



(51) International Patent Classification:

A61B 5/0404 (2006.01) A61B 5/0428 (2006.01)
A61B 5/0408 (2006.01) A61B 5/0452 (2006.01)

(21) International Application Number:

PCT/US2016/031068

(22) International Filing Date:

5 May 2016 (05.05.2016)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

14/750,083 25 June 2015 (25.06.2015) US

(71) Applicant: INTEL CORPORATION [US/US]; 2200 Mission College Boulevard, Santa Clara, California 95054 (US).

(72) Inventors: BAXI, Amit S.; E-503, Raunak Park, Pokhran Road No.2, Thane (West) 400610 (IN). MAGESHKUMAR, Vincent S.; Jaydeep Co-op Hsg Society, Plot-32, Flat-101, Sector-18, Koparkhairane, Navi Mumbai 400709 (IN).

(74) Agents: RASKIN, Vladimir et al.; Schwabe, Williamson & Wyatt, P.C., 1211 SW 5th Avenue, Suite 1600, Portland, Oregon 97204 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,

[Continued on next page]

(54) Title: USER'S PHYSIOLOGICAL CONTEXT SENSING METHOD AND APPARATUS

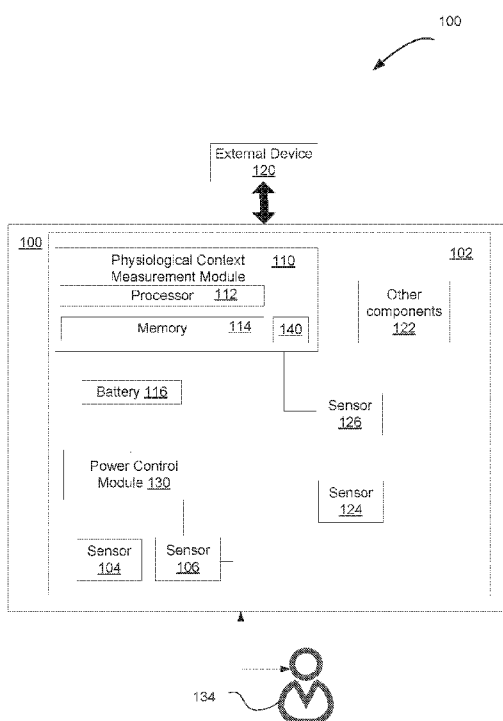


Fig. 1

(57) Abstract: Embodiments of the present disclosure provide techniques and configurations for an apparatus for providing a user's physiological context measurements. In one instance, the apparatus may include a physiological context measurement module including first and second electrodes, to obtain one or more parameters of physiological context of a user in response to a provision of contact of the first and second electrodes with a portion of the user's body while the physiological context measurement module is powered on; and a third electrode coupled with the module, which may be powered on in response to detection of contact between the user's body portion and the third electrode. The first, second, and third electrodes are disposed to facilitate simultaneous contact of the user's body portion with the electrodes, and collection of the one or more parameters of the physiological context while the simultaneous contact is maintained.



SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG). **Published:**

— *with international search report (Art. 21(3))*

5 **USER'S PHYSIOLOGICAL CONTEXT SENSING METHOD AND APPARATUS****Cross-Reference to Related Application**

 This application claims priority to U.S. Application No. 14/750,083, filed June 25, 2015, and entitled "USER'S PHYSIOLOGICAL CONTEXT SENSING METHOD AND
10 APPARATUS," which is hereby incorporated by reference herein in its entirety for all purposes.

Field

 Embodiments of the present disclosure generally relate to the field of sensor devices, and more particularly, to devices, such as wearable devices, configured to sense user's physiological
15 context for various applications, such as biometric authentication.

Background

 With advances in various technologies, wearable sensing devices or systems are increasingly popular. A wearable sensing system may need to be comfortably attached to the
20 human body, and may be able to measure and quantify various parameters of a user's physiological context, such as, for example, electrocardiogram (ECG), electromyogram (EMG), electroencephalogram (EEG), and the like, as well as provide user authentication based on biometric measurements, to enable "no password" device unlocking. However, the quality of a user's physiological context readings and performance of biometric authentication algorithms
25 (e.g., based on ECG readings) are highly dependent on the quality and repeatability of signals (e.g., ECG signals) sensed from the human body. The quality of ECG signals is dependent on the electrode material and the electrode-tissue impedance (ETI). ETI levels may vary dependent on the level of dryness of the hands of the user. This difference in ETI may affect the quality and repeatability of ECG signals and in turn, the accuracy of measurements of the user's
30 physiological context and biometric authentication.

Brief Description of the Drawings

 Embodiments will be readily understood by the following detailed description in conjunction with the accompanying drawings. To facilitate this description, like reference
35 numerals designate like structural elements. Embodiments are illustrated by way of example and not by way of limitation in the figures of the accompanying drawings.

5 FIG. 1 is a block diagram illustrating an example apparatus incorporated with the physiological context sensing technology of the present disclosure, in accordance with some embodiments.

 FIG. 2 is an example schematic diagram of an apparatus for providing a user's physiological context measurements, in accordance with some embodiments.

10 FIGS. 3-4 illustrate different views of an example apparatus of FIGS. 1-2 comprising a wearable device for providing a user's physiological context measurements, removably attachable to a user's wrist, in accordance with some embodiments.

 FIG. 5 is a process flow diagram for assembling a wearable apparatus for providing a user's physiological context measurements, in accordance with some embodiments.

15 FIG. 6 illustrates an example computing device suitable for use with various components of FIGS. 1-4, such as an apparatus for providing a user's physiological context measurements, in accordance with various embodiments.

Detailed Description

20 Embodiments of the present disclosure include techniques and configurations for an apparatus for a user's physiological context measurements. In accordance with embodiments, the apparatus may comprise a physiological context measurement module including first and second electrodes, to obtain one or more parameters of physiological context of a user in response to a provision of contact of the first and second electrodes with at least a portion of a
25 body of the user while the physiological context measurement module is powered on. The apparatus may further comprise a third electrode coupled with the physiological context measurement module, wherein the physiological context measurement module may be powered on in response to detection of contact between the user's body portion and the third electrode. The first, second, and third electrodes may be disposed in the apparatus to facilitate simultaneous
30 contact of the user's body portion with the first, second, and third electrodes, and to facilitate collection of the one or more parameters of the physiological context while the simultaneous contact is maintained. The apparatus may further include a fourth electrode coupled with the physiological context measurement module to provide a common reference signal for the first and second electrodes, wherein the physiological context measurement module may be powered
35 in response to the detection of contact between the user's body portion and the third and fourth electrodes.

 In the following detailed description, reference is made to the accompanying drawings that form a part hereof, wherein like numerals designate like parts throughout, and in which are

5 shown by way of illustration embodiments in which the subject matter of the present disclosure may be practiced. It is to be understood that other embodiments may be utilized and structural or logical changes may be made without departing from the scope of the present disclosure. Therefore, the following detailed description is not to be taken in a limiting sense, and the scope of embodiments is defined by the appended claims and their equivalents.

10 For the purposes of the present disclosure, the phrase “A and/or B” means (A), (B), (A) or (B), or (A and B). For the purposes of the present disclosure, the phrase “A, B, and/or C” means (A), (B), (C), (A and B), (A and C), (B and C), or (A, B, and C).

The description may use perspective-based descriptions such as top/bottom, in/out, over/under, and the like. Such descriptions are merely used to facilitate the discussion and are not intended to restrict the application of embodiments described herein to any particular orientation.

The description may use the phrases “in an embodiment,” or “in embodiments,” which may each refer to one or more of the same or different embodiments. Furthermore, the terms “comprising,” “including,” “having,” and the like, as used with respect to embodiments of the present disclosure, are synonymous.

20 The term “coupled with,” along with its derivatives, may be used herein. “Coupled” may mean one or more of the following. “Coupled” may mean that two or more elements are in direct physical, electrical, or optical contact. However, “coupled” may also mean that two or more elements indirectly contact each other, but yet still cooperate or interact with each other, and may mean that one or more other elements are coupled or connected between the elements that are said to be coupled with each other. The term “directly coupled” may mean that two or more elements are in direct contact.

FIG. 1 is a block diagram illustrating an example apparatus 100 incorporated with the physiological context technology of the present disclosure, in accordance with some embodiments. The apparatus 100 may be a device, such as a wearable device, configured to be attachable to a user’s body in order to conduct measurements associated with the functioning of the user’s body and user’s activities. In some embodiments, the apparatus 100 may comprise a mobile device, e.g., a tablet computer, a smartphone, a 1-in-2 computing device, or the like.

