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(54) **WEARABLE DEVICES WITH PERSPIRATION MEASUREMENT CAPABILITIES**

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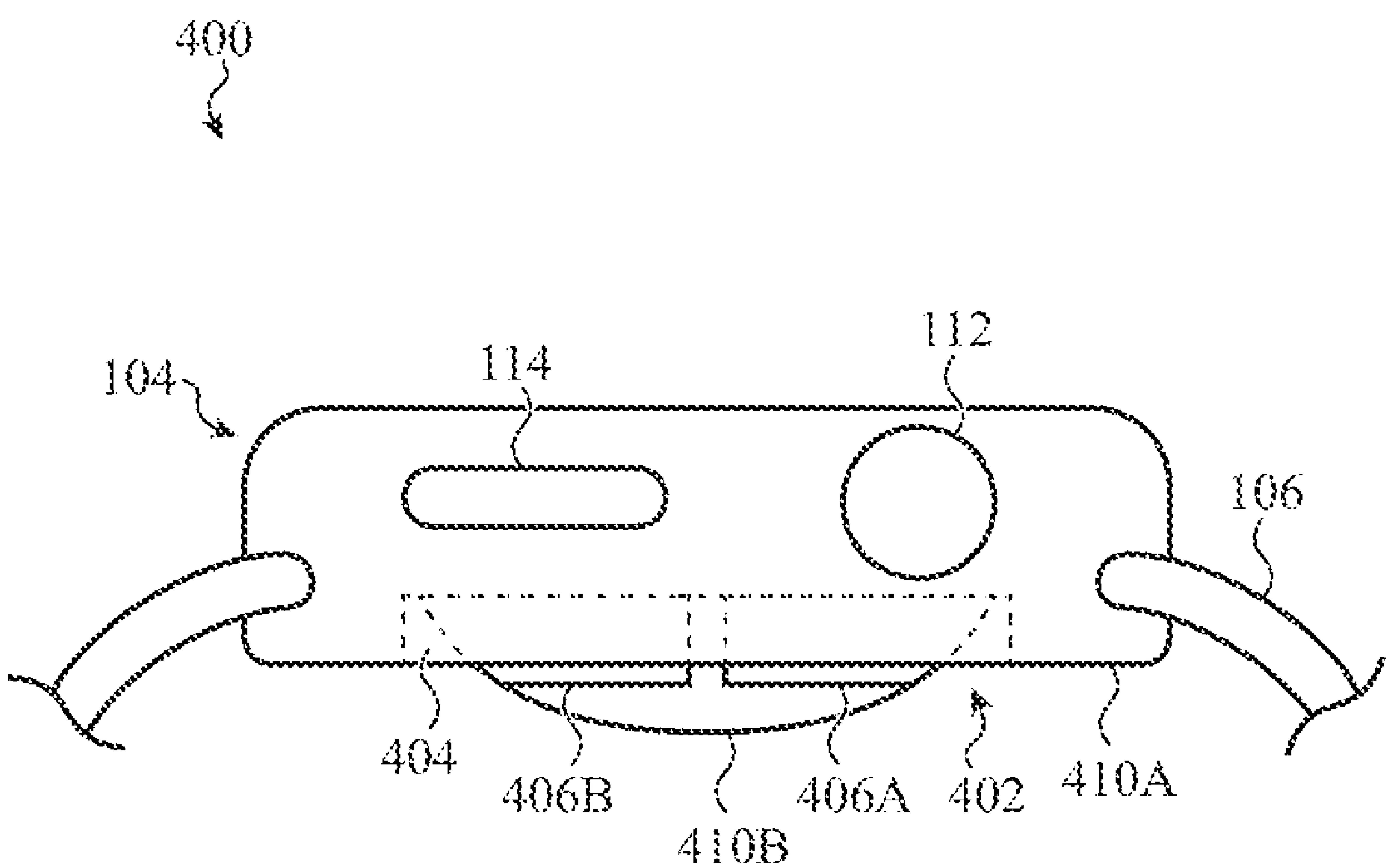
(57) **ABSTRACT**

Embodiments are directed to devices, systems and methods for determining a perspiration metric of a user. In some embodiments, a device may include a perspiration sensor having first and second electrodes positioned on a skin-facing exterior surface of the device. Capacitance circuitry may measure a capacitance between the electrodes, which may be used to calculate the perspiration metric. In some embodiments, the device defines a cavity such that one or both of the electrodes extend at least partially into the cavity. Other embodiments include a second perspiration sensor, and measurements from the second perspiration sensor may be used in calculating the perspiration metric.



