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(54) DETERMINING PHYSIOLOGICAL STATE(S) OF AN ORGANISM BASED ON DATA SENSED WITH SENSORS IN MOTION

(71) Applicants: **Michael Edward Smith Luna**, San Jose, CA (US); **Sankalita Saha**, Union City, CA (US); **Scott Fullam**, Palo Alto, CA (US)

(72) Inventors: **Michael Edward Smith Luna**, San Jose, CA (US); **Sankalita Saha**, Union City, CA (US); **Scott Fullam**, Palo Alto, CA (US)

(73) Assignee: **AliphCom**, San Francisco, CA (US)

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A61B 5/08	(2006.01)
A61B 5/053	(2006.01)
A61B 5/11	(2006.01)
A61M 21/00	(2006.01)
A61B 5/024	(2006.01)

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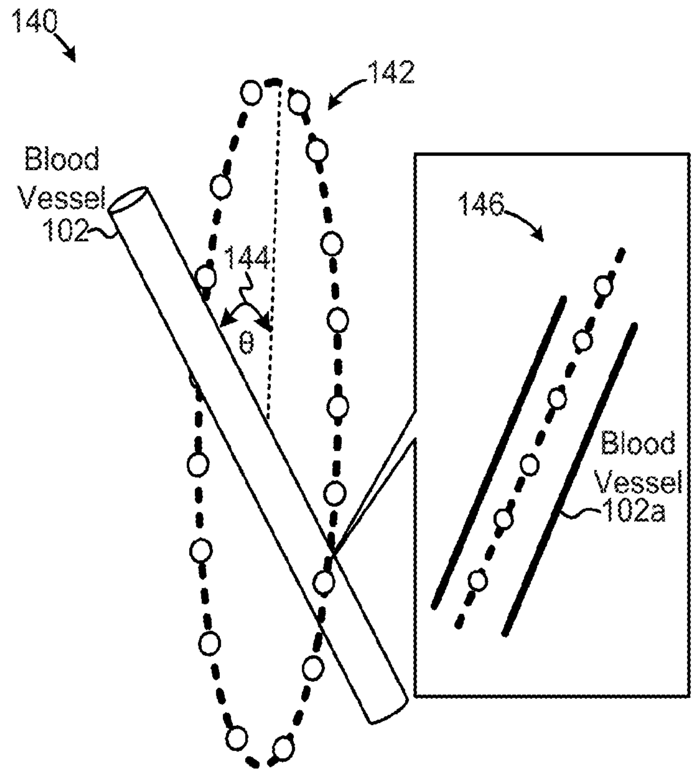
(57) **ABSTRACT**

Embodiments of the invention relate generally to electrical and electronic hardware, computer software, wired and wireless network communications, and wearable computing devices for facilitating health and wellness-related information. More specifically, disclosed are electrodes and methods to determine physiological states using a wearable device (or carried device) and one or more sensors that can be subject to motion. In one embodiment, a method includes receiving a sensor signal including data representing physiological characteristics in a wearable device from a distal end of a limb and a motion sensor signal. The method includes decomposing at a processor the sensor signal to determine physiological signal components. A physiological characteristic signal is generated that includes data representing a physiological characteristic, which can form a basis to determine a physiological state based on, for example, bioimpedance signals originating from the distal end of the limb.



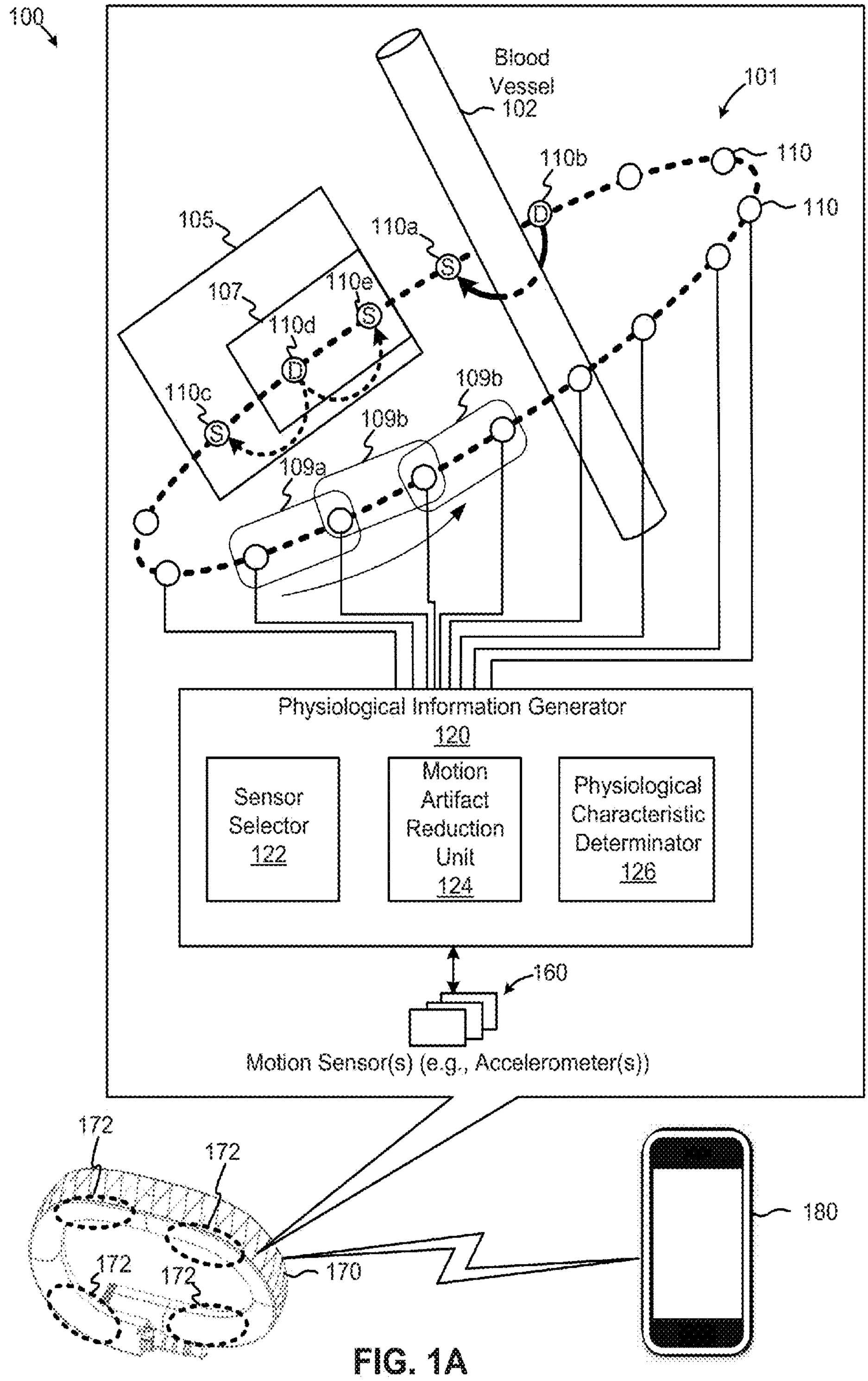

100
Blood
Vessel
102
101
110
110
110b
110a
105
107
110e
110d
110c
109b
109b
109a
Physiological Information Generator
120
Sensor
Selector
122
Motion
Artifact
Reduction
Unit
124
Physiological
Characteristic
Determinator
126
160
Motion Sensor(s) (e.g., Accelerometer(s))
172
172
172
172
170
180

FIG. 1A

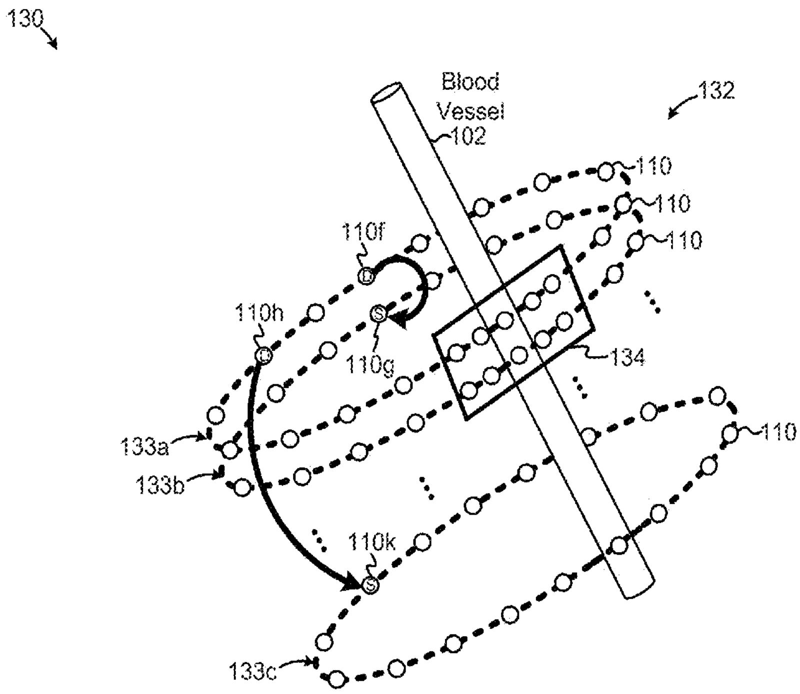


FIG. 1B

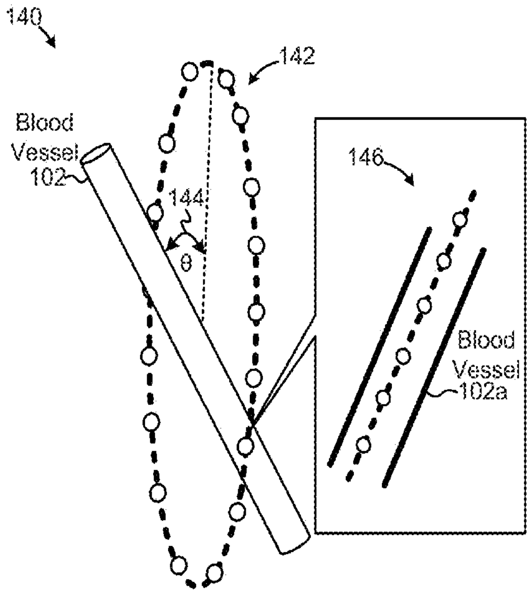


FIG. 1C

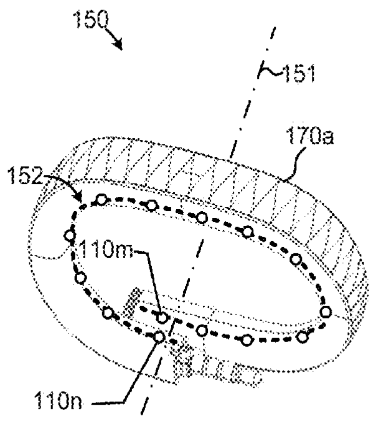


FIG. 1D

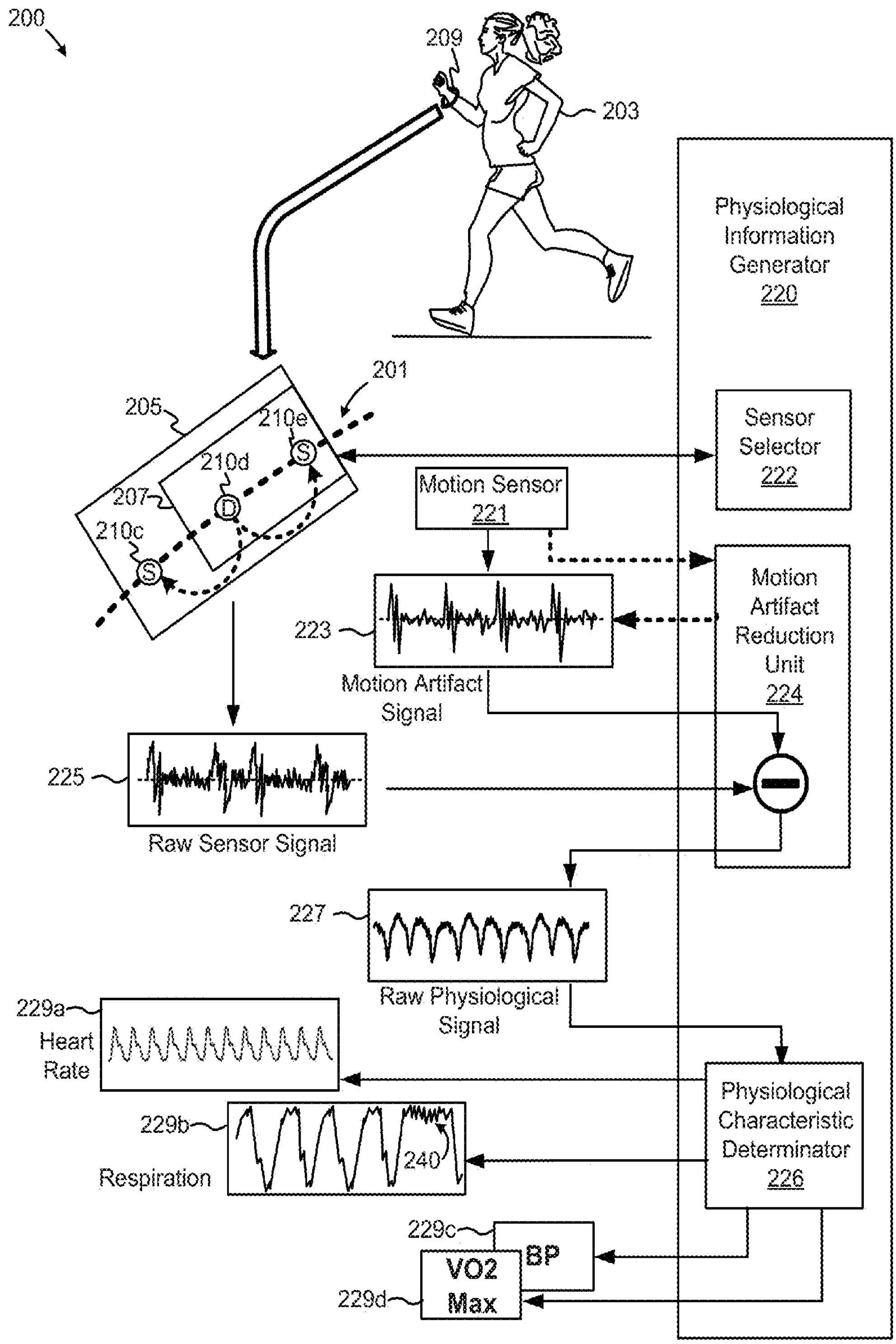

200
209
203
Physiological Information Generator 220
201
205
210e
210d
207
210c
Sensor Selector 222
Motion Sensor 221
Motion Artifact Reduction Unit 224
223
Motion Artifact Signal
225
Raw Sensor Signal
227
Raw Physiological Signal
229a
Heart Rate
229b
Respiration
240
Physiological Characteristic Determinator 226
229c
BP
VO2 Max
229d

FIG. 2

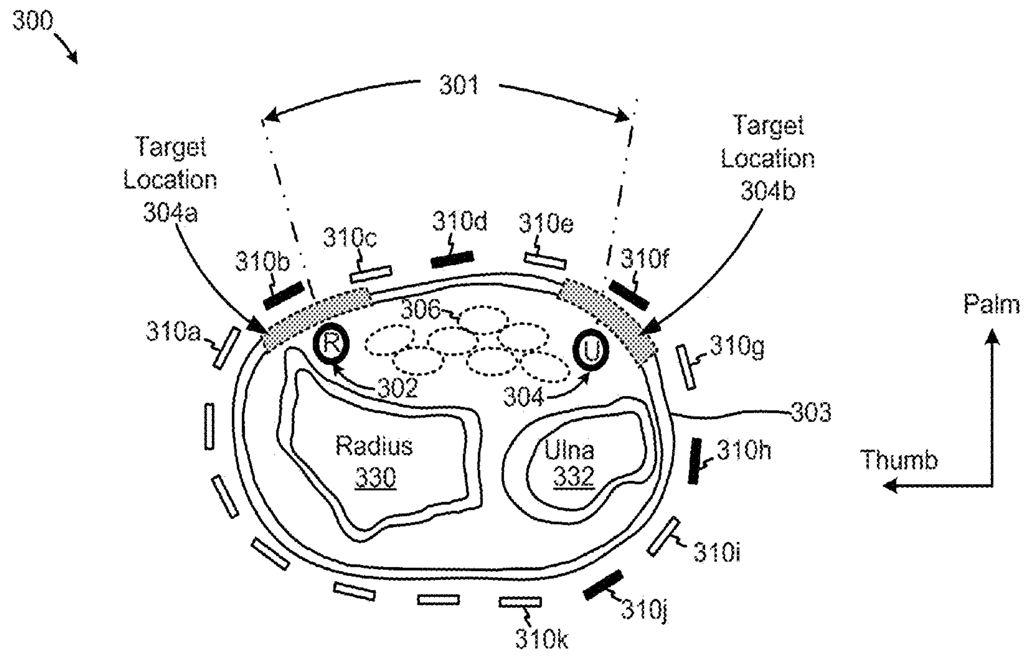

300
301
Target Location 304a
Target Location 304b
310a
310b
310c
310d
310e
310f
310g
310h
310i
310j
310k
306
R
U
302
304
303
Radius 330
Ulna 332
Palm
Thumb

FIG. 3A

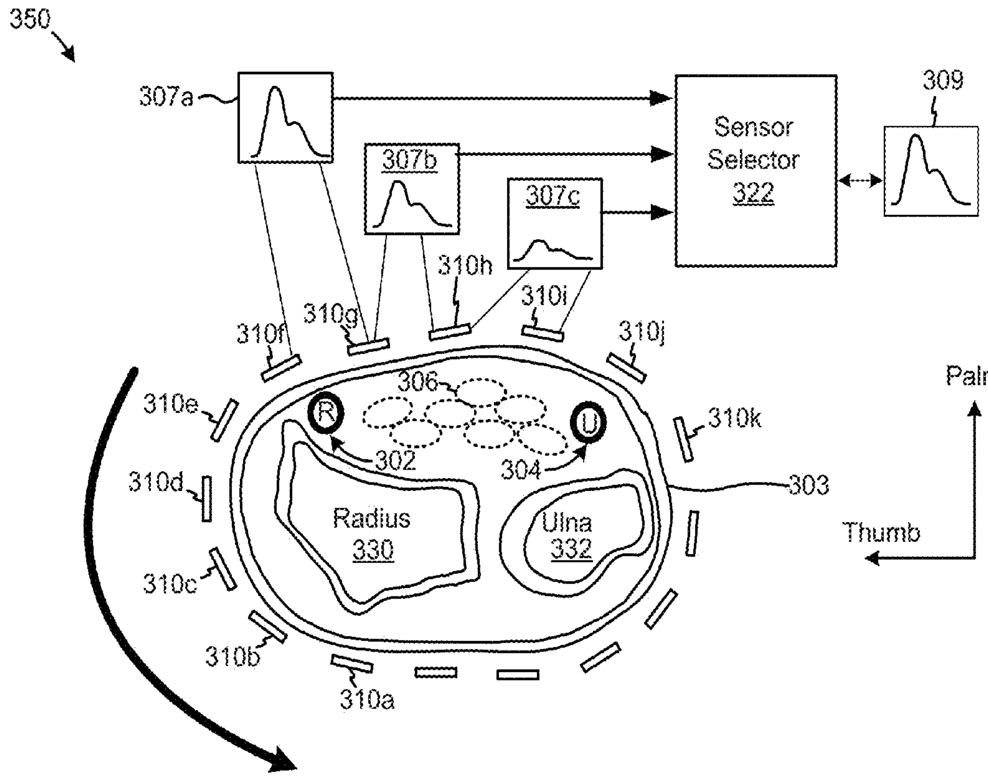

350
307a
307b
307c
Sensor Selector 322
309
310a
310b
310c
310d
310e
310f
310g
310h
310i
310j
310k
306
R
U
302
304
303
Radius 330
Ulna 332
Palm
Thumb

FIG. 3B

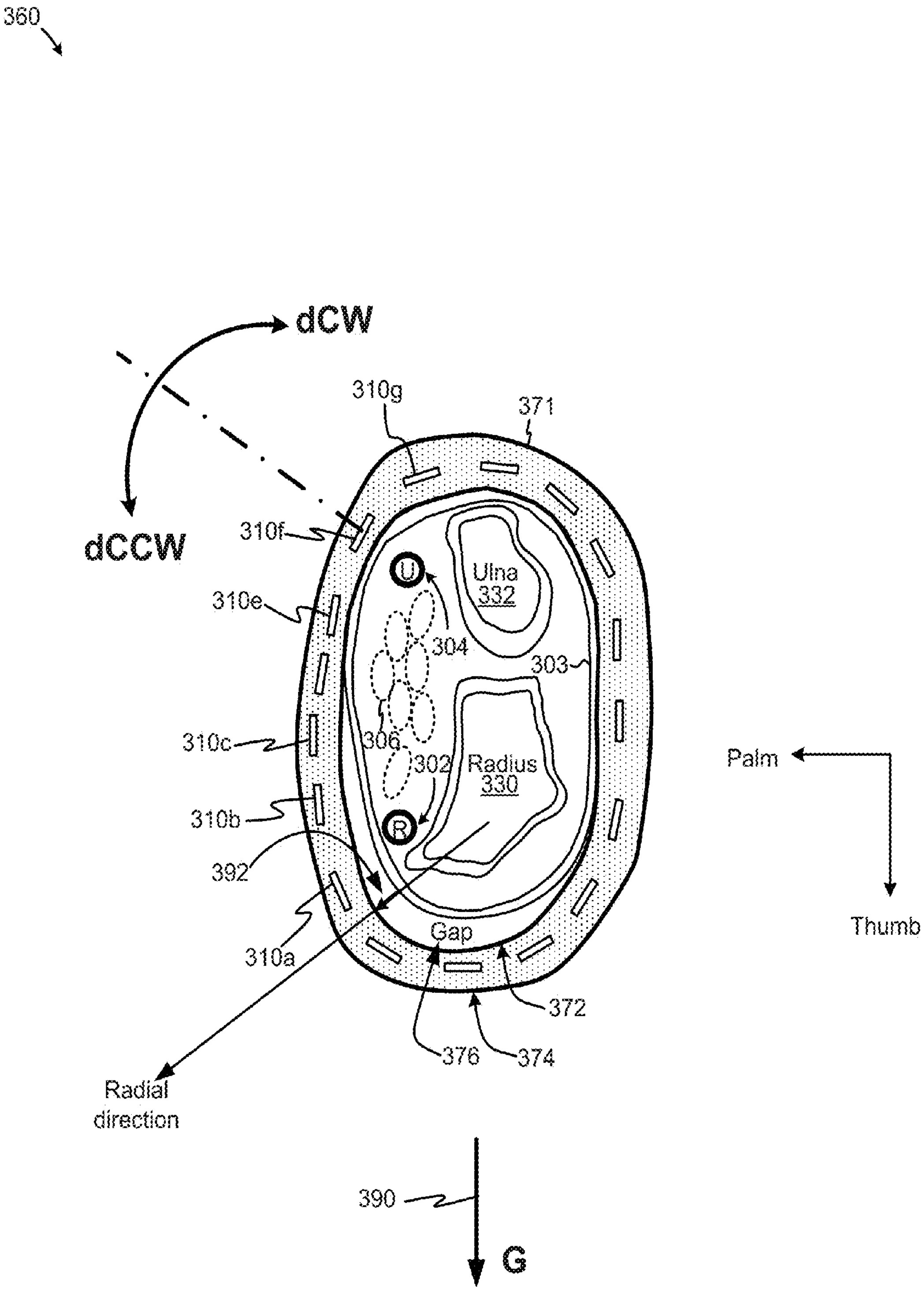

360
dCW
dCCW
310g
371
310f
310e
310c
310b
392
310a
Ulna
332
304
303
306
302
Radius
330
U
R
Gap
372
376
374
Radial
direction
Palm
Thumb
390
G

