays described with respect to AR system **1500** and/or VR system **1610**. While the example artificial-reality systems are respectively described herein as AR system **1500** and VR system **1610**, either or both of the example AR systems described herein can be configured to present fully-immersive virtual-reality scenes presented in substantially all of a user's field of view or subtler augmented-reality scenes that are presented within a portion, less than all, of the user's field of view.

[0135] FIG. **15** show an example visual depiction of AR system **1500**, including an eyewear device **1502** (which may also be described herein as augmented-reality glasses, and/or smart glasses). AR system **1500** can include additional electronic components that are not shown in FIG. **15**, such as a wearable accessory device and/or an intermediary processing device, in electronic communication or otherwise configured to be used in conjunction with the eyewear device **1502**. In some embodiments, the wearable accessory device and/or the intermediary processing device may be configured to couple with eyewear device **1502** via a coupling mechanism in electronic communication with a coupling sensor **1724** (FIG. **17**), where coupling sensor **1724** can detect when an electronic device becomes physically or

electronically coupled with eyewear device **1502**. In some embodiments, eyewear device **1502** can be configured to couple to a housing **1790** (FIG. **17**), which may include one or more additional coupling mechanisms configured to couple with additional accessory devices. The components shown in FIG. **15** can be implemented in hardware, software, firmware, or a combination thereof, including one or more signal-processing components and/or application-specific integrated circuits (ASICs).

[0136] Eyewear device **1502** includes mechanical glasses components, including a frame **1504** configured to hold one or more lenses (e.g., one or both lenses **1506-1** and **1506-2**). One of ordinary skill in the art will appreciate that eyewear device **1502** can include additional mechanical components, such as hinges configured to allow portions of frame **1504** of eyewear device **1502** to be folded and unfolded, a bridge configured to span the gap between lenses **1506-1** and **1506-2** and rest on the user's nose, nose pads configured to rest on the bridge of the nose and provide support for eyewear device **1502**, earpieces configured to rest on the user's ears and provide additional support for eyewear device **1502**, temple arms configured to extend from the hinges to the earpieces of eyewear device **1502**, and the like. One of ordinary skill in the art will further appreciate that some examples of AR system **1500** can include none of the mechanical components described herein. For example, smart contact lenses configured to present artificial reality to users may not include any components of eyewear device **1502**.

[0137] Eyewear device **1502** includes electronic components, many of which will be described in more detail below with respect to FIG. **17**. Some example electronic components are illustrated in FIG. **15**, including acoustic sensors **1525-1**, **1525-2**, **1525-3**, **1525-4**, **1525-5**, and **1525-6**, which can be distributed along a substantial portion of the frame **1504** of eyewear device **1502**. Eyewear device **1502** also includes a left camera **1539A** and a right camera **1539B**, which are located on different sides of the frame **1504**. Eyewear device **1502** also includes a processor **1548** (or any other suitable type or form of integrated circuit) that is embedded into a portion of the frame **1504**.

[0138] FIGS. **16A** and **16B** show a VR system **1610** that includes a head-mounted display (HMD) **1612** (e.g., also referred to herein as an artificial-reality headset, a head-wearable device, a VR headset, etc.), in accordance with some embodiments. As noted, some artificial-reality systems (e.g., AR system **1500**) may, instead of blending an artificial reality with actual reality, substantially replace one or more of a user's visual and/or other sensory perceptions of the real world with a virtual experience (e.g., AR systems **1100** and **1200**).

[0139] HMD **1612** includes a front body **1614** and a frame **1616** (e.g., a strap or band) shaped to fit around a user's head. In some embodiments, front body **1614** and/or frame **1616** include one or more electronic elements for facilitating presentation of and/or interactions with an AR and/or VR system (e.g., displays, IMUs, tracking emitter or detectors). In some embodiments, HMD **1612** includes output audio transducers (e.g., an audio transducer **1618**), as shown in FIG. **16B**. In some embodiments, one or more components, such as the output audio transducer(s) **1618** and frame **1616**, can be configured to attach and detach (e.g., are detachably attachable) to HMD **1612** (e.g., a portion or all of frame **1616**, and/or audio transducer **1618**), as shown in FIG. **16B**.