35 The apparatus 100 may include at least three or more sensors 104, 106, 124, 126. The sensors 124, 126 may be configured to monitor a process that is external to the apparatus 100. For example, in some embodiments, where the apparatus 100 comprises a wearable device, the sensors 124, 126 may provide readings of a user’s physiological context, such as, data related to various user body functions. More specifically, the sensors 124, 126 may include, but may not

5 be limited to, electrocardiogram (ECG) electrodes, electromyography (EMG) electrodes, electroencephalogram (EEG) electrodes, or the like. In embodiments, the sensors 124, 126 may further include temperature sensors, sweat chemical sensors, motion sensors, galvanic skin response (GSR) sensors, piezo crystals, pressure sensors, or the like. In some embodiments, the sensors 124, 126 may comprise capacitive electrodes configured to sense ECG data, for example.

10 In embodiments, the apparatus 100 may be configured to biometrically authenticate the user based at least in part on the collected parameters of the physiological context of the user.

The apparatus 100 may further include sensors 104 and 106 coupled with the sensors (capacitive electrodes) 124, 126. At least one of the sensors (e.g., 104) may be configured to detect contact with the at least a portion of a user's body 134. Another sensor, e.g., 106 may be

15 configured to provide a common reference signal for the sensors (capacitive electrodes) 124, 126. As will be described below in greater detail, sensor 106 may be further configured to inject current of a certain value into the user's body 134, to be detected by the sensor 104 in response to completion of the circuit via the user's body, to detect contact with at least a portion of the user's body 134.

20 The sensors 104, 106, 124, 126 may be disposed around a body 102 of the apparatus 100 in a particular arrangement, such as to provide a possibility for contact with at least a portion of a user's body 134. In embodiments, the body 102 may comprise a printed circuit board (PCB) disposed in the apparatus 100. For example, when the apparatus 100 comprises a wearable device, the sensors 104, 106, 124, 126 may be placed around the body 102 of the apparatus 100,

25 to enable simultaneous contact with the user's body 134. For example, sensors 104, 106, and one of the sensors (capacitive electrodes) 124 or 126 may be placed on one side (e.g., outer surface) of the body 102 of the apparatus 100, in proximity to each other, to enable simultaneous contact with a portion of the user's body 134, such as an index finger, when the user puts her finger on the sensors 104, 106, and one of 124, 126. Another one of the sensors (capacitive

30 electrodes) 124 or 126 may be placed on another, opposite side (e.g., inner surface) of the body 102 of the apparatus 100, to enable contact with the skin of the user's body 134. In another example, sensors 104, 106, 124, 126 may be placed on the same side of the body 102 of the apparatus 100, in proximity to each other, to enable simultaneous contact with a portion of the user's body 134. The disposition of the sensors 104, 106, 124, 126 around the body 102 of the

35 apparatus 100 will be discussed in detail in reference to FIGS. 3-5.

It should be noted that sensors 104, 106, 124, 126 are shown in FIG. 1 for illustration only and are not limiting the implementation of apparatus 100. It will be appreciated that any number or types of sensors may be used in the apparatus 100.

5 In some embodiments, the apparatus 100 may include a physiological context measurement module 110 coupled with the sensors (capacitive electrodes) 124, 126, to obtain one or more parameters of physiological context of a user sensed by the sensors 124, 126. The physiological context measurement module 110 may include a processor 112 and memory 114 having instructions that, when executed on the processor 112, may cause the processor 112 to
10 process readings of the user's physiological context provided by the sensors (capacitive electrodes) 124, 126. The physiological context measurement module 110 may further include module (e.g., circuitry) 140 configured to receive and pre-process readings provided by the sensors 124, 126, and provide pre-processed readings to the processor 112 for further processing. In general, the control module 130 may have hardware or software implementation, or a
15 combination thereof. The components of the physiological context measurement module 110, such as circuitry 140, are described in greater detail in reference to FIG. 2.

 The apparatus 100 may include a battery 116 configured to provide power supply to the apparatus 100 and, more generally, to the components of the apparatus 100, for example, to physiological context measurement module 110.

20 The apparatus 100 may include other components 122 necessary for the functioning of the apparatus 100. For example, other components 122 may include communications interface(s) to enable the apparatus 100 to communicate over one or more wired or wireless network(s) and/or with any other suitable device, such as external device 120 (e.g., mobile or stationary computing device). For example, the other components 122 may include a transmitter
25 to transmit a communication signal provided by the apparatus 100 to different destinations, such as to external device 120. The other components 122 may be further configured to perform signal pre-processing before transmission of sensed signals via the transmitter, such as de-noising, feature extraction, classification, data compression, and the like.

 To enable a user's physiological context measurements, the apparatus 100 may include a
30 power control module 130 communicatively coupled with the sensors 104 and 106 and the battery 116, and configured to control the power supply provided by the battery 116 to the physiological context measurement module 110. The control module 130 may be configured to power on the physiological context measurement module 110 in response to detection of contact between a portion of the user's body 134 (e.g., a finger) and the sensor 104, or, in some
35 embodiments, with the sensors 104 and 106. For example, sensor 104 may detect a contact with a portion of the user's body 134 and provide a corresponding signal to the power control module 130. The power control module 130, in response to a receipt of the signal, may issue a control signal to the battery 116 to power on the physiological context measurement module 110, to

5 enable measurements and processing of the user's physiological context provided by the sensors 124, 126. An example implementation of the operation of the power management of the apparatus 100 will be described in greater detail in reference to FIG. 2.

FIG. 2 is an example schematic diagram of an apparatus for providing a user's physiological context measurements, in accordance with some embodiments. More specifically, the schematic diagram of FIG. 2 may provide at least partial implementation of the components of the apparatus 100 of FIG. 1. For purposes of simplicity, like components of FIGS. 1 and 2 are indicated by like numerals. In embodiments, the apparatus 100 illustrated in FIG. 2 may comprise a wearable device.

The apparatus 100 may include two sensors (e.g., capacitive ECG electrodes) 124 and 126. As briefly described in reference to FIG. 1, the sensors 124, 126 may be mounted on opposite surfaces of the PCB 102. The PCB 102 may be attachably coupled with a strap (not shown) attachable to the user's body (e.g., to the wrist or any other part, such as chest, neck, foot, arm, forehead, or the like). For example, sensor 124 may be mounted on the upper surface of the PCB 102 and sensor 126 may be mounted on the lower surface of the PCB 102. Accordingly, sensor 126 may always be in contact with the user's body because it is located on the underside of the PCB 102, which may be in substantially permanent contact with the user's body (e.g., by virtue of being strapped onto the wrist). Sensors 124, 126 may be connected as inputs to a differential amplifier OP2. OP2 may be configured to amplify the resultant readings of the user's physiological context, such ECG signal, and feed the signal to the input of the physiological context measurement module 110. More specifically, the signal from OP2 may be input into an analog to digital converter ADC for digitization. The ADC may provide the digitized readings to a microcontroller comprising processor 112 and memory 114.

The apparatus 100 may further include sensors 104, 106 that may serve as contact detection electrodes. To measure the user's physiological context (e.g., ECG), the user may be required to place the finger of their hand on the PCB 102 to make simultaneous contact with sensors 104, 106, 124. Because sensors 124, 126 are active capacitive electrodes, they may consume power in standby state. Accordingly, the apparatus 100 may be configured to power gate sensors 124, 126, amplifier OP2, and the physiological context measurement module 110 and power them on when simultaneous contact with at least sensors 104, 106, and 124 (and, in some embodiments, with 126) is detected by the contact detection circuit formed by sensors 104, 106, differential amplifier OP1 and the associated biasing resistors 210 and 212, shown in FIG. 2. More specifically, on placement of the user's finger on the sensors 104, 106, and 124, the bias current through the resistors 210 and 212 at input of OP1 may change, in response to bias

5 voltage provided by the V-bias voltage supply source, as shown. This current change may cause the differential amplifier OP1 to provide a corresponding signal 214 to the power control module 130, to trigger the power control module 130 to enable power (e.g., connect the battery 116, not shown in FIG. 2) to the physiological context measurement module 110, the sensors (capacitive electrodes) 124, 126, and differential amplifier OP2. Accordingly, sensors 124 and 126 may
 10 receive readings of the user's physiological context (e.g., ECG readings) and provide the readings to powered-on physiological context measurement module 110 for processing.

As soon as the finger is removed from the sensors 104, 106, and 124, the bias current of the differential amplifier OP1 may be restored to a nominal value, which may signal the power control module 130 to disable power supply to the sensors 124, 126, OP2, and physiological
 15 context measurement module 110. Additionally, electrode 106, which has an impedance path to ground below a threshold, may also serve as a common reference electrode (ECG-COM) for the capacitive electrodes 124 and 126, to reduce the common mode noise in the user's physiological context readings. Sensors 104 and 106 may be fabricated, for example, on a glass-epoxy
 20 substrate with gold plated copper contacts and separated by at least 1 mm distance, so as to avoid false triggering in humid environments. In embodiments, OP1, OP2, ADC, and resistor 210 and 212 may comprise circuitry 140 of FIG. 1.

FIGS. 3-4 illustrate different views of an example apparatus of FIGS. 1-2 comprising a wearable device for providing a user's physiological context measurements, removably attachable to a user's wrist, in accordance with some embodiments.