FIG. 3C

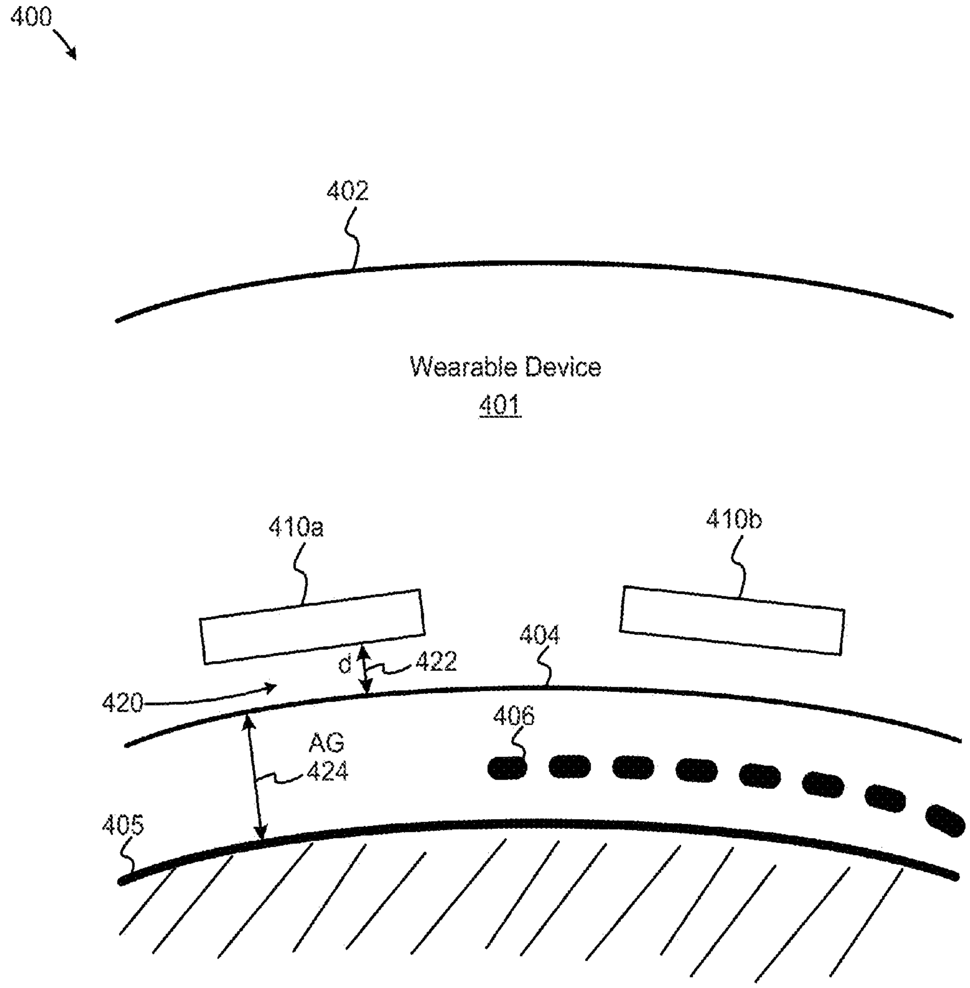

400
402
Wearable Device
401
410a
410b
404
d
422
420
406
AG
424
405

FIG. 4

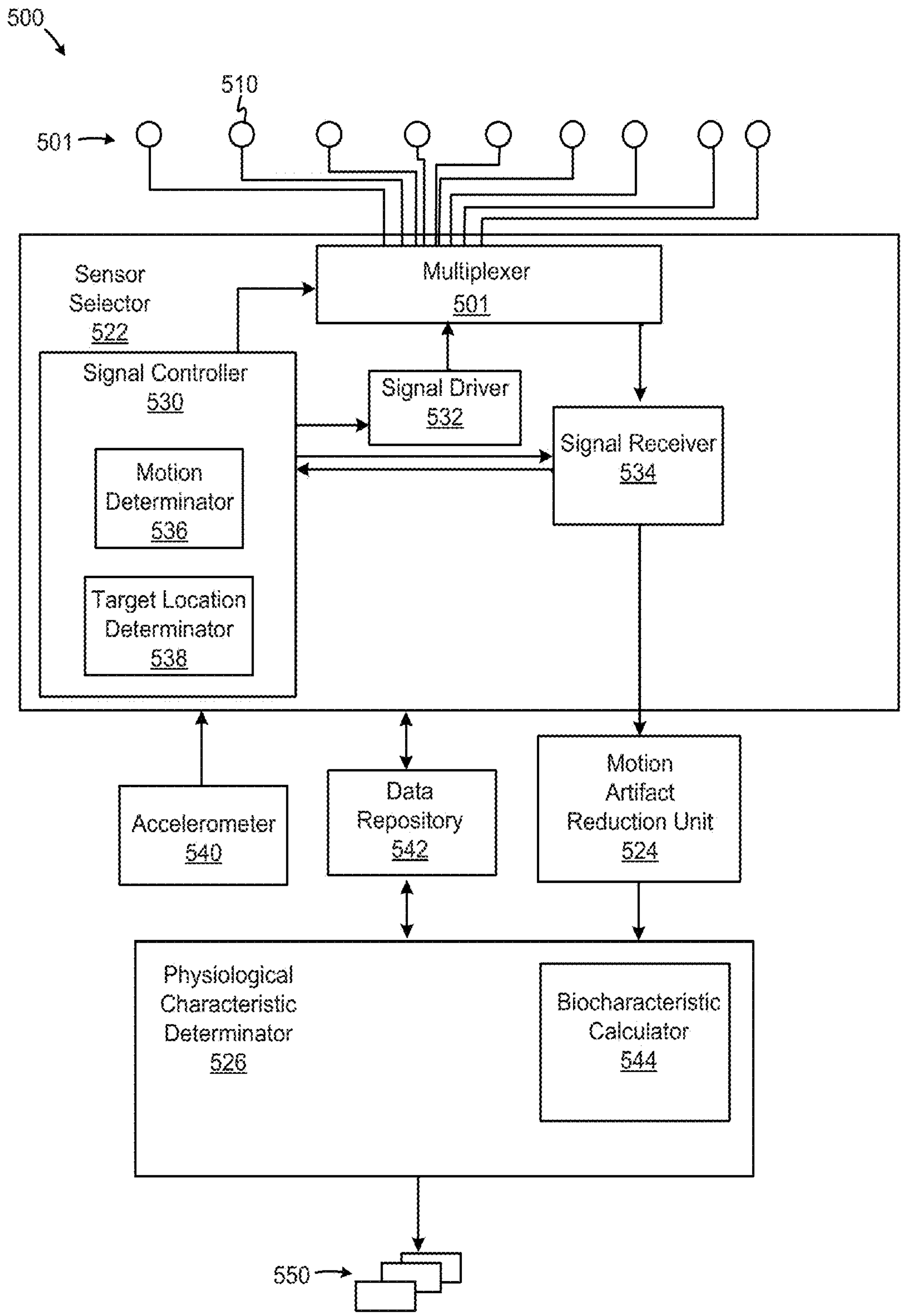

500
510
501
Multiplexer
501
Sensor
Selector
522
Signal Controller
530
Signal Driver
532
Signal Receiver
534
Motion
Determinator
536
Target Location
Determinator
538
Accelerometer
540
Data
Repository
542
Motion
Artifact
Reduction Unit
524
Physiological
Characteristic
Determinator
526
Biocharacteristic
Calculator
544
550

FIG. 5

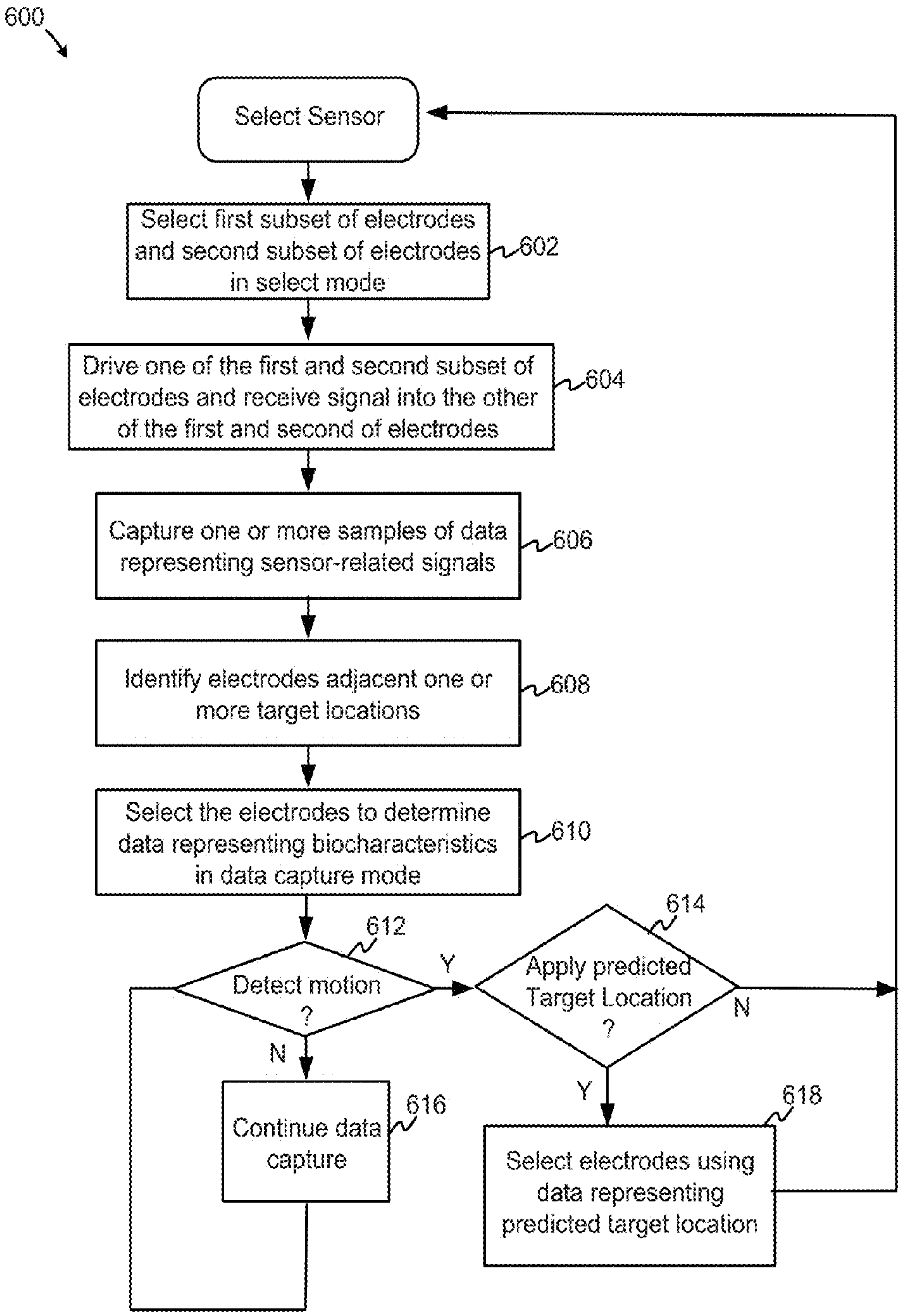

600
Select Sensor
Select first subset of electrodes and second subset of electrodes in select mode
602
Drive one of the first and second subset of electrodes and receive signal into the other of the first and second of electrodes
604
Capture one or more samples of data representing sensor-related signals
606
Identify electrodes adjacent one or more target locations
608
Select the electrodes to determine data representing biocharacteristics in data capture mode
610
Detect motion ?
612
Y
N
Apply predicted Target Location ?
614
N
Y
Continue data capture
616
Select electrodes using data representing predicted target location
618

FIG. 6

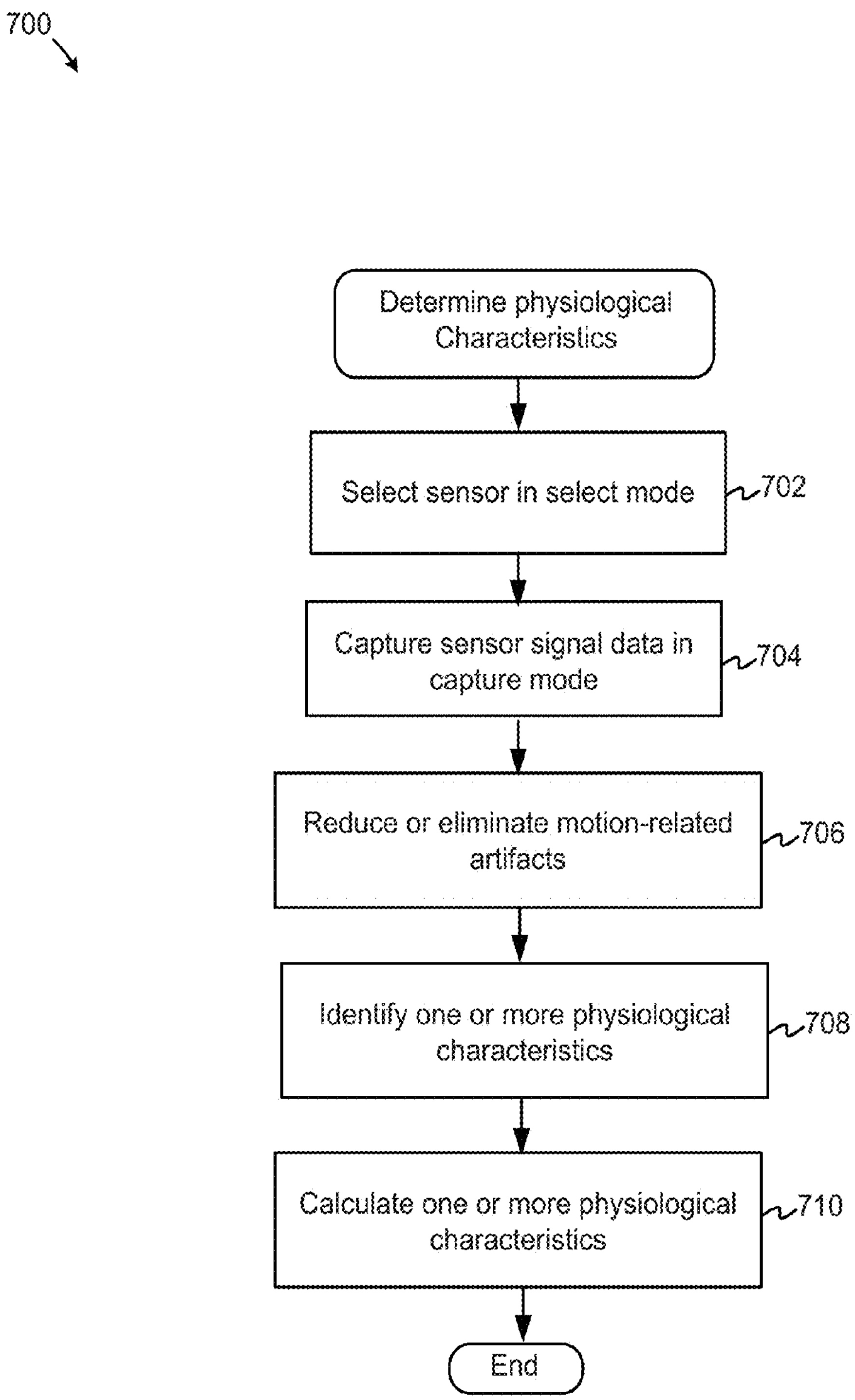

700
Determine physiological Characteristics
Select sensor in select mode
702
Capture sensor signal data in capture mode
704
Reduce or eliminate motion-related artifacts
706
Identify one or more physiological characteristics
708
Calculate one or more physiological characteristics
710
End

FIG. 7

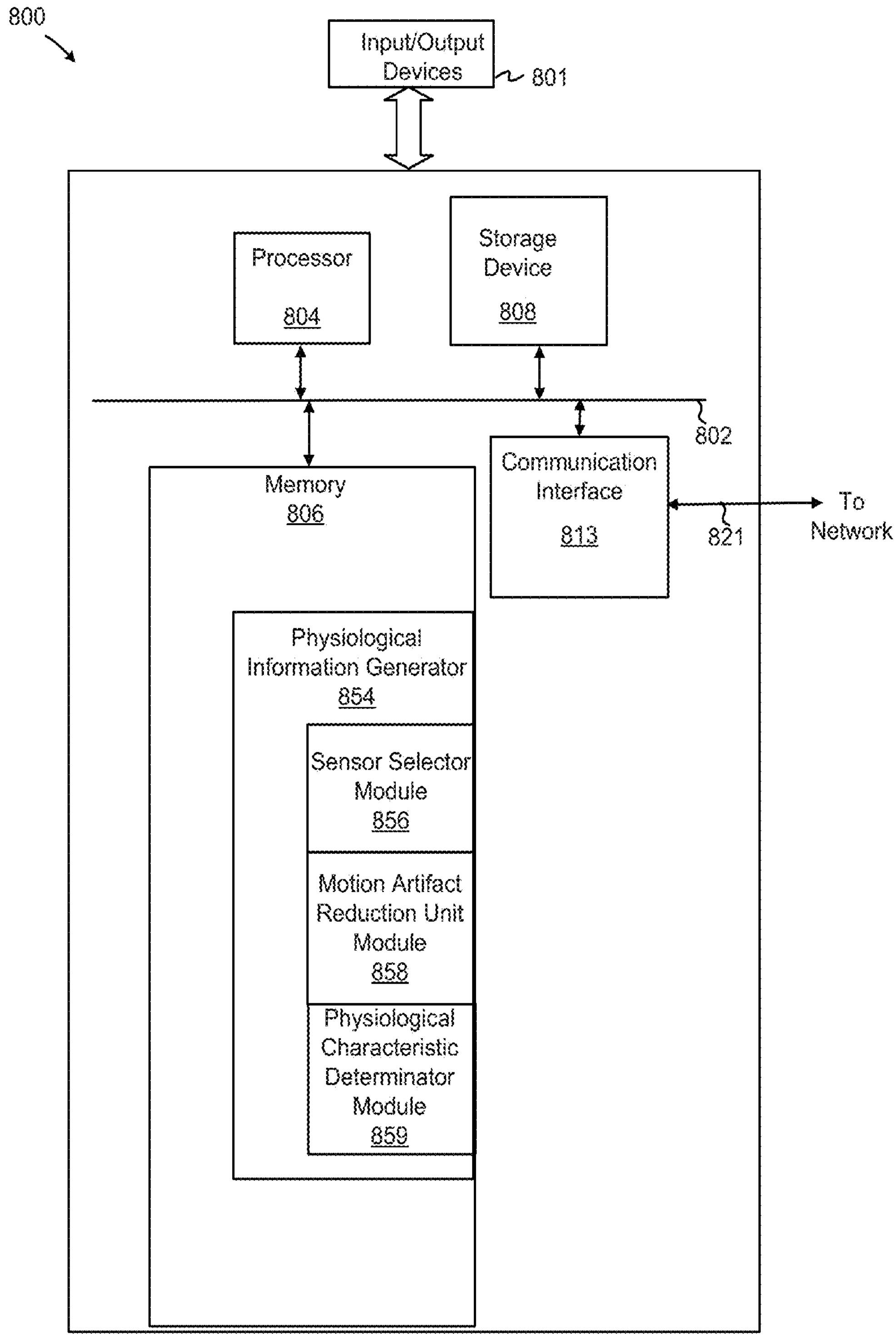

800
Input/Output Devices
801
Processor
804
Storage Device
808
802
Memory
806
Communication Interface
813
821
To Network
Physiological Information Generator
854
Sensor Selector Module
856
Motion Artifact Reduction Unit Module
858
Physiological Characteristic Determinator Module
859

FIG. 8

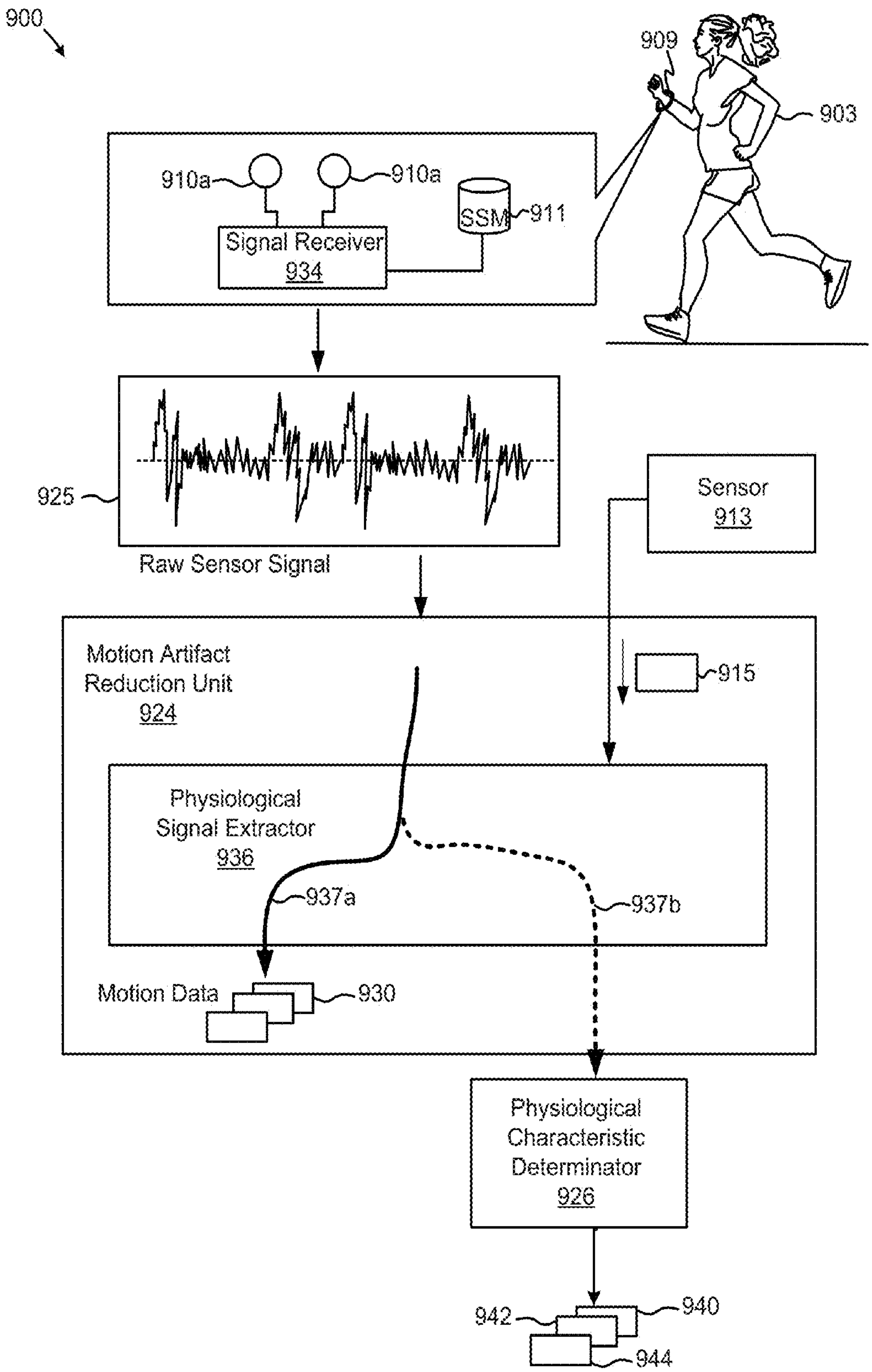

900
909
903
910a
910a
SSM
911
Signal Receiver
934
925
Raw Sensor Signal
Sensor
913
Motion Artifact
Reduction Unit
924
915
Physiological
Signal Extractor
936
937a
937b
Motion Data
930
Physiological
Characteristic
Determinator
926
942
940
944

FIG. 9

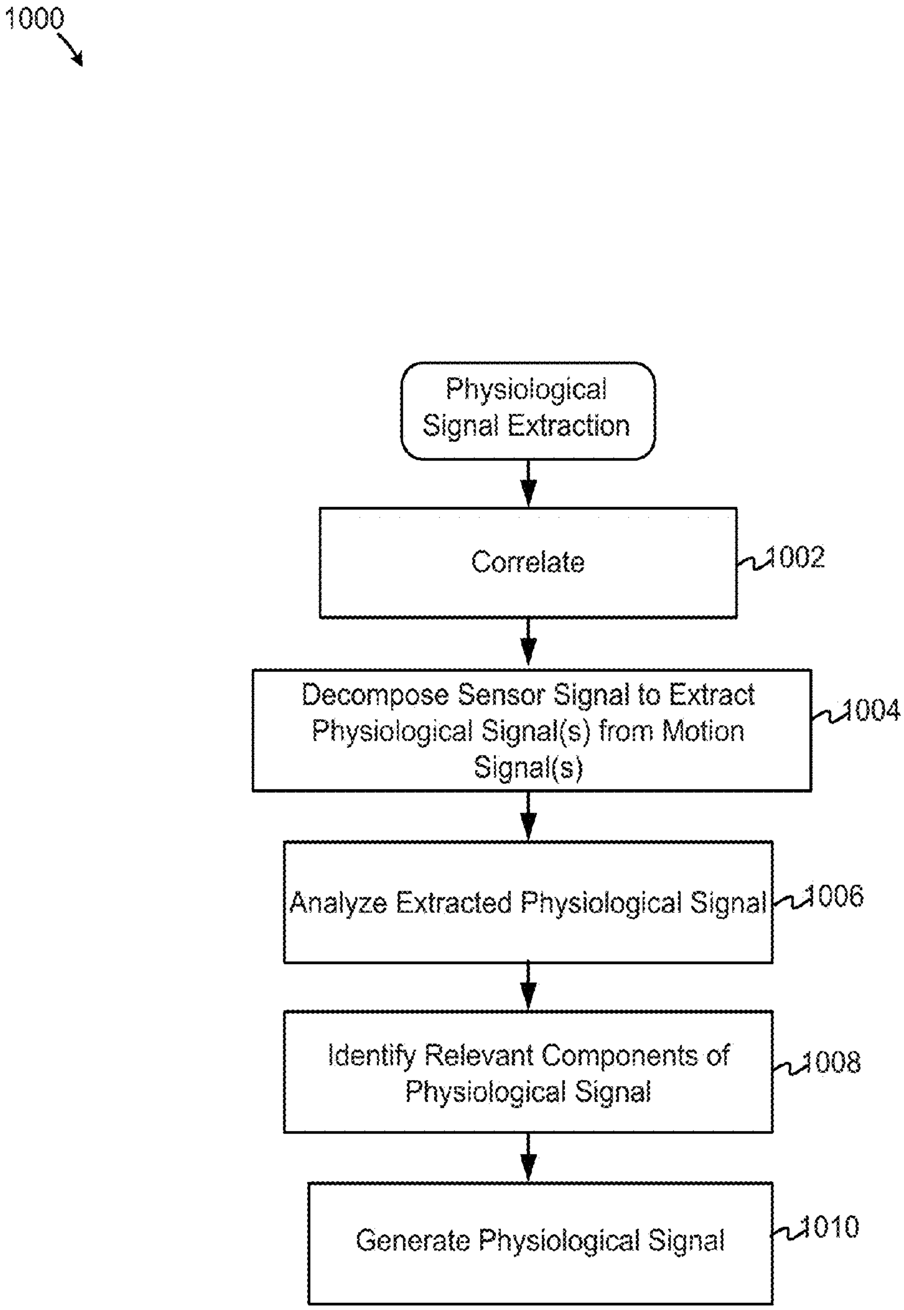

1000
Physiological Signal Extraction
Correlate
1002
Decompose Sensor Signal to Extract Physiological Signal(s) from Motion Signal(s)
1004
Analyze Extracted Physiological Signal
1006
Identify Relevant Components of Physiological Signal
1008
Generate Physiological Signal
1010