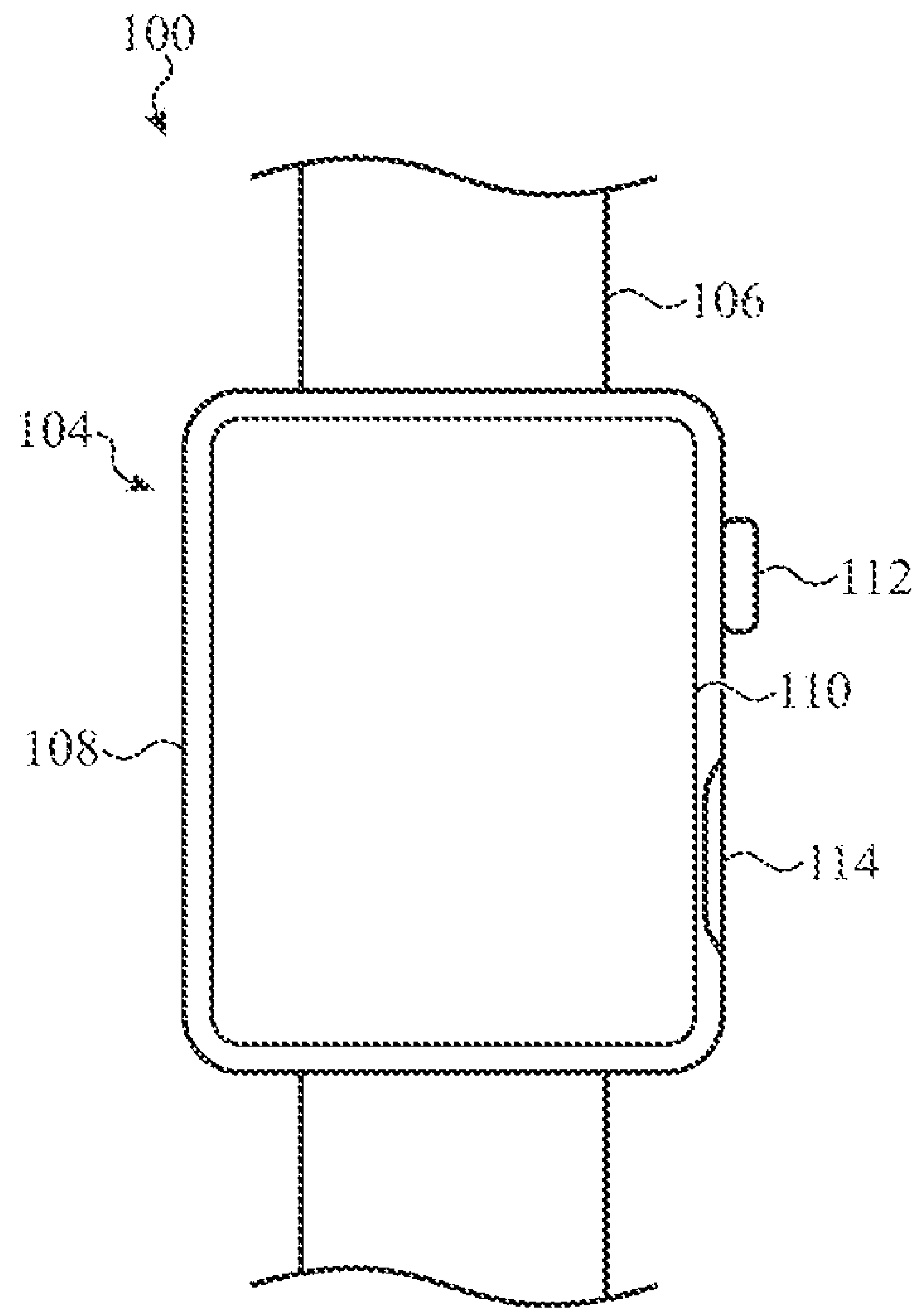

100
106
104
112
110
108
114

FIG. 1A

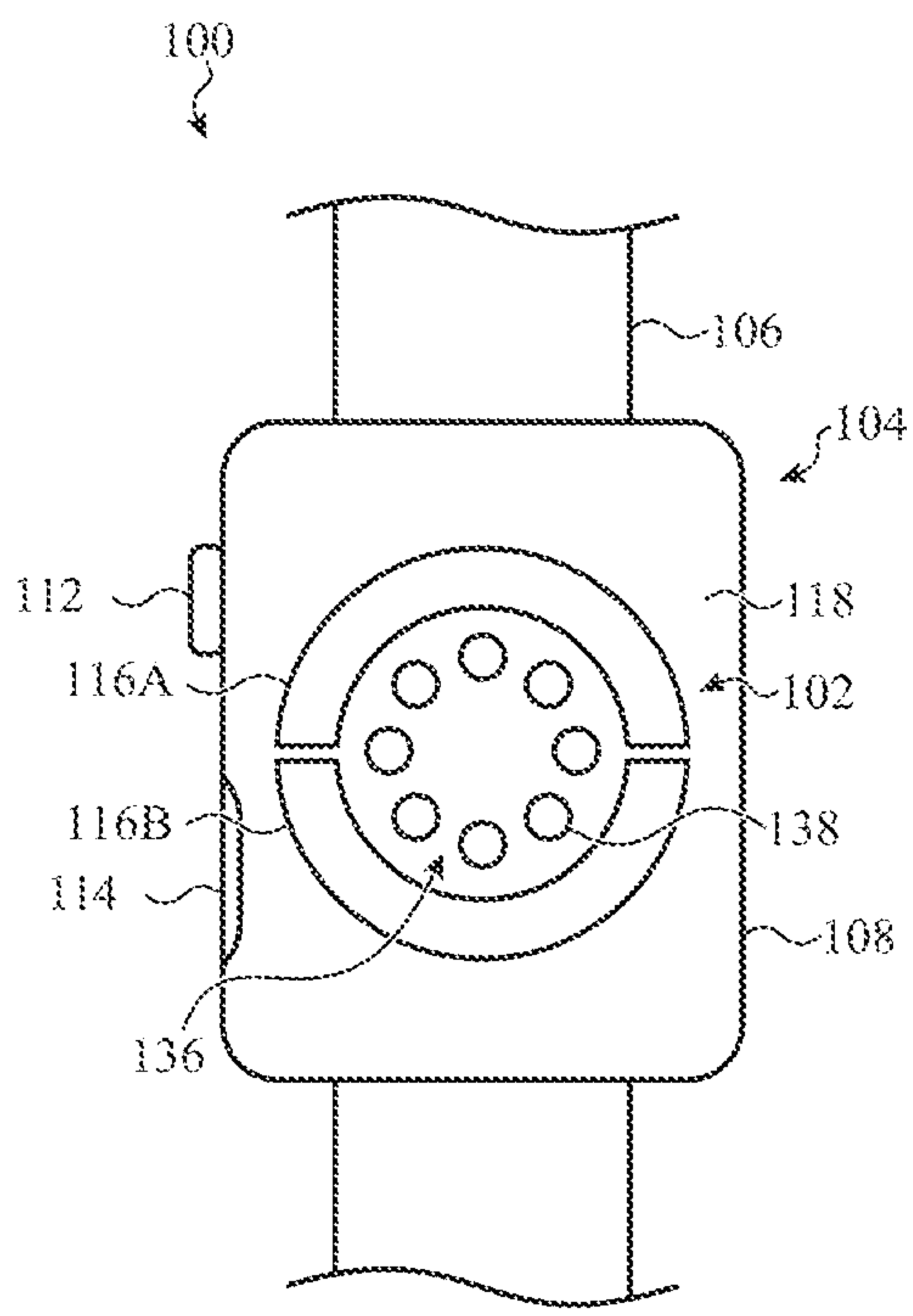

100
106
104
112
118
116A
102
116B
138
114
108
136

FIG. 1B

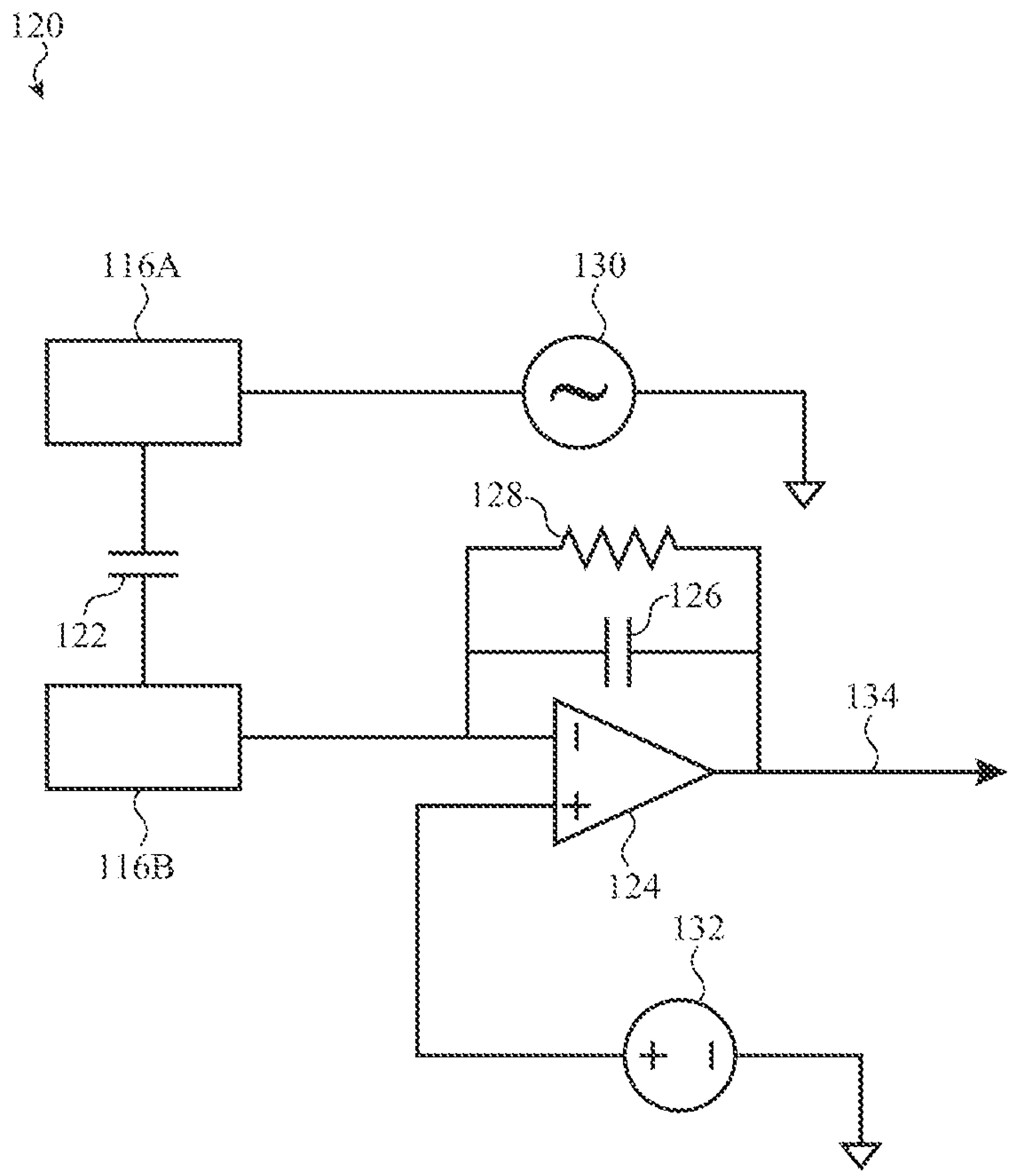


FIG. 1C

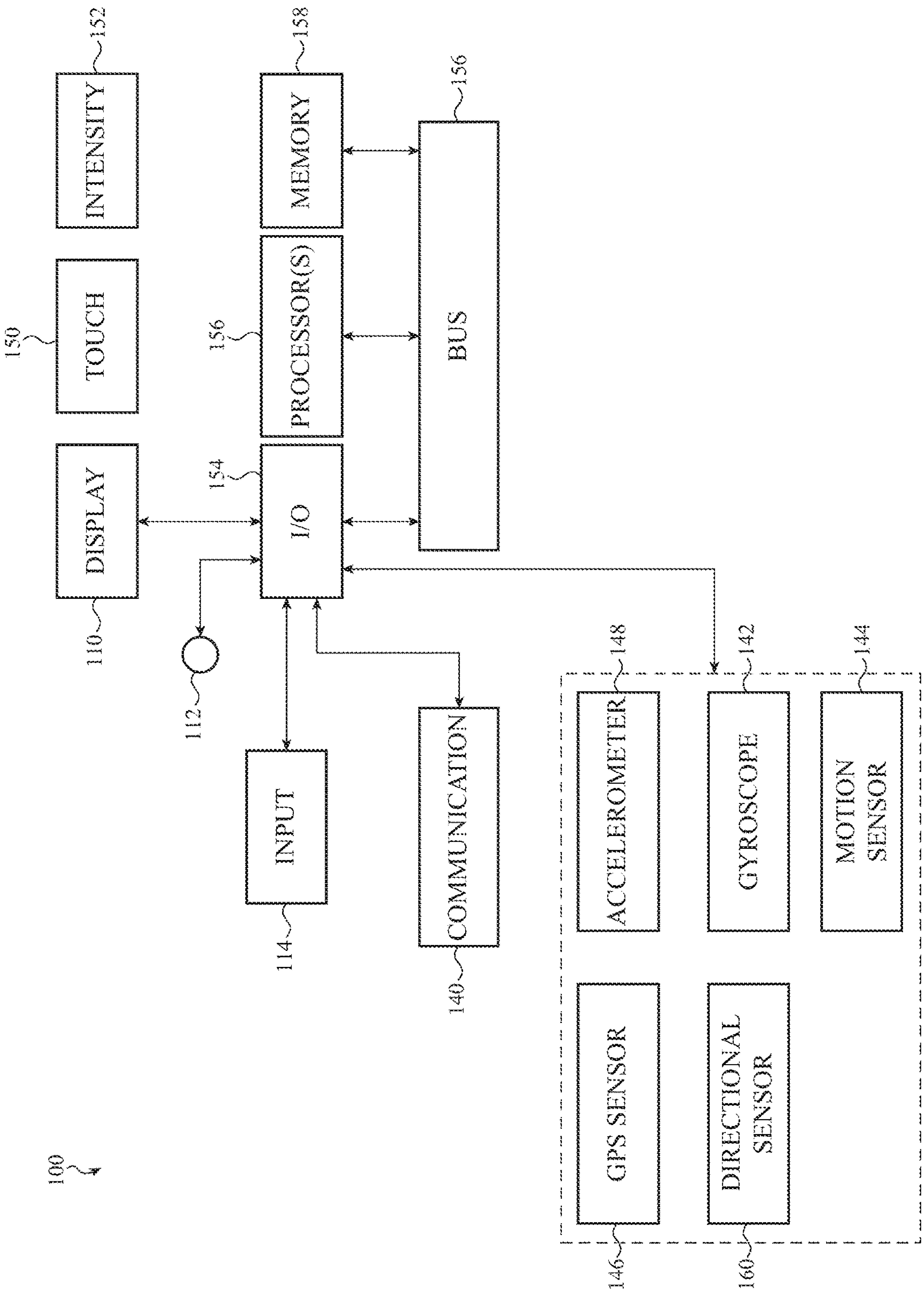

100
DISPLAY
110
TOUCH
150
INTENSITY
152
I/O
154
PROCESSOR(S)
156
MEMORY
158
BUS
156
112
INPUT
114
COMMUNICATION
140
ACCELEROMETER
148
GYROSCOPE
142
MOTION SENSOR
144
GPS SENSOR
146
DIRECTIONAL SENSOR
160

FIG. 1D

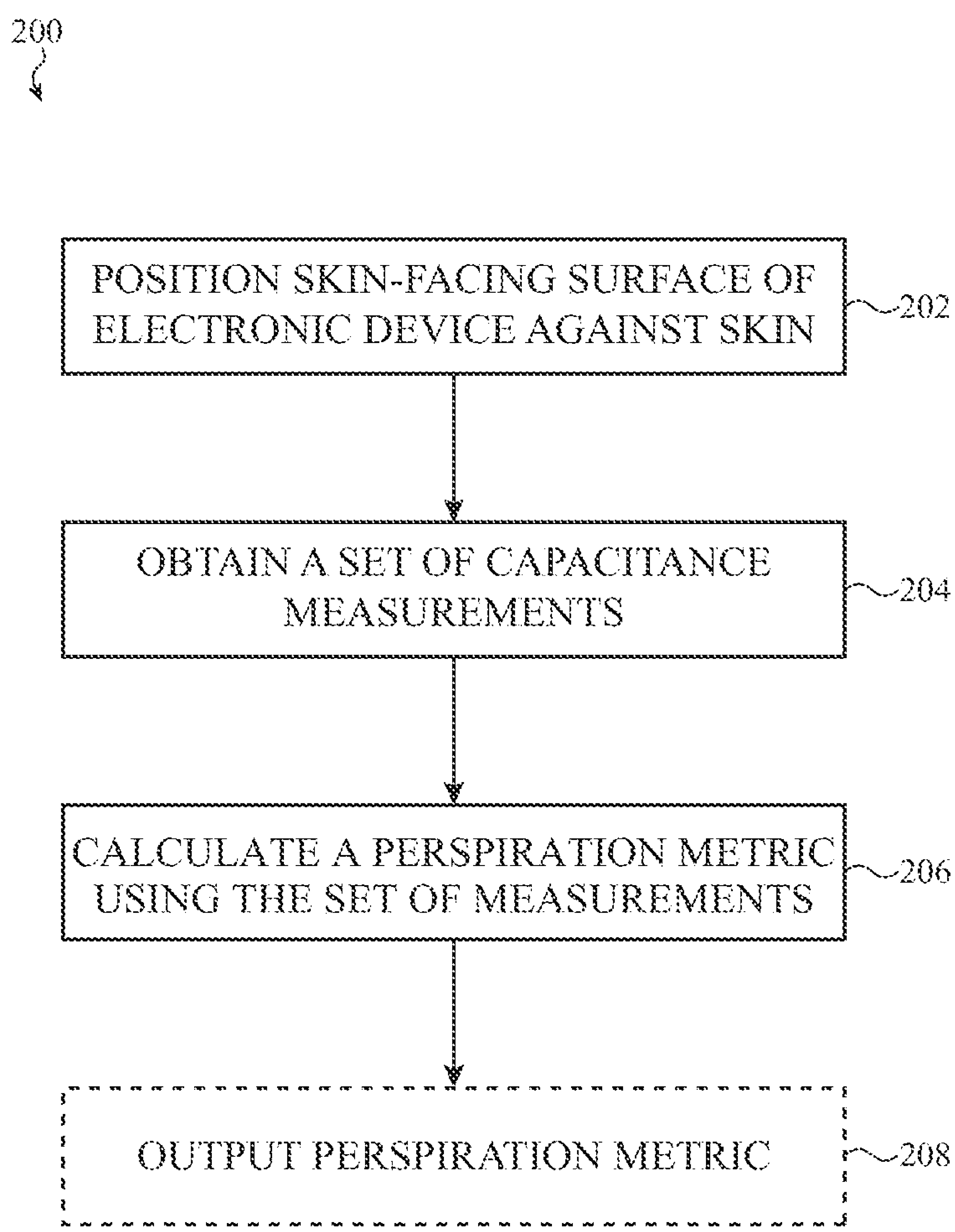

200
POSITION SKIN-FACING SURFACE OF ELECTRONIC DEVICE AGAINST SKIN
202
OBTAIN A SET OF CAPACITANCE MEASUREMENTS
204
CALCULATE A PERSPIRATION METRIC USING THE SET OF MEASUREMENTS
206
OUTPUT PERSPIRATION METRIC
208