25 FIG. 3 illustrates a top view 350 and a bottom view 360 of a wearable device 300 removably attachable to the user's wrist, in accordance with some embodiments. The views 350 and 360 may include the components of the apparatus 100. As shown, the wearable device 300 may comprise a PCB 102 housing the components of apparatus 100 and disposed on a wrist band 304, attachable to the user's wrist 302. More specifically, the PCB 102 is shown as housing the
 30 capacitive sensor 124 and contact detection sensors 104, 106 on the top (outer) surface of the PCB 102, and the capacitive sensor 126 on the bottom (inner) surface of the PCB 102, to provide substantially simultaneous contact for the user's finger with sensors 104, 106, 124 (if placed on these sensors), and substantially permanent contact of the sensor 126 with the user's wrist 302 (when device 300 is placed on the user's wrist 302), to complete the circuit formed by the user's
 35 finger and the sensors 104, 106, 124 via the user's body, in response to a placement of the finger on the sensors 104, 106, 124. As shown, the sensors 104, 106, 124 are placed on the PCB 102 in proximity to each other, to facilitate simultaneous contact with the user's finger. A dummy

5 sensor shell 306 may be disposed on the inner surface of the PCB 102, opposite the sensors 104, 106, as shown.

It will be understood that the wristband implementation of the apparatus 100 is described for illustration only. In general, the apparatus for the user's physiological context described herein may be implemented as a biometric wearable device, a smart watch, or a mobile
10 computing device. The apparatus may include a wearable knee strap, a wearable chest strap, a wearable neck strap, a wearable wrist strap, or a wearable foot strap and be used in connection with knee bands, ankle caps, vests, garments, or the like. In principle, apparatus 100 may be applied to any human joint or body part, such as a knee, arm, neck, chest, forehead, or the like.

FIG. 4 illustrates the wearable device of FIG. 3 in operation, in accordance with some
15 embodiments. As shown, the wearable device 300 is placed on the user's wrist 302. The user may enable the measurements of his or her physiological context by the device 300 by placing index finger 402 of his or her other hand on top-side sensors (electrodes) 104, 106, 124 (not shown in FIG. 4) to ensure simultaneous contact with these electrodes. As discussed above, the provision of simultaneous contact with the sensors 104, 106, 124 enables powering on the
20 sensors 104, 106, and the physiological context measurement module 110, and the measurements of the user's physiological context may commence by the capacitive electrodes 124, 126 (not shown in FIG. 4) taking the readings from the user's index finger 402.

A wearable device implemented as described above may provide a number of advantages compared to conventional wearable sensor device solutions configured to measure a user's
25 physiological context. For example, using capacitive electrodes instead of conventional metal ones (e.g., for ECG sensing) may help reduce the adverse impact of dryness of hands on ECG measurements quality. Accordingly, ECG signal quality may improve even with different dryness levels of hands across an individual user and across a group of users using the wearable device described above. Better and more reliable ECG signal quality is an important factor in
30 reducing equal error rate, thereby making wrist-based ECG-based authentication more robust.

To improve performance of capacitive electrodes (124, 126 of FIG. 1) that may be susceptible to noise pickup (due to their high internal impedance and large capacitance), a third electrode (e.g., 106) may be used as a virtual ground reference electrode to improve common
mode rejection ratio (CMRR) of the readings sensed by capacitive electrodes. Utilizing a pair of
35 capacitive electrodes, in conjunction with a reference ground electrode, may result in better measurement (e.g., ECG) signal quality due to lesser baseline wandering, lesser low-frequency artifacts and reduced 50/60Hz mains interference.

5 The user's physiological context measurement circuits (e.g., electrodes 124, 126, OP2, and physiological context measurement module 110 as described in reference to FIG. 2) may be power gated to reduce standby power consumption. That is, the circuits and module 110 may be powered on in response to a detection of the user's body portion (e.g., a finger) simultaneously touching both electrode sets (e.g., 104-106 and 124-26). The four-electrode design may enable a
10 more robust measurement signal (e.g., ECG signal) quality and repeatability, for example, in a wrist worn form factor described in reference to FIGS. 3-4, compared to the conventional designs utilizing two or three dry metallic electrodes.

 FIG. 5 is a process flow diagram for assembling a wearable apparatus for providing a user's physiological context measurement, in accordance with some embodiments. The process
15 500 may comport with some of the apparatus embodiments described in reference to FIGS. 1-4. In alternate embodiments, the process 500 may be practiced with more or less operations, or a different order of the operations.

 The process 500 may begin at block 502 and include disposing a physiological context measurement module having first and second electrodes in a PCB, to obtain one or more
20 parameters of physiological context of a user in response to a contact of the first and second electrodes with at least a portion of a body of a user of the wearable device while the physiological context measurement module is powered on.

 At block 504, the process 500 may include disposing a third electrode in the PCB to facilitate simultaneous contact of the user's body portion with the first, second, and third
25 electrodes, wherein the physiological context measurement module is to be powered on in response to detection of contact between the user's body portion and the third electrode.

 At block 506, the process 500 may include providing a connection path between the physiological context measurement module and the third electrode, to enable collection of the one or more parameters of the physiological context while the simultaneous contact of the user's
30 body portion with the first, second, and third electrodes is maintained.

 At block 508, the process 500 may include disposing a power control module in the PCB; providing a connection path between the power control module and the physiological context measurement module; and providing a connection path between the power control module and the third electrode, to facilitate powering on of the physiological context measurement module,
35 wherein the power control module is to power on the physiological context measurement module in response to the detection of contact between the user's body portion and the third electrode.

 At block 510, the process 500 may include mounting a fourth electrode on the PCB, providing a connection path between the fourth electrode and the physiological context

5 measurement module, to provide a common reference signal for the first and second electrodes, and providing a connection path between the fourth electrode and the power control module, to enable powering on, by the power control module, the physiological context measurement module, in response to detection of contact between the user's body portion and the fourth electrode. The fourth electrode may be disposed in proximity to the first, second, and third
10 electrodes, to enable simultaneous contact of the user's body portion with the first, second, third, and fourth electrodes. The first, third, and fourth electrodes may be on a first surface of the PCB; and the second electrode may be disposed on the first surface of the PCB or on a second surface of the PCB, opposite the first surface.

FIG. 6 illustrates an example computing device 600 suitable for use with various
15 components of FIGS. 1-4, such as an apparatus for providing a user's physiological context measurements, in accordance with various embodiments. In some embodiments, various components of the example computing device 600 may be used to configure the apparatus 100 or wearable device 300. In some embodiments, various components of the example computing device 600 may be used to configure the external device 120. As shown, computing device 600
20 may include one or more processors or processor cores 602 and system memory 604. For the purpose of this application, including the claims, the terms "processor" and "processor cores" may be considered synonymous, unless the context clearly requires otherwise. The processor 602 may include any type of processors, such as a central processing unit (CPU), a microprocessor, and the like. The processor 602 may be implemented as an integrated circuit
25 having multi-cores, e.g., a multi-core microprocessor. The computing device 600 may include mass storage devices 606 (such as solid state drives, volatile memory (e.g., dynamic random-access memory (DRAM)), and so forth). In general, system memory 604 and/or mass storage devices 606 may be temporal and/or persistent storage of any type, including, but not limited to, volatile and non-volatile memory, optical, magnetic, and/or solid state mass storage, and so forth.
30 Volatile memory may include, but is not limited to, static and/or dynamic random-access memory. Non-volatile memory may include, but is not limited to, electrically erasable programmable read-only memory, phase change memory, resistive memory, and so forth. System memory 604 and/or mass storage devices 606 may include respective copies of programming instructions configured to perform operations related to apparatus 100, for
35 example, collectively denoted as computational logic 622.

The computing device 600 may further include input/output (I/O) devices 608 (such as a display, soft keyboard, touch sensitive screen, image capture device, and so forth) and communication interfaces 610 (such as network interface cards, modems, infrared receivers,

5 radio receivers (e.g., Near Field Communication (NFC), Bluetooth, WiFi, 4G/5G Long-Term Evolution (LTE)), and so forth).

The communication interfaces 610 may include communication chips (not shown) that may be configured to operate the device 600 in accordance with a Global System for Mobile Communication (GSM), General Packet Radio Service (GPRS), Universal Mobile
10 Telecommunications System (UMTS), High Speed Packet Access (HSPA), Evolved HSPA (E-HSPA), or LTE network. The communication chips may also be configured to operate in accordance with Enhanced Data for GSM Evolution (EDGE), GSM EDGE Radio Access Network (GERAN), Universal Terrestrial Radio Access Network (UTRAN), or Evolved
15 UTRAN (E-UTRAN). The communication chips may be configured to operate in accordance with Code Division Multiple Access (CDMA), Time Division Multiple Access (TDMA), Digital Enhanced Cordless Telecommunications (DECT), Evolution-Data Optimized (EV-DO), derivatives thereof, as well as any other wireless protocols that are designated as 3G, 4G, 5G, and beyond. The communication interfaces 610 may operate in accordance with other wireless protocols in other embodiments.