FIG. 10

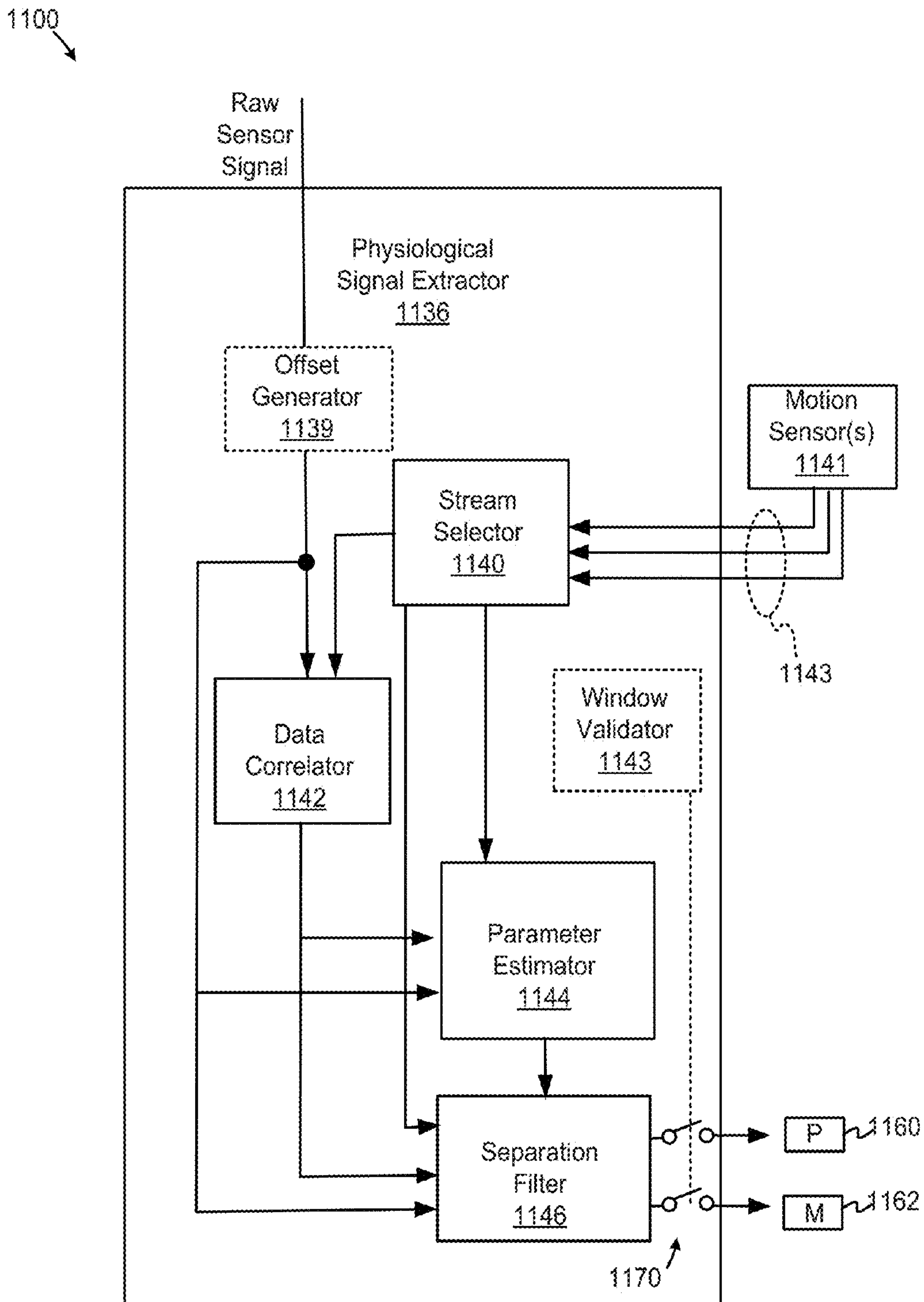

1100
Raw Sensor Signal
Physiological Signal Extractor 1136
Offset Generator 1139
Motion Sensor(s) 1141
Stream Selector 1140
1143
Window Validator 1143
Data Correlator 1142
Parameter Estimator 1144
Separation Filter 1146
P
1160
M
1162
1170

FIG. 11

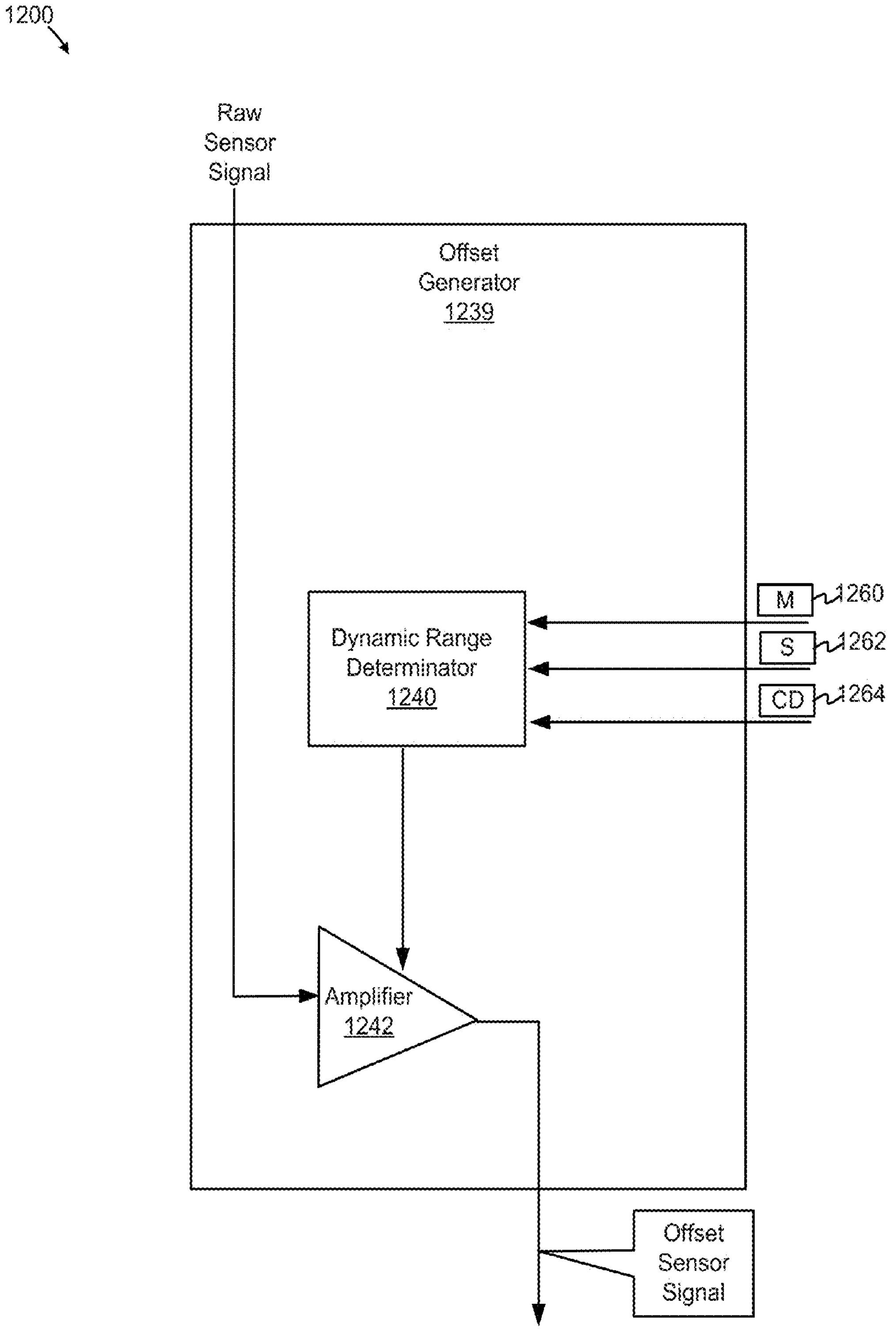

1200
Raw Sensor Signal
Offset Generator 1239
Dynamic Range Determinator 1240
M
1260
S
1262
CD
1264
Amplifier 1242
Offset Sensor Signal

FIG. 12

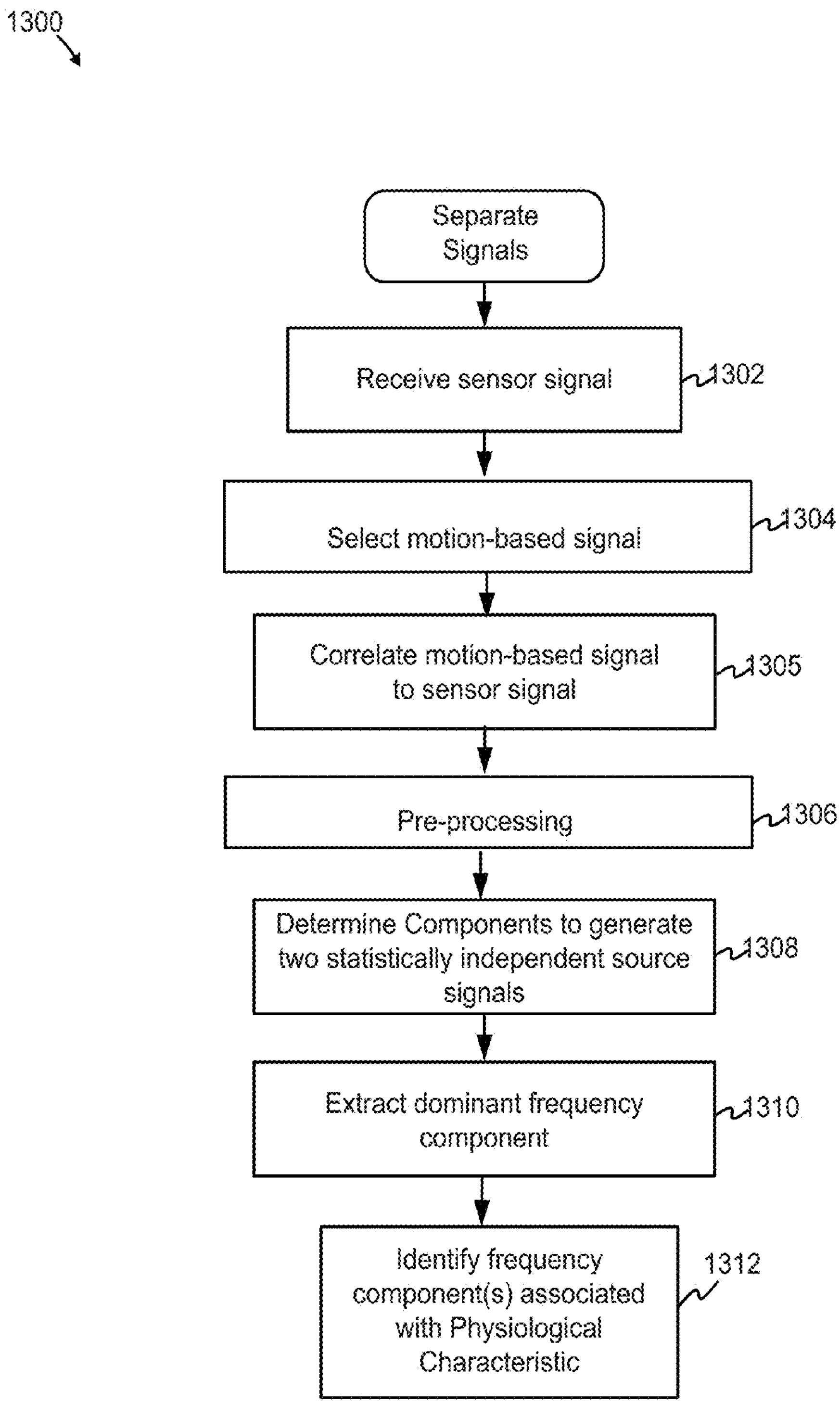

1300
Separate Signals
Receive sensor signal
1302
Select motion-based signal
1304
Correlate motion-based signal to sensor signal
1305
Pre-processing
1306
Determine Components to generate two statistically independent source signals
1308
Extract dominant frequency component
1310
Identify frequency component(s) associated with Physiological Characteristic
1312

FIG. 13

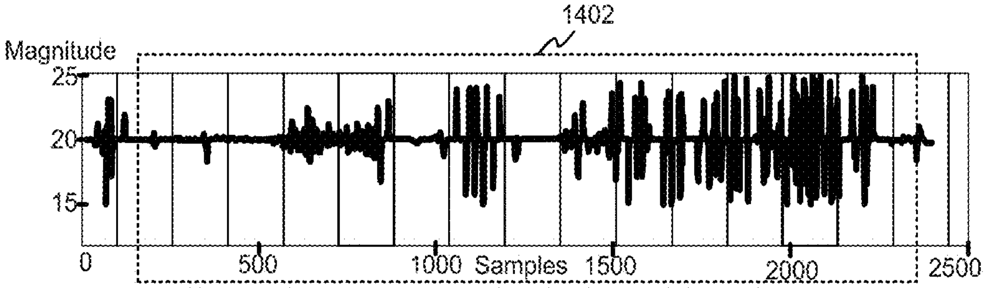


FIG. 14A

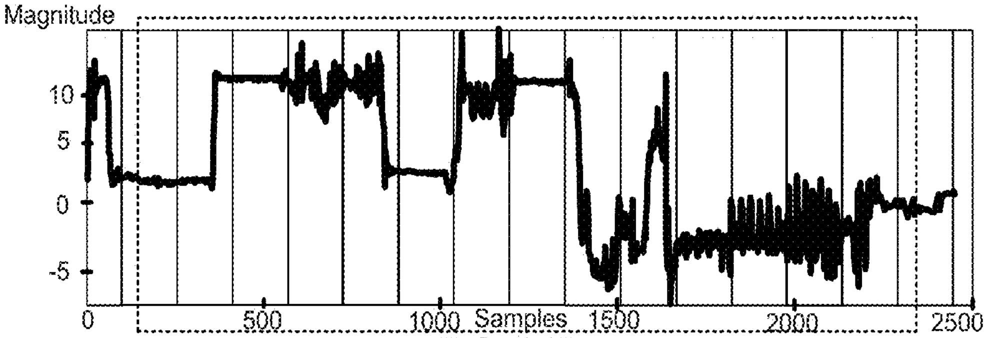


FIG. 14B

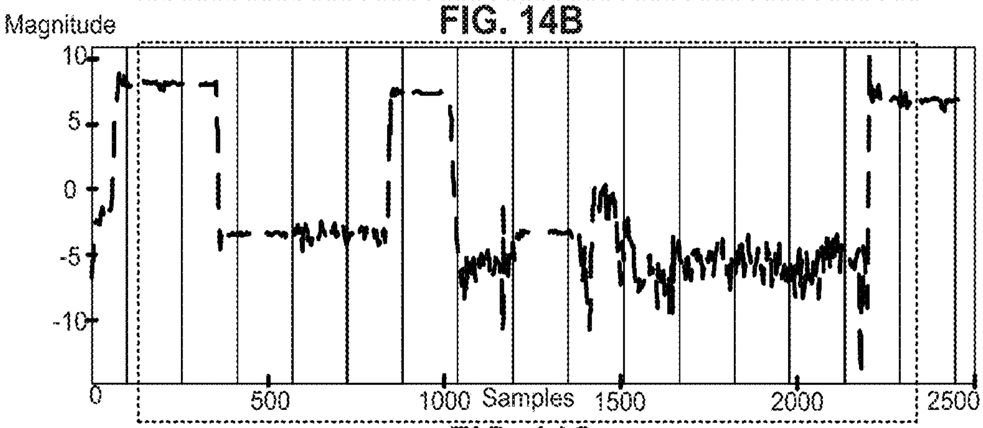


FIG. 14C

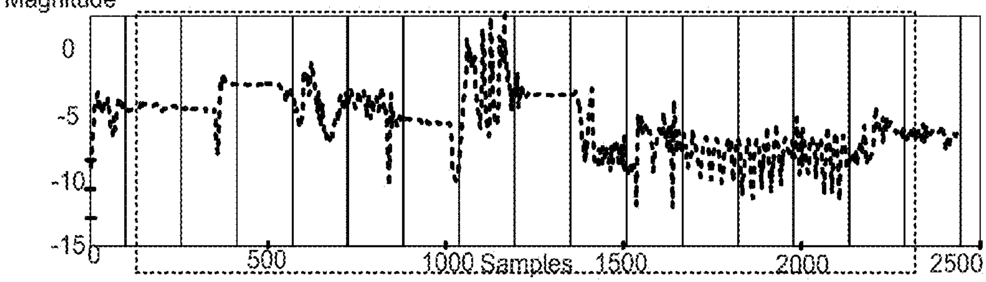


FIG. 14D

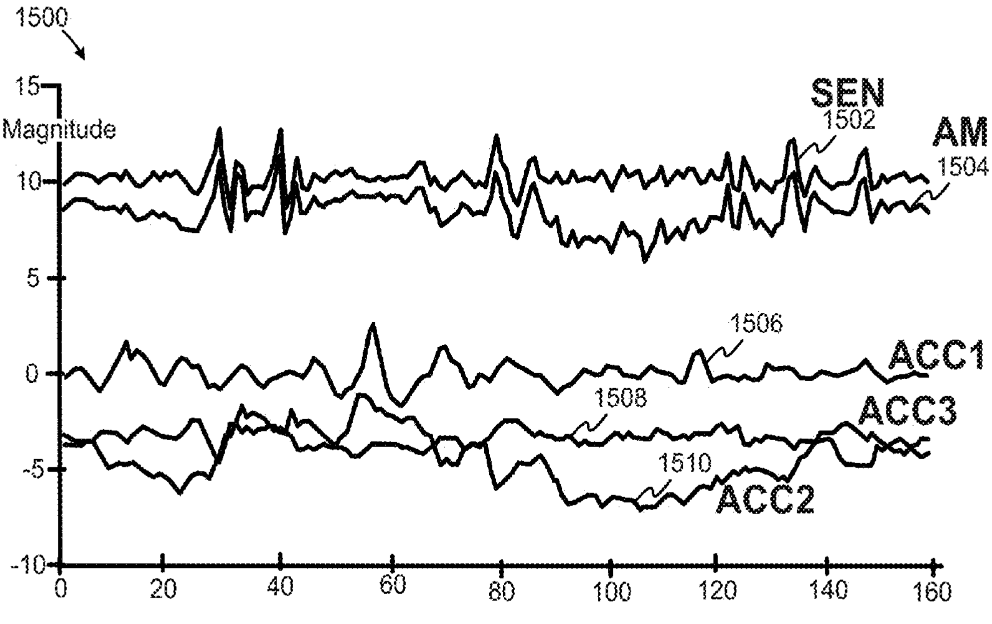

1500
15
Magnitude
10
5
0
-5
-10
SEN
1502
AM
1504
1506
ACC1
1508
ACC3
1510
ACC2
0
20
40
60
80
100
120
140
160
Samples

FIG. 15

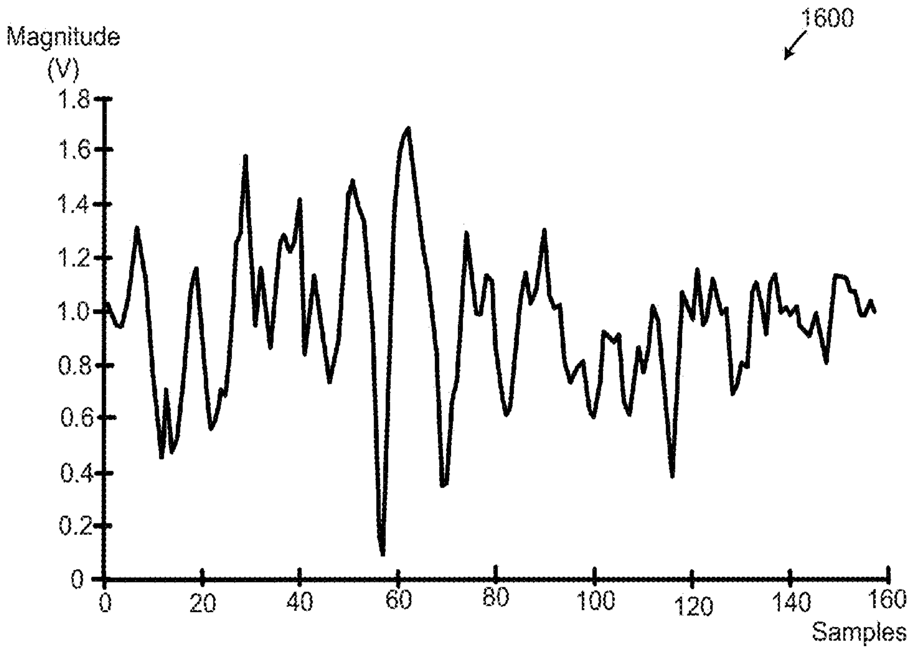

Magnitude
(V)
1600
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
140
160
Samples

FIG. 16

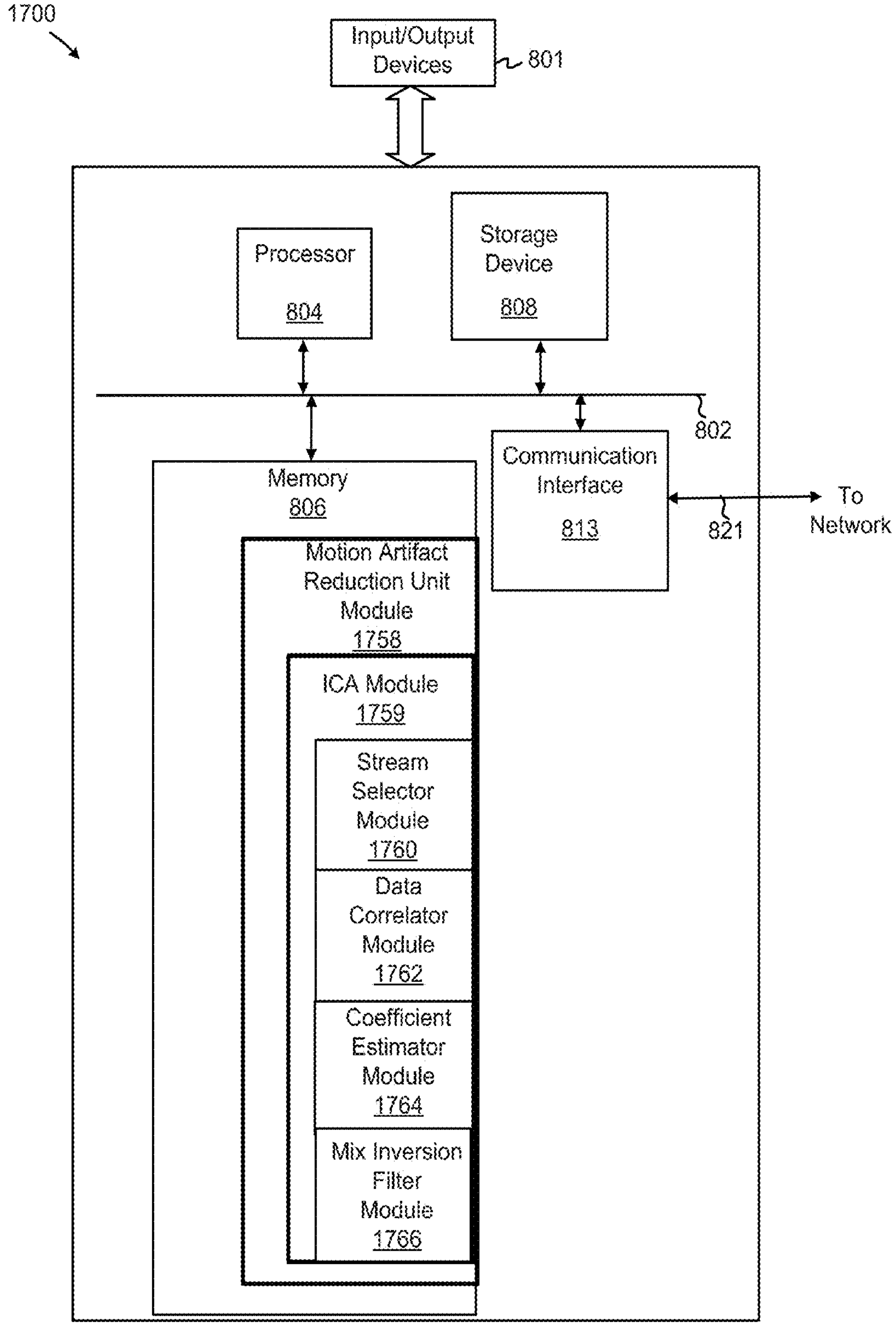

1700
Input/Output Devices
801
Processor
804
Storage Device
808
802
Communication Interface
813
821
To Network
Memory
806
Motion Artifact Reduction Unit Module
1758
ICA Module
1759
Stream Selector Module
1760
Data Correlator Module
1762
Coefficient Estimator Module
1764
Mix Inversion Filter Module
1766

FIG. 17

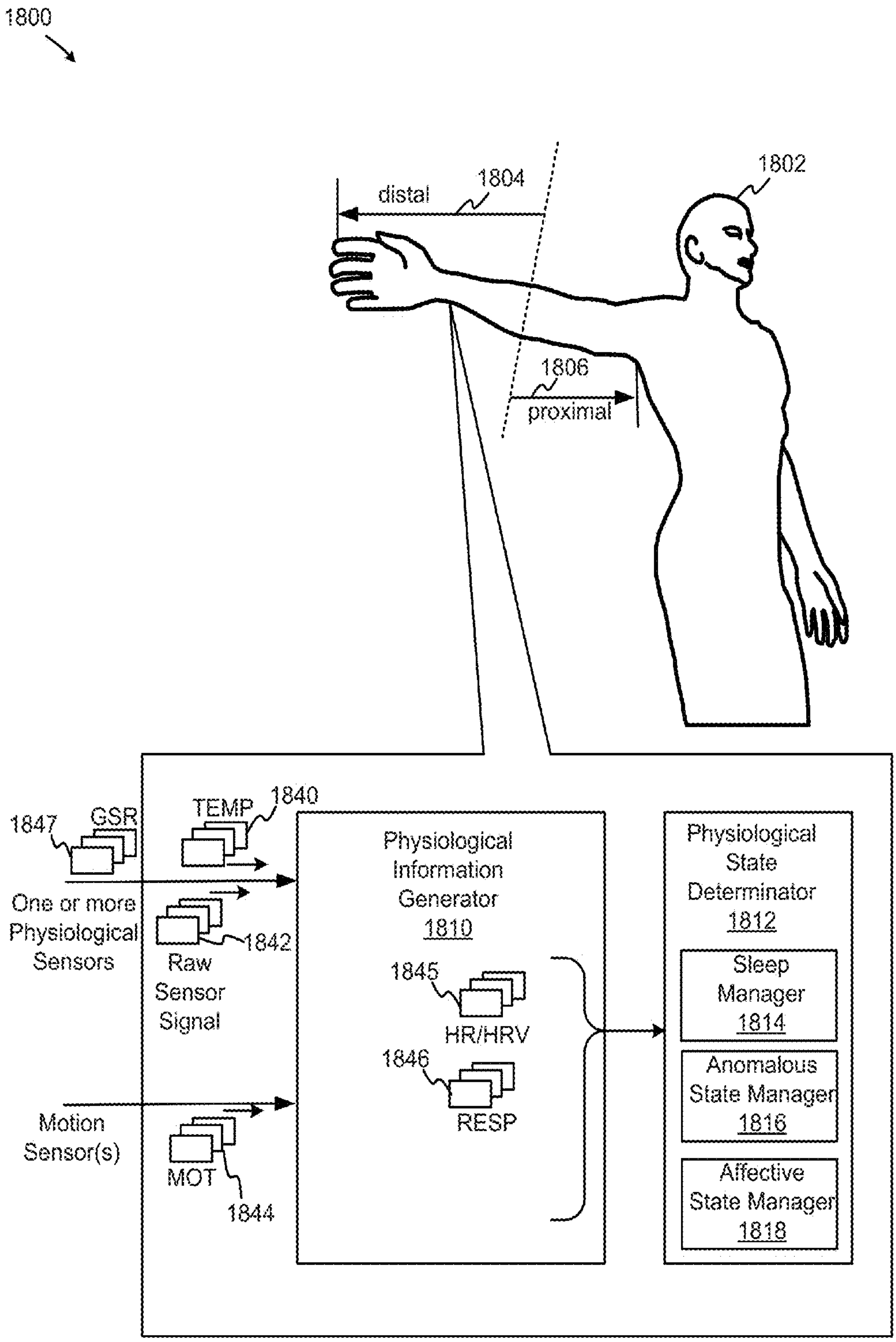

1800
1802
distal
1804
1806
proximal
1847
GSR
TEMP
1840
One or more Physiological Sensors
1842
Raw Sensor Signal
Motion Sensor(s)
MOT
1844
Physiological Information Generator 1810
1845
HR/HRV
1846
RESP
Physiological State Determinator 1812
Sleep Manager 1814
Anomalous State Manager 1816
Affective State Manager 1818