In some embodiments, coupling a detachable component to HMD 1612 causes the detachable component to come into electronic communication with HMD 1612.

[0140] FIGS. 16A and 16B also show that VR system 1610 includes one or more cameras, such as left camera 1639A and right camera 1639B, which can be analogous to left and right cameras 1539A and 1539B on frame 1504 of eyewear device 1502. In some embodiments, VR system 1610 includes one or more additional cameras (e.g., cameras 1639C and 1639D), which can be configured to augment image data obtained by left and right cameras 1639A and 1639B by providing more information. For example, camera 1639C can be used to supply color information that is not discerned by cameras 1639A and 1639B. In some embodiments, one or more of cameras 1639A to 1639D can include an optional IR cut filter configured to remove IR light from being received at the respective camera sensors.

[0141] FIG. 17 illustrates a computing system 1720 and an optional housing 1790, each of which show components that can be included in AR system 1500 and/or VR system 1610. In some embodiments, more or fewer components can be included in optional housing 1790 depending on practical restraints of the respective AR system being described.

[0142] In some embodiments, computing system 1720 can include one or more peripherals interfaces 1722A and/or optional housing 1790 can include one or more peripherals interfaces 1722B. Each of computing system 1720 and optional housing 1790 can also include one or more power systems 1742A and 1742B, one or more controllers 1746 (including one or more haptic controllers 1747), one or more processors 1748A and 1748B (as defined above, including any of the examples provided), and memory 1750A and 1750B, which can all be in electronic communication with each other. For example, the one or more processors 1748A and 1748B can be configured to execute instructions stored in memory 1750A and 1750B, which can cause a controller of one or more of controllers 1746 to cause operations to be performed at one or more peripheral devices connected to peripherals interface 1722A and/or 1722B. In some embodiments, each operation described can be powered by electrical power provided by power system 1742A and/or 1742B.

[0143] In some embodiments, peripherals interface 1722A can include one or more devices configured to be part of computing system 1720, some of which have been defined above and/or described with respect to the wrist-wearable devices shown in FIGS. 13 and 14. For example, peripherals interface 1722A can include one or more sensors 1723A. Some example sensors 1723A include one or more coupling sensors 1724, one or more acoustic sensors 1725, one or more imaging sensors 1726, one or more EMG sensors 1727, one or more capacitive sensors 1728, one or more IMU sensors 1729, and/or any other types of sensors explained above or described with respect to any other embodiments discussed herein.

[0144] In some embodiments, peripherals interfaces 1722A and 1722B can include one or more additional peripheral devices, including one or more NFC devices 1730, one or more GPS devices 1731, one or more LTE devices 1732, one or more Wi-Fi and/or Bluetooth devices 1733, one or more buttons 1734 (e.g., including buttons that are slidable or otherwise adjustable), one or more displays 1735A and 1735B, one or more speakers 1736A and 1736B, one or more microphones 1737, one or more cameras 1738A and 1738B (e.g., including the left camera 1739A and/or a

right camera 1739B), one or more haptic devices 1740, and/or any other types of peripheral devices defined above or described with respect to any other embodiments discussed herein.

[0145] AR systems can include a variety of types of visual feedback mechanisms (e.g., presentation devices). For example, display devices in AR system 1500 and/or VR system 1610 can include one or more liquid-crystal displays (LCDs), light emitting diode (LED) displays, organic LED (OLED) displays, and/or any other suitable types of display screens. Artificial-reality systems can include a single display screen (e.g., configured to be seen by both eyes), and/or can provide separate display screens for each eye, which can allow for additional flexibility for varifocal adjustments and/or for correcting a refractive error associated with a user's vision. Some embodiments of AR systems also include optical subsystems having one or more lenses (e.g., conventional concave or convex lenses, Fresnel lenses, or adjustable liquid lenses) through which a user can view a display screen.