20 In embodiments, the computing device 600 may comprise the apparatus 100 of FIGS. 1-2 or device 300 of FIGS. 3-4. In some embodiments, the device 600 may include sensors 104, 106, 124, 126, and components of physiological context module 110 and power control module 130 disposed in PCB 102 as described herein.

The above-described computing device 600 elements may be coupled to each other via
25 system bus 612, which may represent one or more buses. In the case of multiple buses, they may be bridged by one or more bus bridges (not shown). Each of these elements may perform its conventional functions known in the art. In particular, system memory 604 and mass storage devices 606 may be employed to store a working copy and a permanent copy of the programming instructions implementing the operations associated with the apparatus 100 of FIG.
30 1. The various elements may be implemented by assembler instructions supported by processor(s) 602 or high-level languages that may be compiled into such instructions.

The permanent copy of the programming instructions of computational logic 622 may be placed into permanent storage devices 606 in the factory, or in the field, through, for example, a distribution medium (not shown), such as a compact disc (CD), or through communication
35 interfaces 610 (from a distribution server (not shown)). That is, one or more non-transitory distribution media having an implementation of the agent program may be employed to distribute the agent and to program various computing devices. In embodiments, the distribution media may be transitory, e.g., signals encoded with the instructions.

5 The number, capability, and/or capacity of the elements 608, 610, 612 may vary, depending on whether computing device 600 is used as a stationary computing device, such as a set-top box or desktop computer, or a mobile computing device, such as a tablet computing device, laptop computer, game console, or smartphone. Their constitutions are otherwise known, and accordingly will not be further described.

10 At least one of processors 602 may be packaged together with memory having computational logic 622 configured to practice aspects of embodiments described in reference to FIGS. 1-4. For one embodiment, at least one of processors 602 may be packaged together with memory having computational logic 622 to form a System in Package (SiP) or a System on Chip (SoC). For at least one embodiment, the SoC may be utilized in, e.g., but not limited to, a
15 computing device, such as external device 120 of FIG. 1. In another embodiment, the SoC may be utilized to form the physiological context measurement module 110 of FIG. 1.

 In various implementations, the computing device 600 may comprise a mobile device, a wearable device, a laptop, a netbook, a notebook, an ultrabook, a smartphone, a tablet, a personal digital assistant (PDA), or an ultra mobile PC. In further implementations, the computing device
20 600 may be any other electronic device that processes data.

 Example 1 is an apparatus, comprising a physiological context measurement module including first and second electrodes, to obtain one or more parameters of physiological context of a user in response to a provision of contact of the first and second electrodes with at least a portion of the body of the user while the physiological context measurement module is powered
25 on; and a third electrode coupled with the physiological context measurement module, wherein the physiological context measurement module is to be powered on in response to detection of contact between the user's body portion and the third electrode, wherein the first, second, and third electrodes are disposed in the apparatus to facilitate simultaneous contact of the user's body portion with the first, second, and third electrodes, and collection of the one or more parameters
30 of the physiological context while the simultaneous contact is maintained.

 Example 2 may include the subject matter of Example 1, further comprising: a power control module coupled with the physiological context measurement module and the third electrode, wherein the power control module is to power on the physiological context measurement module in response to the detection of contact between the user's body portion and
35 the third electrode.

 Example 3 may include the subject matter of Example 2, further comprising: a fourth electrode coupled with the physiological context measurement module to provide a common reference signal for the first and second electrodes, wherein the power control module is to

- 5 further power on the physiological context measurement module in response to detection of contact between the user's body portion and the fourth electrode.

Example 4 may include the subject matter of Example 3, wherein the first and second electrodes are capacitive electrodes, wherein the fourth electrode has impedance to ground that is below a threshold.

- 10 Example 5 may include the subject matter of Example 3, wherein the fourth electrode is further coupled to the power control module, wherein the power control module is to power on the physiological context measurement module in response to detection of contact between the user's body portion and the fourth electrode.

- 15 Example 6 may include the subject matter of Example 5, wherein the fourth electrode is disposed in the apparatus to enable simultaneous contact of the user's body portion with the first, second, third and fourth electrodes.

Example 7 may include the subject matter of Example 6, wherein the first, third, and fourth electrodes are disposed on a first surface of the apparatus.

- 20 Example 8 may include the subject matter of Example 7, wherein the second electrode is disposed on the first surface of the apparatus or on a second surface of the apparatus, opposite the first surface.

- 25 Example 9 may include the subject matter of Example 8, further comprising a printed circuit board (PCB), wherein the first and second surfaces comprise respective surfaces of the PCB, and wherein the physiological context measurement module and power control module are disposed in the PCB.

- 30 Example 10 may include the subject matter of Example 9, wherein the apparatus further includes: a first differential amplifier coupled to the third and fourth electrodes, wherein the third and fourth electrodes are coupled with first and second resistors respectively at an input of the first differential amplifier, wherein bias current of the differential amplifier passing through the first and second resistors is to change in response to the simultaneous contact; and wherein the power control module is coupled with the first differential amplifier, to receive a signal outputted by the differential amplifier in response to a change of the bias current, and to provide an output signal to power on the physiological context measurement module.

- 35 Example 11 may include the subject matter of Example 10, wherein the physiological context measurement module further includes: a second differential amplifier coupled with the first and second electrodes, to receive readings of the one or more parameters of the user's physiological context; an analog to digital controller (ADC) coupled with the second differential amplifier, to receive amplified readings of the one or more parameters provided by the second

5 differential amplifier and to digitize the amplified readings; and a processing unit coupled with the ADC, to receive and process the digitized readings.

Example 12 may include the subject matter of Example 11, wherein the third and fourth electrodes comprise a metal disposed on a glass epoxy substrate.

10 Example 13 may include the subject matter of Example 12, wherein the physiological context is selected from one of: electrocardiogram (ECG), electromyogram (EMG), or electroencephalogram (EEG), wherein the apparatus is to biometrically authenticate the user based at least in part on the collected one or more parameters of the physiological context of the user.

15 Example 14 may include the subject matter of Example 13, wherein the physiological context is ECG, and wherein the user's body portion is a finger.

Example 15 may include the subject matter of any of Examples 1 to 14, wherein the apparatus is a wearable device, wherein the wearable device comprises a wearable knee strap, a wearable chest strap, a wearable neck strap, a wearable wrist strap, or a wearable foot strap.

20 Example 16 is a wearable device, comprising: a printed circuit board (PCB), including: a physiological context measurement module including first and second capacitive electrodes to obtain one or more parameters of physiological context of a user in response to a provision of contact of the first and second electrodes with at least a portion of the body of the user while the physiological context measurement module is powered on; and a third electrode coupled with the physiological context measurement module, wherein the physiological context measurement
25 module is to be powered on in response to detection of contact between the user's body portion and the third electrode, wherein the first and second capacitive electrodes and the third electrode are disposed in the PCB to facilitate simultaneous contact of the user's body portion with the first and second capacitive electrodes and the third electrode, and collection of the one or more parameters of the physiological context while the simultaneous contact is maintained.

30 Example 17 may include the subject matter of Example 16, wherein the PCB further includes: a power control module coupled with the physiological context measurement module and the third electrode, wherein the power control module is to power on the physiological context measurement module in response to the detection of contact between the user's body portion and the third electrode.

35 Example 18 may include the subject matter of Example 17, wherein the PCB further includes: a fourth electrode coupled with the physiological context measurement module to provide a common reference signal for the first and second capacitive electrodes, wherein the fourth electrode has impedance to ground that is below a threshold, and wherein the fourth

5 electrode is further coupled to the power control module, wherein the power control module is to power on the physiological context measurement module in response to detection of contact between the user's body portion and the fourth electrode.

Example 19 may include the subject matter of Example 18, wherein the fourth electrode is disposed on the PCB to enable simultaneous contact of the user's body portion with the first,
10 second, third, and fourth electrodes.

Example 20 may include the subject matter of any of Examples 16 to 19, further comprising a strap, wherein the PCB is attachably coupled with the strap, wherein the wearable system is selected from one of: a biometric wearable device, a smart watch, or a mobile computing device.

15 Example 21 is a method of fabricating a wearable device, comprising: disposing a physiological context measurement module having first and second electrodes in a printed circuit board (PCB), to obtain one or more parameters of physiological context of a user in response to a contact of the first and second electrodes with at least a portion of a body of a user of the wearable device while the physiological context measurement module is powered on; disposing a
20 third electrode in the PCB to facilitate simultaneous contact of the user's body portion with the first, second, and third electrodes, wherein the physiological context measurement module is to be powered on in response to detection of contact between the user's body portion and the third electrode; and providing a connection path between the physiological context measurement module and the third electrode, to enable collection of the one or more parameters of the
25 physiological context while the simultaneous contact of the user's body portion with the first, second, and third electrodes is maintained.