FIG. 2

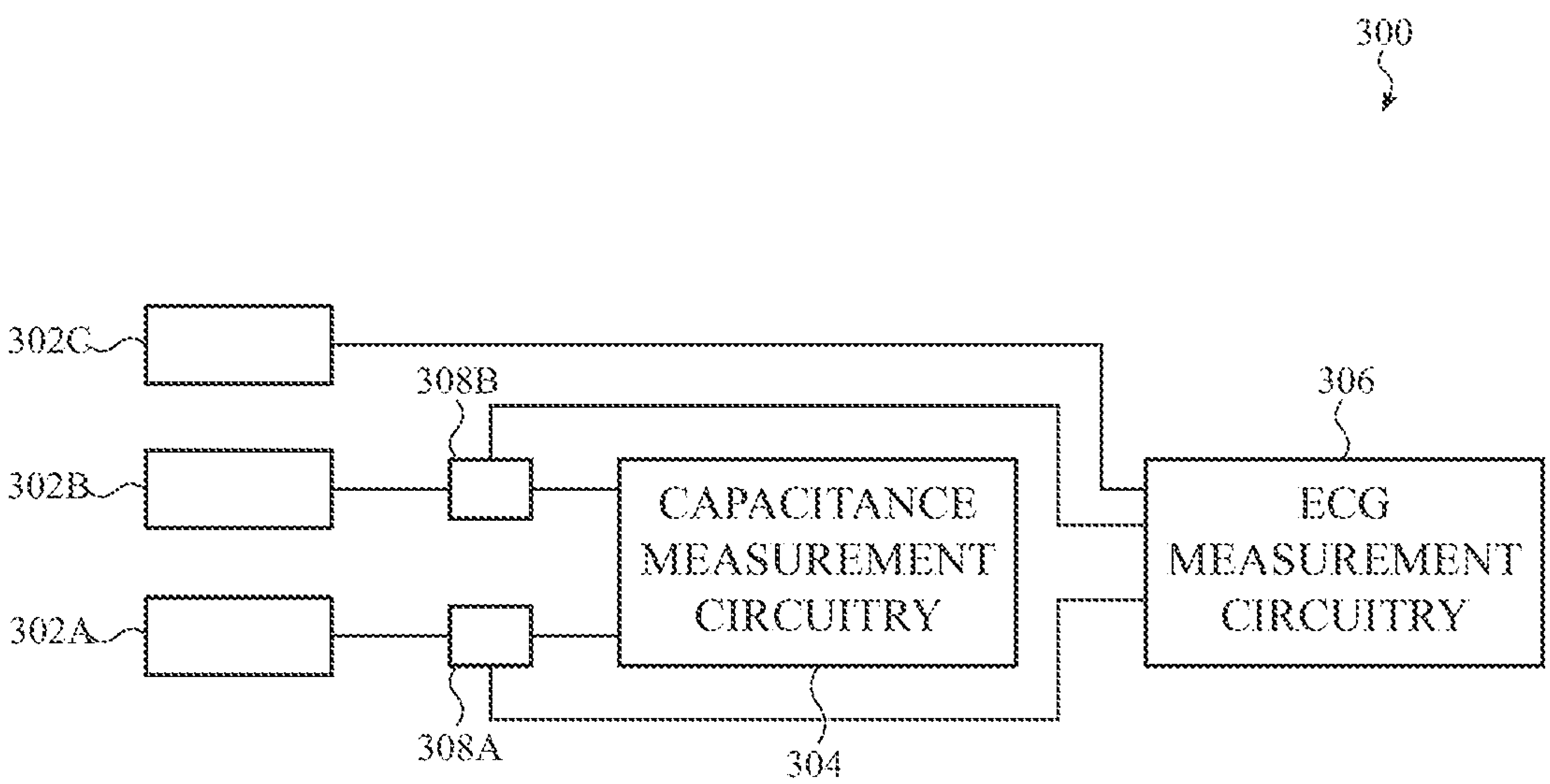

300
302C
302B
302A
308B
308A
CAPACITANCE MEASUREMENT CIRCUITRY
304
306
ECG MEASUREMENT CIRCUITRY

FIG. 3A

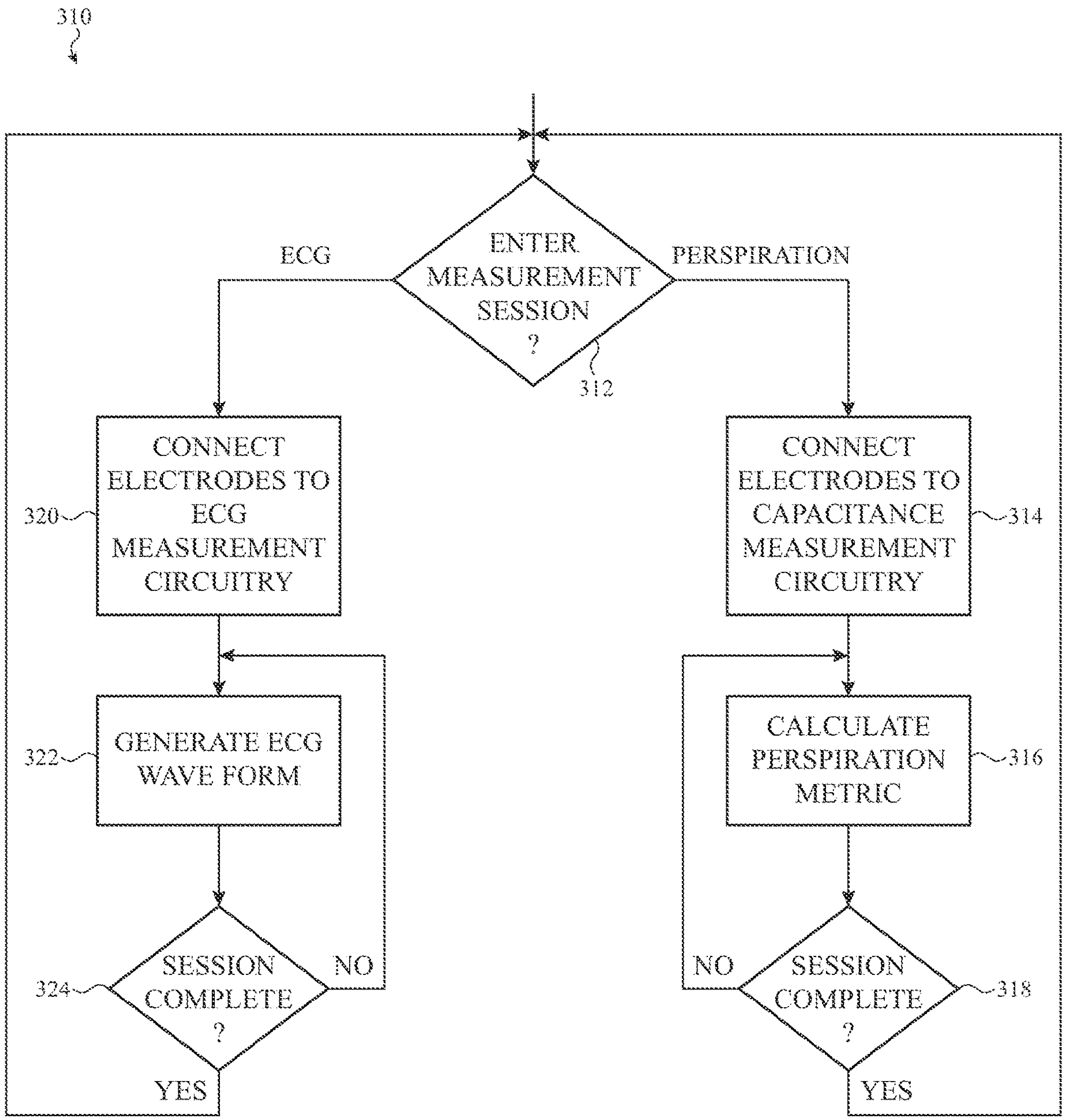

310
ENTER MEASUREMENT SESSION ?
312
ECG
PERSPIRATION
CONNECT ELECTRODES TO ECG MEASUREMENT CIRCUITRY
320
CONNECT ELECTRODES TO CAPACITANCE MEASUREMENT CIRCUITRY
314
GENERATE ECG WAVE FORM
322
CALCULATE PERSPIRATION METRIC
316
SESSION COMPLETE ?
324
NO
YES
SESSION COMPLETE ?
318
NO
YES