[0146] For example, respective displays 1735A and 1735B can be coupled to each of the lenses 1506-1 and 1506-2 of AR system 1500. Displays 1735A and 1735B may be coupled to each of lenses 1506-1 and 1506-2, which can act together or independently to present an image or series of images to a user. In some embodiments, AR system 1500 includes a single display 1735A or 1735B (e.g., a near-eye display) or more than two displays 1735A and 1735B. In some embodiments, a first set of one or more displays 1735A and 1735B can be used to present an augmented-reality environment, and a second set of one or more display devices 1735A and 1735B can be used to present a virtual-reality environment. In some embodiments, one or more waveguides are used in conjunction with presenting artificial-reality content to the user of AR system 1500 (e.g., as a means of delivering light from one or more displays 1735A and 1735B to the user's eyes). In some embodiments, one or more waveguides are fully or partially integrated into the eyewear device 1502. Additionally, or alternatively to display screens, some artificial-reality systems include one or more projection systems. For example, display devices in AR system 1500 and/or VR system 1610 can include micro-LED projectors that project light (e.g., using a waveguide) into display devices, such as clear combiner lenses that allow ambient light to pass through. The display devices can refract the projected light toward a user's pupil and can enable a user to simultaneously view both artificial-reality content and the real world. Artificial-reality systems can also be configured with any other suitable type or form of image projection system. In some embodiments, one or more waveguides are provided additionally or alternatively to the one or more display(s) 1735A and 1735B.

[0147] Computing system 1720 and/or optional housing 1790 of AR system 1500 or VR system 1610 can include some or all of the components of a power system 1742A and 1742B. Power systems 1742A and 1742B can include one or more charger inputs 1743, one or more PMICs 1744, and/or one or more batteries 1745A and 1744B.

[0148] Memory 1750A and 1750B may include instructions and data, some or all of which may be stored as non-transitory computer-readable storage media within the memories 1750A and 1750B. For example, memory 1750A and 1750B can include one or more operating systems 1751, one or more applications 1752, one or more communication

interface applications **1753A** and **1753B**, one or more graphics applications **1754A** and **1754B**, one or more AR processing applications **1755A** and **1755B**, and/or any other types of data defined above or described with respect to any other embodiments discussed herein.

[0149] Memory **1750A** and **1750B** also include data **1760A** and **1760B**, which can be used in conjunction with one or more of the applications discussed above. Data **1760A** and **1760B** can include profile data **1761**, sensor data **1762A** and **1762B**, media content data **1763A**, AR application data **1764A** and **1764B**, and/or any other types of data defined above or described with respect to any other embodiments discussed herein.

[0150] In some embodiments, controller **1746** of eyewear device **1502** may process information generated by sensors **1723A** and/or **1723B** on eyewear device **1502** and/or another electronic device within AR system **1500**. For example, controller **1746** can process information from acoustic sensors **1525-1** and **1525-2**. For each detected sound, controller **1746** can perform a direction of arrival (DOA) estimation to estimate a direction from which the detected sound arrived at eyewear device **1502** of AR system **1500**. As one or more of acoustic sensors **1725** (e.g., the acoustic sensors **1525-1**, **1525-2**) detects sounds, controller **1746** can populate an audio data set with the information (e.g., represented in FIG. 17 as sensor data **1762A** and **1762B**).

[0151] In some embodiments, a physical electronic connector can convey information between eyewear device **1502** and another electronic device and/or between one or more processors **1548**, **1748A**, **1748B** of AR system **1500** or VR system **1610** and controller **1746**. The information can be in the form of optical data, electrical data, wireless data, or any other transmittable data form. Moving the processing of information generated by eyewear device **1502** to an intermediary processing device can reduce weight and heat in the eyewear device, making it more comfortable and safer for a user. In some embodiments, an optional wearable accessory device (e.g., an electronic neckband) is coupled to eyewear device **1502** via one or more connectors. The connectors can be wired or wireless connectors and can include electrical and/or non-electrical (e.g., structural) components. In some embodiments, eyewear device **1502** and the wearable accessory device can operate independently without any wired or wireless connection between them.

