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(54) **NON-INVASIVE CONTINUOUS MONITORING OF PHYSIOLOGICAL PARAMETERS**

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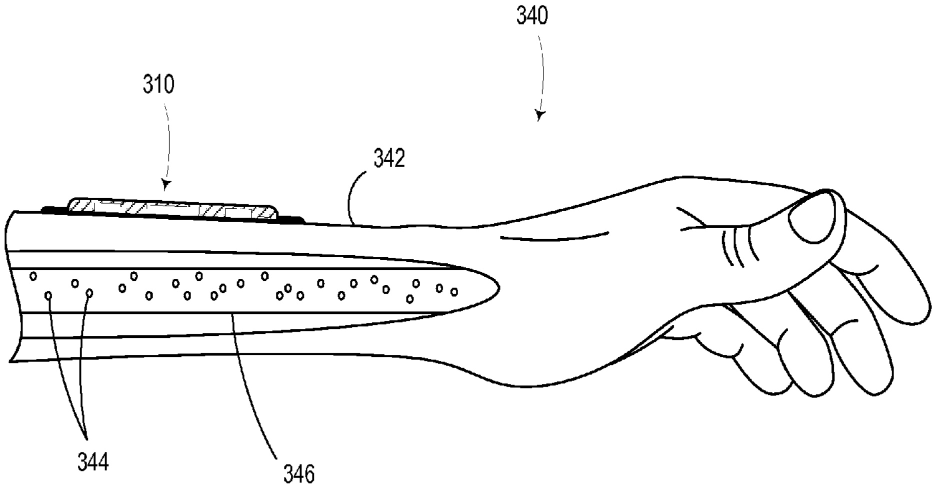
(57) **ABSTRACT**

Systems and methods are described that relate to a body-mountable device. The body-mountable device includes a first light source and a second light source, which may emit light having at least a first and second wavelength, respectively. The body-mountable device includes at least one sensor configured to detect light having the first wavelength and the second wavelength. The body-mountable device includes a battery, a communication interface, and a controller. The controller includes a memory, a processor, and a sigma-delta analog-to-digital converter (ADC) having one or more channels. The controller performs various operations, such as causing the first light source and the second light sources to emit light and receiving information indicative of at least one physiological parameter via the at least one sensor. The controller may also perform processing, via the sigma delta ADC, the information indicative of the at least one physiological parameter so as to provide physiological data.



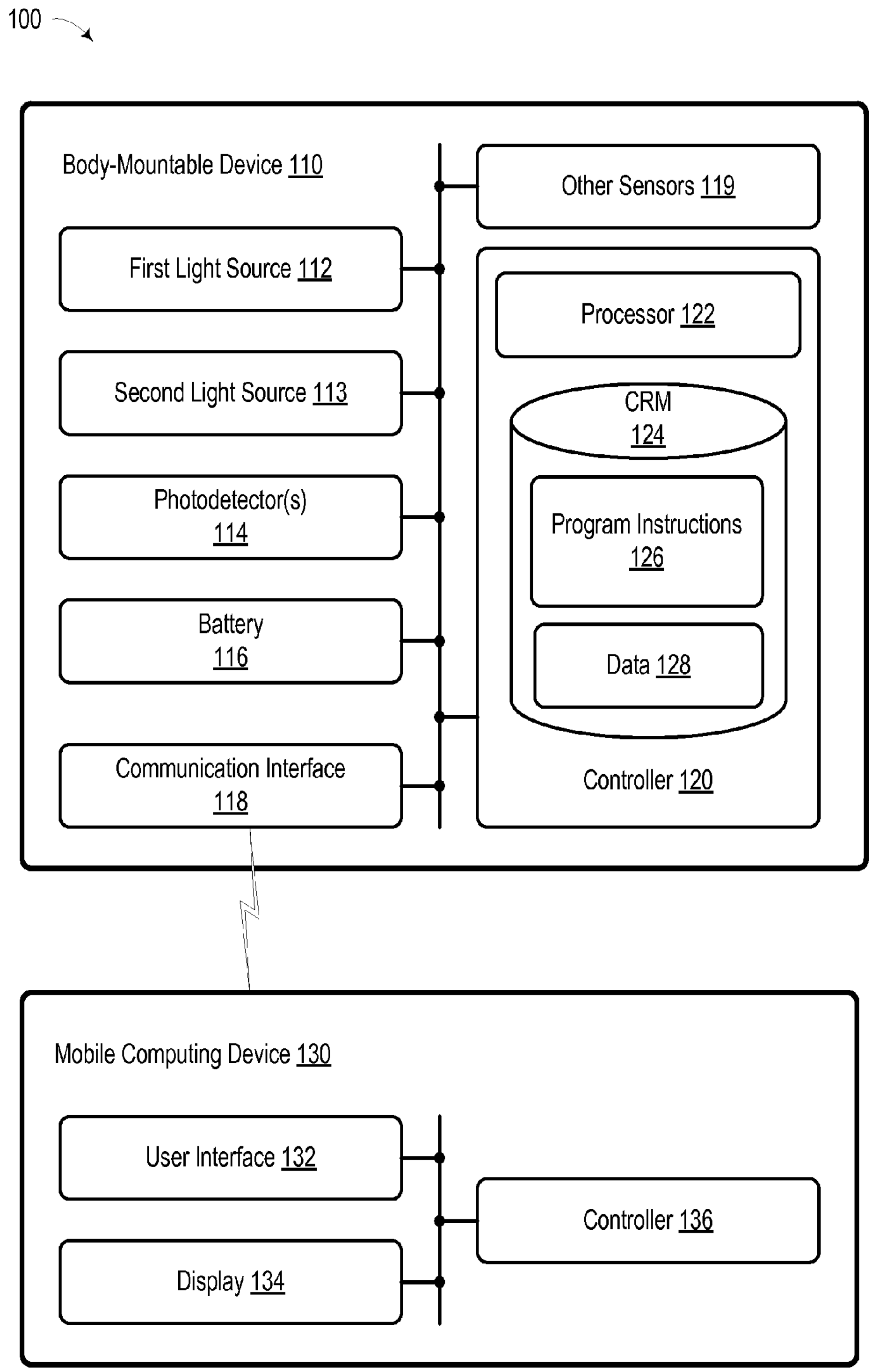

100
Body-Mountable Device 110
Other Sensors 119
First Light Source 112
Processor 122
Second Light Source 113
CRM 124
Photodetector(s) 114
Program Instructions 126
Battery 116
Data 128
Communication Interface 118
Controller 120
Mobile Computing Device 130
User Interface 132
Controller 136
Display 134