FIG. 3B

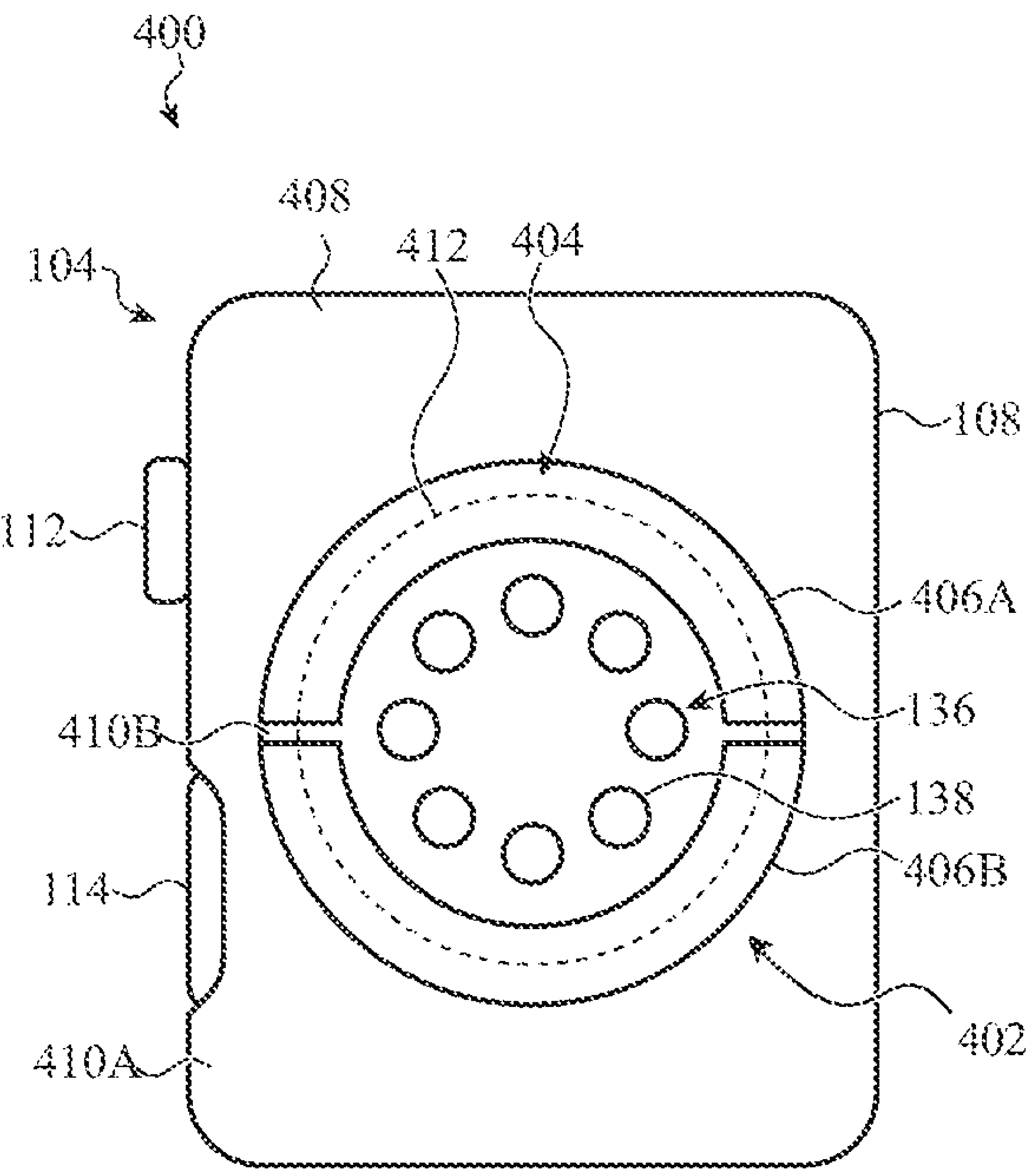

400
408
412
404
104
108
112
406A
136
410B
138
114
406B
402
410A

FIG. 4A

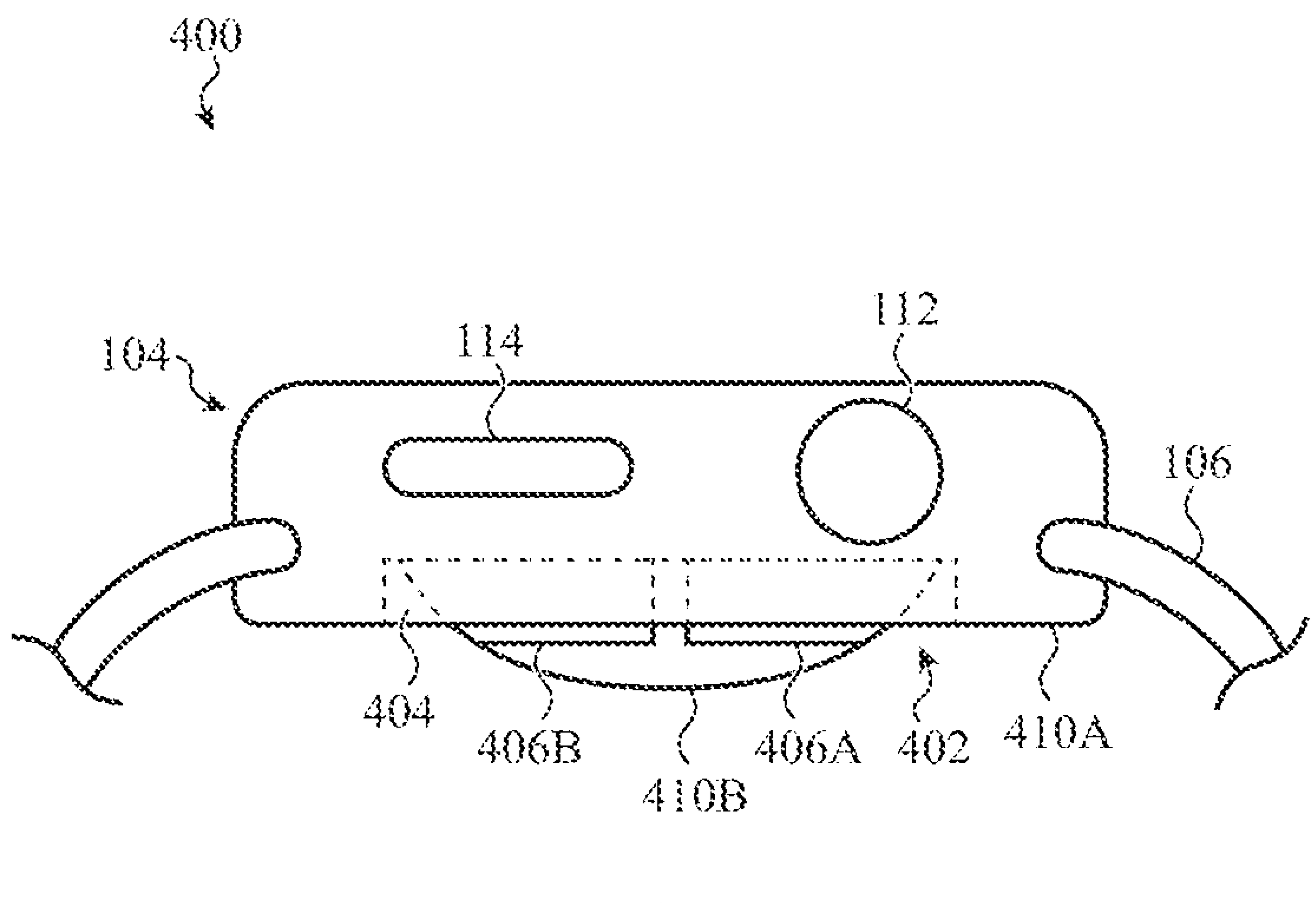

400
112
104
114
106
404
406B
410B
406A
402
410A

FIG. 4B

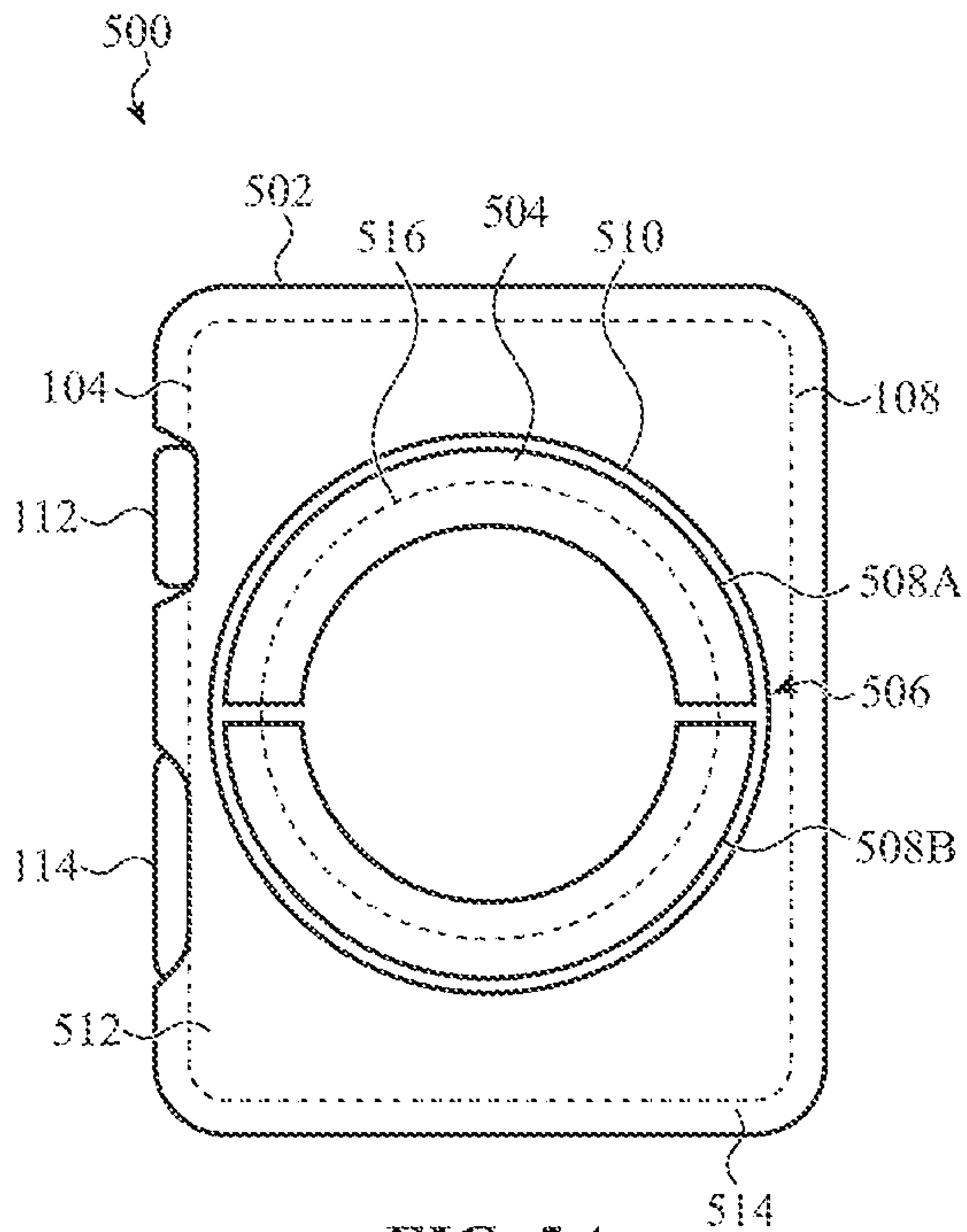

500
502
516
504
510
104
108
112
508A
506
508B
114
512
514

FIG. 5A

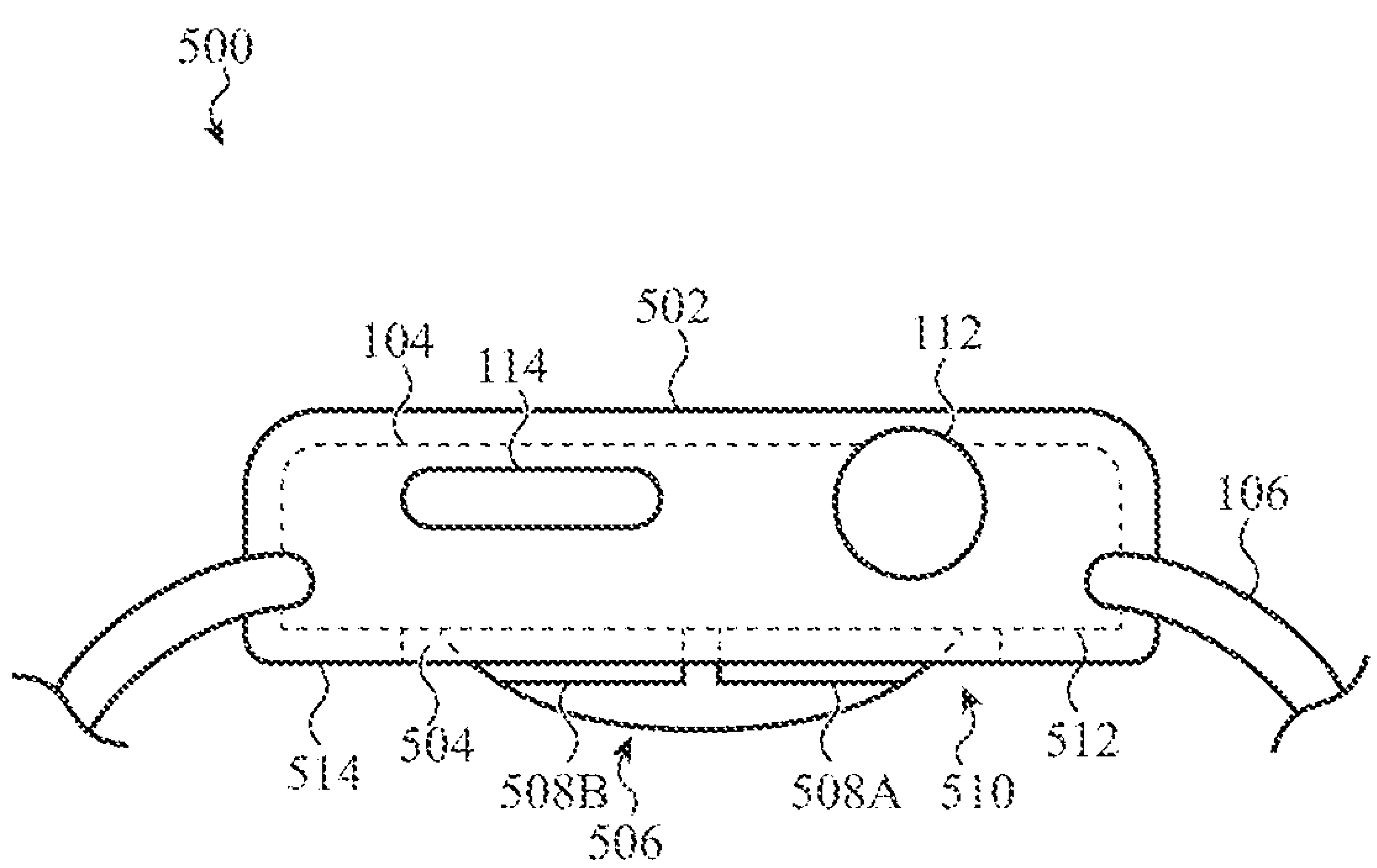

500
104
114
502
112
106
514
504
508B
506
508A
510
512

FIG. 5B

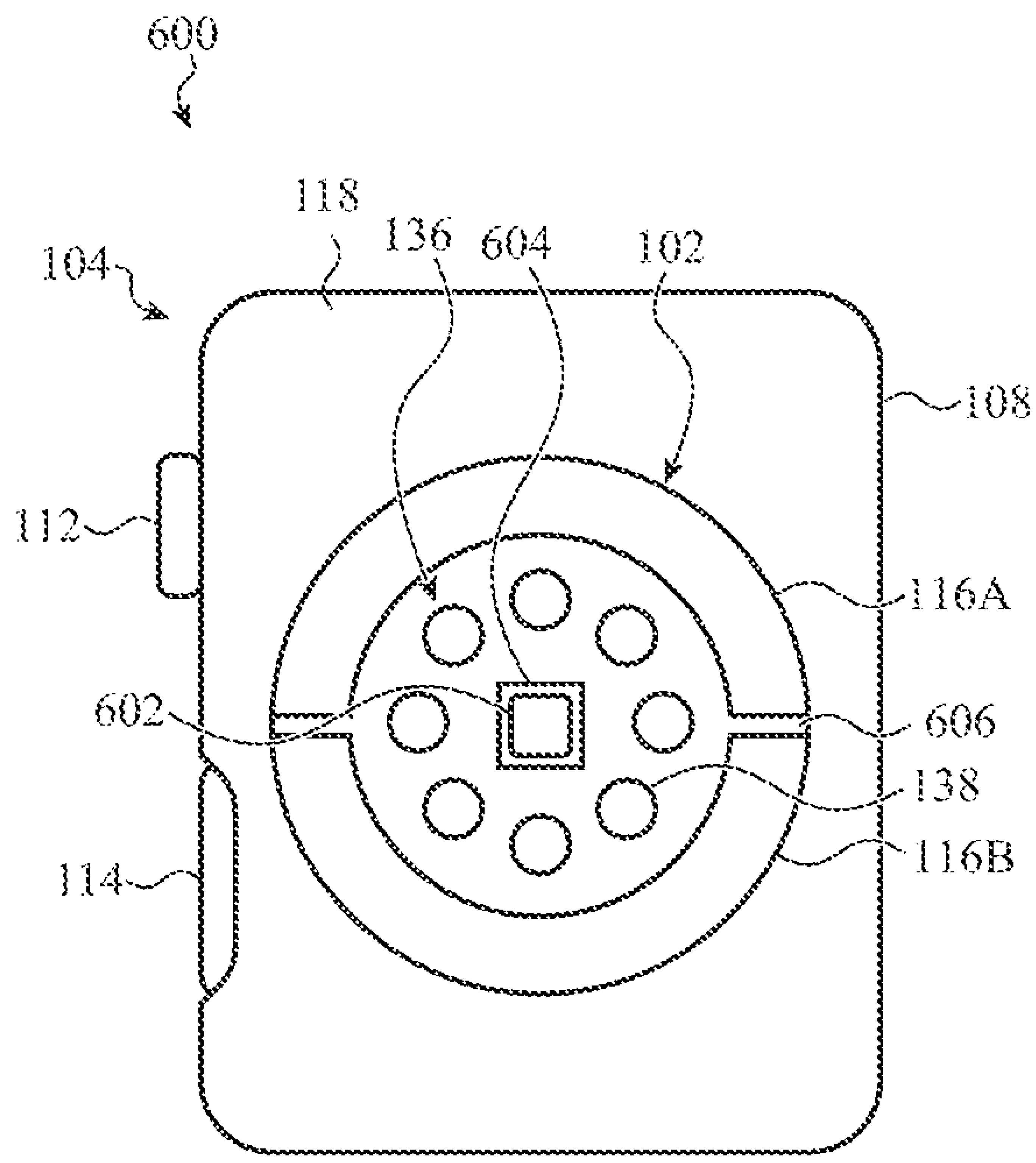

600
104
118
136
604
102
108
112
116A
602
606
138
114
116B

FIG. 6A

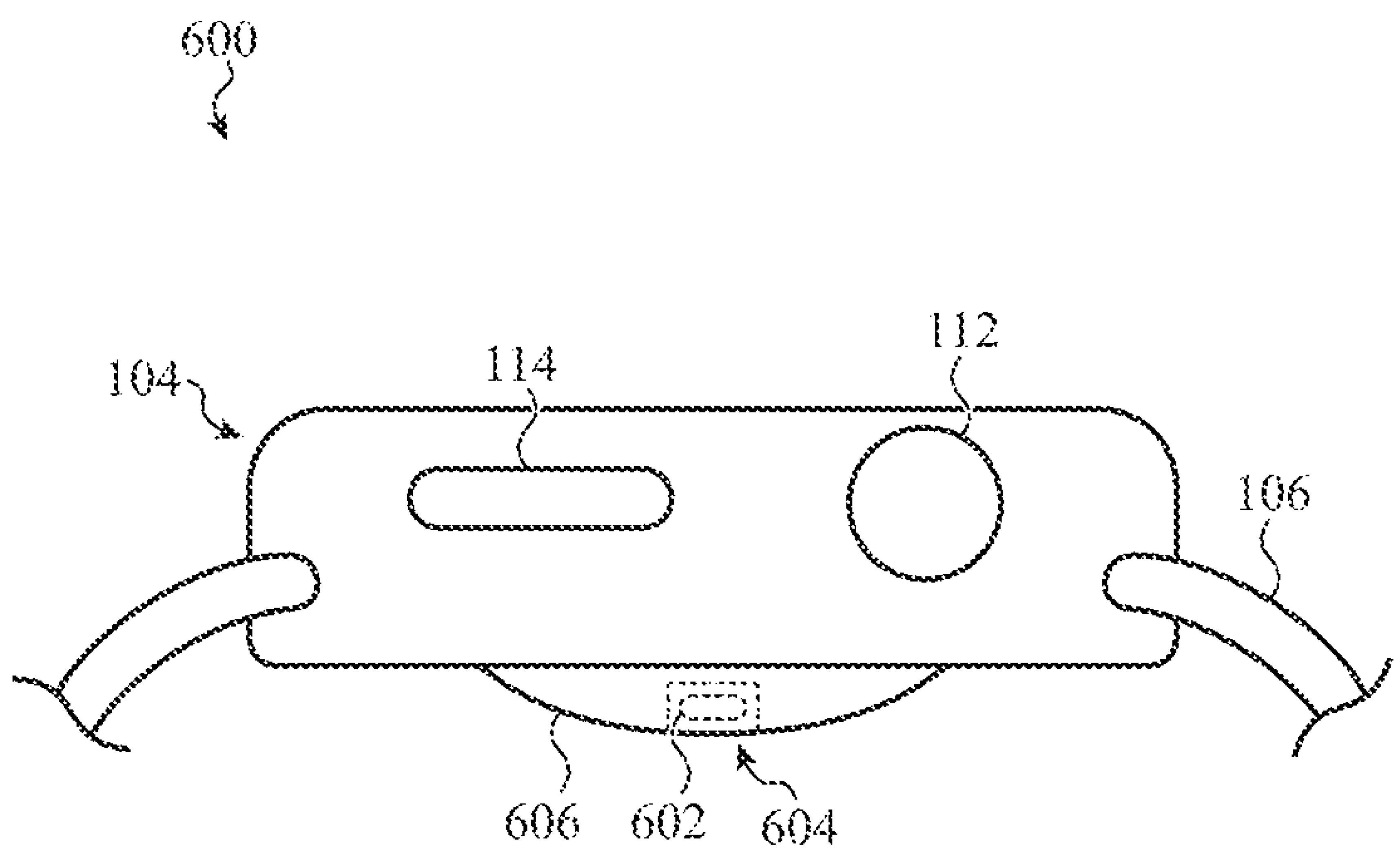

600
104
114
112
106
606
602
604

FIG. 6B

WEARABLE DEVICES WITH PERSPIRATION MEASUREMENT CAPABILITIES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit under 35 U.S.C. § 119(e) of U.S. Provisional Patent Application No. 63/397,013, filed Aug. 11, 2022, the contents of which are incorporated herein by reference in their entirety.