FIG.18

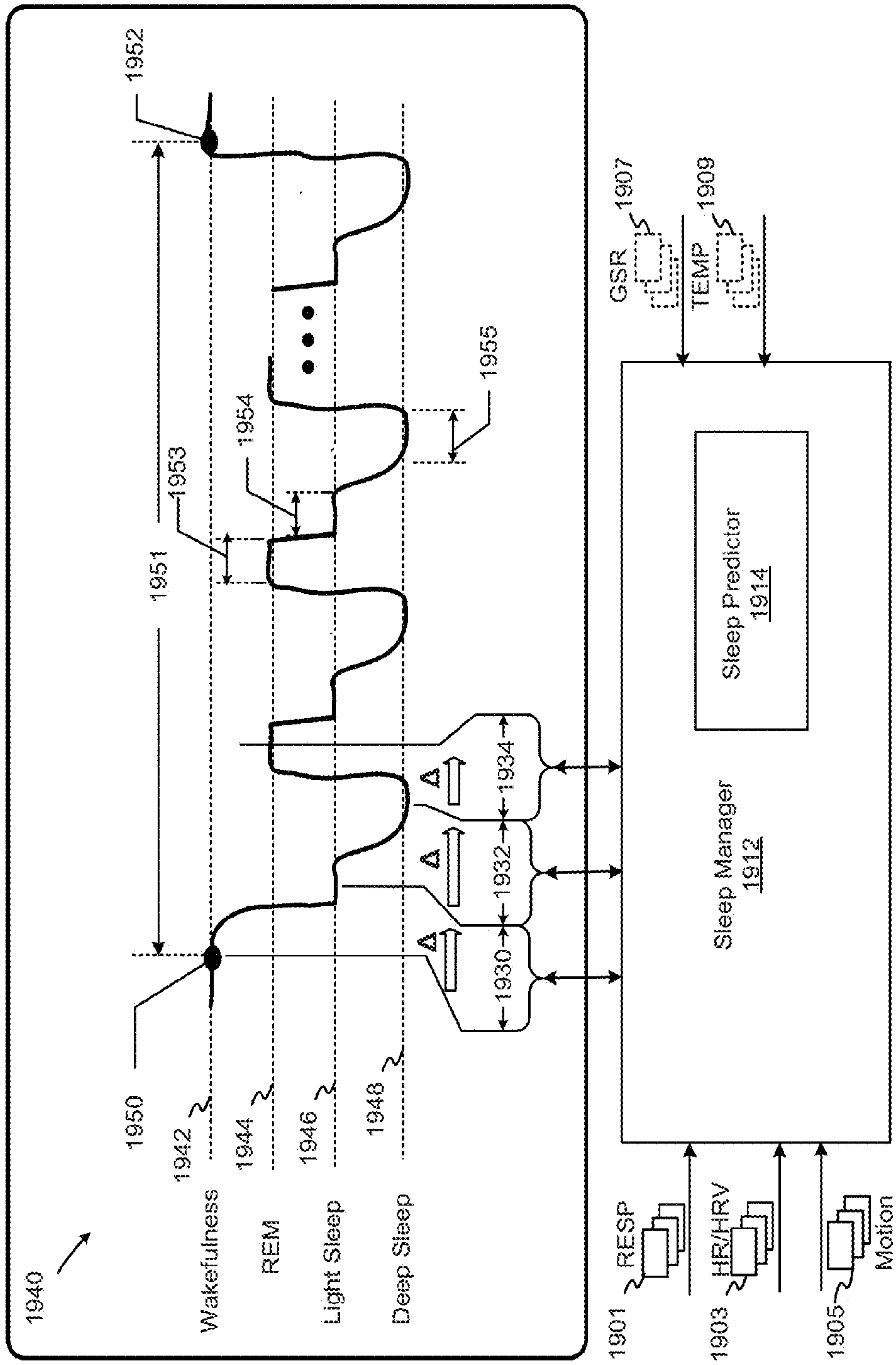

1940
Wakefulness
REM
Light Sleep
Deep Sleep
1942
1944
1946
1948
1950
1952
1951
1953
1954
1955
1930
1932
1934
Δ
Δ
Δ
Sleep Manager
1912
Sleep Predictor
1914
RESP
HR/HRV
Motion
GSR
TEMP
1901
1903
1905
1907
1909

FIG.19

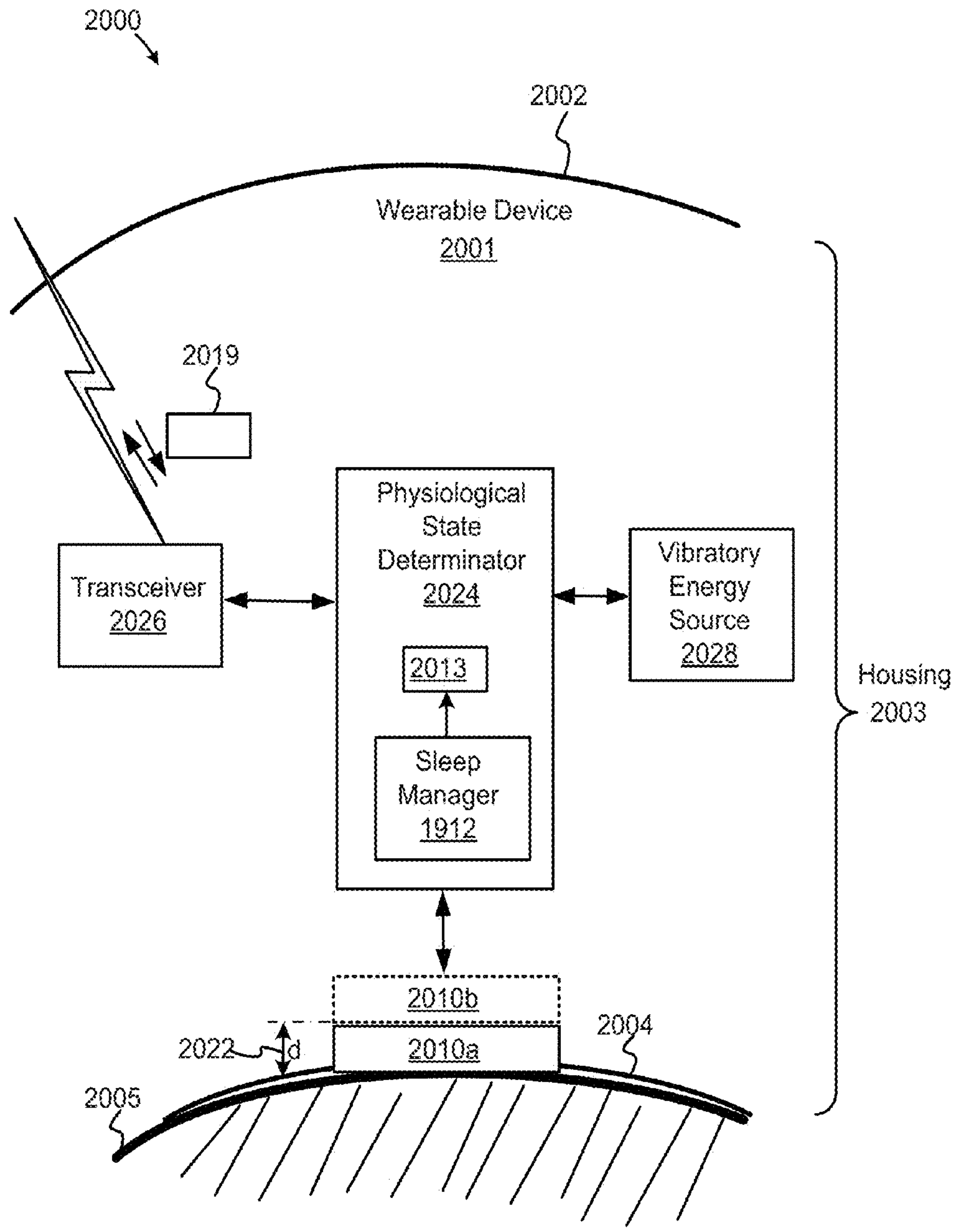

2000
2002
Wearable Device
2001
2019
Physiological
State
Determinator
2024
Transceiver
2026
Vibratory
Energy
Source
2028
2013
Sleep
Manager
1912
Housing
2003
2010b
2010a
2004
2022
d
2005

FIG. 20A

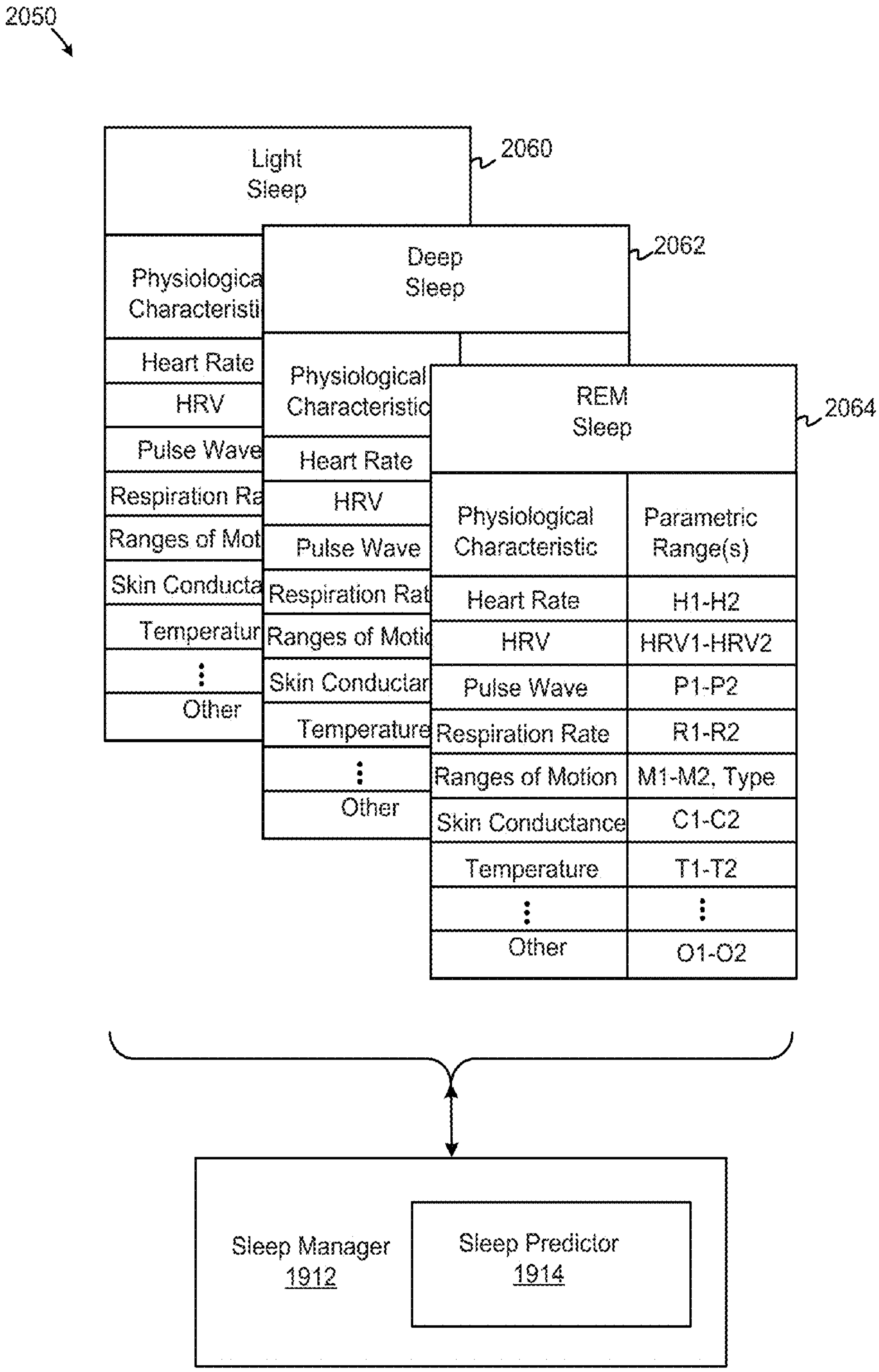

2050
Light Sleep
2060
Physiological Characteristic
Heart Rate
HRV
Pulse Wave
Respiration Rate
Ranges of Motion
Skin Conductance
Temperature
Other
Deep Sleep
2062
REM Sleep
2064
Physiological Characteristic
Parametric Range(s)
Heart Rate
H1-H2
HRV
HRV1-HRV2
Pulse Wave
P1-P2
Respiration Rate
R1-R2
Ranges of Motion
M1-M2, Type
Skin Conductance
C1-C2
Temperature
T1-T2
Other
O1-O2
Sleep Manager
1912
Sleep Predictor
1914

FIG. 20B

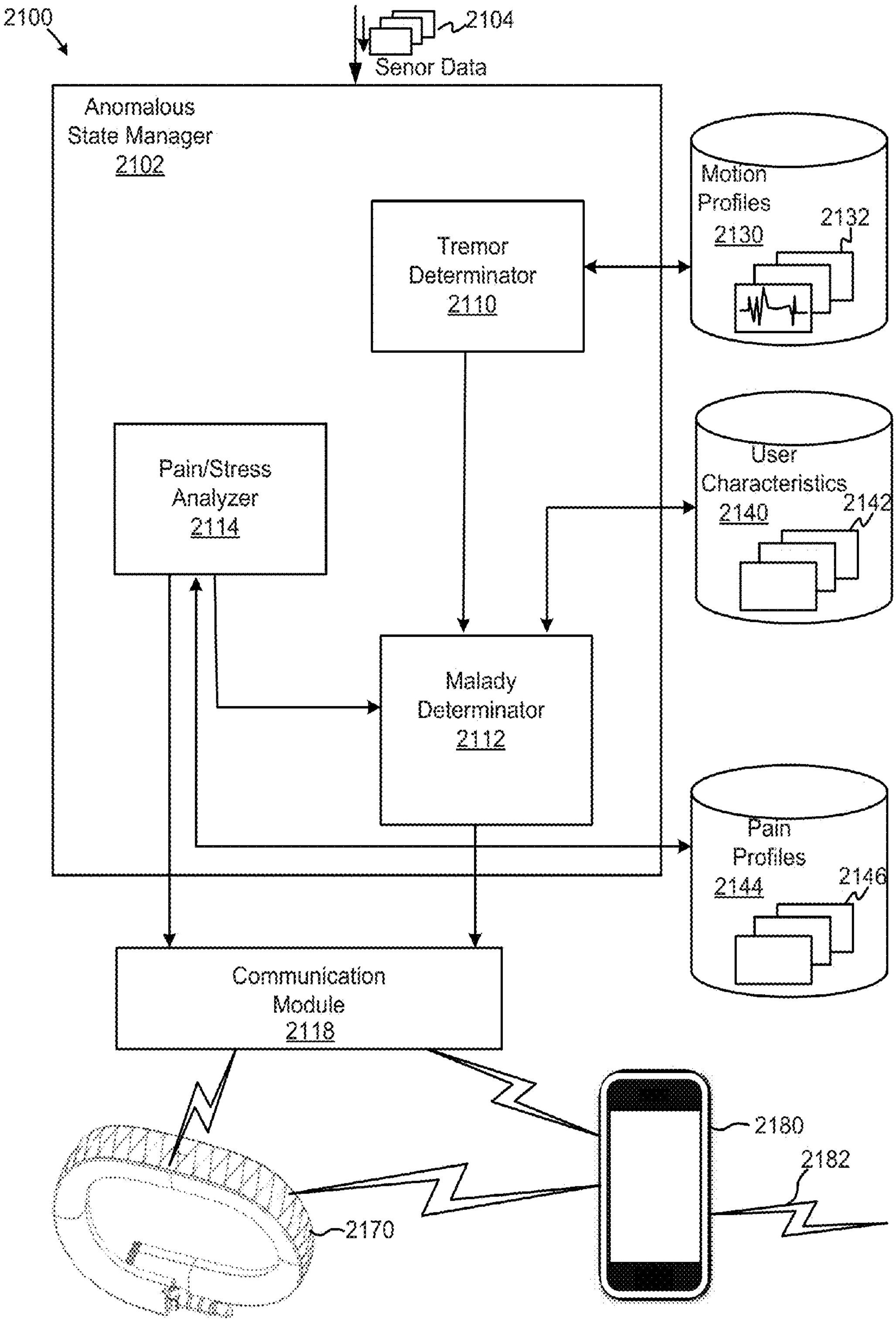

2100
2104
Senor Data
Anomalous
State Manager
2102
Tremor
Determinator
2110
Motion
Profiles
2130
2132
Pain/Stress
Analyzer
2114
User
Characteristics
2140
2142
Malady
Determinator
2112
Pain
Profiles
2144
2146
Communication
Module
2118
2180
2182
2170

FIG. 21

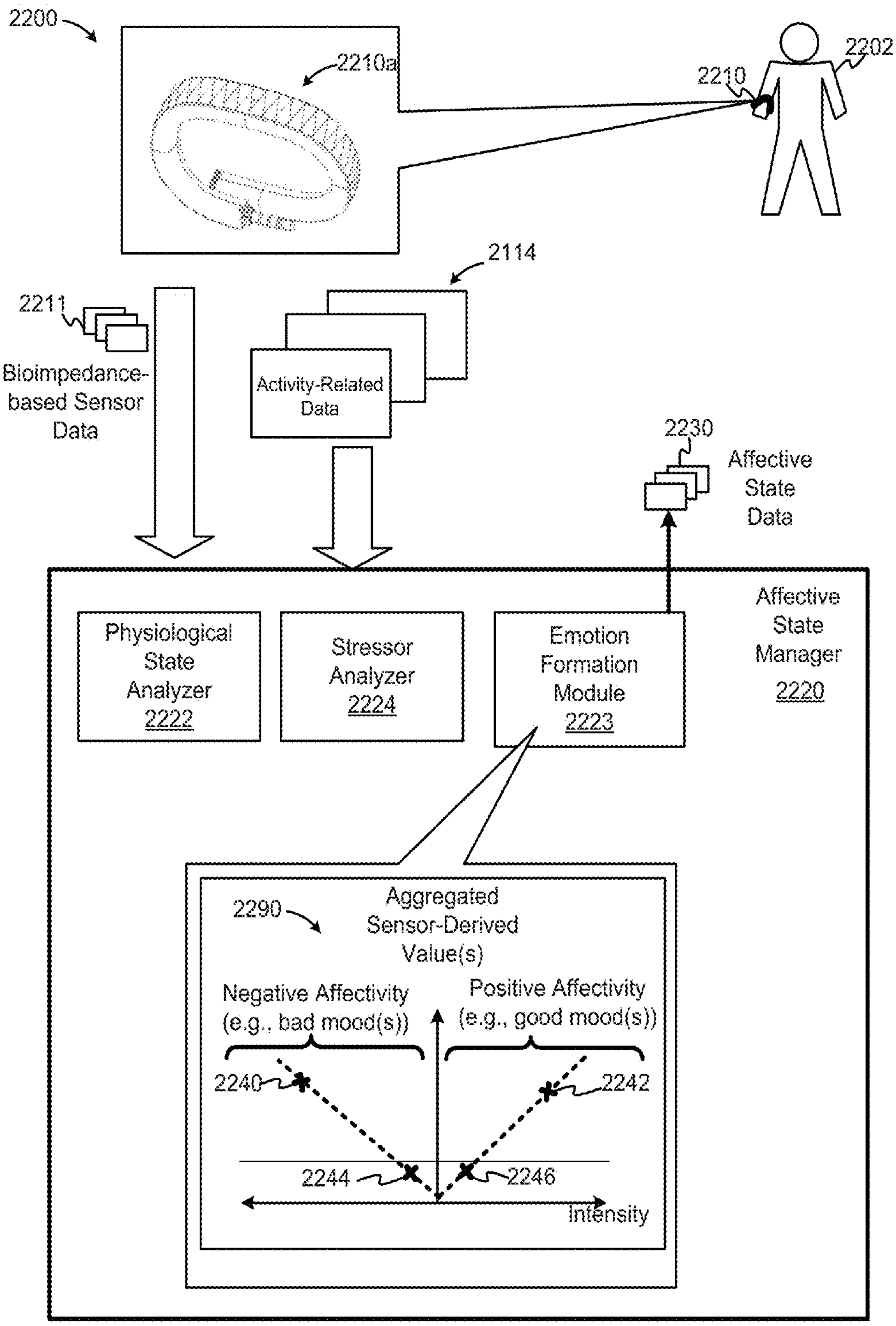

2200
2210a
2210
2202
2211
Bioimpedance-based Sensor Data
2114
Activity-Related Data
2230
Affective State Data
Physiological State Analyzer 2222
Stressor Analyzer 2224
Emotion Formation Module 2223
Affective State Manager 2220
2290
Aggregated Sensor-Derived Value(s)
Negative Affectivity (e.g., bad mood(s))
Positive Affectivity (e.g., good mood(s))
2240
2242
2244
2246
Intensity

FIG. 22

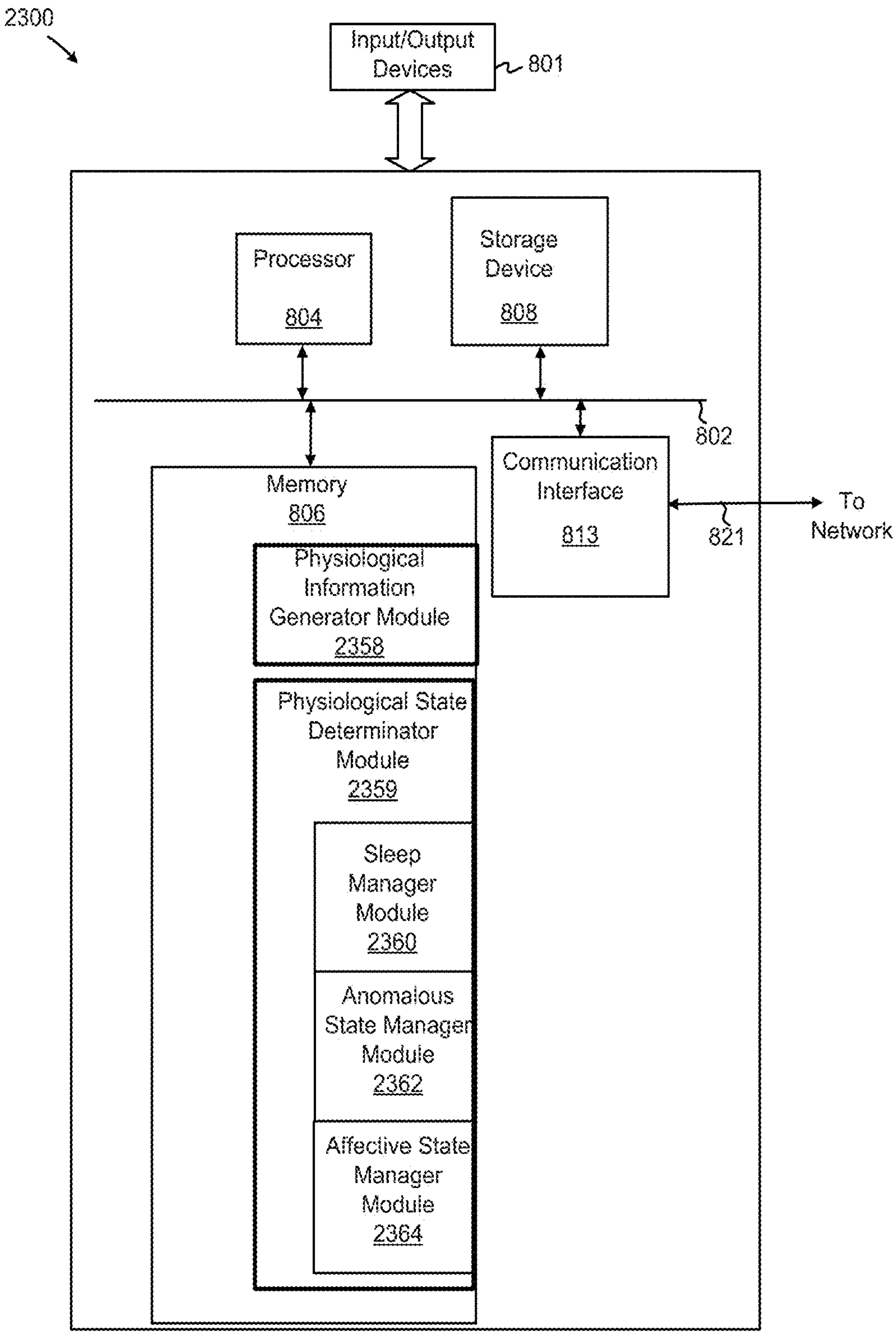

2300
Input/Output Devices
801
Processor
804
Storage Device
808
802
Communication Interface
813
821
To Network
Memory
806
Physiological Information Generator Module
2358
Physiological State Determinator Module
2359
Sleep Manager Module
2360
Anomalous State Manager Module
2362
Affective State Manager Module
2364

FIG. 23

DETERMINING PHYSIOLOGICAL STATE(S) OF AN ORGANISM BASED ON DATA SENSED WITH SENSORS IN MOTION

CROSS-RELATED APPLICATIONS

[0001] This application claims priority to Chinese Utility Model Patent Application Number 201220513278.5 filed on Sep. 29, 2012, which is incorporated by reference herein for all purposes. This applications also is related to U.S. U.S. Nonprovisional patent application Ser. No. 13/xxx,xxx filed, filed Mar. XX, 2013, with Attorney Docket No. ALI-147 and U.S. Nonprovisional patent application Ser. No. 13/xxx,xxx filed, filed Mar. XX, 2013, with Attorney Docket No. ALI-267, all of which are incorporated by reference for all purposes.