Figure 1

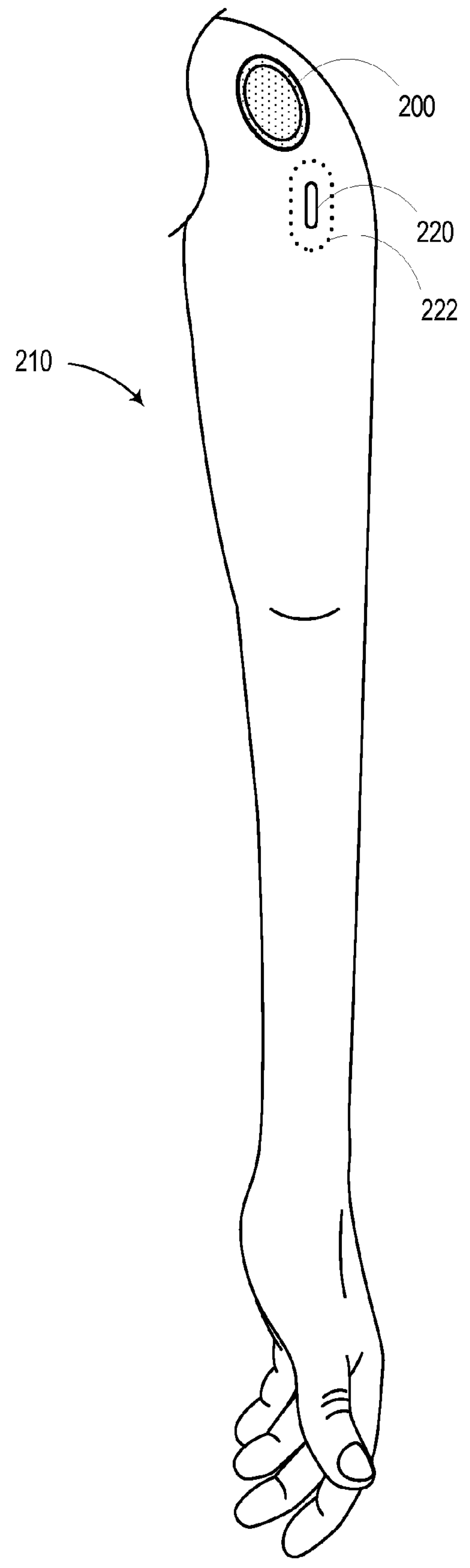


Figure 2

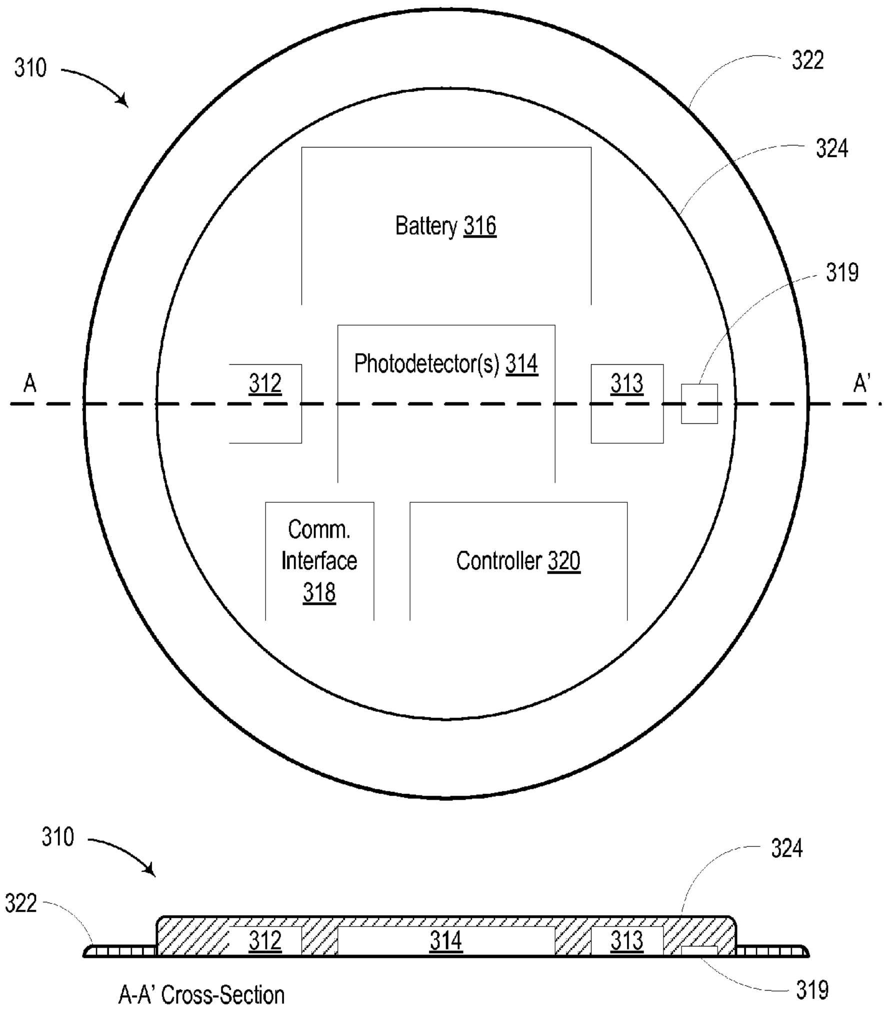

310
322
324
319
Battery 316
Photodetector(s) 314
A
312
313
A'
Comm.
Interface
318
Controller 320
310
324
322
312
314
313
319
A-A' Cross-Section