FIELD

[0002] The described embodiments relate generally to systems and methods for measuring perspiration, and more particularly for measuring perspiration using capacitance measurement circuitry.

BACKGROUND

[0003] Wearable electronic devices are increasingly incorporating sensors that measure physiological information and activity of a user, which in turn may be used to provide a user information relating to their health and fitness. For example, a smartwatch or band worn by a user may be able to detect motion while a user is exercising. The detected motion may be used to derive one or more motion-based metrics, such as step count, step length, speed, or distance traveled. Motion-based metrics may be used in conjunction with physiological measurements, such as a user's heart rate, to provide an estimate of how many calories a user has burned. Collectively, information determined from the sensors of a wearable electronic device may provide a user helpful information in understanding and monitoring aspects of their wellbeing. It may be desirable to add additional functionality to these wearable electronic devices to improve the scope and/or quality of information they can provide.

SUMMARY

[0004] Embodiments described herein are directed to systems, devices, and methods for calculating a perspiration metric of a user. Some embodiments are directed to a method for measuring physiological signals using an electronic device comprising a plurality of electrodes. The method includes, during a perspiration measurement session, connecting a first set of electrodes of the plurality of electrodes to capacitive measurement circuitry, performing a set of capacitance measurements using the first set of electrodes, and calculating a perspiration metric using the set of capacitance measurements. The method further includes, during an electrocardiogram measurement, connecting a second set of electrodes of the plurality of electrodes to electrocardiogram measurement circuitry and performing an electrocardiogram measurement to generate an ECG waveform. The plurality of electrodes comprises a first electrode and a second electrode, such that the first set of electrodes includes the first electrode and the second electrode and the second set of electrodes includes the first electrode.

[0005] In some variations, the second set of electrodes also includes the second electrode. In some of these variations, the plurality of electrodes includes a third electrode and the second set of electrodes includes the third electrode. The perspiration may be an estimated sweat rate or another perspiration metric as described herein. Additionally or alternatively, the perspiration measurement session is initiated while the electronic device is tracking an exercise session. In some of these instances, the perspiration measurement session is initiated automatically in response to the electronic device tracking the exercise session.

[0006] Other embodiments are directed to a device for calculating a perspiration metric of a user, where the device includes a housing having a skin-facing exterior surface, a perspiration sensor that includes a first electrode and a second electrode, and a processer configured to calculate the perspiration metric using the perspiration sensor. The skin-facing exterior surface of the housing defines a cavity, and the first electrode extends at least partially into the cavity. In some variations, the second electrode also extends at least partially into the cavity. Additionally or alternatively, a portion of the first electrode is positioned outside of the cavity.

[0007] In some variations, the skin-facing exterior surface includes a first region surrounding a second region such that a first portion of the second region is recessed relative to the second region to define the cavity. In some of these variations, a second portion of the second region protrudes past the first region. Additionally or alternatively, the cavity has an annular shape. In some variations, the device includes an optical sensor comprising a set of windows, wherein the set of windows is positioned in the second region. Additionally or alternatively, the perspiration sensor is a first perspiration sensor, and the device further includes a second perspiration sensor. In some instances, the perspiration sensor includes capacitance measurement circuitry configured to measure a capacitance between the first electrode and the second electrode.

[0008] Yet other embodiments are directed to a device for calculating a perspiration metric of a user, and that includes a housing having a skin-facing exterior surface that defines a first cavity and a first perspiration sensor comprising a first electrode defining a first portion of the skin-facing exterior surface and a second electrode defining a second portion of the skin-facing exterior surface. The device further includes a second perspiration sensor contained within the first cavity, and a processer configured to calculate the perspiration metric using both the first perspiration sensor and the second perspiration sensor.

[0009] In some of these variations, the housing defines a second cavity, and the first electrode extends at least partially into the second cavity. In some of these variations, the second cavity encircles the first cavity. In other variations, the first cavity is positioned between at least a portion of the first electrode and at least a portion of the second electrode. Additionally or alternatively, the first cavity is positioned closer to a center of the skin-facing exterior surface of the housing relative to the first electrode.

[0010] In addition to the example aspects and embodiments described above, further aspects and embodiments will become apparent by reference to the drawings and by study of the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The disclosure will be readily understood by the following detailed description in conjunction with the accompanying drawings, wherein like reference numerals designate like structural elements, and in which:

[0012] FIGS. **1**A and **1**B show front and rear views, respectively, of a wearable electronic device having a perspiration sensor as described herein. FIG. **1**C shows example capacitance measurement circuitry that may be used with the perspiration sensor of FIGS. **1**A and **1**B. FIG. **1**D shows additional components that may be incorporated into the wearable electronic device of FIGS. **1**A and **1**B.

[0013] FIG. **2** shows an example method of calculating a perspiration metric as described herein.

[0014] FIG. **3**A shows a hybrid sensor that may selectively be used to generate an electrocardiogram waveform or calculate a perspiration metric. FIG. **3**B shows a process flow for performing measurements using the hybrid sensor of FIG. **3**A.

[0015] FIGS. **4**A and **4**B show front and side views, respectively, of an example variation of an electronic device having a perspiration sensor as described herein.

[0016] FIGS. **5**A and **5**B show front and side views, respectively, of an example variation of an electronic device having a perspiration sensor and an accessory component as described herein.

[0017] FIGS. **6**A and **6**B show front and side views, respectively, of another variation of an electronic device having a plurality of perspiration sensors as described herein.

[0018] It should be understood that the proportions and dimensions (either relative or absolute) of the various features and elements (and collections and groupings thereof) and the boundaries, separations, and positional relationships presented therebetween, are provided in the accompanying figures merely to facilitate an understanding of the various embodiments described herein and, accordingly, may not necessarily be presented or illustrated to scale, and are not intended to indicate any preference or requirement for an illustrated embodiment to the exclusion of embodiments described with reference thereto.

DETAILED DESCRIPTION

[0019] Reference will now be made in detail to representative embodiments illustrated in the accompanying drawings. It should be understood that the following descriptions are not intended to limit the embodiments to one preferred embodiment. To the contrary, it is intended to cover alternatives, modifications, and equivalents as can be included within the spirit and scope of the described embodiments as defined by the appended claims.

[0020] Embodiments disclosed herein are directed to devices, systems, and methods for calculating a perspiration metric of a user. In some embodiments, a device may include a perspiration sensor having first and second electrodes positioned on a skin-facing exterior surface of a housing of the device. Capacitance measurement circuitry may measure a capacitance between the electrodes, which may be used to calculate the perspiration metric. In some embodiments, the device (alone or in combination with a removable accessory) defines a cavity such that one or both of the electrodes extend at least partially into the cavity. Other embodiments include a second perspiration sensor, and measurements from the second perspiration sensor may be used in calculating the perspiration metric.

[0021] These and other embodiments are discussed below with reference to FIGS. **1**A-**6**B. However, those skilled in the art will readily appreciate that the detailed description given herein with respect to these Figures is for explanatory purposes only and should not be construed as limiting.

[0022] The devices, systems, and methods described herein are configured to perform perspiration measurements using one or more perspiration sensors. These measurements are in turn used to calculate an estimated sweat rate of a user and/or additional metrics that utilize a user's estimated sweat rate. Specifically, the estimated sweat rate of a user is a measure of the amount of fluid lost over an interval of time. In instances where an estimated sweat rate is presented to a user, it may be presented in a number of different ways. In some instances the estimated sweat rate may be presented as a rate of fluid loss (e.g., expressed in fluid ounces per hour, or the like) or as an amount of fluid loss for a specific period of time (e.g., expressed as a volume of fluid).

[0023] For example, when the devices described herein are used to track an exercise session (e.g., while a user is engaged in a physical activity such as walking, running, cycling, or the like), the device may calculate and present a first estimated sweat rate over a first interval of time corresponding to the exercise session. This may provide a user with information about the average sweat rate or total fluid loss over the course of the exercise session. Additionally or alternatively, the device may calculate and present a second estimated sweat rate over a second interval of time shorter than the first interval of time (i.e., shorter than the entire duration of the exercise session). This second interval of time may be relatively short (e.g., the last five seconds, the last 15 seconds, the last 30 seconds, or the like), and may represent an "instantaneous" sweat rate of the user. In this way, a user may be able to understand their current rate of fluid loss at any given point within the exercise session, as well as their total fluid loss during the exercise session.

[0024] Because the measurements performed by a perspiration sensor (or sensors) of a device are taken at a particular location, the measurement is indicative of the perspiration at that particular location (e.g., measurements taken at the wrist of a user reflects how much the user is perspiring at the user's wrist). The devices, systems, and methods may be used to calculate a local estimated sweat rate, which represents an estimate of the sweat rate at the measurement site where the perspiration measurements are performed. Accordingly, this local estimated sweat rate may be converted into a global estimated sweat rate, which represents an indication of the overall sweat rate across the user's entire body. This may provide an estimate of the overall amount of fluid lost by the user's body (e.g., during an exercise session). In these instances, a predetermined relationship between the local estimated sweat rate and the global estimated sweat rate (which may optionally be based on other inputs as discussed below) may be used to convert the local estimated sweat rate to a global estimated sweat rate. Unless otherwise specified, when the systems, devices, and methods are discussed herein as calculating, using, or outputting an "estimated sweat rate" this may be either a local estimated sweat rate or a global estimated sweat rate.

[0025] An estimated sweat rate may also be used to calculate one or more additional metrics. In some instances, the estimated sweat rate may be used in calculating a metric indicative of a user's hydration (e.g., a hydration level, a change in hydration of an interval of time, or the like). In other instances, the estimated sweat rate may be used in calculating an exercise metric, such as workout intensity, calories burned, or the like. While some or all of these exercise metrics may be calculated without a perspiration measurement, the use of the estimated sweat rate as an input may improve the accuracy of these measurements. The estimated sweat rate, as well as any additional metric calculated using the estimated sweat rate (such as those described above), are collectively referred to herein as "perspiration metrics."

[0026] The devices and methods described herein may utilize additional measurements in calculating a perspiration metric, which may help improve the accuracy of the calculated perspiration metrics. In some instances, ambient temperature and/or humidity may be used in calculating a perspiration metric. For example, in instances where a local estimated sweat rate is converted to a global estimated sweat rate, the conversion may utilize this ambient temperature and/or humidity information. The overall amount that a user perspires may be dependent on the ambient temperature and/or humidity, and thus the relationship between the local estimated sweat rate and the global estimated sweat rate may also depend on the ambient temperature and/or humidity.

[0027] Additionally or alternatively, a body temperature measurement may be used in calculating a perspiration metric. For example, a body temperature measurement may be used in converting a local estimated sweat rate to a global estimated sweat rate. It should be appreciated that any of these additional measurements (e.g., ambient temperature, ambient humidity, body temperature), may be performed by the same device that contains the perspiration sensor or may be performed by a separate device. In some instances, the devices and methods described herein may utilize location information (e.g., from a GPS system and/or from user input) to obtain an ambient temperature and/or humidity value associated with a location of the user.

[0028] Generally, the perspiration sensors described herein may be placed against a user's skin to perform the measurements that are used to calculate a perspiration metric. In some instances, a perspiration sensor may be incorporated into a wearable electronic device that may be configured to be releasably coupled to a portion of a user's body. For example, FIGS. **1**A and **1**B show front and rear views, respectively, of a variation of a wearable electronic device **100** that incorporates a perspiration sensor **102**. In the variation shown in FIGS. **1**A and **1**B, the wearable electronic device **100** is configured as a watch having a watch body **104** and a strap **106**. The strap **106** may be attached to the watch body **104** (either releasably, thereby allowing the watch body **104** to be used with different straps, or permanently), and may at least partially encircle a portion of a user's body (e.g., the user's wrist) to releasably couple the wearable electronic device **100** to the user. In other variations, the wearable electronic device **100** may be configured as a band, bracelet, or ring having a housing configured to at least partially encircle a portion of a user's body to releasably couple the wearable electronic device **100** to the user. In still other variations, the wearable electronic device **100** may be releasably coupled to a user via an adhesive.