FIELD

[0002] Embodiments of the invention relate generally to electrical and electronic hardware, computer software, wired and wireless network communications, and wearable computing devices for facilitating health and wellness-related information. More specifically, disclosed are electrodes and methods to determine physiological states using a wearable device (or carried device) and one or more sensors that can be subject to motion.

BACKGROUND

[0003] Devices and techniques to gather physiological information, such as a heart rate of a person, while often readily available, are not well-suited to capture such information other than by using conventional data capture devices. Conventional devices typically lack capabilities to capture, analyze, communicate, or use physiological-related data in a contextually-meaningful, comprehensive, and efficient manner, such as during the day-to-day activities of a user, including high impact and strenuous exercising or participation in sports. Further, traditional devices and solutions to obtaining physiological information generally require that the sensors remain firmly affixed to the person, such as being affixed to the skin. In some conventional approaches, a few sensors are placed directly on the skin of a person while the sensors and the person are relatively stationary during the measurement process. While functional, the traditional devices and solutions to collecting physiological information are not well-suited for active participants in sports or over the course of over a period of time, such as one or more days.

[0004] Conventional biometric sensing devices and techniques to obtaining physiological information are susceptible to motion artifacts in the sensing signals. Typically, motion-related noise typically gives rise to motion artifacts, which usually affect sensing signals generated by sensors. Motion-related noise typically occludes or otherwise distorts sensed physiological signals, such as heart rate, respiration and the like. One example of motion-related noise is electrical noise generated by intermittent contact between sensors and the tissue from which physiological signals are sensed. Another example of motion-related noise is the electrical noise signals generated by nerve firings due in the muscles during contraction and during movement of a person's body. Such electrical noise signals can emanate from electrical impulses of muscles (e.g., as evidenced, in some cases, by electromyography ("EMG"), which is typically used to determine the existence and/or amounts of motion based on electrical signals generated by muscle cells at rest or in contraction).

[0005] To reduce or minimize the effects of motion-related noise, traditional approaches generally require a person to remain substantially motionless and/or locate the sensing mechanisms (i.e., sensors) on proximal portions of a person's appendage or limb proximal (i.e., near the point of attachment to a torso of the person, such as at or on the upper arm between the elbow and shoulder). Proximal portions of an appendage or limb generally experience less motion and/or acceleration (or less degrees of motion and/or acceleration) than distal portions of an appendage or limb. Examples of distal portions of appendages or limbs include wrists, ankles, toes, fingers, and the like. Distal portions or locations are those that are furthest away from, for example, a torso relative to the proximal portions or locations. Therefore, conventional biometric sensing devices and techniques, especially those susceptible to motion, are generally located at the proximal portions to reduce or minimize the effects of motion.

[0006] When motion is present, traditional biometric sensing devices and techniques are not well-suited to obtain physiological information. Another drawback to traditional biometric sensing devices and techniques is the requirement to locate such devices at proximal portions of a limb. In some cases, the extremities of a person's body typically exhibit the presence of an infirmity, ailment or condition more readily than a person's core (i.e., torso). Thus, sensors co-located at proximal portions of a limb may be less likely to sense or otherwise detect the infirmity, ailment or condition, thereby foregoing opportunities to alert the wearer of physiological changes that may indicate the onset of, for example, sleep or tremors.

[0007] Further, co-locating sensors at proximal portions of a limb hinders an ability to determine or predict the onset of a physiological state or a change from one physiological state to another. For example, in some conventional sensing techniques, the detection of the onset of sleep, as well as and the various sleep stages, is typically performed by using sensors located at the proximal regions. By co-locating the sensors at the proximal regions rather than at the extremities of a limb, the prediction of sleep or any other physiological state is made more difficult. As an example, consider the detection of an ailment or malady, such as a diabetic tremor, Parkinson's tremors, and/or an epileptic tremor. The use of sensors at proximal portions of a limb is typically sub-optimal for the detection of such tremors prior to the afflicted person's awareness of such a change in physiological state.

[0008] Thus, what is needed is a solution for data capture devices, such as for wearable devices, without the limitations of conventional techniques.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Various embodiments or examples ("examples") of the invention are disclosed in the following detailed description and the accompanying drawings:

[0010] FIG. **1**A illustrates an exemplary array of electrodes and a physiological information generator disposed in a wearable data-capable band, according to some embodiments;

[0011] FIGS. **1**B to **1**D illustrate examples of electrode arrays, according to some embodiments;

[0012] FIG. **2** is a functional diagram depicting a physiological information generator implemented in a wearable device, according to some embodiments;

[0013] FIGS. **3**A to **3**C are cross-sectional views depicting arrays of electrodes including subsets of electrodes adjacent an arm of a wearer, according to some embodiments;

[0014] FIG. **4** depicts a portion of an array of electrodes disposed within a housing material of a wearable device, according to some embodiments;

[0015] FIG. **5** depicts an example of a physiological information generator, according to some embodiments;

[0016] FIG. **6** is an example flow diagram for selecting a sensor, according to some embodiments;

[0017] FIG. **7** is an example flow diagram for determining physiological characteristics using a wearable device with arrayed electrodes, according to some embodiments;

[0018] FIG. **8** illustrates an exemplary computing platform disposed in a wearable device in accordance with various embodiments

[0019] FIG. **9** depicts the physiological signal extractor, according to some embodiments;

[0020] FIG. **10** is a flowchart for extracting a physiological signal, according to some embodiments;

[0021] FIG. **11** is a block diagram depicting an example of a physiological signal extractor, according to some embodiments;

[0022] FIG. **12** depicts an example of an offset generator, according to some embodiments;

[0023] FIG. **13** is a flowchart depicting example of a flow for decomposing a sensor signal to form separate signals, according to some embodiments;

[0024] FIGS. **14**A to **14**C depict various signals used for physiological characteristic signal extraction, according to various embodiments;

[0025] FIG. **15** depicts recovered signals, according to some embodiments;

[0026] FIG. **16** depicts an extracted physiological signal, according to various embodiments;

[0027] FIG. **17** illustrates an exemplary computing platform disposed in a wearable device in accordance with various embodiments;

[0028] FIG. **18** is a diagram depicting a physiological state determinator configured to receive sensor data originating, for example, at a distal portion of a limb, according to some embodiments;

[0029] FIG. **19** depicts a sleep manager, according to some embodiments;

[0030] FIG. **20**A depicts a wearable device including a skin surface microphone ("SSM"), according to some embodiments;

[0031] FIG. **20**B depicts an example of data arrangements for physiological characteristics and parametric values that can identify a sleep state, according to some embodiments;

[0032] FIG. **21** depicts an anomalous state manager, according to some embodiments;

[0033] FIG. **22** depicts an affective state manager configured to receive sensor data derived from bioimpedance signals, according to some embodiments; and

[0034] FIG. **23** illustrates an exemplary computing platform disposed in a wearable device in accordance with various embodiments.

DETAILED DESCRIPTION

[0035] Various embodiments or examples may be implemented in numerous ways, including as a system, a process, an apparatus, a user interface, or a series of program instructions on a computer readable medium such as a computer readable storage medium or a computer network where the program instructions are sent over optical, electronic, or wireless communication links. In general, operations of disclosed processes may be performed in an arbitrary order, unless otherwise provided in the claims.

[0036] A detailed description of one or more examples is provided below along with accompanying figures. The detailed description is provided in connection with such examples, but is not limited to any particular example. The scope is limited only by the claims and numerous alternatives, modifications, and equivalents are encompassed. Numerous specific details are set forth in the following description in order to provide a thorough understanding. These details are provided for the purpose of example and the described techniques may be practiced according to the claims without some or all of these specific details. For clarity, technical material that is known in the technical fields related to the examples has not been described in detail to avoid unnecessarily obscuring the description.

[0037] FIG. **1**A illustrates an exemplary array of electrodes and a physiological information generator disposed in a wearable data-capable band, according to some embodiments. Diagram **100** depicts an array **100** of electrodes **110** coupled to a physiological information generator **120** that is configured to generate data representing one or more physiological characteristics associated with a user that is wearing or carrying array **101**. Also shown are motion sensors **160**, which, for example, can include accelerometers. Motion sensors **160** are not limited to accelerometers. Examples of motion sensors **160** can also include gyroscopic sensors, optical motion sensors (e.g., laser or LED motion detectors, such as used in optical mice), magnet-based motion sensors (e.g., detecting magnetic fields, or changes thereof, to detect motion), electromagnetic-based sensors, etc., as well as any sensor configured to detect or determine motion, such as motion sensors based on physiological characteristics (e.g., using electromyography ("EMG") to determine existence and/or amounts of motion based on electrical signals generated by muscle cells), and the like. Electrodes **110** can include any suitable structure for transferring signals and picking up signals, regardless of whether the signals are electrical, magnetic, optical, pressure-based, physical, acoustic, etc., according to various embodiments. According to some embodiments, electrodes **110** of array **101** are configured to couple capacitively to a target location. In some embodiments, array **101** and physiological information generator **120** are disposed in a wearable device, such as a wearable data-capable band **170**, which may include a housing that encapsulates, or substantially encapsulates, array **101** of electrodes **110**. In operations, physiological information generator **120** can determine the bioelectric impedance ("bioimpedance") of one or more types of tissues of a wearer to identify, measure, and monitor physiological characteristics. For example, a drive signal having a known amplitude and frequency can be applied to a user, from which a sink signal is received as bioimpedance signal. The bioimpedance signal is a measured signal that includes real and complex components. Examples of real components include extra-cellular and intra-cellular spaces of tissue, among other things, and examples of complex components include cellular membrane capacitance, among other things. Further, the measured bioimpedance signal can include real and/or complex components associated with arterial structures (e.g., arterial cells, etc.) and the presence (or absence) of blood pulsing through an arterial structure. In some examples, a heart rate signal, or other physiological signals, can be determined (i.e., recovered) from the measured bioimpedance signal by, for example, comparing the measured bioimpedance signal against the waveform of the drive signal to determine a phase delay (or shift) of the measured complex components.

[0038] Physiological information generator **120** is shown to include a sensor selector **122**, a motion artifact reduction unit **124**, and a physiological characteristic determinator **126**. Sensor selector **122** is configured to select a subset of electrodes, and is further configured to use the selected subset of electrodes to acquire physiological characteristics, according to some embodiments. Examples of a subset of electrodes include subset **107**, which is composed of electrodes **110***d* and **110***e*, and subset **105**, which is composed of electrodes **110***c*, **110***d* and **110***e*. More or fewer electrodes can be used. Sensor selector **122** is configured to determine which one or more subsets of electrodes **110** (out of a number of subsets of electrodes **110**) are adjacent to a target location. As used herein, the term "target location" can, for example, refer to a region in space from which a physiological characteristic can be determined. A target region can be adjacent to a source of the physiological characteristic, such as blood vessel **102**, with which an impedance signal can be captured and analyzed to identify one or more physiological characteristics. The target region can reside in two-dimensional space, such as an area on the skin of a user adjacent to the source of the physiological characteristic, or in three-dimensional space, such as a volume that includes the source of the physiological characteristic. Sensor selector **122** operates to either drive a first signal via a selected subset to a target location, or receive a second signal from the target location, or both. The second signal includes data representing one or more physiological characteristics. For example, sensor selector **122** can configure electrode ("D") **110***b* to operate as a drive electrode that drives a signal (e.g., an AC signal) into the target location, such as into the skin of a user, and can configure electrode ("S") **110***a* to operate as a sink electrode (i.e., a receiver electrode) to receive a second signal from the target location, such as from the skin of the user. In this configuration, sensor selector **112** can drive a current signal via electrode ("D") **110***b* into a target location to cause a current to pass through the target location to another electrode ("S") **110***a*. In various examples, the target location can be adjacent to or can include blood vessel **102**. Examples of blood vessel **102** include a radial artery, an ulnar artery, or any other blood vessel. Array **101** is not limited to being disposed adjacent blood vessel **102** in an arm, but can be disposed on any portion of a user's person (e.g., on an ankle, ear lobe, around a finger or on a fingertip, etc.). Note that each electrode **110** can be configured as either a driver or a sink electrode. Thus, electrode **110***b* is not limited to being a driver electrode and can be configured as a sink electrode in some implementations. As used herein, the term "sensor" can refer, for example, to a combination of one or more driver electrodes and one or more sink electrodes for determining one or more bioimpedance-related values and/or signals, according to some embodiments.

[0039] In some embodiments, sensor selector **122** can be configured to determine (periodically or aperiodically) whether the subset of electrodes **110***a* and **110***b* are optimal electrodes **110** for acquiring a sufficient representation of the one or more physiological characteristics from the second signal. To illustrate, consider that electrodes **110***a* and **110***b* may be displaced from the target location when, for instance, wearable device **170** is subject to a displacement in a plane substantially perpendicular to blood vessel **102**. The displacement of electrodes **110***a* and **110***b* may increase the impedance (and/or reactance) of a current path between the electrodes **110***a* and **110***b*, or otherwise move those electrodes away from the target location far enough to degrade or attenuate the second signals retrieved therefrom. While electrodes **110***a* and **110***b* may be displaced from the target location, other electrodes are displaced to a position previously occupied by electrodes **110***a* and **110***b* (i.e., adjacent to the target location). For example, electrodes **110***c* and **110***d* may be displaced to a position adjacent to blood vessel **102**. In this case, sensor selector **122** operates to determine an optimal subset of electrodes **110**, such as electrodes **110***c* and **110***d*, to acquire the one or more physiological characteristics. Therefore, regardless of the displacement of wearable device **170** about blood vessel **102**, sensor selector **122** can repeatedly determine an optimal subset of electrodes for extracting physiological characteristic information from adjacent a blood vessel. For example, sensor selector **122** can repeatedly test subsets in sequence (or in any other matter) to determine which one is disposed adjacent to a target location. For example, sensor selector **122** can select at least one of subset **109***a*, subset **109***b*, subset **109***c*, and other like subsets, as the subset from which to acquire physiological data.

[0040] According to some embodiments, array **101** of electrodes can be configured to acquire one or more physiological characteristics from multiple sources, such as multiple blood vessels. To illustrate, consider that, for example, blood vessel **102** is an ulnar artery adjacent electrodes **110***a* and **110***b* and a radial artery (not shown) is adjacent electrodes **110***c* and **110***d*. With multiple sources of physiological characteristic information being available, there are thus multiple target locations. Therefore, sensor selector **122** can select multiple subsets of electrodes **110**, each of which is adjacent to one of a multiple number of target locations. Physiological information generator **120** then can use signal data from each of the multiple sources to confirm accuracy of data acquired, or to use one subset of electrodes (e.g., associated with a radial artery) when one or more other subsets of electrodes (e.g., associated with an ulnar artery) are unavailable.

[0041] Note that the second signal received into electrode **110***a* can be composed of a physiological-related signal component and a motion-related signal component, if array **101** is subject to motion. The motion-related component includes motion artifacts or noise induced into an electrode **110***a*. Motion artifact reduction unit **124** is configured to receive motion-related signals generated at one or more motion sensors **160**, and is further configured to receive at least the motion-related signal component of the second signal. Motion artifact reduction unit **124** operates to eliminate the magnitude of the motion-related signal component, or to reduce the magnitude of the motion-related signal component relative to the magnitude of the physiological-related signal component, thereby yielding as an output the physiological-related signal component (or an approximation thereto). Thus, motion artifact reduction unit **124** can reduce the magnitude of the motion-related signal component (i.e., the motion artifact) by an amount associated with the motion-related signal generated by one or more accelerometers to yield the physiological-related signal component.

[0042] Physiological characteristic determinator **126** is configured to receive the physiological-related signal component of the second signal and is further configured to process (e.g., digitally) the signal data including one or more physiological characteristics to derive physiological signals, such as either a heart rate ("HR") signal or a respiration signal, or both. For example, physiological characteristic determinator **126** is configured to amplify and/or filter the physiological-related component signals (e.g., at different frequency ranges) to extract certain physiological signals. According to various embodiments, a heart rate signal can include (or can be based on) a pulse wave. A pulse wave includes systolic components based on an initial pulse wave portion generated by a contracting heart, and diastolic components based on a reflected wave portion generated by the reflection of the initial pulse wave portion from other limbs. In some examples, an

[0043] HR signal can include or otherwise relate to an electrocardiogram ("ECG") signal. Physiological characteristic determinator **126** is further configured to calculate other physiological characteristics based on the acquired one or more physiological characteristics. Optionally, physiological characteristic determinator **126** can use other information to calculate or derive physiological characteristics. Examples of the other information include motion-related data, including the type of activity in which the user is engaged, such as running or sleep, location-related data, environmental-related data, such as temperature, atmospheric pressure, noise levels, etc., and any other type of sensor data, including stress-related levels and activity levels of the wearer.

[0044] In some cases, a motion sensor **160** can be disposed adjacent to the target location (not shown) to determine a physiological characteristic via motion data indicative of movement of blood vessel **102** through which blood pulses to identify a heart rate-related physiological characteristic. Motion data, therefore, can be used to supplement impedance determinations of to obtain the physiological characteristic. Further, one or more motion sensors **160** can also be used to determine the orientation of wearable device **170**, and relative movement of the same to determine or predict a target location. By predicting a target location, sensor selector **122** can use the predicted target location to begin the selection of optimal subsets of electrodes **110** in a manner that reduces the time to identify a target location.

[0045] In view of the foregoing, the functions and/or structures of array **101** of electrodes and physiological information generator **120**, as well as their components, can facilitate the acquisition and derivation of physiological characteristics in situ—during which a user is engaged in physical activity that imparts motion on a wearable device, thereby exposing the array of electrodes to motion-related artifacts. Physiological information generator **120** is configured to dampen or otherwise negate the motion-related artifacts from the signals received from the target location, thereby facilitating the provision of heart-related activity and respiration activity to the wearer of wearable device **170** in real-time (or near real-time). As such, the wearer of wearable device **170** need not be stationary or otherwise interrupt an activity in which the wearer is engaged to acquire health-related information. Also, array **101** of electrodes **110** and physiological information generator **120** are configured to accommodate displacement or movement of wearable device **170** about, or relative to, one or more target locations. For example, if the wearer intentionally rotates wearable device **170** about, for example, the wrist of the user, then initial subsets of electrodes **110** adjacent to the target locations (i.e., before the rotation) are moved further away from the target location. As another example, the motion of the wearer (e.g., impact forces experienced during running) may cause wearable device **170** to travel about the wrist. As such, physiological information generator **120** is configured to determine repeatedly whether to select other subsets of electrodes **110** as optimal subsets of electrodes **110** for acquiring physiological characteristics. For example, physiological information generator **120** can be configured to cycle through multiple combinations of driver electrodes and sink electrodes (e.g., subsets **109***a*, **109***b*, **109***c*, etc.) to determine optimal subsets of electrodes. In some embodiments, electrodes **110** in array **101** facilitate physiological data capture irrespective of the gender of the wearer. For example, electrodes **110** can be disposed in array **101** to accommodate data collection of a male or female were irrespective of gender-specific physiological dimensions. In at least one embodiment, data representing the gender of the wearer can be accessible to assist physiological information generator **120** in selecting the optimal subsets of electrodes **110**. While electrodes **110** are depicted as being equally-spaced, array **101** is not so limited. In some embodiments, electrodes **110** can be clustered more densely along portions of array **101** at which blood vessels **102** are more likely to be adjacent. For example, electrodes **110** may be clustered more densely at approximate portions **172** of wearable device **170**, whereby approximate portions **172** are more likely to be adjacent a radial or ulnar artery than other portions. While wearable device **170** is shown to have an elliptical-like shape, it is not limited to such a shape and can have any shape.

[0046] In some instances, a wearable device **170** can select multiple subsets of electrodes to enable data capture using a second subset adjacent to a second target location when a first subset adjacent a first target location is unavailable to capture data.

[0047] For example, a portion of wearable device **170** including the first subset of electrodes **110** (initially adjacent to a first target location) may be displaced to a position farther away in a radial direction away from a blood vessel, such as depicted by a radial distance **392** of FIG. **3**C from the skin of the wearer. That is, subset of electrodes **310***a* and **310***b* are displaced radially be distance **392**. Further to FIG. **3**C, the second subset of electrodes **310***f* and **310***g* adjacent to the second target location can be closer in a radial direction toward another blood vessel, and, thus, the second subset of electrodes can acquire physiological characteristics when the first subset of electrodes cannot. Referring back to FIG. **1**A, array **101** of electrodes **110** facilitates a wearable device **170** that need not be affixed firmly to the wearer. That is, wearable device **170** can be attached to a portion of the wearer in a manner in which wearable device **170** can be displaced relative to a reference point affixed to the wearer and continue to acquire and generate information regarding physiological characteristics. In some examples, wearable device **170** can be described as being "loosely fitting" on or "floating" about a portion of the wearer, such as a wrist, whereby array **101** has sufficient sensors points from which to pick up physiological signals.

[0048] In addition, accelerometers **160** can be used to replace the implementation of subsets of electrodes to detect motion associated with pulsing blood flow, which, in turn, can be indicative of whether oxygen-rich blood is present or not present. Or, accelerometers **160** can be used to supplement the data generated by acquired one or more bioimpedance signals acquired by array **101**. Accelerometers **160** can also be used to determine the orientation of wearable device **170** and relative movement of the same to determine or predict a target location. Sensor selector **122** can use the predicted target location to begin the selection of the optimal subsets of electrodes **110**, which likely decreases the time to identify a target location. Electrodes **110** of array **101** can be disposed within a material constituting, for example, a housing, according to some embodiments. Therefore, electrodes **110** can be protected from the environment and, thus, need not be subject to corrosive elements. In some examples, one or more electrodes **110** can have at least a portion of a surface exposed. As electrodes **110** of array **101** are configured to couple capacitively to a target location, electrodes **110** thereby facilitate high impedance signal coupling so that the first and second signals can pass through fabric and hair. As such, electrodes **110** need not be limited to direct contact with the skin of a wearer. Further, array **101** of electrodes **110** need not circumscribe a limb or source of physiological characteristics. An array **101** can be linear in nature, or can configurable to include linear and curvilinear portions.

[0049] In some embodiments, wearable device **170** can be in communication (e.g., wired or wirelessly) with a mobile device **180**, such as a mobile phone or computing device. In some cases, mobile device **180**, or any networked computing device (not shown) in communication with wearable device **170** or mobile device **180**, can provide at least some of the structures and/or functions of any of the features described herein. As depicted in FIG. **1** A and subsequent figures, the structures and/or functions of any of the above-described features can be implemented in software, hardware, firmware, circuitry, or any combination thereof. Note that the structures and constituent elements above, as well as their functionality, may be aggregated or combined with one or more other structures or elements. Alternatively, the elements and their functionality may be subdivided into constituent sub-elements, if any. As software, at least some of the above-described techniques may be implemented using various types of programming or formatting languages, frameworks, syntax, applications, protocols, objects, or techniques. For example, at least one of the elements depicted in FIG. **1**A (or any subsequent figure) can represent one or more algorithms. Or, at least one of the elements can represent a portion of logic including a portion of hardware configured to provide constituent structures and/or functionalities.

[0050] For example, physiological information generator **120** and any of its one or more components, such as sensor selector **122**, motion artifact reduction unit **124**, and physiological characteristic determinator **126**, can be implemented in one or more computing devices (i.e., any mobile computing device, such as a wearable device or mobile phone, whether worn or carried) that include one or more processors configured to execute one or more algorithms in memory. Thus, at least some of the elements in FIG. **1**A (or any subsequent figure) can represent one or more algorithms. Or, at least one of the elements can represent a portion of logic including a portion of hardware configured to provide constituent structures and/or functionalities. These can be varied and are not limited to the examples or descriptions provided.

[0051] As hardware and/or firmware, the above-described structures and techniques can be implemented using various types of programming or integrated circuit design languages, including hardware description languages, such as any register transfer language ("RTL") configured to design field-programmable gate arrays ("FPGAs"), application-specific integrated circuits ("ASICs"), multi-chip modules, or any other type of integrated circuit. For example, physiological information generator **120**, including one or more components, such as sensor selector **122**, motion artifact reduction unit **124**, and physiological characteristic determinator **126**, can be implemented in one or more computing devices that include one or more circuits. Thus, at least one of the elements in FIG. **1**A (or any subsequent figure) can represent one or more components of hardware. Or, at least one of the elements can represent a portion of logic including a portion of circuit configured to provide constituent structures and/or functionalities.

[0052] According to some embodiments, the term "circuit" can refer, for example, to any system including a number of components through which current flows to perform one or more functions, the components including discrete and complex components. Examples of discrete components include transistors, resistors, capacitors, inductors, diodes, and the like, and examples of complex components include memory, processors, analog circuits, digital circuits, and the like, including field-programmable gate arrays ("FPGAs"), application-specific integrated circuits ("ASICs"). Therefore, a circuit can include a system of electronic components and logic components (e.g., logic configured to execute instructions, such that a group of executable instructions of an algorithm, for example, and, thus, is a component of a circuit). According to some embodiments, the term "module" can refer, for example, to an algorithm or a portion thereof, and/or logic implemented in either hardware circuitry or software, or a combination thereof (i.e., a module can be implemented as a circuit). In some embodiments, algorithms and/or the memory in which the algorithms are stored are "components" of a circuit. Thus, the term "circuit" can also refer, for example, to a system of components, including algorithms. These can be varied and are not limited to the examples or descriptions provided.