Figure 3A

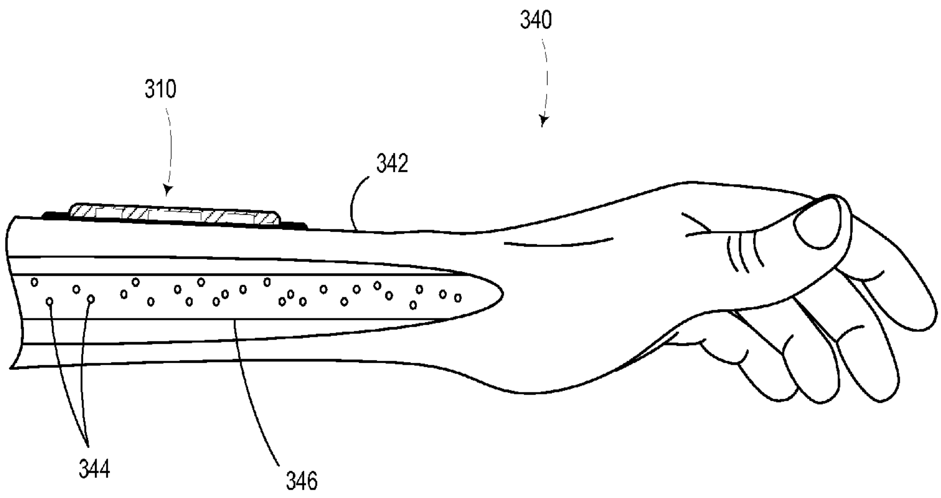


Figure 3B

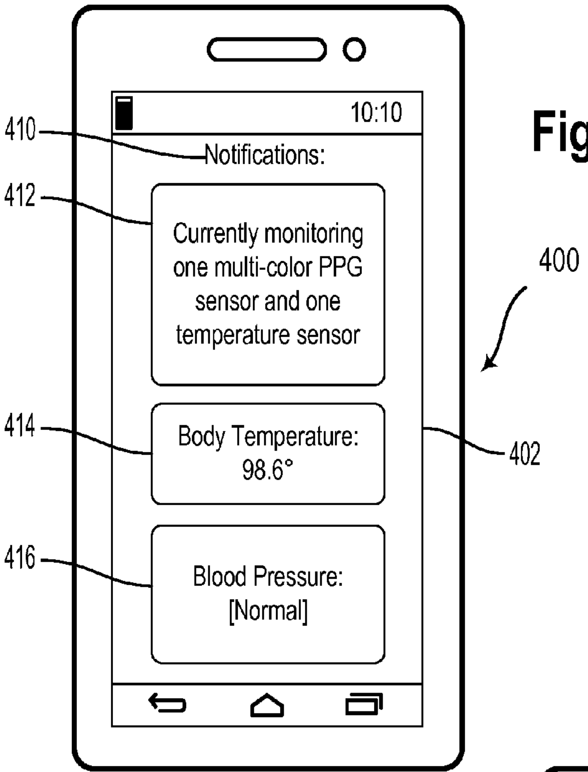


Figure 4A

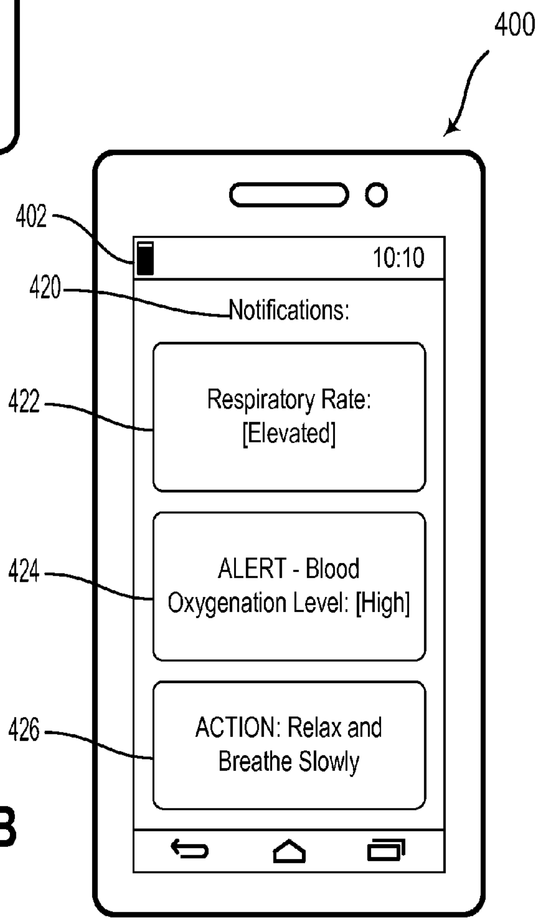


Figure 4B

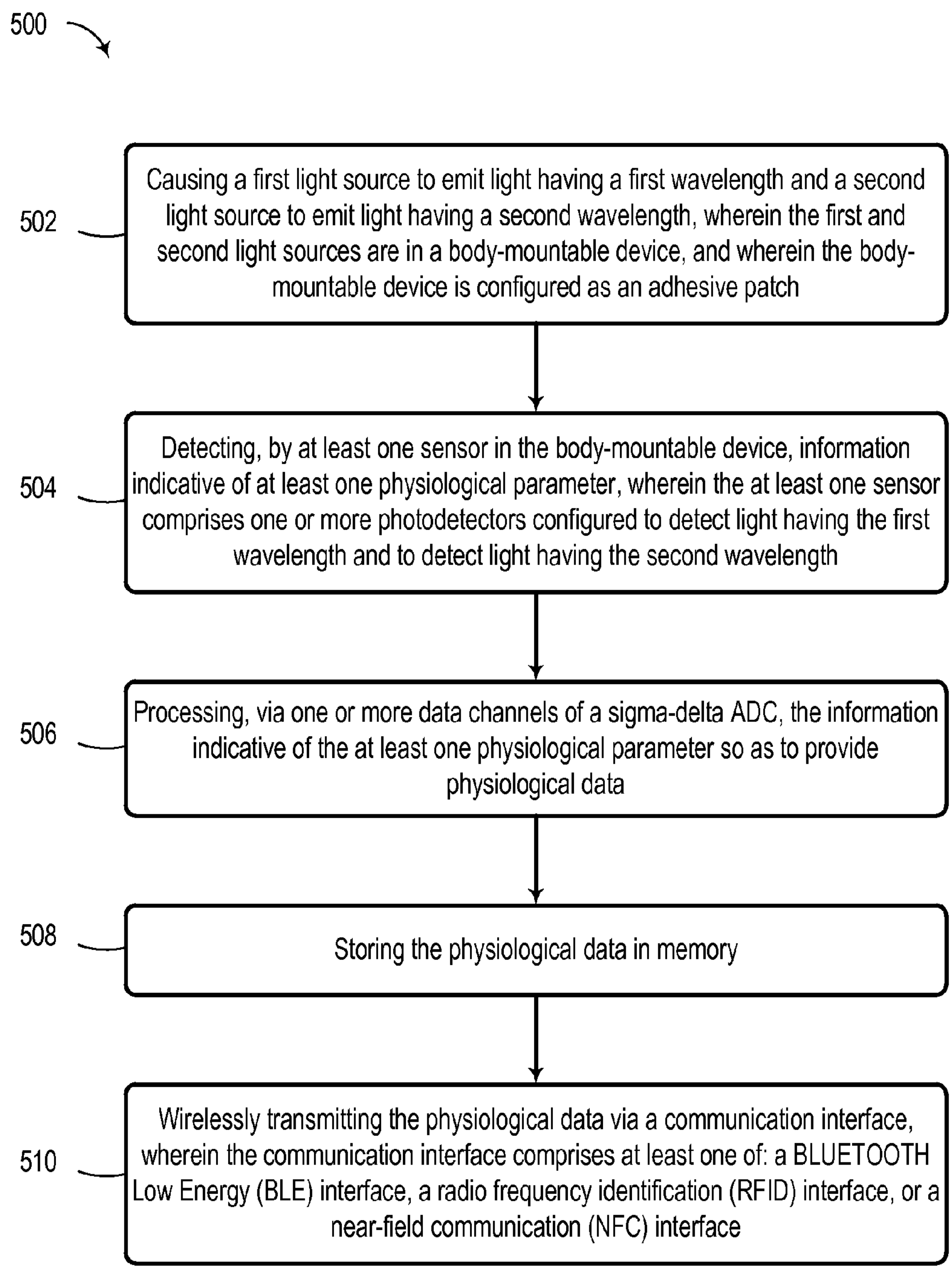

500
502
Causing a first light source to emit light having a first wavelength and a second light source to emit light having a second wavelength, wherein the first and second light sources are in a body-mountable device, and wherein the body-mountable device is configured as an adhesive patch
504
Detecting, by at least one sensor in the body-mountable device, information indicative of at least one physiological parameter, wherein the at least one sensor comprises one or more photodetectors configured to detect light having the first wavelength and to detect light having the second wavelength
506
Processing, via one or more data channels of a sigma-delta ADC, the information indicative of the at least one physiological parameter so as to provide physiological data
508
Storing the physiological data in memory
510
Wirelessly transmitting the physiological data via a communication interface, wherein the communication interface comprises at least one of: a BLUETOOTH Low Energy (BLE) interface, a radio frequency identification (RFID) interface, or a near-field communication (NFC) interface

Figure 5

NON-INVASIVE CONTINUOUS MONITORING OF PHYSIOLOGICAL PARAMETERS

BACKGROUND

[0001] Unless otherwise indicated herein, the materials described in this section are not prior art to the claims in this application and are not admitted to be prior art by inclusion in this section.