[0152] In some situations, pairing external devices, such as an intermediary processing device (e.g., HIPD **906**, **1006**, **1106**) with eyewear device **1502** (e.g., as part of AR system **1500**) enables eyewear device **1502** to achieve a similar form factor of a pair of glasses while still providing sufficient battery and computation power for expanded capabilities. Some, or all, of the battery power, computational resources, and/or additional features of AR system **1500** can be provided by a paired device or shared between a paired device and eyewear device **1502**, thus reducing the weight, heat profile, and form factor of eyewear device **1502** overall while allowing eyewear device **1502** to retain its desired functionality. For example, the wearable accessory device can allow components that would otherwise be included on eyewear device **1502** to be included in the wearable accessory device and/or intermediary processing device, thereby shifting a weight load from the user's head and neck to one or more other portions of the user's body. In some embodiments, the intermediary processing device has a larger

surface area over which to diffuse and disperse heat to the ambient environment. Thus, the intermediary processing device can allow for greater battery and computation capacity than might otherwise have been possible on eyewear device **1502** standing alone. Because weight carried in the wearable accessory device can be less invasive to a user than weight carried in the eyewear device **1502**, a user may tolerate wearing a lighter eyewear device and carrying or wearing the paired device for greater lengths of time than the user would tolerate wearing a heavier eyewear device standing alone, thereby enabling an artificial-reality environment to be incorporated more fully into a user's day-to-day activities.

[0153] AR systems can include various types of computer vision components and subsystems. For example, AR system **1500** and/or VR system **1610** can include one or more optical sensors such as two-dimensional (2D) or three-dimensional (3D) cameras, time-of-flight depth sensors, structured light transmitters and detectors, single-beam or sweeping laser rangefinders, 3D LiDAR sensors, and/or any other suitable type or form of optical sensor. An AR system can process data from one or more of these sensors to identify a location of a user and/or aspects of the user's real-world physical surroundings, including the locations of real-world objects within the real-world physical surroundings. In some embodiments, the methods described herein are used to map the real world, to provide a user with context about real-world surroundings, and/or to generate digital twins (e.g., interactable virtual objects), among a variety of other functions. For example, FIGS. 16A and 16B show VR system **1610** having cameras **1639A** to **1639D**, which can be used to provide depth information for creating a voxel field and a two-dimensional mesh to provide object information to the user to avoid collisions.

[0154] In some embodiments, AR system **1500** and/or VR system **1610** can include haptic (tactile) feedback systems, which may be incorporated into headwear, gloves, body suits, handheld controllers, environmental devices (e.g., chairs or floor mats), and/or any other type of device or system, such as the wearable devices discussed herein. The haptic feedback systems may provide various types of cutaneous feedback, including vibration, force, traction, shear, texture, and/or temperature. The haptic feedback systems may also provide various types of kinesthetic feedback, such as motion and compliance. The haptic feedback may be implemented using motors, piezoelectric actuators, fluidic systems, and/or a variety of other types of feedback mechanisms. The haptic feedback systems may be implemented independently of other artificial-reality devices, within other artificial-reality devices, and/or in conjunction with other artificial-reality devices.

[0155] In some embodiments of an artificial reality system, such as AR system **1500** and/or VR system **1610**, ambient light (e.g., a live feed of the surrounding environment that a user would normally see) can be passed through a display element of a respective head-wearable device presenting aspects of the AR system. In some embodiments, ambient light can be passed through a portion less than is less than all of an AR environment presented within a user's field of view (e.g., a portion of the AR environment co-located with a physical object in the user's real-world environment that is within a designated boundary (e.g., a guardian boundary) configured to be used by the user while they are interacting with the AR environment). For example, a visual

user interface element (e.g., a notification user interface element) can be presented at the head-wearable device, and an amount of ambient light (e.g., 15-50% of the ambient light) can be passed through the user interface element such that the user can distinguish at least a portion of the physical environment over which the user interface element is being displayed.

[0156] The present disclosure also includes the following example embodiments:

[0157] Example 1. A battery assembly, including: a battery cell unit enclosed in a steel can; and a battery management unit overmolded to the steel can with an overmold material.

[0158] Example 2. The battery assembly of Example 1, further including a bracket extending from the steel can and into the overmold material.