[0053] FIGS. **1**B to **1**D illustrate examples of electrode arrays, according to some embodiments. Diagram **130** of FIG. **1**B depicts an array **132** that includes sub-arrays **133***a*, **133***b*, and **133***c* of electrodes **110** that are configured to generate data that represent one or more characteristics associated with a user associated with array **132**. In various embodiments, drive electrodes and sink electrodes can be disposed in the same sub-array or in different sub-arrays. Note that arrangements of sub-arrays **133***a*, **133***b*, and **133***c* can denote physical or spatial orientations and need not imply electrical, magnetic, or cooperative relationships among electrodes **110** within each sub-array. For example, drive electrode ("D") **110***f* can be configured in sub-array **133***a* as a drive electrode to drive a signal to sink electrode ("S") **110***g* in sub-array **133***b*. As another example, drive electrode ("D") **110***h* can be configured in sub-array **133***a* to drive a signal to sink electrode ("S") **110***k* in sub-array **133***c*. In some embodiments, distances between electrodes **110** in sub-arrays can vary at different regions, including a region in which the placement of electrode group **134** near blood vessel **102** is more probable relative to the placement of other electrodes near blood vessel **102**. Electrode group **134** can include a higher density of electrodes **110** than other portions of array **132** as group **134** can be expected to be disposed adjacent blood vessel **102** more likely than other groups of electrodes **110**. For example, an elliptical-shaped array (not shown) can be disposed in device **170** of FIG. **1**A. Therefore, group **134** of electrodes is disposed at a region **172** of FIG. **1**A, which is likely adjacent either a radial artery or an ulna artery. While three sub-arrays are shown, more or fewer are possible.

[0054] Referring to FIG. **1**C, diagram **140** depicts an array **142** oriented at any angle ("**0**") **144** to an axial line coincident with or parallel to blood vessel **102**. Therefore, an array **142** of electrodes need not be oriented orthogonally in each implementation; rather array **142** can be oriented at angles between **0** and **90** degrees, inclusive thereof. In a specific embodiment, an array **146** can be disposed parallel (or substantially parallel) to blood vessel **102***a* (or a portion thereof).

[0055] FIG. **1**D is a diagram **150** depicting a wearable device **170***a* including a helically-shaped array **152** of electrodes disposed therein, whereby electrodes **110***m* and **110***n* can be configured as a pair of drive and sink electrodes. As shown, electrodes **110***m* and **110***n* substantially align in a direction parallel to an axis **151**, which can represent a general direction of blood flow through a blood vessel.

[0056] FIG. **2** is a functional diagram depicting a physiological information generator implemented in a wearable device, according to some embodiments.

[0057] Functional diagram **200** depicts a user **203** wearing a wearable device **209**, which includes a physiological information generator **220** configured to generate signals including data representing physiological characteristics. As shown, sensor selector **222** is configured to select a subset **205** of electrodes or a subset **207** of electrodes. Subset **205** of electrodes includes electrodes **210***c*, **210***d*, and **210***e*, and subset **207** of electrodes includes electrodes **210***d* and **210***e*. For purposes of illustration, consider that sensor selector **222** selects electrodes **210***d* and **210***c* as a subset of electrodes with which to capture physiological characteristics adjacent a target location. Sensor selector **222** applies an AC signal, as a first signal, into electrodes **210***d* to generate a sensor signal ("raw sensor signal") **225**, as a second signal, from electrode **210***c*. Sensor signal **222** includes a motion-related signal component and a physiological-related signal component. A motion sensor **221** is configured to capture generate a motion artifact signal **223** based on motion data representing motion experienced by wearable device **209** (or at least the electrodes). A motion artifact reduction unit **224** is configured to receive sensor signal **225** and motion artifact signal **223**. Motion artifact reduction unit **224** operates to subtract motion artifact signal **223** from sensor signal **225** to yield the physiological-related signal component (or an approximation thereof) as a raw physiological signal **227**. In some examples, raw physiological signal **227** represents an unamplified, unfiltered signal including data representative of one or more physiological characteristics. In some embodiments, motion sensor **221** generates motion signals, such as accelerometer signals. These signals are provided to motion artifact reduction unit **224** (e.g., via dashed lines as shown), which, in turn, is configured to determine motion artifact signal **223**. In some embodiments, motion artifact signal **223** represents motion included or embodied within raw sensor signal **225** (e.g., with physiological signal(s)).

[0058] Thus, a motion artifact signal can describe a motion signal, whether sensed by a motion sensor or integrated with one or more physiological signals. A physiological characteristic determinator **226** is configured to receive raw physiological signal **227** to amplify and/or filter different physiological signal components from raw physiological signal **227**. For example, raw physiological signal **227** may include a respiration signal modulated on (or in association with) a heart rate ("HR") signal. Regardless, physiological characteristic determinator **226** is configured to perform digital signal processing to generate a heart rate ("HR") signal **229***a* and/or a respiration signal **229***b*. Portion **240** of respiration signal **229***b* represents an impedance signal due to cardiac activity, at least in some instances. Further, physiological characteristic determinator **226** is configured to use either HR signal **229***a* or a respiration signal **229***b*, or both, to derive other physiological characteristics, such as blood pressure data ("BP") **229***c*, a maximal oxygen consumption ("VO2 max") **229***d*, or any other physiological characteristic.

[0059] Physiological characteristic determinator **226** can derive other physiological characteristics using other data generated or accessible by wearable device **209**, such as the type of activity the wear is engaged, environmental factors, such as temperature, location, etc., whether the wearer is subject to any chronic illnesses or conditions, and any other health or wellness-related information. For example, if the wearer is diabetic or has Parkinson's disease, motion sensor **221** can be used to detect tremors related to the wearer's ailment. With the detection of small, but rapid movements of a wearable device that coincide with a change in heart rate (e.g., a change in an HR signal) and/or breathing, physiological information generator **220** may generate data (e.g., an alarm) indicating that the wearer is experiencing tremors. For a diabetic, the wearer may experience shakiness because the blood-sugar level is extremely low (e.g., it drops below a range of 38 to 42 mg/dl). Below these levels, the brain may become unable to control the body. Moreover, if the arms of a wearer shakes with sufficient motion to displace a subset of electrodes from being adjacent a target location, the array of electrodes, as described herein, facilitates continued monitoring of a heart rate by repeatedly selecting subsets of electrodes that are positioned optimally (e.g., adjacent a target location) for receiving robust and accurate physiological-related signals.

[0060] FIGS. **3**A to **3**C are cross-sectional views depicting arrays of electrodes including subsets of electrodes adjacent an arm portion of a wearer, according to some embodiments. Diagram **300** of FIG. **3**A depicts an array of electrodes arranged about, for example, a wrist of a wearer. In this cross-sectional view, an array of electrodes includes electrodes **310***a*, **310***b*, **310***c*, **310***d*, **310***e*, **310***f*, **310***g*, **310***h*, **310***i*, **310***j*, and **310***k*, among others, arranged about wrist **303** (or the forearm). The cross-sectional view of wrist **303** also depicts a radius bone **330**, an ulna bone **332**, flexor muscles/ligaments **306**, a radial artery ("R") **302**, and an ulna artery ("U") **304**. Radial artery **302** is at a distance **301** (regardless of whether linear or angular) from ulna artery **304**. Distance **301** may be different, on average, for different genders, based on male and female anatomical structures. Notably, the array of electrodes can obviate specific placement of electrodes due to different anatomical structures based on gender, preference of the wearer, issues associated with contact (e.g., contact alignment), or any other issue that affects placement of electrode that otherwise may not be optimal. To effect appropriate electrode selection, a sensor selector, as described herein, can use gender-related information (e.g., whether the wearer is male or female) to predict positions of subsets of electrodes such that they are adjacent (or substantially adjacent) to one or more target locations **304***a* and **304***b*. Target locations **304***a* and **304***b* represent optimal areas (or volumes) at which to measure, monitor and capture data related to bioimpedances. In particular, target location **304***a* represents an optimal area adjacent radial artery **302** to pick up bioimpedance signals, whereas target location **304***b* represents another optimal area adjacent ulna artery **304** to pick up other bioimpedance signals.

[0061] To illustrate the resiliency of a wearable device to maintain an ability to monitor physiological characteristics over one or more displacements of the wearable device (e.g., around or along wrist **303**), consider that a sensor selector configures initially electrodes **310***b*, **310***d*, **310***f*, **310***h*, and **310***j* as driver electrodes and electrodes **310***a*, **310***c*, **310***e* **310***g*, **310***i*, and **310***k* as sink electrodes. Further consider that the sensor selector identifies a first subset of electrodes that includes electrodes **310***b* and **310***c* as a first optimal subset, and also identifies a second subset of electrodes that include electrodes **310***f* and **310***g* as a second optimal subset. Note that electrodes **310***b* and **310***c* are adjacent target location **304***a* and electrodes **310***f* and **310***g* are adjacent to target location **304***b*. These subsets are used to periodically (or aperiodically) monitor the signals from electrodes **310***c* and **310***g*, until the first and second subsets are no longer optimal (e.g., when movement of the wearable device displaces the subsets relative to the target locations). Note that the functionality of driver and sink electrodes for electrodes **310***b*, **310***c*, **310***f*, and **310***g* can be reversed (e.g., electrodes **310***a* and **310***g* can be configured as drive electrodes).

[0062] FIG. **3**B depicts an array of FIG. **3**A being displaced from an initial position, according to some examples. In particular, diagram **350** depicts that electrodes **310***f* and **310***g* are displaced to a location adjacent radial artery **302** and electrodes **310***j* and **310***k* are displaced to a location adjacent ulna artery **304**. According to some embodiments, a sensor selector **322** is configured to test subsets of electrodes to determine at least one subset, such as electrodes **310***f* and **310**, being located adjacent to a target location (next to radial artery **302**). To identify electrodes **310***f* and **310***g* as an optimal subset, sensor selector **322** is configured to apply drive signals to the drive electrodes to generate a number of data samples, such as data samples **307***a*, **307***b*, and **307***c*. In this example, each data sample represents a portion of a physiological characteristic, such as a portion of an HR signal. Sensor selector **322** operates to compare the data samples against a profile **309** to determine which of data samples **307***a*, **307***b*, and **307***c* best fits or is comparable to a predefined set of data represented by profile data **309**. Profile data **309**, in this example, represents an expected HR portion or thresholds indicating a best match. Also, profile data **309** can represent the most robust and accurate HR portion measured during the sensor selection mode relative to all other data samples (e.g., data sample **307***a* is stored as profile data **309** until, and if, another data sample provides a more robust and/or accurate data sample). As shown, data sample **307***a* substantially matches profile data **309**, whereas data samples **307***b* and **307***c* are increasingly attenuated as distances increase away from radial artery **302**. Therefore, sensor selector **322** identifies electrodes **310***f* and **310***g* as an optimal subset and can use this subset in data capture mode to monitor (e.g., continuously) the physiological characteristics of the wearer. Note that the nature of data samples **307***a*, **307***b*, and **307***c* as portions of an HR signal is for purposes of explanation and is not intended to be limiting. Data samples **307***a*, **307***b*, and **307***c* need not be portions of a waveform or signal, and need not be limited to an HR signal. Rather, data samples **307***a*, **307***b*, and **307***c* can relate to a respiration signal, a raw sensor signal, a raw physiological signal, or any other signal. Data samples **307***a*, **307***b*, and **307***c* can represent a measured signal attribute, such as magnitude or amplitude, against which profile data **309** is matched. In some cases, an optimal subset of electrodes can be associated with a least amount of impedance and/or reactance (e.g., over a period of time) when applying a first signal (e.g., a drive signal) to a target location.

[0063] FIG. **3**C depicts an array of electrodes of FIG. **3**A oriented differently due to a change in orientation of a wrist of a wearer, according to some examples. In this example, the array of electrodes is shown to be disposed in a wearable device **371**, which has an outer surface **374** and an inner surface **372**. In some embodiments, wearable device **371** can be configured to "loosely fit" around the wrist, thereby enabling rotation about the wrist. In some cases, a portion of wearable devices **371** (and corresponding electrodes **310***a* and **310***b*) are subject to gravity ("G") **390**, which pulls the portion away from wrist **303**, thereby forming a gap **376**. Gap **376**, in turn, causes inner surface **372** and electrodes **310***a* and **310***b* to be displaced radially by a radial distance **392** (i.e., in a radial direction away from wrist **303**). Gap **376**, in some cases, can be an air gap. Radial distance **392**, at least in some cases, may impact electrodes **310***a* and **310***b* and the ability to receive signals adjacent to radial artery **302**. Regardless, electrodes **310***f* and **310***g* are positioned in another portion of wearable device **371** and can be used to receive signals adjacent to ulna artery **304** in cooperation with, or instead of, electrodes **310***a* and **310***b*. Therefore, electrodes **310***f* and **310***g* (or any other subset of electrodes) can provide redundant data capturing capabilities should other subsets be unavailable.

[0064] Next, consider that sensor selector **322** of FIG. **3**B is configured to determine a position of electrodes **310***f* and **310***g* (e.g., on the wearable device **371**) relative to a direction of gravity **390**. A motion sensor (not shown) can determine relative movements of the position of electrodes **310***f* and **310***g* over any number of movements in either a clockwise direction ("dCW") or a counterclockwise direction ("dCCW"). As wearable device **371** need not be affixed firmly to wrist **303**, at least in some examples, the position of electrodes **310***f* and **310***g* may "slip" relative to the position of ulna artery **304**. In one embodiment, sensor selector **322** can be configured to determine whether another subset of electrodes are optimal, if electrodes **310***f* and **310***g* are displaced farther away than a more suitable subset. In sensor selecting mode, sensor selector **322** is configured to select another subset, if necessary, by beginning the capture of data samples at electrodes **310***f* and **310***g* and progressing to other nearby subsets to either confirm the initial selection of electrodes **310***f* and **310***g* or to select another subset. In this manner, the identification of the optimal subset may be determined in less time than if the selection process is performed otherwise (e.g., beginning at a specific subset regardless of the position of the last known target location).

[0065] FIG. **4** depicts a portion of an array of electrodes disposed within a housing material of a wearable device, according to some embodiments. Diagram **400** depicts electrodes **410***a* and **410***b* disposed in a wearable device **401**, which has an outer surface **402** and an inner surface **404**. In some embodiments, wearable device **401** includes a material in which electrodes **410***a* and **410***b* can be encapsulated in a material to reduce or eliminate exposure to corrosive elements in the environment external to wearable device **401**. Therefore, material **420** is disposed between the surfaces of electrodes **410***a* and **410***b* and inner surface **404**. Driver electrodes are capacitively coupled to skin **405** to transmit high impedance signals, such as a current signal, over distance ("d") **422** through the material, and, optionally, through fabric **406** or hair into skin **405** of the wearer. Also, the current signal can be driven through an air gap ("AG") **424** between inner surface **404** and skin **405**. Note that in some implementations, electrodes **410***a* and **410***b* can be exposed (or partially exposed) out through inner surface **404**. In some embodiments, electrodes **410***a* and **410***b* can be coupled via conductive materials, such as conductive polymers or the like, to the external environment of wearable device **401**.

[0066] FIG. **5** depicts an example of a physiological information generator, according to some embodiments. Diagram **500** depicts an array **501** of electrodes **510** that can be disposed in a wearable device. A physiological information generator can include one or more of a sensor selector **522**, an accelerometer **540** for generating motion data, a motion artifact reduction unit **524**, and a physiological characteristic determinator **526**. Sensor selector **522** includes a signal controller **530**, a multiplexer **501** (or equivalent switching mechanism), a signal driver **532**, a signal receiver **534**, a motion determinator **536**, and a target location determinator **538**. Sensor selector **522** is configured to operate in at least two modes. First, sensor selector **522** can select a subset of electrodes in a sensor select mode of operation. Second, sensor selector **522** can use a selected subset of electrodes to acquire physiological characteristics, such as in a data capture mode of operation, according to some embodiments. In sensor select mode, signal controller **530** is configured to serially (or in parallel) configure subsets of electrodes as driver electrodes and sink electrodes, and to cause multiplexer **501** to select subsets of electrodes **510**. In this mode, signal driver **532** applies a drive signal via multiplexer **501** to a selected subset of electrodes, from which signal receiver **534** receives via multiplexer **501** a sensor signal. Signal controller **530** acquires a data sample for the subset under selection, and then selects another subset of electrodes **510**. Signal controller **530** repeats the capture of data samples, and is configured to determine an optimal subset of electrodes for monitoring purposes. Then, sensor selector **522** can operate in the data capture mode of operation in which sensor selector **522** continuously (or substantially continuously) captures sensor signal data from at least one selected subset of electrodes **501** to identify physiological characteristics in real time (or in near real-time).

[0067] In some embodiments, a target location determinator **538** is configured to initiate the above-described sensor selection mode to determine a subset of electrodes **510** adjacent a target location. Further, target location determinator **538** can also track displacements of a wearable device in which array **501** resides based on motion data from accelerometer **540**. For example, target location determinator **538** can be configured to determine an optimal subset if the initially-selected electrodes are displaced farther away from the target location. In sensor selecting mode, target location determinator **538** can be configured to select another subset, if necessary, by beginning the capture of data samples at electrodes for the last known subset adjacent to the target location, and progressing to other nearby subsets to either confirm the initial selection of electrodes or to select another subset. In some examples, orientation of the wearable device, based on accelerometer data (e.g., a direction of gravity), also can be used to select a subset of electrodes **501** for evaluation as an optimal subset. Motion determinator **536** is configured to detect whether there is an amount of motion associated with a displacement of the wearable device. As such, motion determinator **536** can detect motion and generate a signal to indicate that the wearable device has been displaced, after which signal controller **530** can determine the selection of a new subset that is more closely situated near a blood vessel than other subsets, for example. Also, motion determinator **536** can cause signal controller **530** to disable data capturing during periods of extreme motion (e.g., during which relatively large amounts of motion artifacts may be present) and to enable data capturing during moments when there is less than an extreme amount of motion (e.g., when a tennis player pauses before serving). Data repository **542** can include data representing the gender of the wearer, which is accessible by signal controller **530** in determining the electrodes in a subset.

[0068] In some embodiments, signal driver **532** may be a constant current source including an operational amplifier configured as an amplifier to generate, for example, 100 μA of alternating current ("AC") at various frequencies, such as 50 kHz.

[0069] Note that signal driver **532** can deliver any magnitude of AC at any frequency or combinations of frequencies (e.g., a signal composed of multiple frequencies). For example, signal driver **532** can generate magnitudes (or amplitudes), such as between 50 μA and 200 μA, as an example. Also, signal driver **532** can generate AC signals at frequencies from below 10 kHz to 550 kHz, or greater. According to some embodiments, multiple frequencies may be used as drive signals either individually or combined into a signal composed of the multiple frequencies. In some embodiments, signal receiver **534** may include a differential amplifier and a gain amplifier, both of which can include operational amplifiers.

[0070] Motion artifact reduction unit **524** is configured to subtract motion artifacts from a raw sensor signal received into signal receiver **534** to yield the physiological-related signal components for input into physiological characteristic determinator **526**. Physiological characteristic determinator **526** can include one or more filters to extract one or more physiological signals from the raw physiological signal that is output from motion artifact reduction unit **524**. A first filter can be configured for filtering frequencies for example, between 0.8 Hz and 3 Hz to extract an HR signal, and a second filter can be configured for filtering frequencies between 0 Hz and 0.5 Hz to extract a respiration signal from the physiological-related signal component. Physiological characteristic determinator **526** includes a biocharacteristic calculator that is configured to calculate physiological characteristics **550**, such as VO2 max, based on extracted signals from array **501**.

[0071] FIG. **6** is an example flow diagram for selecting a sensor, according to some embodiments. At **602**, flow **600** provides for the selection of a first subset of electrodes and the selection of a second subset of electrodes in a select sensor mode. At **604**, one of the first and second subset of electrodes is selected as a drive electrode and the other of the first and second subset of electrodes is selected as a sink electrode. In particular, the first subset of electrodes can, for example, include one or more drive electrodes, and the second subset of electrodes can include one or more sink electrodes. At **606**, one or more data samples are captured, the data samples representing portions of a measured signal (or values thereof). Based on a determination that one of the data samples is indicative of a subset of electrodes adjacent a target location, the electrodes of the optimal subset are identified at **608**. At **610**, the identified electrodes are selected to capture signals including physiological-relate components. While there is no detected motion at **612**, flow **600** moves to **616** to capture, for example, heart and respiration data continuously. When motion is detected at **612**, data capture may continue. But flow **600** moves to **614** to determine whether to apply a predicted target location. In some cases, a predicted target location is based on the initial target location (e.g., relative to the initially-determined subset of electrodes), with subsequent calculations based on amounts and directions of displacement, based on accelerometer data, to predict a new target location. One or more motion sensors can be used to determine the orientation of a wearable device, and relative movement of the same (e.g., over a period of time or between events), to determine or predict a target location. Or, the predicted target location can refer to the last known target location and/or subset of electrodes. At **618**, electrodes are selected based on the predicted target location for confirming whether the previously-selected subset of electrodes are optimal, or whether a new, optimal subset is to be determined as flow **600** moves back to **602**.

[0072] FIG. **7** is an example flow diagram for determining physiological characteristics using a wearable device with arrayed electrodes, according to some embodiments. At **702**, flow **700** provides for the selection of a sensor in sensor select mode, the sensor including, for example, two or more electrodes. At **704**, sensor signal data is captured in data capture mode. At **706**, motion-related artifacts can be reduced or eliminated from the sensor signal to yield a physiological-related signal component. One or more physiological characteristics can be identified at **708**, for example, after digitally processing the physiological-related signal component. At **710**, one or more physiological characteristics can be calculated based on the data signals extracted at **708**. Examples of calculated physiological characteristics include maximal oxygen consumption ("VO2 max").

[0073] FIG. **8** illustrates an exemplary computing platform disposed in a wearable device in accordance with various embodiments. In some examples, computing platform **800** may be used to implement computer programs, applications, methods, processes, algorithms, or other software to perform the above-described techniques. Computing platform **800** includes a bus **802** or other communication mechanism for communicating information, which interconnects subsystems and devices, such as processor **804**, system memory **806** (e.g., RAM, etc.), storage device **808** (e.g., ROM, etc.), a communication interface **813** (e.g., an Ethernet or wireless controller, a Bluetooth controller, etc.) to facilitate communications via a port on communication link **821** to communicate, for example, with a computing device, including mobile computing and/or communication devices with processors. Processor **804** can be implemented with one or more central processing units ("CPUs"), such as those manufactured by Intel® Corporation, or one or more virtual processors, as well as any combination of CPUs and virtual processors. Computing platform **800** exchanges data representing inputs and outputs via input-and-output devices **801**, including, but not limited to, keyboards, mice, audio inputs (e.g., speech-to-text devices), user interfaces, displays, monitors, cursors, touch-sensitive displays, LCD or LED displays, and other I/O-related devices.

[0074] According to some examples, computing platform **800** performs specific operations by processor **804** executing one or more sequences of one or more instructions stored in system memory **806**, and computing platform **800** can be implemented in a client-server arrangement, peer-to-peer arrangement, or as any mobile computing device, including smart phones and the like. Such instructions or data may be read into system memory **806** from another computer readable medium, such as storage device **808**. In some examples, hard-wired circuitry may be used in place of or in combination with software instructions for implementation. Instructions may be embedded in software or firmware. The term "computer readable medium" refers to any tangible medium that participates in providing instructions to processor **804** for execution. Such a medium may take many forms, including but not limited to, non-volatile media and volatile media. Non-volatile media includes, for example, optical or magnetic disks and the like. Volatile media includes dynamic memory, such as system memory **806**.

[0075] Common forms of computer readable media includes, for example, floppy disk, flexible disk, hard disk, magnetic tape, any other magnetic medium, CD-ROM, any other optical medium, punch cards, paper tape, any other physical medium with patterns of holes, RAM, PROM, EPROM, FLASH-EPROM, any other memory chip or cartridge, or any other medium from which a computer can read. Instructions may further be transmitted or received using a transmission medium. The term "transmission medium" may include any tangible or intangible medium that is capable of storing, encoding or carrying instructions for execution by the machine, and includes digital or analog communications signals or other intangible medium to facilitate communication of such instructions. Transmission media includes coaxial cables, copper wire, and fiber optics, including wires that comprise bus **802** for transmitting a computer data signal.

[0076] In some examples, execution of the sequences of instructions may be performed by computing platform **800**. According to some examples, computing platform **800** can be coupled by communication link **821** (e.g., a wired network, such as LAN, PSTN, or any wireless network) to any other processor to perform the sequence of instructions in coordination with (or asynchronous to) one another. Computing platform **800** may transmit and receive messages, data, and instructions, including program code (e.g., application code) through communication link **821** and communication interface **813**. Received program code may be executed by processor **804** as it is received, and/or stored in memory **806** or other non-volatile storage for later execution.

[0077] In the example shown, system memory **806** can include various modules that include executable instructions to implement functionalities described herein. In the example shown, system memory **806** includes a physiological information generator module **854** configured to implement determine physiological information relating to a user that is wearing a wearable device. Physiological information generator module **854** can include a sensor selector module **856**, a motion artifact reduction unit module **858**, and a physiological characteristic determinator **859**, any of which can be configured to provide one or more functions described herein.

[0078] FIG. **9** depicts the physiological signal extractor, according to some embodiments. Diagram **900** depicts a motion artifact reduction unit **924** including a physiological signal extractor **936**. In some embodiments, motion artifact reduction unit **924** can be disposed in or attached to a wearable device **909**, which can be configured to attached to or otherwise be worn by user **903**. As shown, user **903** is running or jogging, whereby movement of the limbs of user **903** imparts forces that cause wearable device **909** to experience motion. Motion artifact reduction unit **924** is configured to receive a sensor signal ("Raw Sensor Signal") **925**, and is further configured to reduce or negate motion artifacts accompanying, or mixed with, physiological signals due to motion-related noise that otherwise affects sensor signal **925**. Further to diagram **900**, a signal receiver **934** is coupled to a sensor including, for example, one or more electrodes. Examples of such electrodes include electrode **910***a* and electrode **910***b*. In some embodiments, signal receiver **934** includes similar structure and/or functionality as signal receiver **534** of FIG. **5**. In operation, signal receiver **934** is configured to receive one or more AC current signals, such as high impedance signals, as bioimpedance-related signals. Signal receiver **934** can include differential amplifiers, gain amplifiers, or any other operational amplifier configured to receive, adapt (e.g., amplify), and transmit sensor signal **925** to motion artifact reduction unit **924**.