[0002] Certain medical conditions or states can be characterized by a physiological property over long periods of time and/or by infrequent, short-timescale events. Such physiological properties can be measured periodically. An implanted or wearable device could be employed to provide continuous or near-continuous measurement of such physiological properties. Such implantable or wearable devices can be battery-powered and/or powered by radio frequency energy or other wireless energy sources. Further, such devices can be configured to indicate measured physiological properties wirelessly.

SUMMARY

[0003] In a first aspect, a system is provided. The system includes a body-mountable device and a mobile computing device. The body-mountable device is configured as an adhesive patch. The body-mountable device includes a first light source and a second light source. The first light source is configured to emit light having at least a first wavelength and the second light source is configured to emit light having at least a second wavelength. The body-mountable device further includes at least one sensor. The at least one sensor includes one or more photodetectors configured to detect light having the first wavelength and to detect light having the second wavelength. The body-mountable device also includes a battery, a communication interface, and a controller. The controller includes a memory and a processor. The memory stores instructions that are executable by the processor to cause the controller to perform operations. The operations include causing the first light source and the second light source to emit light and receiving information from the at least one sensor. The information is indicative of at least one physiological parameter. The operations also include transmitting, via the communication interface, the information indicative of at least one physiological parameter. The mobile computing device is configured to receive the transmitted information indicative of at least one physiological parameter.

[0004] In a second aspect, a body-mountable device is provided. The body-mountable device configured as an adhesive patch. The body-mountable device comprises a first light source and a second light source. The first light source is configured to emit light having at least a first wavelength and the second light source is configured to emit light having at least a second wavelength. The body-mountable device also includes at least one sensor. The at least one sensor includes one or more photodetectors configured to detect light having the first wavelength and to detect light having the second wavelength. The body-mountable device also includes a battery and a communication interface. The communication interface includes at least one of: a BLUETOOTH Low Energy (BLE) interface, a radio frequency identification (RFID) interface, or a near-field communication (NFC) interface. The body-mountable device additionally includes a controller including a memory, a processor, and a sigma-delta analog-to-digital converter (ADC) having one or more data channels. The memory stores instructions that are executable by the processor to cause the controller to perform operations. The operations include causing the first light source and the second light source to emit light. The operations further include receiving information from the at least one sensor. The information is indicative of at least one physiological parameter. The operations additionally include processing, via the one or more data channels of the sigma-delta analog-to-delta converter (ADC), the information indicative of the at least one physiological parameter so as to provide physiological data. The operations yet further include storing the physiological data in the memory and wirelessly transmitting the physiological data via the communication interface.

[0005] In a third aspect, a method is provided. The method includes causing a first light source to emit light having a first wavelength and a second light source to emit light having a second wavelength. The first and second light sources are in a body-mountable device. The body-mountable device is configured as an adhesive patch. The method includes detecting, by at least one sensor in the body-mountable device, information indicative of at least one physiological parameter. The at least one sensor includes one or more photodetectors configured to detect light having the first wavelength and to detect light having the second wavelength. The method includes processing, via one or more data channels of a sigma-delta analog-to-digital converter (ADC), the information indicative of the at least one physiological parameter so as to provide physiological data. The method includes storing the physiological data in memory and wirelessly transmitting the physiological data via a communication interface. The communication interface includes at least one of: a BLUETOOTH Low Energy (BLE) interface, a radio frequency identification (RFID) interface, or a near-field communication (NFC) interface.

[0006] Other aspects, embodiments, and implementations will become apparent to those of ordinary skill in the art by reading the following detailed description, with reference where appropriate to the accompanying drawings.

BRIEF DESCRIPTION OF THE FIGURES

[0007] FIG. **1** is a block diagram of a system according to an example embodiment.

[0008] FIG. **2** illustrates a body-mountable device according to an example embodiment.

[0009] FIG. **3**A illustrates a body-mountable device according to an example embodiment.

[0010] FIG. **3**B illustrates a body-mountable device according to an example embodiment.

[0011] FIG. **4**A illustrates a mobile device according to an example embodiment.

[0012] FIG. **4**B illustrates a mobile device according to an example embodiment.

[0013] FIG. **5** is a flowchart illustrating a method according to an example embodiment.

DETAILED DESCRIPTION

[0014] In the following detailed description, reference is made to the accompanying figures, which form a part hereof. In the figures, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, figures, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are contemplated herein.

[0015] Further, while embodiments disclosed herein make reference to use on or in conjunction with a living human body, it is contemplated that the disclosed methods, systems and devices may be used in any environment where measuring and/or estimating a flow rate of a liquid, such as blood, is desirable. The environment may be any living or non-living body or a portion thereof, a fluid conduit, a fluid reservoir, etc. For example, one of skill in the art will recognize that the embodiments disclosed herein may be used to sense the flow rate of water or another liquid. Moreover, while the present disclosure describes embodiments for use in vivo, one of skill in the art will also recognize that in vitro applications are possible as well. Accordingly, the environment may also include a test tube or other vessel for holding a fluid.

[0016] Additionally, the term "medical condition" as used herein should be understood broadly to include any disease, illness, disorder, injury, condition or impairment—e.g., physiologic, psychological, cardiac, vascular, orthopedic, visual, speech, or hearing—or any situation requiring medical attention.

Overview

[0017] Systems, devices, and methods described herein may relate to continuous monitoring of physiological parameters of a living body. Specifically, the continuous monitoring may be carried out via a body-mountable device, which may be in the form of a small adhesive patch.

[0018] The body-mountable device may include a plurality of light sources and at least one detector operable to detect a physiological parameter via a photoplethysmography (PPG) technique. For example, the body-mountable device may include a first light source and a second light source, which may be operable to emit light at a first wavelength and a second wavelength, respectively.

[0019] The body-mountable device may also include a battery, a communication interface, and a controller. The battery may be a thin film battery, which may be operable to power the body-mountable device for one week, or longer. The communication interface may include a BLUETOOTH Low Energy (BLE) interface or a near-field communication (NFC) interface. The controller may include a memory and a processor. The controller may store instructions in the memory and the processor may be operable to execute the instructions. As such, the controller may be operable to perform various operations, which may relate to obtaining, processing, and transmitting information indicative of a physiological parameter of a wearer of the body-mountable device.

[0020] The operations may include causing the first light source and the second light source to emit light and detecting light via the at least one detector. The light sources and detector may function together as a PPG sensor. The detected light may be used to obtain information about the wearer's pulse rate, blood pressure, etc.

[0021] The operations may further include processing signals from the PPG sensor(s) so as to form physiological data. For example, in an example embodiment, the body-mountable device may include a sigma-delta analog-to-digital converter (ADC) with one or more data channels. In such a scenario, the ADC may process the signals from the PPG sensor(s) via the one or more data channels so as to form physiological data.

[0022] Optionally, the body-mountable device may be configured to obtain physiological data via additional sensors. For example, a respiratory rate can be determined by including information from an accelerometer, and skin temperature (or core body temperature) may be determined via an external thermistor or an implanted temperature sensor.

[0023] The body-mountable device may include a small form factor (e.g. a circular patch with 1.5" diameter and less than 2 mm thick), which may allow the device to be worn at the same level of the heart, reducing effects of posture and movement on the PPG signal and simplifying the estimation of blood pressure. The body-mountable device may include a bio-compatible package. For instance, the body-mountable device may be packaged and/or encapsulated in a flexible polyimide and/or parylene material. Furthermore, while some embodiments herein describe an adhesive patch, other embodiments may include the body-mountable device configured to be mounted via a strap, an implant, etc. Additionally or alternatively, the body-mountable device may be mounted anywhere on or within the living body, such as on the wrist, torso, ankle, neck, etc.