[0029] The wearable electronic device **100** may include a housing **108**. In instances where the wearable electronic device **100** is configured as a watch, the housing **108** may be a housing for the watch body **104**. The housing **108** defines one or more exterior surfaces of the wearable electronic device **100**, and may be formed from a single housing member or formed from two or more housing members that are attached to each other (as will be described in more detail below). Each housing member of the housing **108** may be formed from any suitable material or combination or materials, such as one or more metals, plastics, ceramics, glasses, crystals, or the like.

[0030] In some variations, the wearable electronic device **100** includes a display **110**. The display **110** may be at least partially positioned within the housing **108**, and in some instances includes a transparent cover (e.g., a glass) that protects components of the display **110** positioned within the housing **108**. In these instances, the display **110** forms a portion of an exterior surface of the wearable electronic device **100**. In some instances, such as shown in FIG. **1**A, the display **110** is positioned on (and thereby defines) a front exterior surface of the wearable electronic device **100** such that the display **110** provides a graphical output that is viewable through or at the front exterior surface of the wearable electronic device **100**. The wearable electronic device **100** may be configured such that the display **110** is positioned such that it is visible to a user while releasably coupled to the user.

[0031] The display **110** may include a display portion that can be implemented with any suitable technology, including, but not limited to liquid crystal display (LCD) technology, light emitting diode (LED) technology, organic light-emitting display (OLED) technology, organic electroluminescence (OEL) technology, electronic paper (e.g., electronic ink) display technology, or another type of display technology. In some instances the display **110** is configured as a touchscreen, and is capable of receiving touch inputs from a user. In these instances, the display **110** may include one or more sensors (e.g., capacitive touch sensors, ultrasonic sensors, or other touch sensors) positioned above, below, or integrated within other components of the display **110**.

[0032] In some instances, the wearable electronic device **100** may include at least one input mechanism, such as a crown, scroll wheel, knob, dial, button, or the like. A user may manipulate an input mechanism (e.g., by rotating a scroll wheel or pressing a button) to provide an input to the wearable electronic device **100**, which may in turn be used to control the wearable electronic device **100** (e.g., to manipulate or select various graphics displayed by the display **110**, to adjust a volume of a speaker, to turn the wearable electronic device **100** on or off, or the like). In the variation shown in FIGS. **1**A and **1**B, the watch body **104** includes a crown **112** and a button **114**. The crown **112** may extend at least partially through the housing **108** to allow a user to manipulate the crown **112** (e.g., by rotating or pressing on the crown **112**) to provide inputs via the crown **112**. Similarly, the button **114** may extend at least partially through the housing **108**, and may be depressed by a user to provide an input via the button **114**.

[0033] As mentioned above, the wearable electronic device **100** includes a perspiration sensor **102**. The perspiration sensor **102** includes a first electrode **116**A and a second electrode **116**B that form at least a portion of an exterior surface of the wearable electronic device **100**. For example, as shown in FIG. **1**B, the first electrode **116**A and the second electrode **116**B are positioned on a skin-facing exterior surface **118** of the wearable electronic device **100** (e.g., a skin-facing surface of the watch body **104**). Accordingly, when the wearable electronic device **100** is releasably coupled to a user as discussed above, at least a portion of the first electrode **116**A and the second electrode **116**B may contact the user's skin. In instances where the wearable electronic device **100** includes a display **110**, the display **110** may be positioned on a front exterior surface of the wearable electronic device **100** that is opposite the skin-facing exterior surface **118**. In the variation shown in FIGS. **1**A and **1**B, the display **110** and the electrodes of the perspiration sensor **102** are on opposite sides of the watch body **104**.

[0034] To perform a measurement using the perspiration sensor **102**, the first electrode **116**A and the second electrode **116**B are connected to capacitance measurement circuitry that measures a capacitance between the first and second electrodes **116**A, **116**B. When the skin-facing exterior surface **118** is positioned against a user's skin, the capacitance measured by the capacitance measurement circuitry may vary depending on the amount of moisture present, and thus may be used to calculate one or more perspiration metrics, as will be described in more detail below. FIG. **1**C shows an example capacitance measurement circuitry **120** that may be used to measure a capacitance (illustrated as capacitance **122**) between the first and second electrodes **116**A, **116**B. The capacitance measurement circuitry **120** includes an operational amplifier **124** having an inverting input, a non-inverting input, and an output **134**, a feedback resistor **126**, a feedback capacitor **128**, an input voltage source **130**, and a reference voltage source **132**.

[0035] The input voltage source **130**, which is shown in FIG. **1**C as being an AC voltage source, is connected to the first electrode **116**A. The second electrode **116**B is connected to the inverting input of the operational amplifier **124**, while the reference voltage source **132** (which is shown in FIG. **1**C as being a DC voltage source) is connected to the non-inverting input of the operational amplifier **124**. The output **134** of the operational amplifier **124** is coupled back to the inverting input through the feedback resistor **126** and feedback capacitor **128**. The output **134** of the operational amplifier **124** may vary with changes in voltage of the input voltage source **130**, but also with change in the capacitance **122** between the first electrode **116**A and the second electrode **116**B. Accordingly, the capacitance **122** may be calculated (e.g., using demodulation or other techniques) from the output **134** of the operational amplifier **124**. It should be appreciated that the capacitance measurement circuitry **120** of FIG. **1**C is just one example of circuitry that may be used to measure a capacitance between two electrodes, and there are many other configurations of capacitance measurement circuitries that may be utilized to measure a capacitance between the first and second electrodes **116**A, **116**B.

[0036] Returning to FIG. **1**B, in some variations the wearable electronic device **100** includes one or more additional sensors configured to measure one or more physiological systems. For example, the wearable electronic device **100** may include an optical sensor **136**. The optical sensor **136** includes a set of windows **138** that allow light to be transmitted therethrough. The optical sensor **136** further includes a set of emitters (not shown) positioned within the housing **108** and configured to emit light through at least some of the windows in the set of windows. Similarly, the optical sensor includes a set of light detectors (not shown) positioned within the housing **108** and configured to receive light through at least some of the windows of the set of windows. The set of emitters may direct light from the wearable electronic device **100** toward a user, while the set of detectors may detect light returned from the user to the wearable electronic device **100**. The amount of light detected by the set of detectors may be used to calculate one or more physiological signals (such as heart rate, blood oxygenation, or the like) and/or determine a proximity between the wearable electronic device **100** and the skin of the user.

[0037] FIG. **1**D depicts additional exemplary components of the wearable electronic device **100**. In some embodiments, the wearable electronic device **100** has a bus **156** that operatively couples I/O section **154** with one or more computer processors **156** and memory **158**. I/O section **154** can be connected to display **110**, which can have touch-sensitive component **150** and, optionally, intensity sensor **152** (e.g., contact intensity sensor). In addition, I/O section **154** can be connected with communication unit **140** for receiving application and operating system data, using Wi-Fi, Bluetooth, near field communication (NFC), cellular, and/or other wireless communication techniques. The wearable electronic device **100** can include input mechanisms, such as a crown **112** and/or button **114** as discussed previously. The wearable electronic device **100** optionally includes various sensors, such as GPS sensor **146**, accelerometer **148**, directional sensor **160** (e.g., compass), gyroscope **142**, motion sensor **144**, and/or a combination thereof, all of which can be operatively connected to I/O section **154**.

[0038] Memory **158** of device **100** can include one or more non-transitory computer-readable storage mediums, for storing computer-executable instructions, which, when executed by one or more computer processors **156**, for example, can cause the computer processors to perform the techniques that are described herein (e.g., calculating perspiration metrics). A computer-readable storage medium can be any medium that can tangibly contain or store computer-executable instructions for use by or in connection with the instruction execution system, apparatus, or device. In some examples, the storage medium is a transitory computer-readable storage medium. In some examples, the storage medium is a non-transitory computer-readable storage medium. The non-transitory computer-readable storage medium can include, but is not limited to, magnetic, optical, and/or semiconductor storages. Examples of such storage include magnetic disks, optical discs based on CD, DVD, or Blu-ray technologies, as well as persistent solid-state memory such as flash, solid-state drives, and the like.

[0039] The processor **156** can include, for example, dedicated hardware as defined herein, a computing device as defined herein, a processor, a microprocessor, a programmable logic array (PLA), a programmable array logic (PAL), a generic array logic (GAL), a complex programmable logic device (CPLD), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), or any other programmable logic device (PLD) configurable to execute an operating system and applications of device **100**, as well as to facilitate setting a field of view of a camera and capturing of images as described herein. The wearable electronic device **100** is not limited to the components and configuration of FIG. **1**D, but can include other or additional components in multiple configurations.

[0040] As mentioned above, the perspiration sensor **102** may calculate one or more perspiration metrics using the first electrode **116**A, second electrode **116**B, and capacitance measurement circuitry (such as the capacitance measurement circuitry **120** of FIG. **1**C). For example, FIG. **2** shows a method **200** of calculating a perspiration metric using an electronic device having a perspiration sensor positioned on a skin-facing surface of the electronic device. At step **202**, a skin-facing surface of the electronic device is positioned against the skin of a user such that at least a portion of the skin-facing surface contacts the user's skin (though it should be appreciated that in some instances user movement, such as from exercise, may cause momentary separation between the skin-facing surface of the electronic device and the user's skin). In instances where the electronic device is the wearable electronic device **100** of FIGS. **1A-1D**, this step may include releasably coupling the watch body **104** to the user using the strap **106**, such that at least a portion of the skin-facing exterior surface **118** of the watch body **104** contacts the user's skin. In instances where the wearable electronic device **100** is configured as a watch, the wearable electronic device **100** may be coupled to the wrist. It should be appreciated that the devices described herein may be releasably coupled to different portions of the body (e.g., other locations along a user's arm, their leg, torso, or the like).

[0041] At step **204**, a perspiration sensor (such as perspiration sensor **102** shown in FIG. **1B**) is used to obtain a set of capacitance measurements. For each measurement, a capacitance is measured between first and second electrodes of the perspiration sensor that are positioned on a skin-facing exterior surface of the electronic device. For example, a capacitance measurement circuitry (such as the capacitance measurement circuitry **120** of FIG. **1C**) may measure the capacitance between the first and second electrodes (e.g., first and second electrodes **116**A, **116**B of the perspiration sensor **102** shown in FIG. **1B**) to measure the capacitance. The set of capacitance measurements may be performed over a predetermined measurement window. In some instances, the set of capacitance measurements is a single measurement that measures the capacitance between the first and second electrodes continuously during the measurement window. In other instances, the set of capacitance measurements include multiple individual measurements that measure the capacitance at different times within the measurement window. Each capacitance measurement may output one or multiple capacitance values depending on the duration of the individual measurement. Accordingly, the set of capacitance measurements may output a corresponding set of capacitance values.

[0042] The set of capacitance measurements may be captured on demand (e.g., in response to a request from a user to determine a perspiration metric), automatically on a scheduled basis (e.g., performed at predetermined times during the day), and/or automatically when certain criteria are met. For example, the set of capacitance measurements may be captured automatically while a device is tracking an exercise session (e.g., to provide perspiration metrics associated with the activity).

[0043] At step **206**, a perspiration metric is calculated using the set of capacitance measurements (e.g., using a processor of the electronic device). Specifically, the set of capacitance values obtained by the set of capacitance measurements may be analyzed to determine a perspiration metric. In instances where the perspiration metric is an estimated sweat rate, a predetermined relationship between measured capacitance and sweat rate may be used to convert the set of capacitance values to a value of the estimated sweat rate. Similarity, the set of capacitance measurements may be used as an input in determining other perspiration metrics, such as those discussed above. In some variations, the perspiration metric is calculated using one or more additional inputs, including (but not limited to) ambient temperature, ambient humidity, user temperature, physical parameters of the user such as height, weight, or body composition, information from additional sensors, combinations thereof, or the like.

[0044] At step **208**, the calculated perspiration metric may be outputted. In some instances, this includes storing the perspiration metric in permanent memory (such as a database used to store physiological data of user), which may allow the perspiration metric to later be accessed by the user or another device or application (e.g., a software program on the wearable electronic device **100**) as permitted by the user. Additionally or alternatively, the electronic device may output the calculated perspiration metric to a user. This output may be achieved in a variety of ways including through a user interface (U/I) generated as a display (e.g., display **110**), using audio alerts, through haptic feedback, or any other suitable output mechanism, or combinations thereof.

[0045] In some instances, one or more electrodes of a perspiration sensor may be also be used to perform additional physiological measurements. For example, in some variations, one or more electrodes of the perspiration sensor may be used to measure an electrocardiogram (ECG) waveform of a user (an "ECG measurement"). FIG. **3A** shows an example of a hybrid sensor **300** that may be used to selectively measure an ECG waveform of a user or a perspiration metric of the user. The hybrid sensor **300** includes a plurality of electrodes, including a first electrode **302**A, a second electrode **302**B, and a third electrode **302**C. Different subsets of the plurality of electrodes may be used to perform ECG measurements and perspiration measurements. This allows the same electrode or electrodes to be utilized for multiple different measurements, which may result in space saving and/or reduced cost while still providing the ability of the electronic device to perform this dual functionality.

[0046] The hybrid sensor **300** may be part of an electronic device such as the wearable electronic device **100** of FIGS. **1A-1C**. For example, the first and second electrodes **302**A, **302**B may be positioned on (and thereby define) a portion of a skin-facing surface of an electronic device (such as the wearable electronic device **100** of FIGS. **1A-1D**), and one or both of these electrodes are positioned to at least partially contact a user's skin when the electronic device is releasably coupled to the user. The first and second electrodes **302**A, **302**B may be selectively connected to capacitance measurement circuitry **304** (which may be configured in any suitable manner such as discussed above with respect to the capacitance measurement circuitry **120** of FIG. **1C**). When the first and second electrodes **302**A, **302**B are connected to the capacitance measurement circuitry **304**, the capacitance measurement circuitry **304** may measure a capacitance between first and second electrodes **302**A, **302**B, and may use the measured capacitance to calculate one or more perspiration metrics as described herein.