[0079] In some embodiments, signal receiver **934** is configured to receive electrical signals representing acoustic-related information from a microphone **911**. An example of the acoustic-related information includes data representing a heartbeat or a heart rate as sensed by microphone **911**, such that sensor signal **925** can be an electrical signal derived from acoustic energy associated with a sensed physiological signal, such as a pulse wave or heartbeat. Wearable device **909** can include microphone **911** configured to contact (or to be positioned adjacent to) the skin of the wearer, whereby microphone **911** is adapted to receive sound and acoustic energy generated by the wearer (e.g., the source of sounds associated with physiological information). Microphone **911** can also be disposed in wearable device **909**. According to some embodiments, microphone **911** can be implemented as a skin surface microphone ("SSM"), or a portion thereof, according to some embodiments. An SSM can be an acoustic microphone configured to enable it to respond to acoustic energy originating from human tissue rather than airborne acoustic sources. As such, an SSM facilitates relatively accurate detection of physiological signals through a medium for which the SSM can be adapted (e.g., relative to the acoustic impedance of human tissue). Examples of SSM structures in which piezoelectric sensors can be implemented (e.g., rather than a diaphragm) are described in U.S. patent application Ser. No. 11/199,856, filed on Aug. 8, 2005, and U.S. patent application Ser. No.: 13/672,398, filed on Nov. 8, 2012, both of which are incorporated by reference. As used herein, the term human tissue can refer to, at least in some examples, as skin, muscle, blood, or other tissue. In some embodiments, a piezoelectric sensor can constitute an SSM. Data representing sensor signal **925** can include acoustic signal information received from an SSM or other microphone, according to some examples.

[0080] According to some embodiments, physiological signal extractor **936** is configured to receive sensor signal **925** and data representing sensing information **915** from another, secondary sensor **913**. In some examples, sensor **913** is a motion sensor (e.g., an accelerometer) configured to sense accelerations in one or more axes and generates motion signals indicating an amount of motion and/or acceleration. Note, however, that sensor **913** need not be so limited and can be any other sensor. Examples of suitable sensors are disclosed in U.S. Non-Provisional patent application Ser. No. 13/492,857, filed on Jun. 9, 2012, which is incorporated by reference. Further, physiological signal extractor **936** is configured to operate to identify a pattern (e.g., a motion "signature"), based on motion signal data generated by sensor **913**, that can used to decompose sensor signal **925** into motion signal components **937***a* and physiological signal components **937***b*. As shown, motion signal components **937***a* and physiological signal components **937***b* can correspondingly be used by motion artifact reduction unit **924**, or any other structure and/or function described herein, to form motion data **930** and one or more physiological data signals, such as physiological characteristic signals **940**, **942**, and **944**. Physiological characteristic determinator **926** is configured to receive physiological signal components **937***b* of a raw physiological signal, and to filter different physiological signal components to form physiological characteristic signal(s). For example, physiological characteristic determinator **926** can be configured to analyze the physiological signal components to determine a physiological characteristic, such as a heartbeat, heart rate, pulse wave, respiration rate, a Mayer wave, and other like physiological characteristic. Physiological characteristic determinator **926** is also configured to generate a physiological characteristic signal that includes data representing the physiological characteristic during one or more portions of a time interval during which motion is present. Examples of physiological characteristic signals include data representing one or more of a heart rate **940**, a respiration rate **942**, Mayer wave frequencies **944**, and any other sensed characteristic, such as a galvanic skin response ("GSR") or skin conductance. Note that the term "heart rate" can refer, at least in some embodiments, to any heart-related physiological signal, including, but not limited to, heart beats, heart beats per minute ("bpm"), pulse, and the like. In some examples, the term "heart rate" can refer also to heart rate variability ("HRV"), which describes the variation of a time interval between heartbeats. HRV describes a variation in the beat to beat interval and can be described in terms of frequency components (e.g., low frequency and high frequency components), at least in some cases.

[0081] In view of the foregoing, the functions and/or structures of motion artifact reduction unit **924**, as well as its components and/or neighboring components, can facilitate the extraction and derivation of physiological characteristics in situ—during which a user is engaged in physical activity that imparts motion on a wearable device, whereby biometric sensors, such as electrodes, may receive bioimpedance sensor signals that are exposed to, or include, motion-related artifacts. For example, physiological signal extractor **936** can be configured to receive the sensor signal that includes data representing physical physiological characteristics during one or more portions of the time interval in which the wearable devices is in motion. A user **903** need not be required to remain immobile to determine physiological signal characteristic signals. Therefore, user **903** can receive heart rate information, respiration information, and other physiological information during physical activity or during periods of time in which user **903** is substantially or relatively active. Further, according to various embodiments, physiological signal extractor **936** facilitates the sensing of physiological characteristic signals at a distal end of a limb or appendage, such as at a wrist, of user **903**. Therefore, various implementations of motion artifact reduction unit **924** can enable the detection of physiological signal at the extremities of user **903**, with minimal or reduced effects of motion-related artifacts and their influence on the desired measured physiological signal. By facilitating the detection of physiological signals at the extremities, wearable device **909** can assist user **903** to detect oncoming ailments or conditions of the person's body (e.g., oncoming tremors, states of sleep, etc.) relative to other portions of the person's body, such as proximal portions of a limb or appendage.

[0082] In accordance with some embodiments, physiological signal extractor **936** can include an offset generator, which is not shown. An offset generator can be configured to determine an amount of motion that is associated with the motion sensor signal, such as an accelerometer signal, and to adjust the dynamic range of operation of an amplifier, where the amplifier is configured to receive a sensor signal responsive to the amount of motion. An example of such an amplifier is an operational amplifier configured as a front-end amplifier to enhance, for example, the signal-to-noise ratio. In situations in which the motion related artifacts induce a rapidly-increasing amplitude onto the sensor signal, the amplifier may drive into saturation, which, in turn, causes clipping of the output of the amplifier. The offset generator also is configured to apply in offset value to an amplifier to modify the dynamic range of the amplifier so as to reduce or negate large magnitudes of motion artifacts that may otherwise influence the amplitude of the sensor signal. Examples of an offset generator are described in relation to FIG. **12**. In some embodiments, physiological signal extractor **936** can include a window validator configured to determine durations (i.e., a valid window of time) in which sensor signal data can be predicted to be valid (i.e., durations in which the magnitude of motion-related artifacts signals likely do not influence the physiological signals). An example of a window validator is described in FIG. **11**.

[0083] FIG. **10** is a flowchart for extracting a physiological signal, according to some embodiments. At **1002**, a motion sensor signal is correlated to a sensor signal, which includes one or more physiological characteristic signals and one or more motion-related artifact signals. In some examples, correlating motion sensor signals to bioimpedance signals enables the two signals to be compared against each other, whereby motion-related artifacts can be subtracted from the bioimpedance signals to extract a physiological characteristic signal. In at least one embodiment, data correlation at **1002** can be performed to include scaling data that represents a motion sensor signal, whereby the scaling facilitates making values for the data representing sensor signal equivalent so that they can be compared against each other (e.g., to facilitate subtracting one signal from the other). At **1004**, a sensor signal is decomposed to extract one or more physiological signals and one or more motion sensor signals, thereby separating physiological signals from the motion signals. The extracted physiological signal is analyzed at **1006**. In some examples, the frequency of the extracted physiological signal is analyzed to identify a dominant frequency component or predominant frequency components. Also, such an analysis at **1006** can also determine power spectral densities of the physiological extract physiological signal. At **1008**, the relevant components of the physiological signal can be identified, based on the determination of the predominant frequency components. At **1010**, at least one physiological signal is generated, such as a heart rate signal, a respiration signal, or a Mayer wave signal. These signals each can be associated with one or more corresponding dominant frequency component that are used to form the one or more physiological signals.

[0084] FIG. **11** is a block diagram depicting an example of a physiological signal extractor, according to some embodiments. Diagram **1100** depicts a physiological signal extractor **1136** that includes a stream selector **1140**, a data correlator **1142**, an optional window validator **1143**, a parameter estimator **1144**, and a separation filter **1146**. Physiological signal extractor **1136** can also include an optional offset generator **1139** to be discussed later. As shown in FIG. **11**, physiological signal extractor **1136** receives a raw sensor signal from, for example, a bioimpedance sensor, and also receives one or more motion sensor signals **1143** from a motion sensor **1141**, which can include one or more accelerometers in some examples. Multiple data streams can represent accelerometer data in multiple axes. Stream selector **1140** is configured to receive, for example, multiple accelerometer signals specifying motion along one or more different axes. Further, stream selector **1140** is configured to select an accelerometer data stream having a greatest motion component (e.g., the greatest magnitude of acceleration for an axis). In some examples, stream selector **1140** is configured to select the axis of acceleration having the highest variability in motion, whereby that axis can be used to track motion or identify a general direction or plane of motion. Optionally, offset generator **1139** can receive a magnitude of the raw sensor signal to modify the dynamic range of an amplifier receiving the raw sensor signal prior to that signal entering data correlator **1142**.

[0085] Data correlator **1142** is configured to receive the raw sensor signal and the selected stream of accelerometer data. Data correlator **1142** operates to correlate the sensor signal and the selected motion sensor signal. For example, data correlator **1142** can scale the magnitudes of the selected motion sensor signal to an equivalent range for the sensor signal. In some embodiments, data correlator **1142** can provide for the transformation of the signal data between the bioimpedance sensor signal space and the acceleration data space. Such a transformation can be optionally performed to make the motion sensor signals, especially the selected motion sensor signal, equivalent to the bioimpedance sensor signal. In some examples, a cross-correlation function or an autocorrelation function can be implemented to correlate the sets of data representing the motion sensor signal and the sensor signal.

[0086] Parameter estimator **1144** is configured to receive the selected motion sensor signal from stream selector **1140** and the correlated data signal from data correlator **1142**. In some examples, parameter estimator **1144** is configured to estimate parameters, such as coefficients, for filtering out physiological characteristic signals from motion-related artifact signals. For example, the selected motion sensor signal, such as accelerometer signal, generally does not include biological derived signal data, and, as such, one or more coefficients for physiological signal components can be reduced or effectively determined to be zero. Separation filter **1146** is configured to receive the coefficients as well as data correlated by data correlator **1142** and the selected motion sensor signal from stream selector **1140**. In operation, separation filter **1146** is configured to recover the sources of the signals. For example, separation filter **1146** can generate a recovered physiological characteristic signal ("P") **1160** and a recovered motion signal ("M") **1162**. Separation filter **1146**, therefore, operates to separate a sensor signal including both biological signals and motion-related artifact signals into additive or subtractable components. Recovered signals **1160** and **1162** can be used to further determine one or more physiological characteristics signals, such as a heart rate, respiration rate, and a Mayer wave.

[0087] Window validator **1143** is optional, according to some embodiments. Window validator **1143** is configured to receive motion sensor signal data to determine a duration time (i.e., a valid window of time) in which sensor signal data can be predicted to be valid (i.e., durations in which the magnitude of motion-related artifacts signals likely do not affect the physiological signals). In some cases, window validator **1143** is configured to predict a saturation condition for a front-end amplifier (or any other condition, such as a motion-induced condition), whereby the sensor signal data is deemed invalid.

[0088] FIG. **12** depicts an example of an offset generator according to some embodiments. Diagram **1200** depicts offset generator **1239** including a dynamic range determinator **1240** and an optional amplifier **1242**, which can be disposed within or without offset generator **1239**. In sensing bioimpedance-related signals, the bioimpedance signals generally are "small-signal;" that is, these signals have relatively small amplitudes that can be distorted by changes in impedances, such as when the coupling between the electrodes and the skin is disrupted. Offset generator **1239** can be configured to determine an amount of motion that is associated with motion sensor signal ("M") **1260**, such as an accelerometer signal, and to adjust the dynamic range of operation of amplifier **1242**, which can be an operational amplifier configured as a front-end amplifier. Further, offset generate **1239** can also be optionally configured to receive sensor signal ("S") **1262** and correlated data ("CD") **1264**, either or both of which can be used to determine first whether to modify the dynamic range of amplifier **1242**, and if so, to what degree to which the dynamic range ought to be modified. In some cases, the degree to which the dynamic range ought to be modified specified by an offset value. As shown, amplifier **1242** is configured to generate an offset sensor signal that is conditioned or otherwise adapted to avoid or reduce clipping.

[0089] FIG. **13** is a flowchart depicting example of a flow for decomposing a sensor signal to form separate signals, according to some embodiments. Flow **1300** can be implemented in a variety of different ways using a number of different techniques. In some examples, flow **1300** and its elements can be implemented by one or more of the components or elements described herein, according to various embodiments. In the following example, while not intended to be limiting, flow **1300** is described in terms of an analysis for extracting physiological characteristic signals in accordance with one or more techniques of performing Independent Component Analysis ("ICA"). At **1302**, a sensor signal is received, and at **1304** a motion sensor signal is selected. When a test subject, or user, is wearing a wearable device and is physically active, the received bioimpedance signal can include two signals: 1.) a sensor signal including one or more physiological signals such as heart rate, respiration rate, and Mayer waves, and 2.) motion-related artifact signals. Further, the one or more physiological signals and motion sensor signals (or motion-related artifact signals) may be correlated at **1305**. In this example, a physiological signal is assumed to be statistically independent (or nearly statistically independent) of a motion sensor signal or related artifacts. In some examples, flow **1300** provides for separating a multivariate signal into additive or subtractive subcomponents, based on a presumed mutually-statistical independence between non-Gaussian source signals. Statistical independence of estimated physiological sample components and motion related artifact signal components can be maximized based on for example minimizing mutual information, and maximizing non-Gaussianity of the source signals.

[0090] Further to flow **1300**, consider two statistically independent noun Gaussian source signals S1 and S2, and two observation points O1 and O2. In some examples, observation points O1(t) and O2(t) are time-indexed samples associated with observed samples from the same sensor, at different locations. For example, O1(t) and O2(t) can represent observed samples from a first bioimpedance sensor (or electrode) and from a second bioimpedance sensor (or electrode), respectively. In other examples, O1(t) and O2(t) can represent observed samples from a first sensor, such as a bioimpedance sensor, and a second sensor, such as an accelerometer, respectively. At **1306**, data associated with one or more of the two observation points O1 and O2 are preprocessed. For example, the data for the observation points can be centered, whitened, and/or reduced in dimensions, wherein preprocessing may reduce the complexity of determining the source signals and/or reduce the number of parameters or coefficients to be estimated. An example of a centering process includes subtracting the meaning of data from a sample to translate samples about a center. An example of a whitening process is eigenvalue decomposition. In some embodiments, preprocessing at **1306** can be different from, or similar to, the correlation of data as described herein, at least in some cases.

[0091] Observation points O1(t) and O2(t) can be expressed as follows:

$$O_1(t)=a_{11}S1+a_{12}S2 \quad \text{(Eqn. 1)}$$

$$O_2(t)=a_{21}S1+a_{22}S2 \quad \text{(Eqn. 2)}$$

where O=A×S, which represent matrices, and a11, a12, a21, and a22 represent parameters (or coefficients) that can be estimated. At **1308**, the above equations 1 and 2 can be used to determine components for generating two (2) statistically-independent source signals, whereby A and S can be extracted from O. In some examples, A and S can be extracted iteratively, based on user-specified error rate and/or maximum number of iterations, among other things. Further, coefficients a11, a12, a21, and a22 can be modified such that one or more coefficients for the physiological characteristic and biological component is set to or near zero, as the accelerometer signal generally does not include physiological signals. In at least one embodiment, parameter estimator **1144** of FIG. **11** can be configured to determine estimated coefficients.

[0092] In some examples a matrix can be formed based on estimated coefficients, at **1308**. At least some of the coefficients are configured to attenuate values of the physiological signal components for the motion sensor signal. An example of the matrix is a mixing matrix. Further, the matrix of coefficients can be inverted to form an inverted mixing matrix (e.g., to form an "unmixing" matrix). The inverted mixing matrix of coefficients can be applied (e.g., iteratively) to the samples of observation points O1(t) and O2(t) to recover the source signals, such as a recovered physiological characteristic signal and a recovered motion signal (e.g. a recovered motion-related artifact signal). In at least one embodiment, separation filter **1146** of FIG. **11** can be configured to apply an inverted matrix to samples of the physiological signal components and the motion signal components to determine the recovered physiological characteristic signal and the recovered motion signal (e.g., a recovered muscle movement signal). Note that various described functionalities of flow **1300** can be implemented in or distributed over one or more of the described structures set forth herein. Note, too, that while flow **1300** is described in terms of ICA in the above-mentioned examples, flow **1300** can be implemented using various techniques and structures, and the various embodiments are neither restricted nor limited to the use of ICA. Other signal separation processes may also be implemented, according to various embodiments.

[0093] FIGS. **14**A to **14**C depict various signals used for physiological characteristic signal extraction, according to various embodiments. FIG. **14**A depicts a sensor signal received as, for example, a bioimpedance signal in which the magnitude varies about 20 over a number of samples. In this example, validation window can be used for heart rate extraction, whereby the sensor signal is down-sampled by, for example, a factor of **100** (i.e., the sensor signal is sampled at, for example, 15.63 Hz). Also shown in FIG. **14**A is an optional window **1402** that indicates a validation window in which data is deemed valid as determined by, for example, window validator **1143** of FIG. **11**. Returning back to FIGS. **14**A to **14**C, FIG. **14**B depicts a first stream of accelerometer data for a first axis. FIG. **14**C and FIG. **14**D depict a second stream of accelerometer data for a second axis and a third stream of accelerometer data for a third axis, respectively. FIGS. **14**A to **14**C are intended to depict only a few of many examples and implementations.

[0094] FIG. **15** depicts recovered signals, according to some embodiments. Diagram **1500** depicts the magnitudes of various signals over **160** samples. Signal **1502** represents us magnitude of the sensor signal, whereas signal **1504** represents the magnitude of an accelerometer signal. Signals **1506**, **1508**, and **1510** represent the magnitudes of a first of accelerometer signal, a second accelerometer signal, and a third accelerometer signal, respectively.

[0095] FIG. **16** depicts an extracted physiological signal, according to various embodiments. Diagram **1600** depicts the magnitude, in volts, of an extracted physiological characteristic signal using the first accelerometer stream as the selected accelerometer stream. For this example, a fast Fourier transform ("FFT") analysis of the data set forth in FIG. **16** yields a heart rate estimated at, for example, 77.6274 bpm.

[0096] FIG. **17** illustrates an exemplary computing platform disposed in a wearable device in accordance with various embodiments. In some examples, computing platform **1700** may be used to implement computer programs, applications, methods, processes, algorithms, or other software to perform the above-described techniques, and can include similar structures and/or functions as set forth in FIG. **8**. But in the example shown, system memory **806** can include various modules that include executable instructions to implement functionalities described herein. In the example shown, system memory **806** includes a motion artifact reduction unit module **1758** configured to determine physiological information relating to a user that is wearing a wearable device. Motion artifact reduction unit module **1758** can include a stream selector module **1760**, a data correlator module **1762**, a coefficient estimator module **1764**, and a mix inversion filter module **1766**, any of which can be configured to provide one or more functions described herein.

[0097] FIG. **18** is a diagram depicting a physiological state determinator configured to receive sensor data originating, for example, at a distal portion of a limb, according to some embodiments. As shown, diagram **1800** depicts a physiological information generator **1810** and a physiological state determinator **1812**, which, at least in the example shown, are configured to be disposed at, or receive signals from, at a distal portion **1804** of a user **1802**. In some embodiments, physiological information generating **1810** and physiological state determinator **1812** are disposed in a wearable device (not shown). Physiological information generator **1810** configured to receive signals and/or data from one or more physiological sensors and one or more motion sensors, among other types of sensors. In the example shown, physiological information generator **1810** is configured to receive a raw sensor signal **1842**, which can be similar or substantially similar to other raw sensor signals described herein. Physiological information generator **1810** is also configured to receive other sensor signals including temperature ("TEMP") **1840**, skin conductance (depicted as GSR data signal **1847**), pulse waves, heat rates (e.g., heart beats-per-minute), respiration rates, heart rate variability, and any other sensed signal configured to include physiological information or any other information relating to the physiology of a person. Examples of other sensors are described in U.S. patent application Ser. No. 13/454,040, filed on Apr. 23, 2012, which is incorporated by reference. Physiological information generator **1810** is also configured to receive motion ("MOT") signal data **1844** from one or more motion sensor(s), such as accelerometers. Note that raw sensor signal **1842** can be an electrical signal, such as a bioimpedance signal, or an acoustic signal, or any other type of signal. According to some embodiments, physiological information generator **1810** is configured to extract physiological signals from a raw sensor signal **1842**. For example, a heart rate ("HR") signal and/or heart rate variability ("HRV") signal **1845** and respiration rate ("RESP") **1846** can be determined for example, by a motion artifact reduction unit (not shown). Physiological information generator **1810** is configured to convey sensed physiological characteristics signals or derive physiological characteristic signals (e.g., from sensed signals) for use by physiological state determinator **1812**. In some examples, a physiological characteristic signal can include electrical impulses of muscles (e.g., as evidenced, in some cases, by electromyography ("EMG") to determine the existence and/or amounts of motion based on electrical signals generated by muscle cells at rest or in contraction.

[0098] As shown, physiological state determinator **1812** includes a sleep manager **1814**, an anomalous state manager **1816**, and an affective state manager **1818**. Physiological state determinator **1812** is configured to receive various physiological characteristics signals and to determine a physiological state of a user, such as user **1802**. Physiological states include, but are not limited to, states of sleep, wakefulness, a deviation from a normative physiological state (i.e., an anomalous state), an affective state (i.e., mood, feeling, emotion, etc.). Sleep manager **1814** is configured to detect a stage of sleep as a physiological state, the stages of sleep including REM sleep and non-REM sleep, including as light sleep and deep sleep. Sleep manager **1814** is also configured to predict the onset or change into or between different stages of sleep, even if such changes are imperceptible to user **1802**. Sleep manager **1814** can detect that user **1802** is transitioning from a wakefulness state to a sleep state and, for example, can generate a vibratory response (i.e., generated by vibration) or any other alert to user **1802**. Sleep manager **1814** also can predict a sleep stage transition to either alert user **1802** or to disable such an alert if, for example, the alert is an alarm (i.e., wake-up time alarm) that coincides with a state of REM sleep. By delaying generation of an alarm, the user **1802** is permitted to complete of a state of REM sleep to ensure or enhance the quality of sleep. Such an alert can assist user **1802** to avoid entering a sleep state from a wakefulness state during critical activities, such as driving.

[0099] Anomalous state manager **1860** is configured to detect a deviation from the normative general physiological state in reaction, for example, to various stimuli, such as stressful situations, injuries, ailments, conditions, maladies, manifestations of an illness, and the like. Anomalous state manager **1860** can be configured to determine the presence of a tremor that, for example, can be a manifestation of an ailment or malady. Such a tremor can be indicative of a diabetic tremor, an epileptic tremor, a tremor due to Parkinson's disease, or the like. In some embodiments, anomalous state manager **1860** is configured to detect the onset of tremor related to a malady or condition prior to user **1802** perceiving or otherwise being aware of such a tremor. Therefore, anomalous state manager **1860** can predict the onset of a condition that may be remedied by, for example, medication and can alert user **1802** to the impending tremor. User **1802** then can take the medication before the intensity of the tremor increases (e.g., to an intensity that might impair or otherwise incapacitate user **1802**). Further, anomalous state manager **1860** can be configured to determine if the physiological state of user **1802** is a pain state, in which user **1802** is experiencing pain. Upon determining a pain state, a wearable device (not shown) can be configured to transmit the presence of pain to a third-party via a wireless communication path to alert others of the pain state for resolution.

[0100] Affective state manager **1818** is configured to use at least physiological sensor data to form affective state data representing an approximate affective state of user **1802**. As used herein, the term "affective state" can refer, at least in some embodiments, to a feeling, a mood, and/or an emotional state of a user. In some cases, affective state data can includes data that predicts an emotion of user **1802** or an estimated or approximated emotion or feeling of user **1802** concurrent with and/or in response to the interaction with another person, environmental factors, situational factors, and the like.

[0101] In some embodiments, affective state manager **1818** is configured to determine a level of intensity based on sensor derived values and to determine whether the level of intensity is associated with a negative affectivity (e.g., a bad mood) or positive affectivity (e.g., a good mood). An example of an affective state manager **1818** is an affective state prediction unit as described in U.S. Provisional Patent Application No. 61/705,598 filed on Sep. 25, 2012, which is incorporated by reference herein for all purposes. While affective state manager **1818** is configured to receive any number of physiological characteristics signals in which to determine of an affective state of user **1802**, affective state manager **1818** can use sensed and/or derived Mayer waves based on raw sensor signal **1842**. In some examples, the detected Mayer waves can be used to determine heart rate variability ("HRV") as heart rate variability can be correlated to Mayer waves. Further, affective state manager **1818** can use, at least in some embodiments, HRV to determine an affective state or emotional state of user **1802** as HRV may correlate with an emotion state of user **1802**. Note that, while physiological information generating **1810** and physiological state determinator **1812** are described above in reference to distal portion **1804**, one or more of these elements can be disposed at, or receive signals from, proximal portion **1806**, according to some embodiments.

[0102] FIG. **19** depicts a sleep manager, according to some embodiments. As shown, FIG. **19** depicts a sleep manager **912** including a sleep predictor **1914**. Sleep manager **1912** is configured to determine physiological states of sleep, such as a sleep state or a wakefulness state in which the user is awake. Sleep manager **1912** is configured to receive physiological characteristic signals, such as data representing respiration rates ("RESP") **1901**, heart rate ("HR") **1903** (or heart rate variability, HRV), motion-related data **1905**, and other physiological data such as optional skin conductance ("GSR") **1907** and optional temperature ("TEMP")**1909**, among others. As shown in diagram **1940**, a person who is sleeping passes through one or more sleep cycles over a duration **1951** between a sleep start time **1950** and sleep end time **1952**. There is a general reduction of motion when a person passes from a wakefulness state **1942** into the stages of sleep, such as into light sleep **1946** in duration **1954**. Motion indicative of "hypnic jerks" or involuntary muscle twitching motions typically occur during light sleep state **1946**. The person then passes into a deep sleep state **1948**, in which, a person has a decreased heart rate and body temperature, with the absence of voluntary muscle motions to confirm or establish that a user is in a deep sleep state. Collectively, the light sleep state and the deep sleep state can be described as non-REM sleep states. Further to diagram **1940**, the sleeping person then passes into an REM sleep state **1944** for duration **1953** during which muscles can be immobile.