[0159] Example 3. The battery assembly of Example 1 or Example 2, wherein the battery management unit includes a system in a package configured to manage charging and discharging of the battery cell unit.

[0160] Example 4. The battery assembly of any one of Examples 1 through 3, wherein the battery management unit includes an anode connector and a cathode connector disposed within the overmold material and respectively connecting the battery management unit to an anode and to a cathode of the battery cell unit.

[0161] Example 5. The battery assembly of any one of Examples 1 through 4, wherein the battery management unit is positioned at a longitudinal end of the steel can.

[0162] Example 6. The battery assembly of any one of Examples 1 through 5, wherein the overmold material includes a polymer material.

[0163] Example 7. The battery assembly of any one of Examples 1 through 6, wherein electrical contacts of the battery management unit are exposed through the overmold material.

[0164] Example 8. The battery assembly of any one of Examples 1 through 7, further including an electrical connector providing an electrical connection to the battery management unit, the electrical connector positioned outside of the overmold material.

[0165] Example 9. The battery assembly of Example 8, wherein the electrical connector includes at least one of: spring contacts; or a board-to-board connector.

[0166] Example 10. A battery assembly, including: a battery cell unit enclosed in a steel can; a battery management unit operatively coupled to the battery cell unit, wherein the battery management unit is configured to manage charging and discharging of the battery cell unit; and an overmold material surrounding at least a portion of the battery management unit, the overmold material at least partially coupling the battery management unit to the steel can.

[0167] Example 11. The battery assembly of Example 10, further including at least one bracket extending from the steel can and into the overmold material, wherein the at least one bracket further couples the battery management unit to the steel can.

[0168] Example 12. The battery assembly of Example 11, wherein the at least one bracket comprises a metal material.

[0169] Example 13. The battery assembly of Example 12, wherein the at least one bracket includes a first bracket and a second bracket, wherein the first bracket is configured to function as an anode connector between an anode of the battery cell unit and the battery management unit and the

second bracket is configured to function as a cathode connector between a cathode of the battery cell unit and the battery management unit.

[0170] Example 14. The battery assembly of any one of Examples 11 through 13, wherein the at least one bracket includes at least one through-hole, wherein the overmold material is formed to fill the at least one through-hole.

[0171] Example 15. The battery assembly of any one of Examples 10 through 14, wherein the battery management unit includes conductive contacts, wherein at least a portion of the conductive contacts are not covered by the overmold material.

[0172] Example 16. The battery assembly of any one of Examples 10 through 15, further including a resilient pad coupled to a side of the steel can to dampen movement of the battery assembly when installed in an electronic device.

[0173] Example 17. The battery assembly of any one of Examples 10 through 16, further including at least one retention clip coupled to the steel can for retaining the battery assembly when installed in an electronic device.

[0174] Example 18. The battery assembly of any one of Examples 10 through 17, further including a flexible connector extending from the overmold material for connecting the battery management unit to at least one of an electronic device or a charger.

[0175] Example 19. A battery assembly, including: a steel can containing a battery cell unit; a battery management unit operatively coupled to the battery cell unit and configured to manage charging and discharging of the battery cell unit, wherein the battery management unit is overmolded to the steel can with a polymer overmold material; and contacts electrically coupled to the battery management unit and configured for charging and discharging the battery cell unit, wherein at least a portion of the contacts are not covered by the polymer overmold material.

[0176] Example 20. The battery assembly of Example 19, wherein the steel can has an elongated rectangular prism shape and the battery management unit is coupled to a longitudinal end of the steel can.

[0177] The process parameters and sequence of the steps described and/or illustrated herein are given by way of example only and can be varied as desired. For example, while the steps illustrated and/or described herein may be shown or discussed in a particular order, these steps do not necessarily need to be performed in the order illustrated or discussed. The various example methods described and/or illustrated herein may also omit one or more of the steps described or illustrated herein or include additional steps in addition to those disclosed.