[0047] At other times, the first electrode **302**A and/or second electrode **302**B may be connected to ECG measurement circuitry **306** configured to perform an ECG measurement. In these instances, a third electrode **302**C is also connected to the ECG measurement circuitry **306**. The ECG measurement circuitry **306** may measure a voltage between the third electrode **302**C (referred to as the "measurement electrode" for ease of discussion) and either the first electrode **302**A or the second electrode **302**B (referred to as the "reference electrode" for ease of discussion), and this voltage may be processed to generate one or more ECG waveforms representing the electrical activity of the heart. It should be appreciated that the ECG measurement circuitry **306** may be any suitable known ECG measurement circuitry as will be readily understood by one of ordinary skill in the art.

[0048] To generate the ECG waveform, the measurement electrode and the reference electrode are both placed in contact with user's skin, preferable on different limbs or regions of the user's body. For example, the measurement electrode may be placed in contact with a first arm (e.g., at a wrist) or leg (e.g., at an ankle) and the reference electrode may be placed in contact with a different arm or leg. When the electronic device is releasably coupled to a user, the reference electrode is positioned on the skin-facing surface of the electronic device such that at least a portion of the reference electrode contacts the user. The third electrode **302**C is positioned on a portion of an electronic device (e.g., on a portion of a housing of the electronic device, on an input mechanism such as a crown **112** or button **114** described previously, as part of the display of the electronic device, or the like) that allows it to be touched by a different portion of the user.

[0049] In some variations, such as shown in FIG. **3**A, both the first electrode **302**A and second electrode **302**B are connected to and used by the ECG measurement circuitry **306** to generate one or more ECG waveforms. In these instances, one of the first electrode **302**A and the second electrode **302**B acts as the reference electrode discussed above, while the other acts as a ground electrode. The ground electrode may be used by the ECG measurement circuitry **306** to connect the user's body to the ground of the ECG measurement circuitry **306**. Accordingly, in these instances the ground electrode is also positioned to contact the user's skin when the electronic device is releasably coupled to the user's body.

[0050] In other variations, one of the first electrode **302**A and second electrode **302**B is not used by the ECG measurement circuitry **306** in generating an ECG waveform. For example, the first electrode **302**A may be utilized by the capacitance measurement circuitry **304** but not by the ECG measurement circuitry **306**. In some of these variations, the hybrid sensor **300** may include an additional electrode (not shown) that is connected to and used by the ECG measurement circuitry **306** as a reference or ground electrode, but is not used by the capacitance measurement circuitry **304** to calculate a perspiration metric. In instances where an electrode may be selectively connected to either the ECG measurement circuitry **306** or the capacitance measurement circuitry **304**, the hybrid sensor **300** may include a switching arrangement (e.g., utilizing one or more switches), which may be any arrangement of components configured to selectively switch the electrode's connection. In the variation shown in FIG. **3**A, the hybrid sensor **300** includes a first switching arrangement **308**A that selectively connects the first electrode **302**A to either the ECG measurement circuitry **306** or the capacitance measurement circuitry **304**, and a second switching arrangement **308**B that selectively connects the second electrode **302**B to either the ECG measurement circuitry **306** or the capacitance measurement circuitry **304**.

[0051] FIG. **3**B shows an example process flow **310** by which an electronic device including the hybrid sensor **300** may selectively perform ECG and perspiration measurements using the hybrid sensor **300**. At step **312**, a determination is made (e.g., by a processor of an electronic device incorporating the hybrid sensor **300**) whether to initiate a measurement session. The measurement session may be a perspiration measurement session during which a first set of electrodes is used to calculate a perspiration metric, or may be an ECG measurement session during which a second set of electrodes is used to generate one or more ECG waveforms. At least one electrode is included in both the first and second sets of electrodes. For example, in some instances, the first electrode **302**A of the plurality of electrodes of hybrid sensor **300** is included in both the first and second sets of electrodes. In some of these variations, the second electrode **302**B is also included in both the first and second sets of electrodes.

[0052] The decision to initiate a particular measurement system may be based on any suitable criteria such as discussed above. For example, perspiration measurement sessions may be initiated on demand, automatically on a scheduled basis, or automatically when certain criteria are met. For example, in some variations, the perspiration session is initiated while an electronic device is monitoring a user exercise session. In these instances, the electronic device may include an activity tracking application that may track an exercise session, during which a set of sensors monitors a given user activity (e.g., running, walking, cycling, or the like) during an exercise session and tracks a set of exercise metrics associated with the activity (e.g., step count, distance traveled, calories burned, combinations thereof, or the like). Monitoring of the exercise session may begin automatically in response to determining that a user is engaging in a predetermined activity, or may begin in response to a user input signaling the start of an exercise session. In some instances, the electronic device automatically initiates a perspiration measurement session in response to the electronic device monitoring an exercise session (e.g., either immediately when the electronic device begins monitoring the exercise session or after a set of criteria associated with the exercise session is met). The electronic device may optionally generate a user interface (e.g., via the activity tracking application) while tracking an exercise session, and this user interface may display one or more attributes of the workout. In some instances, this user interface may display a perspiration metric during the exercise session.

[0053] Similarly ECG measurement sessions may be initiated on demand or automatically. Because an ECG measurement session may require that a user actively contact the third electrode **302**C, ECG measurement sessions may, in these instances, only be automatically initiated when a user is actively contacting the second set of electrodes. In some instances, an ECG measurement session may interrupt a perspiration measurement session, or vice versa. For example, if the electronic device is performing a perspiration measurement session while the electronic device is tracking an exercise session, the electronic device may stop the perspiration measurement session and initiate an ECG measurement session in response to a user requesting that the electronic device perform an ECG measurement during the exercise session. In some of these variations, the electronic device may automatically resume the perspiration measurement session after the ECG measurement session has been completed.

[0054] If a perspiration measurement session is selected at step **312**, the first set of electrodes is connected to the capacitance measurement circuitry **304** at step **314**. The first set of electrodes includes at least the first electrode **302**A and the second electrode **302**B. At step **316**, the capacitance measurement circuitry **306** will perform a set of capacitance measurements using the first set of electrodes as described previously, which is used to calculate a perspiration metric. At step **318**, a determination is made whether the perspiration measurement session is complete. If the session is not complete, the process returns to step **316** to perform additional measurements and calculate additional values of one or more perspiration metrics. If the session is complete, the process returns to step **312**.

[0055] Similarly, if an ECG measurement session is selected at step **312**, the second set of electrodes is connected to the ECG measurement circuitry **306** at step **320**. The second set of electrodes may include at least the third electrode **302**C and one or both of the first and second electrodes **302**A, **302**B, and in some instances may further include additional electrodes. As step **322**, the ECG measurement circuitry **306** performs an ECG measurement using the second set of electrodes to generate an ECG waveform as discussed above. At step **324**, a determination is made whether the ECG measurement session is complete. If the session is not complete, the process returns to step **322** to perform additional measurements and generate additional ECG waveforms. If the session is complete, the process returns to step **312**.

[0056] When the perspiration sensors described herein are used to calculate a perspiration metric, the external environment may impact the accuracy of the measurements performed by the perspiration sensors. For example, depending on the configuration of the electronic device incorporating the perspiration sensor and how the electronic device is coupled to the user, parts of the electrodes of a given perspiration sensor may be exposed to the ambient air. Depending on the relative temperature and humidity of the ambient air, sweat near the exposed parts of the electrodes may secrete and evaporate at different rates and thereby impact the capacitance values measured by a capacitance measurement circuit. This impact may be even greater at higher sweat rates. Accordingly, the devices described may be configured to reduce the impact of the external environment on measurements.

[0057] For example, in some variations an electronic device may be configured to define a cavity that houses a portion of the electrodes of a given perspiration sensor. For example, FIGS. **4**A and **4**B show rear and side views, respectively, of a variation of an electronic device **400** having a perspiration sensor **402** and that defines a cavity **404**. The electronic device **400** may otherwise be configured as described above with respect to the wearable electronic device **100** of FIGS. **1**A-**1**D (with like components using the same figure labels). For example, the electronic device **400** may include a watch body **104** having a display (not shown), a crown **112**, a button **114**, and an optical sensor **136** including a plurality of windows **138** (not shown in FIG. **4**B for sake of illustration), and the watch body **104** may be releasably coupled to a user using a strap **106**.

[0058] The perspiration sensor **402** includes a first electrode **406**A and a second electrode **406**B, which may be used to perform perspiration measurements as discussed previously. The first electrode **406**A and the second electrode **406**B are positioned on (and thereby define a portion of) a skin-facing exterior surface **408** of the wearable electronic device **100**. The cavity **404** may be defined in the skin-facing exterior surface **408** of the electronic device **400**. When the skin-facing exterior surface **408** is positioned against the skin of the user (e.g., when the electronic device **400** is releasably coupled to the user), the user's skin may at least partially cover and seal the cavity **404**, which may thereby shield the cavity **404** from the external environment. At least one of the first and second electrodes **406**A and **406**B is positioned to extend at least partially into the cavity **404**. While both the first and second electrodes **406**A, **406**B are shown in FIGS. **4**A and **4**B as extending at least partially into the cavity **404**, in other instances only one of the first and the second electrodes **406**A, **406**B extends at least partially into the cavity **404**.

[0059] In some variations, one or both of the first and second electrodes **406**A, **406**B extend only partially into cavity **404**, such that another portion of that electrode is positioned outside of the cavity **404**. For example, in the variation shown in FIGS. **4**A and **4**B, the first electrode **406**A includes a first portion and a second portion (separated by line **412** in FIG. **4**A) where the first portion (shown in phantom in FIG. **4**B) is positioned inside the cavity **404** and the second portion is positioned outside of the cavity **404**. Similarly, the second electrode **406**B includes a first portion and a second portion (also separated by line **412** in FIG. **4**A) where the first portion (also shown in phantom in FIG. **4**B) is positioned inside the cavity **404** and the second portion is positioned outside of the cavity **404**. In instances where one or both of the first and second electrodes **406**A, **406**B are used to perform an ECG measurement as part of a hybrid sensor (e.g., the hybrid sensor **300** discussed above with respect to FIGS. **3**A and **3**B), having respective portions of these electrodes positioned outside of the cavity **404** may facilitate contact between the electrodes and a user's skin during ECG measurements.

[0060] To define the cavity **404**, the skin-facing exterior surface **408** includes a first region **410**A surrounding a second region **410**B. At least a portion of the second region **410**B (i.e., the portion of the second region **410**B positioned between the first region **410**A and line **412** in FIG. **4**A) is recessed relative to the first region **410**A to define the cavity **404**. In some variations, at least a portion of the second region **410**B (i.e., the portion of the second region **410**B encircled by line **412**) protrudes past the first region **410**A. In other words, line **412** represents the portion of the second region **410**B that is positioned at the same height as the first region **410**A. In the variation shown in FIG. **4**B, the first region **410**A of the skin-facing exterior surface **408** is a flat region of the housing of the electronic device **400**, while the second region **410**B has a circular shape having a domed profile. In these instances, the cavity **404** has an annular shape. It should be appreciated that the first and second regions **410**A, **410**B may have different shapes and profiles that define a cavity having a different shape (e.g., circular, rectangular, or the like). In some variations in which the electronic device **400** includes an optical sensor **138** having a set of windows **138**, the set windows **138** of the optical sensor is positioned in the second region such that the first region surrounds the set of windows **138**.

[0061] In other variations, an electronic device includes a removable accessory component that may, in conjunction with a housing of the electronic device, define a cavity as discussed above. For example, FIGS. **5**A and **5**B show rear-facing and side views, respectively, of a variation of a system that includes an electronic device **500** and a removable accessory component **502** that at least partially defines a cavity **504**. The electronic device **500** may otherwise be configured as described above with respect to the wearable electronic device **100** of FIGS. **1**A-**1**D (with like components using the same figure labels). For example, the electronic device **500** may include a watch body **104** having a display (not shown), a crown **112**, and a button **114**, and the watch body **104** may be releasably coupled to a user using a strap **106**.

[0062] The accessory component **502** is configured to be releasably coupled to a skin-facing surface **512** of a housing of the electronic device **500**. In the variation shown in FIGS. **5**A and **5**B, the accessory component **502** is configured as a case that at least partially encircles a portion of the electronic device **500** (e.g., the watch body **104**) to releasably couple the accessory component **502** thereto. In other instances, the accessory component **502** may include a plate or other body that may be placed against the skin-facing surface **512** and releasably coupled thereto (e.g., using magnets, mechanical fasters, or the like). In this way, a user may decide to releasably couple the accessory component **502** to the electronic device **500** to define the cavity **504**. The cavity **504** may shield a perspiration sensor **506** during perspiration measurements, such as described above with respect to the cavity **404** of FIGS. **4**A and **4**B.

[0063] Specifically, the accessory component **502** defines an opening **510** that at least partially defines the cavity **504**. When the accessory component **502** is releasably coupled to the electronic device **500** the opening **510** is positioned such that at least a portion of the skin-facing surface **512** of the electronic device **500** is exposed through the opening **510**. The perspiration sensor **506**, which may be configured in any suitable manner as described previously, includes a first electrode **508**A and a second electrode **508**B, and the opening **510** is positioned such that at least a portion of each of the first electrode **508**A and the second electrode **508**B are exposed through the opening **510**, thereby allowing the perspiration sensor **506** to perform perspiration measurements as discussed above.