[0103] According to some embodiments, sleep manager **1912** is configured to determine a stage of sleep based on at least the heart rate and respiration rate. For example, sleep manager **1912** can determine the regularity of the heart rate and respiration rate to determine the person is in a non-REM sleep state, and, thereby, can generate a signal indicating the stage of the sleep is a non-REM sleep states, such as light sleep or deep sleep states. During light sleep and deep sleep, a heart rate and/or the respiration rate of the user can be described as regular or without significant variability.

[0104] Thus, the regularity of the heart rate and/or respiration rate can be used to determine physiological sleep state of the user. In some examples the regularity of the heart rate and/or the respiration rate can include any heart rate or respiration rate that varies by no more than 5%. In some other cases, the regularity of the heart rate and/or the respiration rate can vary by any amount up to 15%. These percentages are merely examples and are not intended to be limiting, and ordinarily skilled artisan will appreciate that the tolerances for regular heart rates and respiration rates may be based on user characteristics, such as age, level of fitness, gender and the like. Sleep manager **1912** can use motion data **1905** to confirm whether a user is in a light sleep state or a deep sleep state by detecting indicative amounts of motion, such as a portion of motion that is indicative of involuntary muscle twitching.

[0105] As another example, sleep manager **1912** can determine the irregularity (or variability) of the heart rate and respiration rate to determine the person is in an REM sleep state, and, thereby, can generate a signal indicating the stage of the sleep is an REM sleep states. During REM sleep, a heart rate and/or the respiration rate of the user can be described as irregular or with sufficient variability to identify that a user is REM sleep. Thus, the variability of the heart rate and/or respiration rate can be used to determine physiological sleep state of the user. In some examples the irregularity of the heart rate and/or the respiration rate can include any heart rate or respiration rate that varies by more than 5%. In some other cases, the variability of the heart rate and/or the respiration rate can vary by any amounts up from 10% to 15%. These percentages are merely examples and are not intended to be limiting, and ordinarily skilled artisan will appreciate that the tolerances for variable heart rates and respiration rates may be based on user characteristics, such as age, level fitness, gender and the like. Sleep manager **1912** can use motion data **1905** to confirm whether a user is in an REM sleep state by detecting indicative amounts of motion, such as a portion of motion that includes negligible to no motion.

[0106] Sleep manager **1912** is shown to include sleep predictor **1914**, which is configured to predict the onset or change into or between different stages of sleep. The user may not perceive such changes between sleep states, such as transitioning from a wakefulness state to a sleep state. Sleep predictor **1914** can detect this transition from a wakefulness state to a sleep state, as depicted as transition **1930**. Transition **1930** may be determined by sleep predictor **1940** based on the transitions from irregular heart rate and respiration rates during wakefulness to more regular heart rates and respiration rates during early sleep stages. Also, lowered amounts of motion can also indicate transition **1930**. In some embodiments, motion data **1905** includes a velocity or rate of speed at which a user is traveling, such as an automobile. Upon detecting an impending transition from a wakefulness state into a sleep state, sleep predictor **1914** generates an alert signal, such as a vibratory initiation signal, configuring to generate a vibration (or any other response) to convey to a user that he or she is about to fall asleep. So if the user is driving, predictor **914** assists in maintaining a wakefulness state during which the user can avoid falling asleep behind the wheel. Sleep predictor **1914** can be configured to also detect transition **1932** from a light sleep state to a deep sleep state and a transition **1934** from a deep sleep state to an REM sleep state. In some embodiments, transitions **1932** in **1934** can be determined by detected changes from regular to variable heart rates or respiration rates, in the case of transition **1934**. Also, transition **1934** can be described by a decreased level of motion to about zero during the REM sleep state. Further, sleep predictor **1914** can be configured to predict a sleep stage transition to disable an alert, such as wake-up time alarm, that coincides with a state of REM sleep. By delaying generation of an alarm, the user is permitted to complete of a state of REM sleep to enhance the quality of sleep.

[0107] FIG. **20**A depicts a wearable device including a skin surface microphone ("SSM"), in various configurations, according to some embodiments. According to various embodiments, a skin surface microphone ("SSM") can be implemented in cooperation with (or along with) one or more electrodes for bioimpedance sensors, as described herein. In some cases, a skin surface microphone ("SSM") can be implemented in lieu of electrodes for bioimpedance sensors. Diagram **2000** of FIG. **20** depicts a wearable device **2001**, which has an outer surface **2002** and an inner surface **2004**. In some embodiments, wearable device **2001** includes a housing **2003** configured to position a sensor **2010***a* (e.g., an SSM including, for instance, a piezoelectric sensor or any other suitable sensor) to receive an acoustic signal originating from human tissue, such as skin surface **2005**. As shown, at least a portion of sensor **2010***a* can be formed external to surface **2004** of wearable housing **2003**. The exposed portion of the sensor can be configured to contact skin **2005**. In some embodiments, the sensor (e.g., SSM) can be disposed at position **2010***b* at a distance ("d") **2022** from inner surface **2004**. Material, such as an encapsulant, can be used to form wearable housing **2003** to reduce or eliminate exposure to elements in the environment external to wearable device **2001**. In some embodiments, a portion of an encapsulant or any other material can be disposed or otherwise formed at region **2010***a* to facilitate propagation of an acoustic signal to the piezoelectric sensor. The material and/or encapsulant can have an acoustic impedance value that matches or substantially matches the acoustic impedance of human tissue and/or skin. Values of acoustic impedance of the material and/or encapsulant can be described as being substantially similar to the human tissue and/or skin when the acoustic impedance of the material and/or encapsulant varies no more than 60% of that of human tissue or skin, according to some examples.

[0108] Examples of materials having acoustic impedances matching or substantially matching the impedance of human tissue can have acoustic impedance values in a range that includes 1.5×106 Pa×s/m (e.g., an approximate acoustic impedance of skin). In some examples, materials having acoustic impedances matching or substantially matching the impedance of human tissue can provide for a range between 1.0×106 Pa×s/m and 1.0×107 Pa×s/m. Note that other values of acoustic impedance can be implemented to form one or portions of housing **2003**. In some examples, the material and/or encapsulant can be formed to include at least one of silicone gel, dielectric gel, thermoplastic elastomers (TPE), and rubber compounds, but is not so limited. As an example, the housing can be formed using Kraiburg TPE products. As another example, housing can be formed using Sylgard® Silicone products. Other materials can also be used. In some embodiments, sleep manager **1912** detects increase perspiration via skin conductance during an REM sleep state and determines the user is dreaming, whereby in generates a signal to store such an event or generate an other action.

[0109] Further to FIG. **20**A, wearable device **2001** also includes a physiological state determinator **2024**, a sleep manager **1912**, a vibratory energy source **2028**, and a transceiver **2026**. Physiological state determinator **2024** can be configured to receive signals originating as acoustic signals either from sensor **2010***a* or a sensor at location **2010***b* via acoustic impedance-matched material. Upon detecting a sleep state condition (e.g., a sleep state transition), sleep manager **1912** can be configured to communicate the condition to physiological state determinator **2024**, which, in turn, generates a notification signal as a vibratory activation signal, thereby causing vibratory energy source **2028** (e.g., mechanical motor as a vibrator) to impart vibration through housing **2003** unto a user, responsive to the vibratory activation signal, to indicate the presence of the sleep-related condition (e.g., transitioning from a wakefulness state to a sleep state). According to some embodiments, sleep manager **1912** can generate a wake enable/disable signal **2013** configured to enable or disable the ability of vibratory energy source **2028** to generate an alarm signal. For example, if sleep manager **1912** determines that the user is in a REM sleep state, sleep manager **1912** generates a wake disable signal **2013** to prevent vibratory energy source **2228** from waking the user. But if sleep manager **1912** determines that the user is in a non-REM sleep state that coincides with a wake alarm time, or is there shortly thereafter, sleep manager **1912** will generate enable signal **2013** to permit vibratory energy source **2028** to wake up the user. In some cases, a wake enable signal and awake disable signal can be the same signal, but at different states. Also, wearable device **2001** can optionally include a transceiver **2026** configured to transmit signal **2019** as a notification signal via, for example, an RF communication signal path. In some examples, transceiver **2026** can be configured to transmit signal **2019** to include data representative of the acoustic signal received from sensor **2010**, such as an SSM.

[0110] FIG. **20**B depicts an example of physiological characteristics and parametric values that can identify a sleep state, according to some embodiments. Diagram **2050** depicts a data arrangement **2060** including data for determining light sleep states, a data arrangement **2062** that includes data for determining deep sleep states, and data arrangement **2064** that includes data for determining REM sleep states, according to various embodiments. Also shown in FIG. **20**B, sleep manager **1912** and sleep predictor **1914** can use data arrangements **2060**, **2062** and **2064** to determine the various sleep stages of the user. As shown generally, each of the sleep states can be defined one or more physiological characteristics, such as heart rate, HRV, pulse wave, respiration rate, ranges of motion, types of motion, skin conductance, temperature, and any other physiological characteristic or information. As shown, each physiological characteristic is associated with a parametric range that may include one or more than one value associated with the physical physiological characteristic. For example, should the heart rate of a user fall within the range H1-H2, as shown in data arrangement **2064**, sleep manager can use this information in determining whether the user is in REM sleep. In some cases, the parametric values that set forth the ranges, maybe based on characteristics of a user, such as age, level of fitness, gender, etc. In one example, sleep manager **1912** operates to analyze the various values of the physiological characteristics and calculates a best-fit determination of the parametric values to identify the corresponding sleep state for the user. The physiological characteristics and parametric values, and data arrangements **2062** to **2064** is merely one example and is not intended to be limiting.

[0111] FIG. **21** depicts an anomalous state manager **2102**, according to some embodiments. Diagram **2100** depicts that anomalous state manager **2102** includes a tremor determinator **2110**, a pain/stress analyzer **2114** and a malady determinator **2112**. Anomalous state manager **2102** receives sensor data **2104** and is configured to detect a deviation from the normative general physiological state of a user responsive, for example, to various stimuli, such as stressful situations, injuries, ailments, conditions, maladies, manifestations of an illness, symptoms of a condition, and the like. Also shown in diagram **2100** are repositories accessible by anomalous state manager **2102**, including motion profile repository **2130**, user characteristic repository **2140** and pain profile repository **2144**. Motion profile repository **2130** includes profile data **2132** that includes data defining configured to define a tremor, or a portion thereof, associated with detected motion. User characteristic repository **2140** includes user-related data **2142** that describes the user, for example, in terms of age, fitness level, gender, diseases, conditions, ailments, maladies, and any other characteristic that may influence the determination of the physiological state of the user. Pain profiles **2144** includes data **2146** that can define whether the user is in a pain state. In some embodiments, data **2146** is a data arrangement that includes physiological characteristics similar to those shown in FIG. **20**B. For example, physiological signs of pain may include, for example, an increase in respiration rate, an increase in the length of a respiration cycle (e.g., deeper inhalation and exhalation), changes and/or variations in blood pressure, changes and/or variations in heart rate, an increase in perspiration (e.g., increased skin conductance), an increase in muscle tone (e.g., as determined by physiological characteristics indicating increased electrical impulses to or by musculature, and the like). Based on such physiological characteristics, pain/stress analyzer **2114** can be configured to detect that the user is experiencing pain, and in some cases, the level of pain. Further, pain/stress analyzer **2114** can be configured to transmit data representing pain state information to a communication module **2118** for transmitting of the pain state-related information via wearable device **2170** or other mobile devices **2180** to a third-party (or any other entity or computing device) via communications path **2182** (e.g., wireless communications path and/or networks).

[0112] Tremor determinator **2110** is configured to determine the presence of a tremor that, for example, can be a manifestation of an ailment or malady. As discussed, such a tremor can be indicative of a diabetic tremor, an epileptic tremor, a tremor due to Parkinson's disease, or the like. In some embodiments, tremor determinator **2110** is configured to detect the onset of tremor related to a malady or condition prior to a user perceiving or otherwise being aware of such a tremor. In particular, wearable devices disposed at a distal portion of a limb may be more likely, at least in some cases, to detect tremors more readily than when disposed at a proximal portion.

[0113] Therefore, anomalous state manager **2102** can predict the onset of a condition that may be remedied by, for example, medication and can alert a user to the impending tremor. In some cases, malady determinator **2112** is configured to receive data representing a tremor and data **2142** representing user characteristics, and is further configured to determine the malady afflicting the user. For example, if data **2142** indicates the user is a diabetic, the tremor data received from tremor determinator **2110** is likely to indicate a diabetic-related tremor. Therefore, malady determinator **2112** can be configured to generate an alert that, for example, the user's blood glucose is decreasing to low level amounts that cause such diabetic tremors. The alert can be configured to prompt the user to obtaining medication to treat the impending anomalous physiological state of the user. In another example, tremor determinator **2110** in malady determinator **2112** cooperate to determine that the user is experiencing and an epileptic tremor, and generates an alert to enable the user to either take medication or stop engaging in a critical activity, such as driving, before the tremors become worse (i.e., to an intensity that might impair or otherwise incapacitate the user). Upon detection of tremor and the corresponding malady, anomalous state manager **2102** transmits data indicating the presence of such tremors via communication module **2118** to wearable device **2170** or mobile computing device **2180**, which, in turn, transmit via networks **2182** to a third-party or any other entity. In some examples, anomalous state manager **2102** is configured to distinguish malady-related tremors from movements and/or shaking due to nervousness and or injury.

[0114] FIG. **22** depicts an affective state manager configured to receive sensor data derived from bioimpedance signals, according to some embodiments. FIG. **22** illustrates an exemplary affective state manager **2220** for assessing affective states of a user based on data derived from, for example, a wearable computing device, according to some embodiments. Diagram **2200** depicts a user **2202** including a wearable device **2210**, whereby user **2202** experiences one or more types of stimuli that can changes in physiological states of user **2202**, such as the emotional state of mind. In some embodiments, wearable device **2210** is a wearable computing device **2210***a* that includes one or more sensors to detect attributes of the user, the environment, and other aspects of the responses from/interaction with stimuli.

[0115] Affective state manager **2220** is shown to include a physiological state analyzer **2222**, a stressor analyzer **2224**, and an emotion formation module **2223**. According to some embodiments, physiological state analyzer **2222** is configured to receive and analyze the sensor data, such as bioimpedance-based sensor data **2211**, to compute a sensor-derived value representative of an intensity of an affective state of user **2202**. In some embodiments, the sensor-derived value can represent an aggregated value of sensor data (e.g., an aggregated an aggregated value of sensor data value). In some examples, aggregated value of sensor data can be derived by, first, assigning a weighting to each of the values (e.g., parametric values) sensed by the sensors associated with one or more physiological characteristics, such as those shown in FIG. **20**B, and, second, aggregating each of the weightings to form an aggregated value. Affective state manager **2220** can also receive activity-related data **2114** from a number of activity-related managers (not shown). One or more activity-related managers (not shown) can be configured to receive data representing parameters relating to one or more motion or movement-related activities of a user and to maintain data representing one or more activity profiles. Activity-related parameters describe characteristics, factors or attributes of motion or movements in which a user is engaged, and can be established from sensor data or derived based on computations. Examples of parameters include motion actions, such as a step, stride, swim stroke, rowing stroke, bike pedal stroke, and the like, depending on the activity in which a user is participating. As used herein, a motion action is a unit of motion (e.g., a substantially repetitive motion) indicative of either a single activity or a subset of activities and can be detected, for example, with one or more accelerometers and/or logic configured to determine an activity composed of specific motion actions.

[0116] According to some examples, the activity-related managers can include a nutrition manager, a sleep manager, an activity manager, a sedentary activity manager, and the like, examples of which can be found in U.S. patent application Ser. No. 13/433,204, filed on Mar. 28, 2012 having Attorney Docket No. ALI-013CIP1; U.S. patent application Ser. No. 13/433,208, filed Mar. 28, 2012 having Attorney Docket No. ALI-013CIP2; U.S. patent application Ser. No. 13/433,208, filed Mar. 28, 2012 having Attorney Docket No. ALI-013CIP3; U.S. patent application Ser. No. 13/454,040, filed Apr. 23, 2012 having Attorney Docket No. ALI-013CIP1CIP1; U.S. patent application Ser. No. 13/627,997, filed Sep. 26, 2012 having Attorney Docket No. ALI-100; all of which are incorporated herein by reference for all purposes.

[0117] In some embodiments, stressor analyzer **2224** is configured to receive activity-related data **2114** to determine stress scores that weigh against a positive affective state in favor of a negative affective state. For example, if activity-related data **2114** indicates user **402** has had little sleep, is hungry, and has just traveled a great distance, then user **2202** is predisposed to being irritable or in a negative frame of mine (and thus in a relatively "bad" mood). Also, user **2202** may be predisposed to react negatively to stimuli, especially unwanted or undesired stimuli that can be perceived as stress. Therefore, such activity-related data **2114** can be used to determine whether an intensity derived from physiological state analyzer **2222** is either negative or positive, as shown.

[0118] Emotive formation module **2223** is configured to receive data from physiological state analyzer **2222** and stressor analyzer **2224** to predict an emotion in which user **2202** is experiencing (e.g., as a positive or negative affective state). Affective state manager **2220** can transmit affective state data **2230** via network(s) to a third-party, another person (or a computing device thereof), or any other entity, as emotive feedback. Note that in some embodiments, physiological state analyzer **2222** is sufficient to determine affective state data **2230**. In other embodiments, stressor analyzer **2224** is sufficient to determine affective state data **2230**. In various embodiments, physiological state analyzer **2222** and stressor analyzer **2224** can be used in combination or with other data or functionalities to determine affective state data **2230**.

[0119] As shown, aggregated sensor-derived values **2290** can be generated by a physiological state analyzer **2222** indicating a level of intensity. Stressor analyzer **2224** is configured to determine whether the level of intensity is within a range of negative affectivity or is within a range of positive affectivity. For example, an intensity **2240** in a range of negative affectivity can represent an emotional state similar to, or approximating, distress, whereas intensity **2242** in a range of positive affectivity can represent an emotional state similar to, or approximating, happiness. As another example, an intensity **2244** in a range of negative affectivity can represent an emotional state similar to, or approximating, depression/sadness, whereas intensity **2246** in a range of positive affectivity can represent an emotional state similar to, or approximating, relaxation. As shown, intensities **2240** and **2242** are greater than that of intensities **2244** and **2246**. Emotive formulation module **2223** is configured to transmit this information as affective state data **230** describing a predicted emotion of a user. An example of affective state manager **2220** is described as a affective state prediction unit of U.S. Provisional Patent Application No. 61/705,598 filed on Sep. 25, 2012, which is incorporated by reference herein for all purposes.

[0120] FIG. **23** illustrates an exemplary computing platform disposed in a wearable device in accordance with various embodiments. In some examples, computing platform **2300** may be used to implement computer programs, applications, methods, processes, algorithms, or other software to perform the above-described techniques, and can include similar structures and/or functions as set forth in FIG. **8**. But in the example shown, system memory **806** can include various modules that include executable instructions to implement functionalities described herein. In the example shown, system memory **806** includes a physiological information generator **2358** configured to determine physiological information relating to a user that is wearing a wearable device, and a physiological state determinator **2359**. Physiological state determinator **2359** can include a sleep manager module **2360**, anomalous state manager module **2362**, and an affective state manager module **2364**, any of which can be configured to provide one or more functions described herein.

[0121] In at least some examples, the structures and/or functions of any of the above-described features can be implemented in software, hardware, firmware, circuitry, or a combination thereof Note that the structures and constituent elements above, as well as their functionality, may be aggregated with one or more other structures or elements. Alternatively, the elements and their functionality may be subdivided into constituent sub-elements, if any. As software, the above-described techniques may be implemented using various types of programming or formatting languages, frameworks, syntax, applications, protocols, objects, or techniques. As hardware and/or firmware, the above-described techniques may be implemented using various types of programming or integrated circuit design languages, including hardware description languages, such as any register transfer language ("RTL") configured to design field-programmable gate arrays ("FPGAs"), application-specific integrated circuits ("ASICs"), or any other type of integrated circuit. According to some embodiments, the term "module" can refer, for example, to an algorithm or a portion thereof, and/or logic implemented in either hardware circuitry or software, or a combination thereof These can be varied and are not limited to the examples or descriptions provided.

[0122] Although the foregoing examples have been described in some detail for purposes of clarity of understanding, the above-described inventive techniques are not limited to the details provided. There are many alternative ways of implementing the above-described invention techniques. The disclosed examples are illustrative and not restrictive.

What is claimed:

1. A method comprising:

receiving a sensor signal including data representing physiological characteristics in a wearable device, the wearable device being configured to receive the sensor signal from a distal end of a limb at which the wearable device is disposed;

receiving a motion sensor signal;

decomposing at a processor the sensor signal to determine physiological signal components and motion signal components based on the sensor signal and the motion sensor signal;

generating a physiological characteristic signal that includes data representing a physiological characteristic; and

determining a physiological state based on at least the physiological characteristic derived from the sensor signal originating at the distal end.

2. The method of claim 1, wherein receiving the sensor signal comprises:

receiving the sensor signal during one or more portions of the time interval during which the wearable device is in motion.

3. The method of claim 1, wherein receiving the sensor signal comprises:

receiving a bio-impedance signal from the distal end of the limb at which the wearable device is disposed.

4. The method of claim 1, wherein generating the physiological characteristic signal that includes the data representing the physiological characteristic comprises:

generating the physiological characteristic signal that includes the data representing one or more of a heart rate, a respiration rate, and a Mayer wave rate.

5. The method of claim 4, wherein determining the physiological state further comprises:

determining a stage of sleep based on at least the heart rate and the respiration rate.

6. The method of claim 5, further comprising:

determining regularity of the heart rate and the respiration rate; and

generating a signal indicating the stage of sleep is associated with a non-REM sleep state.

7. The method of claim 6, further comprising:

determining the motion sensor signal includes at least a portion of motion indicative of involuntary muscle twitching.

8. The method of claim 6, further comprising:

generating a wake enable signal to enable the wearable device to generate an alarm signal to wake a user during the non-REM sleep state.

9. The method of claim 5, further comprising:

determining variability of the heart rate and the respiration rate; and

generating a signal indicating the stage of sleep is associated with a REM sleep state.

10. The method of claim 9, further comprising:

determining the motion sensor signal includes a negligible amount of motion associated with the REM sleep state.

11. The method of claim 9, further comprising:

generating a wake disable signal to disable the wearable device to prevent generation of an alarm signal to wake a user during the REM sleep state.

12. The method of claim 1, further comprising:

determining the motion sensor signal includes a portion of motion associated with a tremor; and

characterizing the tremor as a malady based on at least data representing user characteristics.

13. The method of claim 12, further comprising:

transmitting data representing an indication of the presence of the malady via a wireless communication link.

14. The method of claim 12, wherein characterizing the tremor as the malady comprises:

determining the malady is associated with data indicative of one of epilepsy, Parkinson's disease, and diabetes of which the tremor is a diabetic tremor.

15. The method of claim 1, wherein generating the physiological characteristic signal comprises:

generating the physiological characteristic signal that includes the data representing one or more of a heart rate, a respiration rate, and a skin conductance signal; and

determining the physiological state as a pain state based on at least the skin conductance signal.

16. The method of claim 1, wherein generating the physiological characteristic signal that includes the data representing the physiological characteristic comprises:

generating the physiological characteristic signal that includes the data representing a Mayer wave rate;

determining heart rate variability ("HRV") based on the Mayer wave rate; and

determining the malady based on the HRV.

17. The method of claim 1, wherein determining a physiological state comprises:

determining an affective state of a user wearing the wearable device.

18. The method of claim 1, wherein decomposing the sensor signal comprises:

performing independent component analysis ("ICA") to separate physiological signal components and motion signal components; and

using the physiological signal components to determine the physiological state.

19. An apparatus comprising:

a wearable housing configured to couple to a portion of a limb at its distal end;

a motion sensor configured to sense motion associated with the wearable housing and to generate a motion sensor signal;

one or more electrodes disposed in the wearable housing configured to receive a sensor signal including data representing one or more physiological characteristics during one or more portions of a time interval in which the wearable device is in motion; and

a processor configured to execute instructions to implement a motion artifact reduction unit that is configured to:

extract from the sensor signal, which includes a signal component associated with motion artifacts, to determine a physiological signal based on the sensor signal and the motion sensor signal;

generate a physiological characteristic signal that includes data representing the physiological characteristic during at least one of the one or more portions of the time interval, the physiological characteristic including data representing one or more of a heart rate and a respiration rate; and

determine a physiological state based on the one or more of the heart rate and the respiration rate derived from the sensor signal originating at the distal end.

20. The apparatus of claim **19**, wherein the processor further configured to execute instructions to implement a sleep manager that is configured to:

determine a stage of sleep; and

enabling or disabling an alarm based on the stage of sleep.

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专利名称(译)	基于运动中的传感器感测的数据确定生物体的生理状态		
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[标]申请(专利权)人(译)	LUNA MICHAEL EDWARD SMITH SAHA SANKALITA FULLAM SCOTT		
申请(专利权)人(译)	LUNA，MICHAEL EDWARD SMITH 萨哈SANKALITA FULLAM，SCOTT		
当前申请(专利权)人(译)	Alifak		
[标]发明人	LUNA MICHAEL EDWARD SMITH SAHA SANKALITA FULLAM SCOTT		
发明人	LUNA, MICHAEL EDWARD SMITH SAHA, SANKALITA FULLAM, SCOTT		
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摘要(译)

本发明的实施例总体上涉及电气和电子硬件，计算机软件，有线和无线网络通信，以及用于促进健康和健康相关信息的可穿戴计算设备。更具体地，公开了使用可穿戴设备（或携带设备）和可以经受运动的一个或多个传感器来确定生理状态的电极和方法。在一个实施例中，一种方法包括从肢体的远端接收包括表示可穿戴设备中的生理特征的数据的传感器信号和运动传感器信号。该方法包括在处理器处分解传感器信号以确定生理信号分量。产生生理特征信号，其包括表示生理特征的数据，其可以形成基于例如源自肢体远端的生物阻抗信号确定生理状态的基础。