[0024] The physiological parameters contemplated herein may include at least one of: a heart rate, a blood pressure, or a blood oxygenation level. Other physiological parameters that may be detected via a body-mountable device, particularly an adhesive patch, are considered within the scope of this disclosure as well.

[0025] The system may also include a mobile computing device. The mobile computing device may be a handheld reader, a smartphone, a tablet, a smartwatch, a laptop, or another type of mobile computing device. The mobile computing device may be configured to be communicatively coupled to the body-mountable device. For example, the mobile computing device may receive the information indicative of the at least one physiological parameter via the communication interface.

[0026] The mobile computing device may activate the body-mountable device to start data collection, to download the last time period of data, and disable the body-mountable device. The time period of data may range from seconds to hours, depending on sample rate and memory size, with new data overwriting the oldest values. The physiological data may be formatted such that the data has a relative or absolute time stamp. For example, the mobile computing device may be configured to determine a time stamp based on an integrated circuit clock frequency and sample rate.

[0027] Processing of the raw data may be performed at the body-mountable device or at the mobile computing device. The processed raw data may be termed physiological data and may include a ratiometric determination of blood oxygenation, pulse rate from based on data periodicity, blood pressure from PPG data slopes, and respiratory rate from a combination of accelerometer data and pulse rate.

[0028] The systems, devices, and methods described herein may be useful to provide long-term monitoring of physiological parameters. Such monitoring may provide more accurate and/or timelier health information for wearers of the body-mountable device. Furthermore, if elected by the wearer of the body-mountable device, health care professionals may be kept continuously or periodically apprised of the health information so as to provide better health care for patients. Additionally, if the body-mountable device or a combination of the body-mountable device and the mobile computing device detects an emergency situation, emergency personnel may be alerted of the health condition and location of the wearer of the sensor. System Examples

[0029] Some examples of the present disclosure relate to systems and devices that are configured to be worn on a living body and that may be operable to obtain measurements related to physiological conditions of the body via sensors on the devices. Such devices, described herein as body-mountable devices, can be configured to be mounted to an external body surface of a wearer and to enable a variety of applications and functions. The terms "body-mountable device" or "wearable device," as used in this disclosure, refers to any device that is capable of being worn at, on or in proximity to a body surface, such as a shoulder, forearm, wrist, ankle, waist, chest, back, buttocks, or another body part. In an example embodiment, the body-mountable device is configured as an adhesive patch.

[0030] One or more sensors disposed on a portion of the contact surface can detect one or more properties of the body of the wearer when the contact surface is mounted to the external body surface. The body-mountable device may also include a controller configured to receive, store, and transmit information indicative of a physiological parameter of the wearer.

[0031] Such body-mountable devices could enable a variety of applications related to the physiological information about a wearer. For example, a mobile device associated with the body-mountable device may be configured to indicate such measured physiological information or other information to the wearer (e.g., using a haptic feedback system, a display system, an audio feedback system, a communication to a server that is configured to generate an indication to the wearer, or other user interface systems).

[0032] An example body-mountable device can automatically measure multiple physiological parameters of a person wearing the device via sensors included in the device. In order to take measurements in a non-invasive manner from outside of the body, the body-mountable device may be positioned on a portion of the body where subsurface vasculature or other elements of the body of the wearer may be detected. Thus, the body-mountable device may be placed in close proximity to the skin or tissue. For example, the body-mountable device may be configured to adhere to a skin layer of a living body. Depending on the mounting location of the device, the device may accordingly be implemented in a variety of different form factors that are configured to be mounted to a variety of different body surfaces.

[0033] The devices and systems described herein may provide continuous monitoring of vital signs with a single noninvasive body-mountable device. In an example embodiment, the body-mountable device may remain mounted to a skin surface for about one week, which may provide wearers and physicians with a rich data set of physiological parameters. Long-term monitoring of such physiological parameters may provide an indication as to a person's present overall health, and may provide information useful to help improve or maintain a person's health in the future.

[0034] FIG. **1** is a block diagram of a system **100** according to an example embodiment. System **100** includes a body-mountable device **110** and a mobile computing device **130**. The body-mountable device **110** includes a first light source **112** and a second light source **113**. The first light source **112** and the second light source **113** may include a light-emitting diode, a vertical-cavity emitting laser (VCSEL), a ridge waveguide laser, or another type of light source. The first light source **112** and the second light sources **113** may be configured to emit over respective emission wavelengths that are at least partially non-overlapping. That is, the first light source **112** and the second light source **113** may be configured to emit light at different wavelengths. In an example embodiment, the first light source **112** may be configured to emit light at a first wavelength. The first wavelength may include a wavelength in the infrared waveband (e.g. between 750 nanometers and 1 millimeter). The second light source **113** may be configured to emit light at a second wavelength. The second wavelength may include a wavelength in the red portion of the visible light spectrum (e.g. between 620 nanometers and 750 nanometers). The first and the second light sources may be configured to emit within the above-described wavelength ranges to provide pulse oximetry information, however other wavelengths and wavelength ranges are possible.

[0035] In a further example embodiment, at least one of the light sources may be configured to emit in the green portion of the visible light spectrum (e.g. between 495 nanometers and 570 nanomters). In such a scenario, the system **100** may be configured to provide photoplethysmogram information. It is understood that these emission wavelengths are provided as examples and that many other wavelengths and/or wavebands are possible within the scope of the present disclosure. Furthermore, one or more of the light sources may be configured to be tunable over a range of emission wavelengths and/or emission wavebands.

[0036] The body-mountable device **110** additionally includes one or more photodetectors **114** that are configured to detect light from the first light source **112** and/or the second light source **113**. In some embodiments, a single photodetector may be configured to detect light from both the first light source **112** and the second light source **113**. Thus, the photodetector **114** may be configured to detect light having the first wavelength and the second wavelength. In an example embodiment, the one or more photodetectors **114** are mounted proximate to an exterior surface of the living body so as to receive light transmitted through and/or reflected by the living body from the first light source **112** and the second light source **113**. The one or more photodetectors **114** may include photodiodes, photoconductors, cameras, or another type of light-sensitive device. In an example embodiment, the one or more photodetectors **114** are configured to sample light at the first wavelength and/or the second wavelength at a rate of at least 120 samples per second. Higher or lower sampling rates are possible.

[0037] In an example embodiment, the one or more photodetectors **114** may be configured to provide data about light transmission through or reflection from a lumen of a living body. For example, as described above, the light sources and one or more photodetectors **114** may be operable to provide physiological information via a photoplethysmography (PPG) technique. In such a scenario, the intensity, polarization, or another characteristic of transmitted or reflected light may vary depending on a volume of fluid, e.g. blood, in the lumen. Over time, the volume of fluid in the lumen may change, which may indicate a pulse rate. Furthermore, a blood pressure, pulse oximetry, and/or a flow rate of the fluid through the lumen may be estimated and/or inferred.