[0064] In some variations, a portion of the skin-facing surface **512** of the electronic device **500** extends at least partially through the opening **510**. For example, in the variation shown in FIGS. **5**A and **5**B, a portion of the electronic device **500** extends through the opening **510** and protrudes past a skin-facing surface **514** of the accessory component **502**. In these instances, a first portion of the electronic device **500** (e.g., positioned between the perimeter of the opening **510** and line **516** in FIG. **5**A) is recessed relative to the skin-facing surface **514** of the accessory component **502**, which defines, along with the accessory component **502**, the cavity **504**. Additionally, a second portion of the electronic device **500** (e.g., positioned within line **516**) protrudes past the skin-facing surface **514** of the accessory component **502**. In these variations, line **516** represents the portion of the skin-facing surface **512** of the housing that is positioned at the same height as the skin-facing surface **514** of the accessory component **502**. While the cavity **504** has an annular shape in the variation shown in FIGS. **5**A and **5**B, the cavity **504** may be defined with any suitable shape such as described above.

[0065] In some instances, at least a portion of one or both of the first and second electrodes **508**A, **508**B is positioned within the cavity **504** when the accessory device **502** is releasably coupled to the electronic device **500**. Additionally or alternatively, at least a portion of one or both of the first and second electrodes **508**A, **508**B are positioned outside the end of the cavity **504** when the accessory device **502** is releasably coupled to the electronic device **500**. In the variation shown in FIGS. **5**A and **5**B, the first electrode **508**A includes a first portion and a second portion (separated by line **516** in FIG. **5**A) where the first portion is positioned inside the cavity **504** and the second portion is positioned outside of the cavity **504**. Additionally or alternatively, the second electrode **508**B includes a first portion and a second portion (also separated by line **516** in FIG. **5**A) where the first portion is positioned inside the cavity **504** and the second portion is positioned outside of the cavity **504**. In instances where one or both of the first and second electrodes **508**A, **508**B are used to perform an ECG measurement as part of a hybrid sensor (e.g., the hybrid sensor **300** discussed above with respect to FIGS. **3**A and **3**B), having respective portions of these electrodes positioned outside of the cavity **504** may facilitate contact between the electrodes and a user's skin during ECG measurements.

[0066] While the variations of electronic devices described above with respect to FIGS. **1**A-**5**B each are shown as having a single perspiration sensor, in some instances an electronic device (which may otherwise be configured in any manner as described above with respect to FIGS. **1**A-**5**B) may include a plurality of perspiration sensors. FIGS. **6**A and **6**B show one such variation of an electronic device **600** including multiple perspiration sensors. The electronic device **600** may otherwise be configured as described above with respect to the wearable electronic device **100** of FIGS. **1**A-**1**D (with like components using the same figure labels). For example, the electronic device **600** may include a watch body **104** having a display (not shown), a crown **112**, a button **114**, and an optical sensor **136** including a plurality of windows **138** (not shown in FIG. **6**B for the sake of illustration), and the watch body **104** may be releasably coupled to a user using a strap **106**.

[0067] The electronic device **600** includes first and second perspiration sensors. In the variation shown in FIGS. **6**A and **6**B, the first perspiration sensor is configured as the perspiration sensor **102** described above with respect to FIGS. **1**A-**1**D, and that includes a first electrode **116**A and a second electrode **116**B (not depicted in FIG. **6**B) that are positioned on (and thereby define) a portion of a skin-facing surface **118** of a housing **108** of the electronic device **600**. The second perspiration sensor **602** is contained within a cavity **604** in the skin-facing surface **118** of the housing **108**. The second perspiration sensor **604** may comprise any sensor capable of outputting a signal indicative of the amount of moisture present in the cavity **604** (e.g., a humidity sensor, or the like). When the electronic device **600** is releasably coupled to a user such that the skin-facing surface **118** contacts the skin of a user, the user's skin may seal the cavity **604**.

[0068] The second perspiration sensor **602** and cavity **604** may be positioned closer to a center of the skin-facing surface **118** of the housing **108** than one or both of the electrodes of the first perspiration sensor **102**. The second perspiration sensor **602** may be relatively small when compared to the first perspiration sensor **102**, and may produce signals having a lower signal to noise ratio as compared to measurements performed by the first perspiration sensor **102**. By positioning the second perspiration sensor **602** and cavity closer to the center of the skin-facing surface **118**, it may be better shielded relative to the external environment than the electrodes of the first perspiration sensor **102**. For example, in instances where the skin-facing surface **118** of the housing **108** includes a region **606** having a domed profile as discussed above, defining the cavity in the region **606** (e.g., in a center of the region **606**) may increase the likelihood that the user's skin will fully seal the cavity **604** when the electronic device **600** is releasably coupled to a user.

[0069] In the variation shown in FIG. **6**A, first electrode **116**A and second electrode **116**B of the perspiration sensor **102** each have a semi-annular shape, and the cavity **604** (and thereby the second perspiration sensor **602**) is positioned between at least a portion of the first electrode **116**A and at least a portion of the second electrode **116**B of the perspiration sensor **102**. Additionally or alternatively, in variations where one or both of the first electrode **116**A and second electrode **116**B are positioned to extend at least partially into an annular cavity defined in the skin-facing surface (such as some of the embodiments of the electronic device **400** and cavity **404**) described above with respect to FIGS. **4**A and **4**B), this annular cavity may encircle the cavity **604** that encloses the perspiration sensor **602** (i.e., the second perspiration sensor **602** does not extend outside of the cavity **604**). Additionally or alternatively, in instances where the electronic device **600** includes an optical sensor **136** that has a set of windows **138** (not depicted in FIG. **6**B), some or all of the windows may be positioned between the cavity **604** (and with it, the second perspiration sensor **602**) and one or both of the first and second electrodes **116**A, **116**B.

[0070] The electronic device **600** may use measurements from both the first and second perspiration sensors in calculating a perspiration metric. For example, when the method **200** described above with respect to FIG. **2** is performed by a device having a plurality of perspiration sensors (such as electronic device **600** of FIGS. **6**A and **6**B), the method may further comprise obtaining a set of additional measurements using a second perspiration sensor. In these instances, at step **206** the method includes calculating the perspiration metric using both the set of capacitance measurements obtained by a first perspiration sensor and the set of additional measurements obtained by the second perspiration sensor. As an example, a relationship between a measured capacitance and an estimated sweat rate may also utilize information from the set of additional measurements as an input.

[0071] As described above, one aspect of the present technology involves measuring physiological signals, such as perspiration and ECG measurements. The present disclosure contemplates that in some instances this gathered data may include personal information data that uniquely identifies or can be used to contact or locate a specific person. Such personal information data can include demographic data, location-based data, telephone numbers, email addresses, Twitter IDs (or other social media aliases or handles), home addresses, data or records relating to a user's health or level of fitness (e.g., vital signs measurements, medication information, exercise information), date of birth, or any other identifying or personal information.

[0072] The present disclosure recognizes that the use of such personal information data, in the present technology, can be used to the benefit of users. For example, the personal information data can be used to provide haptic or audiovisual outputs that are tailored to the user. Further, other uses for personal information data that benefit the user are also contemplated by the present disclosure. For instance, health and fitness data may be used to provide insights into a user's general wellness or may be used as positive feedback to individuals using technology to pursue wellness goals.

[0073] The present disclosure contemplates that the entities responsible for the collection, analysis, disclosure, transfer, storage, or other use of such personal information data will comply with well-established privacy policies and/or privacy practices. In particular, such entities should implement and consistently use privacy policies and practices that are generally recognized as meeting or exceeding industry or governmental requirements for maintaining the privacy and security of personal information data. Such policies should be easily accessible by users and should be updated as the collection and/or use of data changes. Personal information from users should be collected for legitimate and reasonable uses of the entity and not shared or sold outside of those legitimate uses. Further, such collection/sharing should occur after receiving the informed consent of the users. Additionally, such entities should consider taking any needed steps for safeguarding and securing access to such personal information data and ensuring that others with access to the personal information data adhere to their privacy policies and procedures. Further, such entities can subject themselves to evaluation by third parties to certify their adherence to widely accepted privacy policies and practices. In addition, policies and practices should be adapted for the particular types of personal information data being collected and/or accessed and revised to adhere to applicable laws and standards, including jurisdiction-specific considerations. For instance, in the US, collection of or access to certain health data may be governed by federal and/or state laws, such as the Health Insurance Portability and Accountability Act ("HIPAA"); whereas health data in other countries may be subject to other regulations and policies and should be handled accordingly. Hence different privacy practices should be maintained for different personal data types in each country.

[0074] Despite the foregoing, the present disclosure also contemplates embodiments in which users selectively block the use of, or access to, personal information data. That is, the present disclosure contemplates that hardware and/or software elements can be provided to prevent or block access to such personal information data. For example, in the case of determining spatial parameters, the present technology can be configured to allow users to select to "opt in" or "opt out" of participation in the collection of personal information data during registration for services or anytime thereafter. In addition to providing "opt in" and "opt out" options, the present disclosure contemplates providing notifications relating to the access or use of personal information. For instance, a user may be notified upon downloading an app that their personal information data will be accessed and then reminded again just before personal information data is accessed by the app.

[0075] Moreover, it is the intent of the present disclosure that personal information data should be managed and handled in a way to minimize risks of unintentional or unauthorized access or use. Risk can be minimized by limiting the collection of data and deleting data once it is no longer needed. In addition, and when applicable, including in certain health related applications, data de-identification can be used to protect a user's privacy. De-identification may be facilitated, when appropriate, by removing specific identifiers (e.g., date of birth, etc.), controlling the amount or specificity of data stored (e.g., collecting location data at a city level rather than at an address level), controlling how data is stored (e.g., aggregating data across users), and/or other methods.

[0076] Therefore, although the present disclosure broadly covers use of personal information data to implement one or more various disclosed embodiments, the present disclosure also contemplates that the various embodiments can also be implemented without the need for accessing such personal information data. That is, the various embodiments of the present technology are not rendered inoperable due to the lack of all or a portion of such personal information data. For example, haptic outputs may be provided based on non-personal information data or a bare minimum amount of personal information, such as events or states at the device associated with a user, other non-personal information, or publicly available information.

[0077] The foregoing description, for purposes of explanation, used specific nomenclature to provide a thorough understanding of the described embodiments. However, it will be apparent to one skilled in the art that the specific details are not required in order to practice the described embodiments. Thus, the foregoing descriptions of the specific embodiments described herein are presented for purposes of illustration and description. They are not targeted to be exhaustive or to limit the embodiments to the precise forms disclosed. It will be apparent to one of ordinary skill in the art that many modifications and variations are possible in view of the above teachings.

What is claimed is:

1. A method for measuring physiological signals using an electronic device comprising a plurality of electrodes, the method comprising:

during a perspiration measurement session:
- connecting a first set of electrodes of the plurality of electrodes to capacitive measurement circuitry;
- performing a set of capacitance measurements using the first set of electrodes; and
- calculating a perspiration metric using the set of capacitance measurements; and
- during an electrocardiogram measurement;
- connecting a second set of electrodes of the plurality of electrodes to electrocardiogram measurement circuitry; and
  - performing an electrocardiogram measurement to generate an ECG waveform; wherein:
  - the plurality of electrodes comprises a first electrode and a second electrode;
  - the first set of electrodes comprises the first electrode and the second electrode; and
  - the second set of electrodes comprises the first electrode.

2. The method of claim **1**, wherein:

the second set of electrodes comprises the second electrode.

3. The method of claim **2**, wherein:

the plurality of electrodes comprises a third electrode; and

the second set of electrodes comprises the third electrode.

4. The method of claim **1**, wherein the perspiration metric is an estimated sweat rate.

5. The method of claim **1**, wherein the perspiration measurement session is initiated while the electronic device is tracking an exercise session.

6. The method of claim **5**, wherein the perspiration measurement session is initiated automatically in response to the electronic device tracking the exercise session.

7. A device for calculating a perspiration metric of a user, comprising:

a housing having an exterior surface;

a perspiration sensor comprising:
- a first electrode; and
- a second electrode; and

a processer configured to calculate the perspiration metric using the perspiration sensor; wherein:
- the exterior surface of the housing defines a cavity; and
- the first electrode extends at least partially into the cavity.

8. The device of claim **7**, wherein:

the second electrode extends at least partially into the cavity.

9. The device of claim **7**, wherein:

a portion of the first electrode is positioned outside of the cavity.

10. The device of claim **7**, wherein:

the exterior surface comprises a first region surrounding a second region; and

a first portion of the second region is recessed relative to the second region to define the cavity.

11. The device of claim **10**, wherein:

a second portion of the second region protrudes past the first region.

12. The device of claim **10**, wherein:

the cavity has an annular shape.

13. The device of claim **10**, further comprising:

an optical sensor comprising a set of windows; wherein the set of windows is positioned in the second region.

14. The device of claim **7**, wherein:

the perspiration sensor is a first perspiration sensor; and

the device comprises a second perspiration sensor.

15. The device of claim **7**, wherein:

the perspiration sensor comprises capacitance measurement circuitry configured to measure a capacitance between the first electrode and the second electrode.

16. A device for calculating a perspiration metric of a user, comprising:

a housing having an exterior surface that defines a first cavity;

a first perspiration sensor comprising:
- a first electrode defining a first portion of the exterior surface; and
- a second electrode defining a second portion of the exterior surface;

a second perspiration sensor contained within the first cavity; and

a processer configured to calculate the perspiration metric using both the first perspiration sensor and the second perspiration sensor.

17. The device of claim **16**, wherein:

the housing defines a second cavity; and

the first electrode extends at least partially into the second cavity.

18. The device of claim **17**, wherein:
the second cavity encircles the first cavity.

19. The device of claim **16**, wherein:
the first cavity is positioned between at least a portion of the first electrode and at least a portion of the second electrode.

20. The device of claim **16**, wherein:
the first cavity is positioned closer to a center of the exterior surface of the housing relative to the first electrode.

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