Example 22 may include the subject matter of Example 21, further comprising: disposing a power control module in the PCB; providing a connection path between the power control module and the physiological context measurement module; and providing a connection path
30 between the power control module and the third electrode, to facilitate powering on of the physiological context measurement module, wherein the power control module is to power on the physiological context measurement module in response to the detection of contact between the user's body portion and the third electrode.

Example 23 may include the subject matter of Example 22, further comprising: mounting
35 a fourth electrode on the PCB; providing a connection path between the fourth electrode and the physiological context measurement module, to provide a common reference signal for the first and second electrodes; providing a connection path between the fourth electrode and the power control module, to enable powering on, by the power control module, the physiological context

5 measurement module, in response to detection of contact between the user's body portion and the fourth electrode.

Example 24 may include the subject matter of Example 23, wherein mounting a fourth electrode on the PCB includes disposing the fourth electrode in proximity to the first, second, and third electrodes, to enable simultaneous contact of the user's body portion with the first,
10 second, third, and fourth electrodes.

Example 25 may include the subject matter of Example 24, wherein mounting first, second, third, and fourth electrodes on the PCB includes: disposing the first, third, and fourth electrodes on a first surface of the PCB; and disposing the second electrode on the first surface of the PCB or on a second surface of the PCB, opposite the first surface.

15 Various operations are described as multiple discrete operations in turn, in a manner that is most helpful in understanding the claimed subject matter. However, the order of description should not be construed as to imply that these operations are necessarily order dependent. Embodiments of the present disclosure may be implemented into a system using any suitable hardware and/or software to configure as desired.

20 Although certain embodiments have been illustrated and described herein for purposes of description, a wide variety of alternate and/or equivalent embodiments or implementations calculated to achieve the same purposes may be substituted for the embodiments shown and described without departing from the scope of the present disclosure. This application is intended to cover any adaptations or variations of the embodiments discussed herein. Therefore,
25 it is manifestly intended that embodiments described herein be limited only by the claims and the equivalents thereof.

5

Claims

What is claimed is:

1. An apparatus, comprising:
a physiological context measurement module including first and second
10 electrodes, to obtain one or more parameters of physiological context of a user in response to a
provision of contact of the first and second electrodes with at least a portion of a body of the user
while the physiological context measurement module is powered on; and
a third electrode coupled with the physiological context measurement module,
wherein the physiological context measurement module is to be powered on in response to
15 detection of contact between the user's body portion and the third electrode, wherein the first,
second, and third electrodes are disposed in the apparatus to facilitate simultaneous contact of the
user's body portion with the first, second, and third electrodes, and collection of the one or more
parameters of the physiological context while the simultaneous contact is maintained.
- 20 2. The apparatus of claim 1, further comprising: a power control module
coupled with the physiological context measurement module and the third electrode, wherein the
power control module is to power on the physiological context measurement module in response
to the detection of contact between the user's body portion and the third electrode.
- 25 3. The apparatus of claim 2, further comprising: a fourth electrode coupled
with the physiological context measurement module to provide a common reference signal for
the first and second electrodes, wherein the power control module is to further power on the
physiological context measurement module in response to detection of contact between the
user's body portion and the fourth electrode.
- 30 4. The apparatus of claim 3, wherein the first and second electrodes are
capacitive electrodes, wherein the fourth electrode has impedance to ground that is below a
threshold.
- 35 5. The apparatus of claim 3, wherein the fourth electrode is further coupled
to the power control module, wherein the power control module is to power on the physiological
context measurement module in response to detection of contact between the user's body portion
and the fourth electrode.

5

6. The apparatus of claim 5, wherein the fourth electrode is disposed in the apparatus to enable simultaneous contact of the user's body portion with the first, second, third and fourth electrodes.

10

7. The apparatus of claim 6, wherein the first, third, and fourth electrodes are disposed on a first surface of the apparatus.

15

8. The apparatus of claim 7, wherein the second electrode is disposed on the first surface of the apparatus or on a second surface of the apparatus, opposite the first surface.

20

9. The apparatus of claim 8, further comprising a printed circuit board (PCB), wherein the first and second surfaces comprise respective surfaces of the PCB, and wherein the physiological context measurement module and power control module are disposed in the PCB.

25

10. The apparatus of claim 9, wherein the apparatus further includes:
a first differential amplifier coupled to the third and fourth electrodes, wherein the third and fourth electrodes are coupled with first and second resistors respectively at an input of the first differential amplifier, wherein bias current of the differential amplifier passing through the first and second resistors is to change in response to the simultaneous contact; and
wherein the power control module is coupled with the first differential amplifier, to receive a signal outputted by the differential amplifier in response to a change of the bias current, and to provide an output signal to power on the physiological context measurement module.

30

11. The apparatus of claim 10, wherein the physiological context measurement module further includes:

35

a second differential amplifier coupled with the first and second electrodes, to receive readings of the one or more parameters of the user's physiological context;
an analog to digital controller (ADC) coupled with the second differential amplifier, to receive amplified readings of the one or more parameters provided by the second differential amplifier and to digitize the amplified readings; and

5 a processing unit coupled with the ADC, to receive and process the digitized readings.

12. The apparatus of claim 11, wherein the third and fourth electrodes comprise a metal disposed on a glass epoxy substrate.

10

13. The apparatus of claim 12, wherein the physiological context is selected from one of: electrocardiogram (ECG), electromyogram (EMG), or electroencephalogram (EEG), wherein the apparatus is to biometrically authenticate the user based at least in part on the collected one or more parameters of the physiological context of the user.

15

14. The apparatus of claim 13, wherein the physiological context is ECG, and wherein the user's body portion is a finger.

15. The apparatus of any of claims 1 to 14, wherein the apparatus is a wearable device, wherein the wearable device comprises a wearable knee strap, a wearable chest strap, a wearable neck strap, a wearable wrist strap, or a wearable foot strap.

20

16. A wearable device, comprising:
a printed circuit board (PCB), including:

25

a physiological context measurement module including first and second capacitive electrodes to obtain one or more parameters of physiological context of a user in response to a provision of contact of the first and second electrodes with at least a portion of a body of the user while the physiological context measurement module is powered on; and

30

a third electrode coupled with the physiological context measurement module, wherein the physiological context measurement module is to be powered on in response to detection of contact between the user's body portion and the third electrode, wherein the first and second capacitive electrodes and the third electrode are disposed in the PCB to facilitate simultaneous contact of the user's body portion with the first and second capacitive electrodes and the third electrode, and collection of the one or more parameters of the physiological context while the simultaneous contact is maintained.

35

17. The wearable device of claim 16, wherein the PCB further includes:

5 a power control module coupled with the physiological context measurement module and the third electrode, wherein the power control module is to power on the physiological context measurement module in response to the detection of contact between the user's body portion and the third electrode.

10 18. The wearable device of claim 17, wherein the PCB further includes: a fourth electrode coupled with the physiological context measurement module to provide a common reference signal for the first and second capacitive electrodes, wherein the fourth electrode has impedance to ground that is below a threshold, and
 wherein the fourth electrode is further coupled to the power control module,
15 wherein the power control module is to power on the physiological context measurement module in response to detection of contact between the user's body portion and the fourth electrode.

 19. The wearable device of claim 18, wherein the fourth electrode is disposed on the PCB to enable simultaneous contact of the user's body portion with the first, second,
20 third, and fourth electrodes.

 20. The wearable device of any of claims 16 to 19, further comprising a strap, wherein the PCB is attachably coupled with the strap, wherein the wearable system is selected from one of: a biometric wearable device, a smart watch, or a mobile computing device.