[0038] The body-mountable device **110** also includes a battery **116**, a communication interface **118**, an antenna (not illustrated) and other sensors **119**. The battery **116** may include a primary (non-rechargeable) or a secondary (rechargeable) battery. In an example embodiment, the battery **116** may include a thin film cell battery. Furthermore, in an example embodiment, battery **116** may include an alkaline battery, a nickel-metal-hydride battery or a lithium-ion battery. Other types of batteries are possible.

[0039] The communication interface **118** may be operable to establish a communication link with the mobile computing device **130** via one or more communication protocols. For example, the communication interface **118** may be configured to communicate with the mobile computing device **130** via a BLUETOOTH LOW-ENERGY (BLE), ZIGBEE, and/or Wi-Fi communication protocol. Additionally or alternatively, the communication interface **118** may be configured to establish the communication link with the mobile computing device **130** via near-field communication (NFC) and/or radio-frequency identification (RFID). Other types of communication protocols are possible and contemplated herein.

[0040] The communication interface **118** may include hardware and/or software configured to enable wireless communication between the body-mountable device **110** and other devices. For example, the communication interface **118** may enable messaging and/or data transfers between the body-mountable device **100**, the mobile computing device **130**, and/or a cloud-computing server.

[0041] While FIG. **1** illustrates one body-mountable device **110** as being communicatively-coupled to one mobile computing device **130**, it is understood that any number of body-mountable devices **110** may be communicatively-coupled to any number of mobile computing devices **130**. For example, a plurality of body-mountable devices **110** may be mounted via a skin surface of a living body. Each of the plurality of body-mountable devices **110** may be communicatively-coupled to one or more mobile computing devices **130** that may interrogate and/or monitor information obtained by the body-mountable devices **110**. As such, an individual may be able to obtain more reliable and/or accurate information relating to one or more physiological parameters.

[0042] The body-mountable device **110** may optionally include other sensors **119**. The other sensors **119** may include an accelerometer, a temperature sensor, or a piezoresistor. Other sensors configured to obtain information about a physiological parameter of a living body are contemplated herein. It is understood that the other sensors **119** may include a variety of different biometric sensors that may be operable to provide electrical, chemical, and/or mechanical information about a physiological parameter of a living body. The physiological parameter may include, but is not limited to, a heart rate, a blood pressure, a blood flow rate, a body temperature, a galvanic skin response measurement, or a blood oxygenation level. Other types of physiological parameters are contemplated.

[0043] The body-mountable device **110** includes a controller **120**, which may include a processor **122** and a computer-readable medium (CRM) **124**. The CRM **124** may include program instructions **126** and/or data storage **128**. Controller **120** may include one or more computers, a computing network, and/or a cloud computing server.

[0044] In an example embodiment, the body-mountable device **110** and/or the controller **120** may include a sigma-delta analog to digital converter (ADC). The sigma-delta ADC may encode analog signals, such as those from the one or more photodetectors **114** and/or other sensors **119**, into digital signals. The analog signals may be encoded as a stream of current and/or voltage pulses. Specifically, the analog signals may be encoded as a pulse frequency proportional to the analog input voltage. When decoded accurately, the analog signal may be recovered almost noiselessly from the digital signal using the sigma-delta modulation technique. The sigma-delta ADC may be implemented via hardware or software or a combination of hardware and software. In an example embodiment, the sigma-delta ADC may include one or more channels, e.g. output channels. Each channel of the sigma-delta ADC may be assigned and/or associated with one or more sensors of the body-mountable device **110**. In the scenario where the sigma-delta ADC includes a plurality of channels, information from multiple sensors may be simultaneously digitized and/or transmitted from the body-mountable device **110**. In a further example embodiment, multiple sigma-delta ADCs may be included in the body-mountable device **110** and/or the controller **120**.

[0045] The mobile computing device **130** may include a user interface **132**, a display **134**, and a controller **136**. The user interface **132** may include a touch screen, touch pad, and/or one or more buttons. In an example embodiment, the user interface **132** may provide a way to interact with the mobile computing device **130** and/or the body-mountable device **110**. The display **134** may be operable to provide notifications, information, and/or options to a user of the mobile computing device **130**.

[0046] The controller **136** of the mobile computing device **130** may include a processor and a memory. The controller **136** may be operable to execute operations on the mobile computing device **130**. For example, the controller **136** of the mobile computing device **130** may be operable to receive data from the body-mountable device **110**, store the data, and further transmit the data to correspondent computing devices, such as a cloud network server. The controller **136** may be configured to process some or all of the data received from the body-mountable device **110**. In an example embodiment, the controller **136** may include a sigma delta analog-to-digital converter (ADC). Furthermore, various signal processing functions (e.g. summing, denoising, amplification, etc.) may be provided by the controller **136**. Furthermore, the controller **136** may be configured to infer, predict, measure, and/or calculate various physiological parameters as described herein.

[0047] Examples of body-mountable devices, which may include the body-mountable device **100**, are now described in reference to FIGS. **2**, **3**A, and **3**B. FIG. **2** illustrates a body-mountable device **200** according to an example embodiment. In an example embodiment, the body-mountable device **200** may be configured and/or implemented as an adhesive patch. The adhesive patch may be mounted via adhesive to a skin surface of a living body **210**. Namely, the body-mountable device **200** may be mounted on a shoulder or another location on the living body **210**. In an example embodiment, the body-mountable device **200** may be mounted at or near the level of the heart, which may reduce the effects of body motion on measured physiological parameters (e.g. blood pressure). The body-mountable device **200** may include a housing that is biocompatible and/or hypoallergenic. For example, the housing of the body-mountable device **200** may include one or more of parylene, polyimide, polyethylene, polycarbonate, or polymethylmethacrylate (PMMA). Other materials are possible.

[0048] The body-mountable device **200** may be associated and/or communicatively coupled with other sensors. For example, body-mountable device **200** may be communicatively coupled to thermal sensor **220**. Thermal sensor **220** may be a thermistor implanted in the skin at an implant location **222**, which may be at a different location than the body-mountable device **200**. Additionally or alternatively, the other sensors may be collocated with and/or integrated into the body-mountable device **200**. The body-mountable device **200** and the other sensors may be communicatively coupled via BLUETOOTH or another communication protocol.

[0049] FIG. **3**A illustrates a body-mountable device **310** according to an example embodiment. The body-mountable device **310** may be similar or identical to body-mountable devices **110** and **200** illustrated and described in reference to FIGS. **1** and **2**. For example, the body-mountable device **310** may be configured as an adhesive patch and may be mountable on a skin surface of a living body. Mounting the body-mountable device **310** proximate to the heart, for example on a skin surface of the chest, shoulder, or back, may reduce motion artifacts compared to other PPG measurements obtained from extremities, such as from a finger.

[0050] The body-mountable device **310** includes a first light source **312** and a second light source **313**. The body-mountable device **310** includes one or more photodetectors **314** and a battery **316**. The body-mountable device **310** also includes a communication interface **318** and a controller **320**.

[0051] As described elsewhere herein, the first light source **312**, the second light source **313**, and the one or more photodetectors **314** may be operable as elements of a multi-color photoplethysmography (PPG) system. Namely, the first light source **312** may be configured to emit light having a first wavelength and the second light source **313** may be configured to emit light having a second wavelength. The combination of multiple wavelength light sources and the one or more photodetectors **314** may provide optical information indicative of a volume of a subcutaneous region of the living body, e.g. subsurface vasculature. For example, the optical information may relate to a volume of blood within the subcutaneous region. The optical information may be processed in various ways to measure, calculate, and/or infer a variety of physiological parameters.