[0178] The preceding description has been provided to enable others skilled in the art to best utilize various aspects of the example embodiments disclosed herein. This example description is not intended to be exhaustive or to be limited to any precise form disclosed. Many modifications and variations are possible without departing from the spirit and scope of the present disclosure. The embodiments disclosed herein should be considered in all respects illustrative and not restrictive. Reference should be made to the appended claims and their equivalents in determining the scope of the present disclosure.

[0179] Unless otherwise noted, the terms “connected to” and “coupled to” (and their derivatives), as used in the specification and claims, are to be construed as permitting both direct and indirect (i.e., via other elements or compo-

nents) connection. In addition, the terms “a” or “an,” as used in the specification and claims, are to be construed as meaning “at least one of.” Finally, for ease of use, the terms “including” and “having” (and their derivatives), as used in the specification and claims, are interchangeable with and have the same meaning as the word “comprising.”

What is claimed is:

1. A battery assembly, comprising:
 - a battery cell unit enclosed in a steel can; and
 - a battery management unit overmolded to the steel can with an overmold material.
2. The battery assembly of claim 1, further comprising a bracket extending from the steel can and into the overmold material.
3. The battery assembly of claim 1, wherein the battery management unit comprises a system in a package configured to manage charging and discharging of the battery cell unit.
4. The battery assembly of claim 1, wherein the battery management unit comprises an anode connector and a cathode connector disposed within the overmold material and respectively connecting the battery management unit to an anode and to a cathode of the battery cell unit.
5. The battery assembly of claim 1, wherein the battery management unit is positioned at a longitudinal end of the steel can.
6. The battery assembly of claim 1, wherein the overmold material comprises a polymer material.
7. The battery assembly of claim 1, wherein electrical contacts of the battery management unit are exposed through the overmold material.
8. The battery assembly of claim 1, further comprising an electrical connector providing an electrical connection to the battery management unit, the electrical connector positioned outside of the overmold material.
9. The battery assembly of claim 8, wherein the electrical connector comprises at least one of:
 - spring contacts; or
 - a board-to-board connector.
10. A battery assembly, comprising:
 - a battery cell unit enclosed in a steel can;
 - a battery management unit operatively coupled to the battery cell unit, wherein the battery management unit is configured to manage charging and discharging of the battery cell unit; and
 - an overmold material surrounding at least a portion of the battery management unit, the overmold material at least partially coupling the battery management unit to the steel can.
11. The battery assembly of claim 10, further comprising at least one bracket extending from the steel can and into the

overmold material, wherein the at least one bracket further couples the battery management unit to the steel can.

12. The battery assembly of claim 11, wherein the at least one bracket comprises a metal material.

13. The battery assembly of claim 12, wherein the at least one bracket comprises a first bracket and a second bracket, wherein the first bracket is configured to function as an anode connector between an anode of the battery cell unit and the battery management unit and the second bracket is configured to function as a cathode connector between a cathode of the battery cell unit and the battery management unit.

14. The battery assembly of claim 11, wherein the at least one bracket includes at least one through-hole, wherein the overmold material is formed to fill the at least one through-hole.

15. The battery assembly of claim 10, wherein the battery management unit comprises conductive contacts, wherein at least a portion of the conductive contacts are not covered by the overmold material.

16. The battery assembly of claim 10, further comprising a resilient pad coupled to a side of the steel can to dampen movement of the battery assembly when installed in an electronic device.

17. The battery assembly of claim 10, further comprising at least one retention clip coupled to the steel can for retaining the battery assembly when installed in an electronic device.

18. The battery assembly of claim 10, further comprising a flexible connector extending from the overmold material for connecting the battery management unit to at least one of an electronic device or a charger.

19. A battery assembly, comprising:

a steel can containing a battery cell unit;

a battery management unit operatively coupled to the battery cell unit and configured to manage charging and discharging of the battery cell unit, wherein the battery management unit is overmolded to the steel can with a polymer overmold material; and

contacts electrically coupled to the battery management unit and configured for charging and discharging the battery cell unit, wherein at least a portion of the contacts are not covered by the polymer overmold material.

20. The battery assembly of claim 19, wherein the steel can has an elongated rectangular prism shape and the battery management unit is coupled to a longitudinal end of the steel can.

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