25 21. A method of fabricating a wearable device, comprising:
 disposing a physiological context measurement module having first and second electrodes in a printed circuit board (PCB), to obtain one or more parameters of physiological context of a user in response to a contact of the first and second electrodes with at least a portion
30 of a body of a user of the wearable device while the physiological context measurement module is powered on;

 disposing a third electrode in the PCB to facilitate simultaneous contact of the user's body portion with the first, second, and third electrodes, wherein the physiological context measurement module is to be powered on in response to detection of contact between the user's
35 body portion and the third electrode; and

 providing a connection path between the physiological context measurement module and the third electrode, to enable collection of the one or more parameters of the

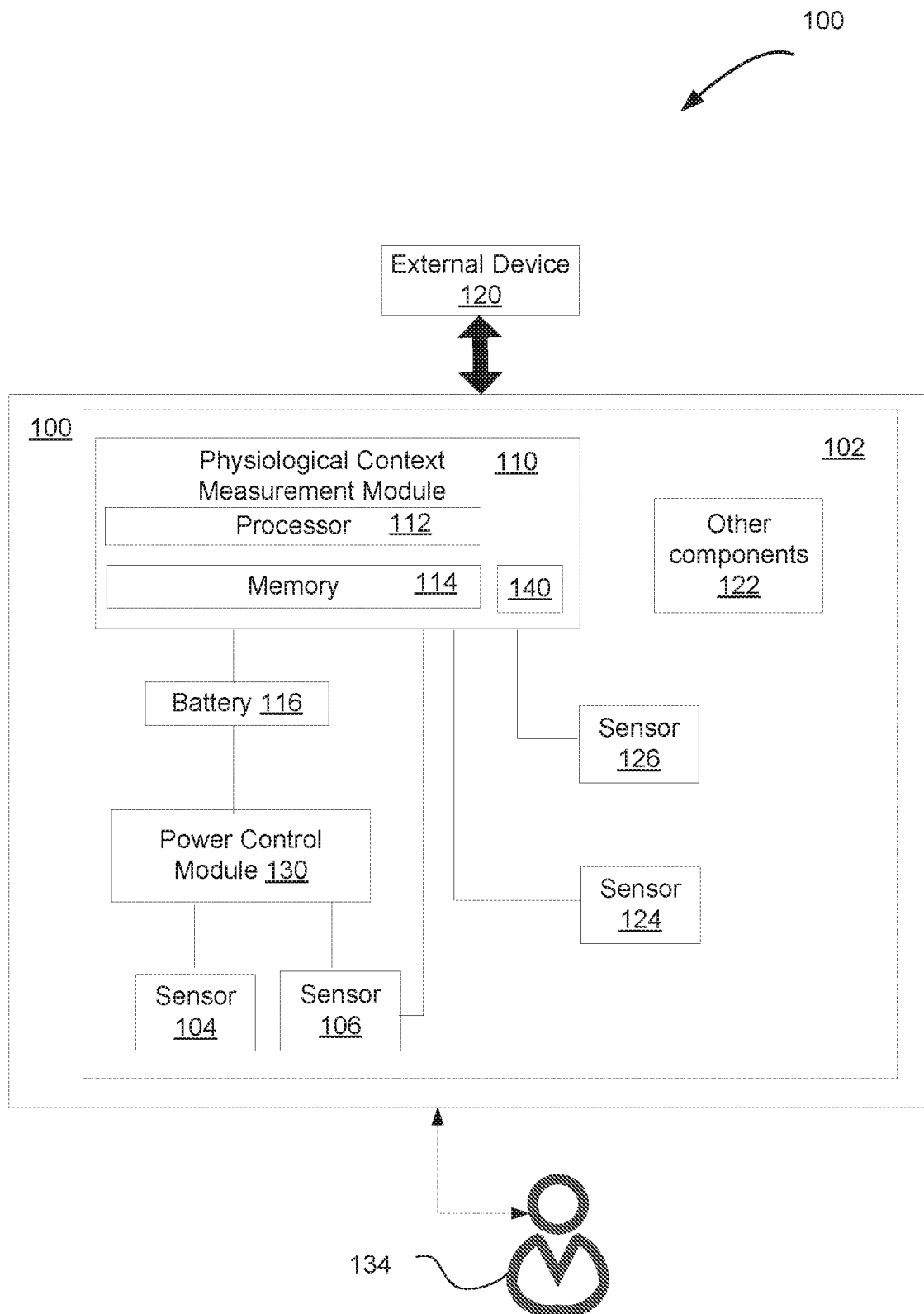
5 physiological context while the simultaneous contact of the user's body portion with the first, second, and third electrodes is maintained.

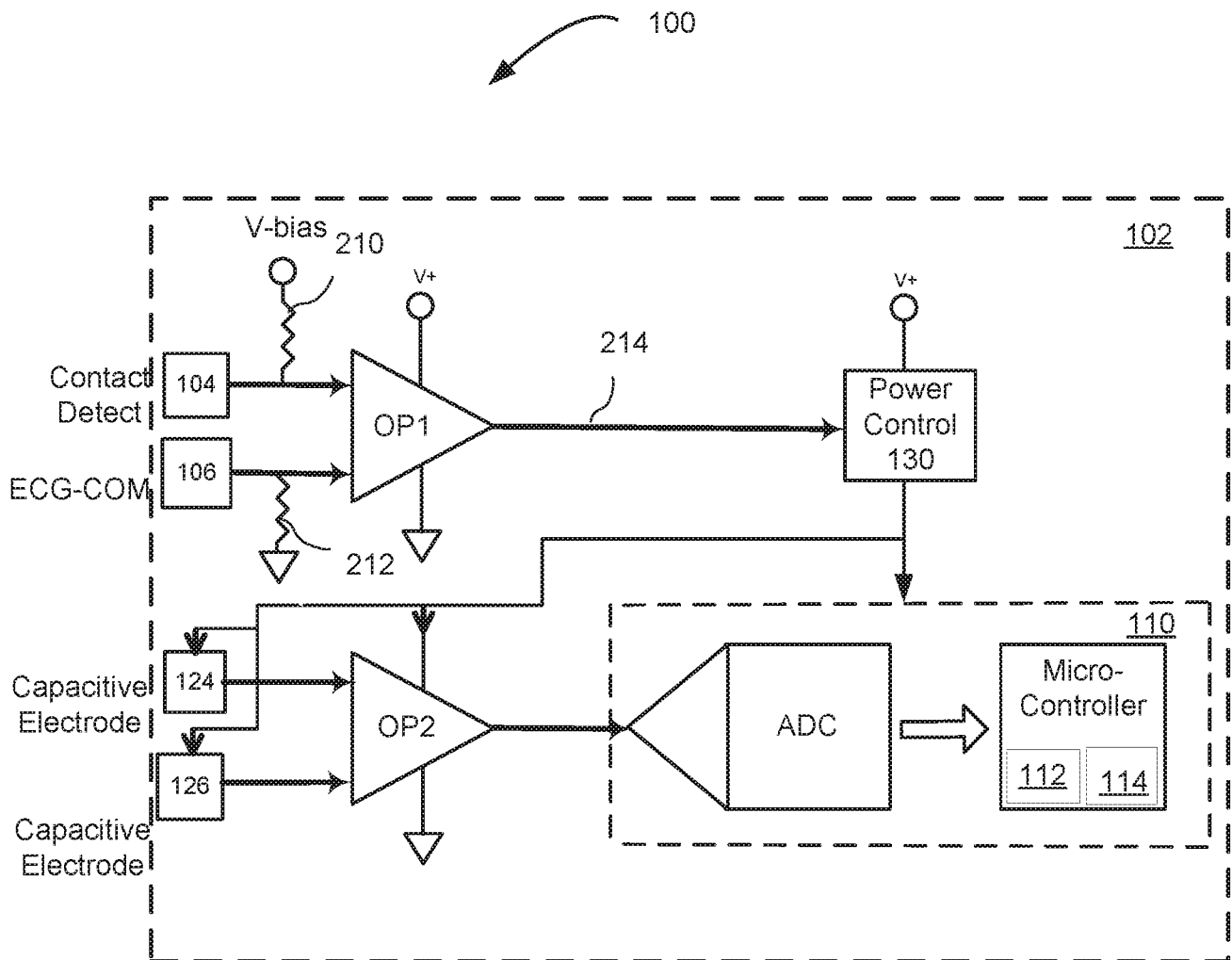
22. The method of claim 21, further comprising:
disposing a power control module in the PCB;
10 providing a connection path between the power control module and the physiological context measurement module; and
providing a connection path between the power control module and the third electrode, to facilitate powering on of the physiological context measurement module, wherein
the power control module is to power on the physiological context measurement module in
15 response to the detection of contact between the user's body portion and the third electrode.

23. The method of claim 22, further comprising:
mounting a fourth electrode on the PCB;
providing a connection path between the fourth electrode and the physiological
20 context measurement module, to provide a common reference signal for the first and second electrodes;
providing a connection path between the fourth electrode and the power control module, to enable powering on, by the power control module, the physiological context measurement module, in response to detection of contact between the user's body portion and
25 the fourth electrode.

24. The method of claim 23, wherein mounting a fourth electrode on the PCB includes disposing the fourth electrode in proximity to the first, second, and third electrodes, to enable simultaneous contact of the user's body portion with the first, second, third, and fourth
30 electrodes.

25. The method of claim 24, wherein mounting first, second, third, and fourth electrodes on the PCB includes:
disposing the first, third, and fourth electrodes on a first surface of the PCB; and
35 disposing the second electrode on the first surface of the PCB or on a second surface of the PCB, opposite the first surface.