[0052] In an example embodiment, a blood oxygenation level may be obtained via a ratiometric comparison between the multiple wavelengths received via the one or more photodetectors. In another embodiment, a pulse rate may be obtained via a periodicity of the optical information. In yet another embodiment, blood pressure may be calculated and/or inferred via a time-dependent slope (e.g. derivative) of the periodic optical information. Additionally or alternatively, a respiratory rate may be obtained via a combination of accelerometer data and pulse rate. Other types of physiological parameters are contemplated herein.

[0053] While FIG. **3**A illustrates the first light source **312** and the second light source **313** as being spatially separated, some embodiments may include multiple light sources that are configured to emit light along the same optical path. For example, light emitted from the first and second light sources **312** and **313** may be coupled into an optical fiber, which may provide a collinear optical path for the light to enter the skin surface. It is understood that various other optical elements may be incorporated into the body-mountable device **310** so as to form a multi-color PPG system. For example, the other optical elements may include, but are not limited to, spectral filters, lenses, collimators, diffusers, mirrors, gratings, splitters, and optical fibers.

[0054] The body-mountable device **310** may include other sensors **319**. For example, the other sensor **319** may include an accelerometer configured to provide information about a movement of the living body.

[0055] In some embodiments, the body-mountable device **310** may include a main body portion **324** and an adhesive portion **322**. For example, the main body portion **324** may house and/or encapsulate the electronic and/or mechanical elements of the body-mountable device **310**. Furthermore, the adhesive portion **322** may include woven fabric, plastic or latex. The adhesive portion **322** may include at least one surface coated with an adhesive material. The adhesive portion **322** may be operable to keep the skin area under the main body portion **324** free from dirt, dust, abrasion, etc. Before mounting to the body, the adhesive portion **322** may be coupled to a disposable backing material, similar to an adhesive bandage, e.g. BAND-AID. Additionally or alternatively, the body-mountable device **310** may be adhered to the skin surface of the living body via a skin bonding material such a cyanoacrylate or a liquid bandage.

[0056] FIG. **3**B illustrates a scenario **340** including body-mountable device **310** according to an example embodiment. In the illustrated scenario **340**, the body-mountable device **310** may be adhered or otherwise mounted to a skin surface of a living body **342**, e.g. a forearm. The living body **342** includes one or more lumens **346**, which may be part of a circulatory system. In an example embodiment, lumen **346** may include an artery, a vein, or another type of blood vessel. The circulatory system could be part of a cardiovascular system of a human. However, other types of circulatory systems are contemplated. For example, the body-mountable device **310** may interact with other systems involving fluid flow.

[0057] As described in reference to FIG. **3**A, the body-mountable device **310** may be configured to obtain optical information in the form of a photoplethysmogram (PPG). For example, the optical information may relate to a volume of the one or more lumens **346** and/or the blood contained therein. Namely, a PPG may measure and/or monitor volumetric changes in arteries or arterioles from blood perfusion near the surface of the skin.

[0058] In another example embodiment, the body-mountable device **310** may be configured to sense information relating to an analyte **344** within the lumen **346**. Optionally, the living body **342** may include functionalized particles, which may be introduced into the circulatory system. In an example embodiment, the functionalized particles may be added to the bloodstream via injection, inhalation, and/or ingestion. In some embodiments, the body-mountable device **310** may be configured to detect a flow rate, concentration, or other information relating to the functionalized particles.

[0059] FIG. **4**A illustrates a mobile device **400** according to an example embodiment. The mobile device **400** may be similar or identical to the mobile computing device **130** illustrated and described in reference to FIG. **1**. Namely, the mobile device **400** may be a smartphone, laptop, tablet, e-reader, or another type of handheld computing device. The mobile device **400** includes a display **402**. The mobile device **400** may include one or more buttons (not illustrated), icons, and/or touch-sensitive surfaces.

[0060] The mobile device **400** may be communicatively coupled to any of the body-mountable devices described herein. For example, the mobile device **400** may be coupled via a BLUETOOTH communication link with body-mountable devices **110**, **200**, or **310** as illustrated and described in reference to FIGS. **1**, **2**, **3**A, and **3**B.

[0061] The mobile device **400** may provide various notifications **410** via the display **402** that may relate to information from the communicatively-coupled body-mountable device. For example, the mobile device **400** may be operable to provide a monitoring notification **412** that may relate to the number and types of sensors being monitored. Specifically, the monitoring notification **412** may state "Currently monitoring one multi-color PPG sensor and one temperature sensor".

[0062] Furthermore, the mobile device **400** may be configured to provide a temperature notification **414**. The temperature notification **414** may provide information about an individual's body temperature. Additionally, the mobile device **400** may provide a blood pressure notification **416**. The blood pressure notification **416** may provide a result from a comparison between an inferred blood pressure from the multi-color PPG sensor and a look-up table that includes blood pressure information based, for example, on height, weight, age, and/or sex.

[0063] FIG. **4**B illustrates a mobile device **400** according to an example embodiment. FIG. **4**B may illustrate further notifications **420** that may be provided via the display **402** of the mobile device **400**. For example, a respiratory rate notification **422** may include a comparison between the inferred, measured, and/or calculated respiratory rate with a look-up table that includes respiratory rate information based on, for example, weight, age, and/or sex.

[0064] The notifications **420** may include alerts and/or warnings relating to physiological parameters. For example, the mobile device **400** may be configured to provide an alert **424** related to an elevated blood oxygenation level. Such an alert **424** may be provided to a user of the mobile device **400** and/or the wearer of the body-mountable device so as to avoid a hyperventilation state.

[0065] The notifications **420** may include instructions or advice relating to physiological parameters. For instance, the mobile device **400** may be configured to provide an action notification **426**. The action notification **426** may relate to alert **424**, however other types of physiological parameters, physiological conditions, and/or measurements may trigger action notifications. In an example embodiment, the action notification **426** may provide a prompt or suggestion for a user of the mobile device **400** to perform an action. In the above scenario, the action notification **426** may state "Relax and Breathe Slowly". It is understood that many other types of general, action, and alert notifications are possible within the context of this disclosure. All such notifications are contemplated herein.

Method Examples

[0066] FIG. **5** illustrates a method **500**, according to an embodiment. The method **500** includes blocks that may be carried out in any order. Furthermore, various blocks may be added to or subtracted from method **500** within the intended scope of this disclosure. The method **500** may correspond to steps that may be carried out using any or all of the devices and/or systems illustrated and described in reference to FIG. **1**, **2**A, **3**A, **3**B, **4**A, or **4**B.

[0067] Block **502** includes causing a first light source to emit light having a first wavelength and a second light source to emit light having a second wavelength. The first and second light sources are in a body-mountable device. The body-mountable device is configured as an adhesive patch. The body-mountable device described in the method could be body-mountable device **110**, **200**, or **310** as illustrated and described in reference to FIGS. **1**, **2**, and **3**A, respectively. As described elsewhere herein, the first light source and the second light source may include light-emitting diodes (LEDs) or other light-emitting devices, such as one or more laser diodes.