**Fig. 1**

**Fig. 2**

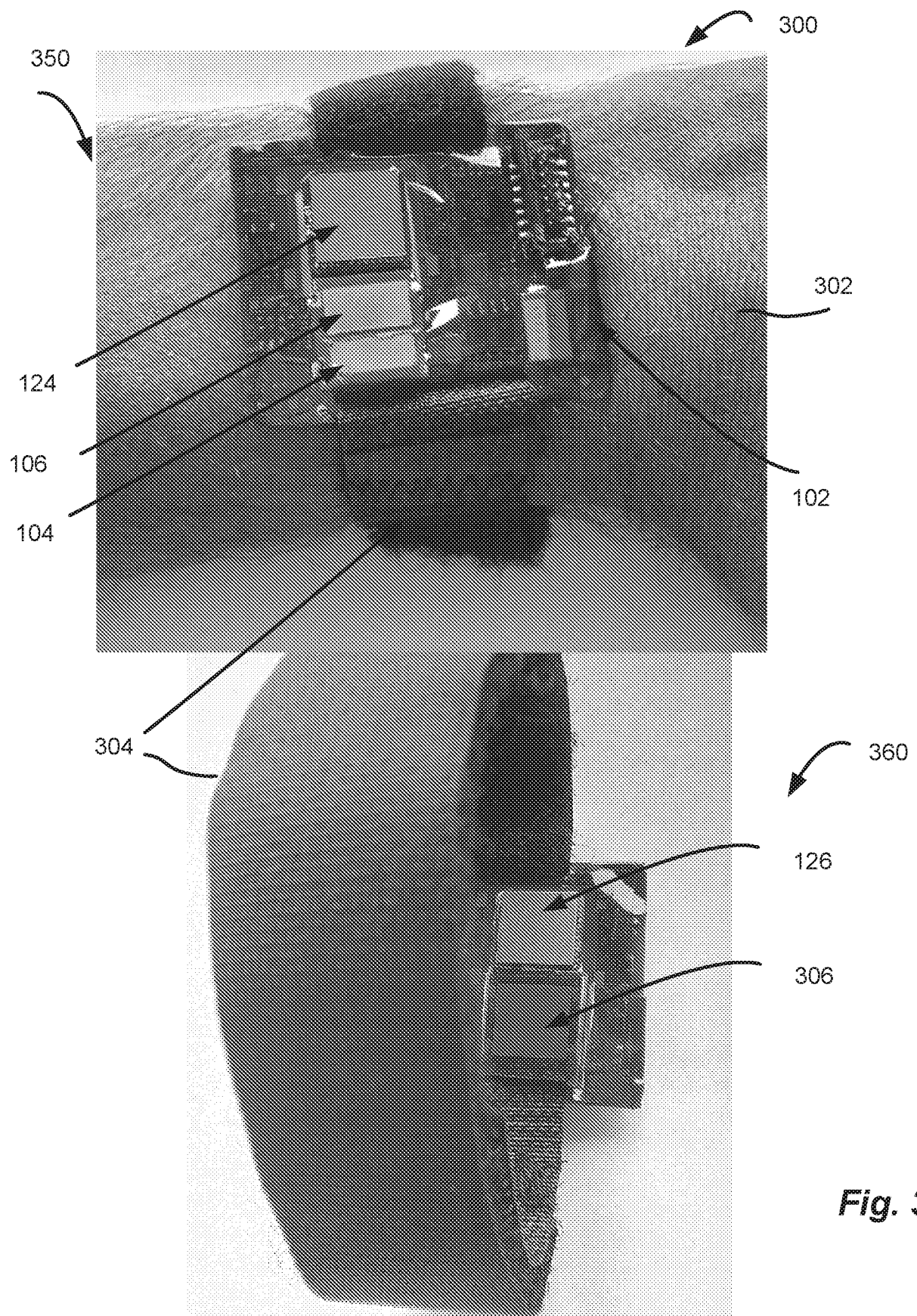


Fig. 3

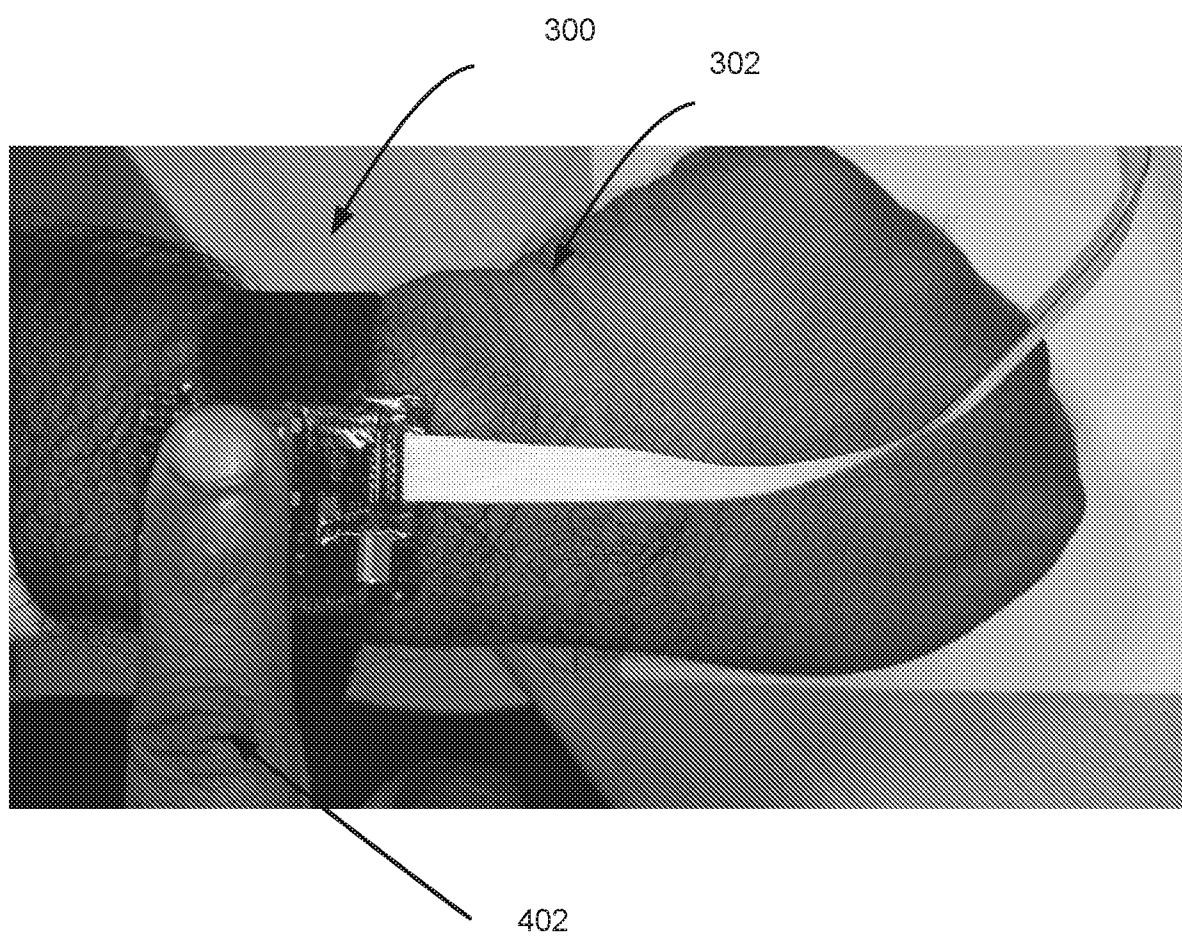
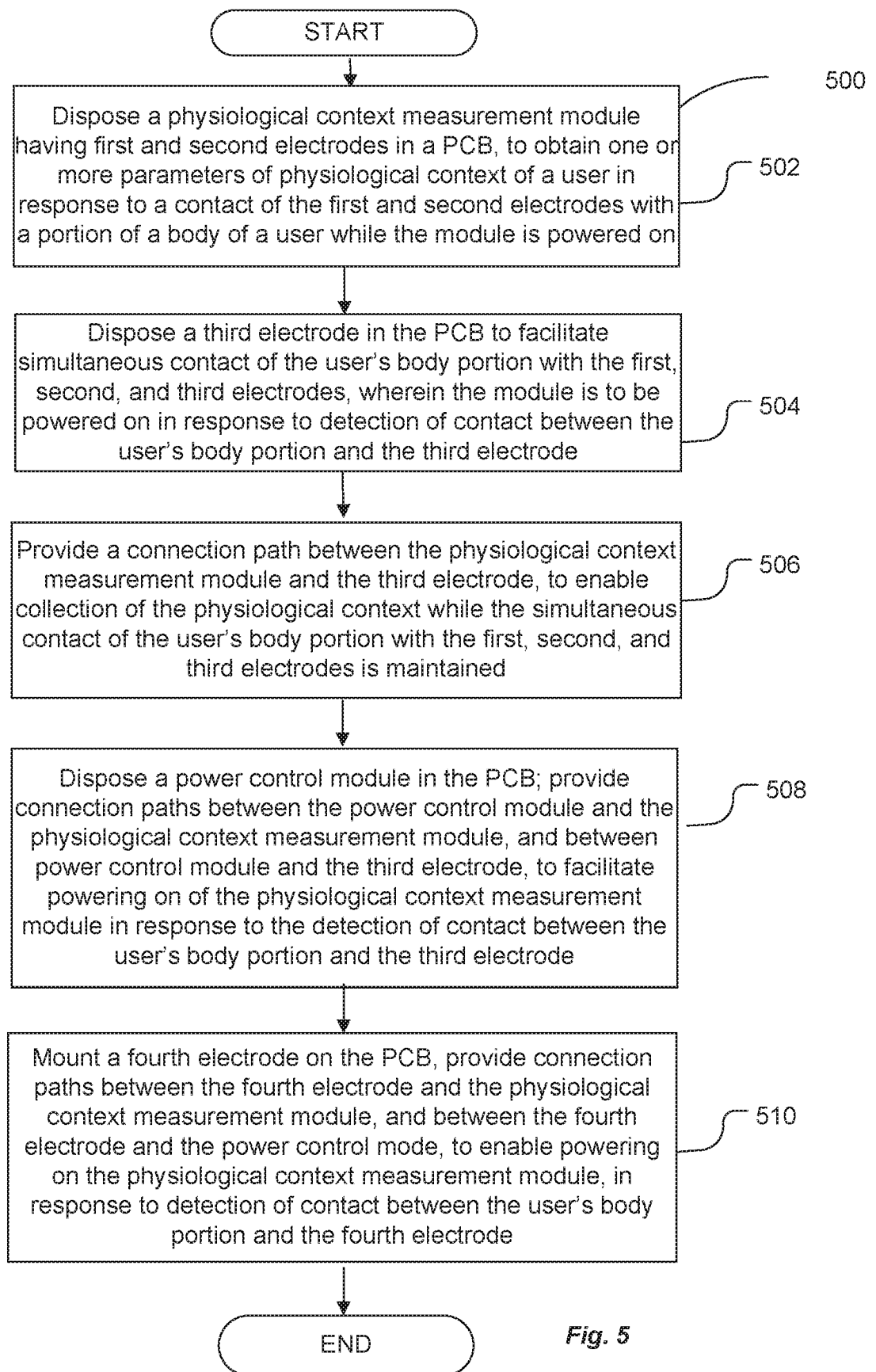
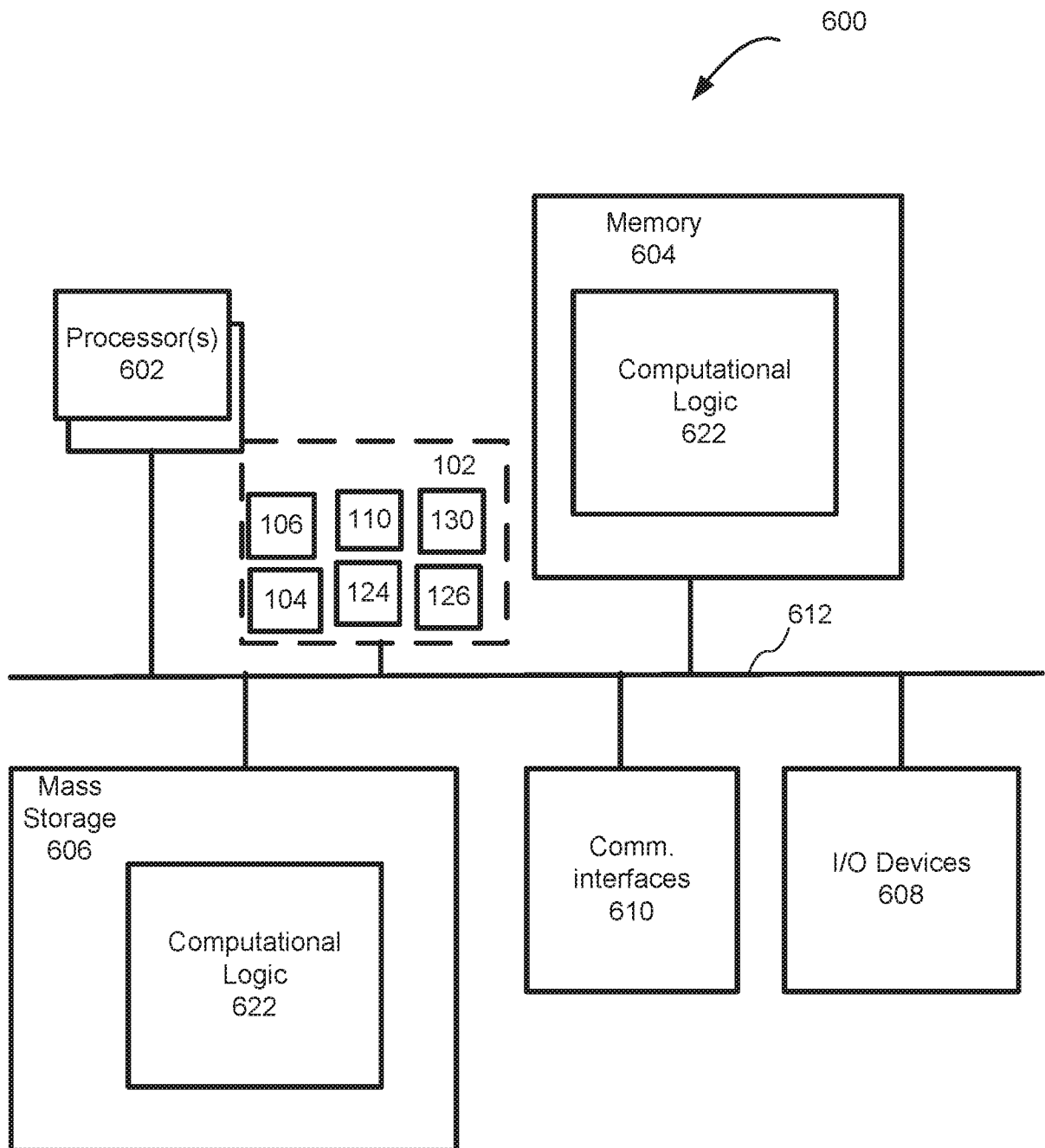


Fig. 4



**FIG. 6**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/031068**A. CLASSIFICATION OF SUBJECT MATTER****A61B 5/0404(2006.01)i, A61B 5/0408(2006.01)i, A61B 5/0428(2006.01)i, A61B 5/0452(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A61B 5/0404; A61B 5/04; A61B 5/01; A61B 5/053; A61B 5/11; A61B 5/22; A61B 5/0408; A61B 5/0428; A61B 5/0452

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: physiological, sensor, electrode, power, contact, body, EEG, EMG, ECG

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2006-0155183 A1 (STEPHAN V KROECKER et al.) 13 July 2006 See abstract, claims 1-9 and figures 1,2.	1-20
Y	US 2011-0092780 A1 (TAO ZHANG et al.) 21 April 2011 See abstract, paragraph [46], claim 1 and figures 1,6B.	1-20
Y	US 2012-0116198 A1 (JEROEN VEEN et al.) 10 May 2012 See abstract, paragraphs [78],[88], claims 1-12 and figures 2,5.	3-14, 18-19
A	WO 2014-043739 A1 (HEARD SYSTEMS PTY LTD.) 27 March 2014 See abstract, claim 1 and figures 1,2.	1-20
A	JP 2007-209430 A (SEIKO INSTRUMENTS INC.) 23 August 2007 See abstract, claims 1-8 and figures 1-4.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

10 August 2016 (10.08.2016)

Date of mailing of the international search report

11 August 2016 (11.08.2016)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

Facsimile No. +82-42-481-8578

Authorized officer

KIM, Yeon Kyung

Telephone No. +82-42-481-3325



Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 21-25
because they relate to subject matter not required to be searched by this Authority, namely:
Claims 21-25 pertain to a diagnostic methods, and thus relate to a subject matter which this International Searching Authority is not required to search under PCT Article 17(2)(a)(i) and PCT Rule 39.1(iv).
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of any additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/031068

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2006-0155183 A1	13/07/2006	AU 2002-308580 B2 CA 2445385 A1 EP 1383425 A1 JP 2004-529709 A KR 10-2003-0092120 A MX PA03010059 A NZ 529191 A US 7970450 B2 WO 02-089667 A1 ZA 200308435 A	08/03/2007 14/11/2002 28/01/2004 30/09/2004 03/12/2003 06/12/2004 29/09/2006 28/06/2011 14/11/2002 02/09/2004
US 2011-0092780 A1	21/04/2011	US 2011-0092790 A1 US 2011-0092791 A1 US 8311605 B2 US 8774893 B2	21/04/2011 21/04/2011 13/11/2012 08/07/2014
US 2012-0116198 A1	10/05/2012	CN 102469949 A CN 102469949 B EP 2453792 A1 JP 2012-532731 A JP 5602227 B2 WO 2011-007292 A1	23/05/2012 25/06/2014 23/05/2012 20/12/2012 08/10/2014 20/01/2011
WO 2014-043739 A1	27/03/2014	None	
JP 2007-209430 A	23/08/2007	JP 4822208 B2	24/11/2011