[0068] Block **504** includes detecting, by at least one sensor in the body-mountable device, information indicative of at least one physiological parameter. The at least one sensor includes one or more photodetectors configured to detect light having the first wavelength and to detect light having the second wavelength. A combination of the multiple light sources and the one or more photodetectors may be operable to provide photoplethysmogram data relating to volumetric measurements of a lumen of subsurface vasculature.

[0069] Block **506** includes processing, via one or more data channels of a sigma-delta analog to digital converter (ADC), the information indicative of the at least one physiological parameter so as to provide physiological data. As described elsewhere herein, the sigma-delta ADC may convert or encode an analog amplitude of a photodetector signal into a pulse code modulated signal with the pulse frequency being related to the amplitude of the photodetector signal.

[0070] Block **508** includes storing the physiological data in memory. The memory may be a static random access memory (SRAM) chip, however many other types of memory devices are contemplated herein. In some embodiments, a time period of physiological data may be limited based on sensor sample rate, the number of sensors sampled, and/or memory size. In such a scenario, the most recent data collected may overwrite the oldest data.

[0071] Block **510** includes wirelessly transmitting the physiological data via a communication interface. The physiological data may be transmitted to a mobile computing device, such as mobile computing device **130** as illustrated and described in reference to FIG. **1**. The communication interface may include at least one of: a BLUETOOTH Low Energy (BLE) interface, a radio frequency identification (RFID) interface, or a near-field communication (NFC) interface. In some examples, the physiological data may include raw data from the various sensors of the body-mountable device. In other example embodiments, the body-mountable device may at least partially process the raw sensor data before wireless transmission.

[0072] The wireless transmission of physiological data may be provided substantially continuously or may occur in response to a trigger. For example, in the case of an RFID communication interface, the wireless transmission of data may be triggered when a handheld reader, such as mobile communication device **130**, comes into close proximity to the body-mountable device, e.g. within 2 meters. In other embodiments, the wireless transmission of physiological data may be triggered in response to a message from the mobile computing device **130**. In yet further embodiments, the body-mountable device may wirelessly broadcast the physiological data.

[0073] The particular arrangements shown in the Figures should not be viewed as limiting. It should be understood that other embodiments may include more or less of each element shown in a given Figure. Further, some of the illustrated elements may be combined or omitted. Yet further, an illustrative embodiment may include elements that are not illustrated in the Figures.

[0074] While various examples and embodiments have been disclosed, other examples and embodiments will be apparent to those skilled in the art. The various disclosed examples and embodiments are for purposes of illustration and are not intended to be limiting, with the true scope being indicated by the following claims.

What is claimed is:

1. A system comprising:
- a body-mountable device configured as an adhesive patch, the body-mountable device comprising:
  - a first light source and a second light source, wherein the first light source is configured to emit light having at least a first wavelength and the second light source is configured to emit light having at least a second wavelength;
  - at least one sensor, wherein the at least one sensor comprises one or more photodetectors configured to detect light having the first wavelength and to detect light having the second wavelength;
  - a battery;
  - a communication interface; and
  - a controller comprising a memory and a processor, wherein the memory stores instructions that are executable by the processor to cause the controller to perform operations comprising:
    - causing the first light source and the second light source to emit light;
    - receiving information from the at least one sensor, wherein the information is indicative of at least one physiological parameter; and
    - transmitting, via the communication interface, the information indicative of at least one physiological parameter; and
- a mobile computing device configured to:
  - receive the transmitted information indicative of at least one physiological parameter.

2. The system of claim **1**, wherein the body-mountable device is configured to adhere to a skin layer of a living body.

3. The system of claim **1**, wherein the at least one sensor further comprises an accelerometer, wherein receiving information from the at least one sensor comprises receiving at least a portion of the information from the accelerometer.

4. The system of claim **1**, wherein the at least one sensor further comprises a temperature sensor, wherein receiving information from the at least one sensor comprises receiving at least a portion of the information from the temperature sensor.

5. The system of claim **1**, wherein the at least one sensor further comprises a piezoresistor, wherein receiving information from the at least one sensor comprises receiving at least a portion of the information from the piezoresistor.

6. The system of claim **1**, wherein the at least one physiological parameter comprises at least one of: a heart rate, a blood pressure, or a blood oxygenation level.

7. The system of claim **1**, wherein the first wavelength is within a range between 750 nanometers and 1 millimeter and the second wavelength is within a range between 620 nanometers and 750 nanometers.

8. The system of claim **1**, wherein receiving information from the at least one sensor comprises receiving at least 120 samples per second from the at least one sensor.

9. The system of claim **1**, wherein the communication interface comprises at least one of: a BLUETOOTH Low Energy (BLE) interface, a radio frequency identification (RFID) interface, or a near-field communication (NFC) interface.

10. The system of claim **1**, wherein the controller further comprises a sigma-delta analog-to-digital converter (ADC) having one or more data channels.

11. A body-mountable device configured as an adhesive patch, the body-mountable device comprising:
- a first light source and a second light source, wherein the first light source is configured to emit light having at least a first wavelength and the second light source is configured to emit light having at least a second wavelength;
- at least one sensor, wherein the at least one sensor comprises one or more photodetectors configured to detect light having the first wavelength and to detect light having the second wavelength;
- a battery;
- a communication interface, wherein the communication interface comprises at least one of: a BLUETOOTH Low Energy (BLE) interface, a radio frequency identification (RFID) interface, or a near-field communication (NFC) interface; and
- a controller comprising a memory, a processor, and a sigma-delta analog-to-digital converter (ADC) having one or more data channels, wherein the memory stores instructions that are executable by the processor to cause the controller to perform operations comprising:
  - causing the first light source and the second light source to emit light;
  - receiving information from the at least one sensor, wherein the information is indicative of at least one physiological parameter;
  - processing, via the one or more data channels of the sigma-delta ADC, the information indicative of the at least one physiological parameter so as to provide physiological data;
  - storing the physiological data in the memory; and
  - wirelessly transmitting the physiological data via the communication interface.

12. The body-mountable device of claim **11**, wherein the body-mountable device is configured to adhere to a skin layer of a living body.

13. The body-mountable device of claim **11**, wherein the at least one sensor further comprises an accelerometer, wherein receiving information from the at least one sensor comprises receiving at least a portion of the information from the accelerometer.

14. The body-mountable device of claim **11**, wherein the at least one sensor further comprises a temperature sensor, wherein receiving information from the at least one sensor comprises receiving at least a portion of the information from the temperature sensor.

15. The body-mountable device of claim **11**, wherein the at least one sensor further comprises a piezoresistor, wherein receiving information from the at least one sensor comprises receiving at least a portion of the information from the piezoresistor.

16. The body-mountable device of claim **11**, wherein the at least one physiological parameter comprises at least one of: a heart rate, a blood pressure, or a blood oxygenation level.

17. A method comprising:

causing a first light source to emit light having a first wavelength and a second light source to emit light having a second wavelength, wherein the first and second light sources are in a body-mountable device, and wherein the body-mountable device is configured as an adhesive patch;

detecting, by at least one sensor in the body-mountable device, information indicative of at least one physiological parameter, wherein the at least one sensor comprises one or more photodetectors configured to detect light having the first wavelength and to detect light having the second wavelength;

processing, via one or more data channels of a sigma-delta analog-to-digital converter (ADC), the information indicative of the at least one physiological parameter so as to provide physiological data;

storing the physiological data in memory; and

wirelessly transmitting the physiological data via a communication interface, wherein the communication interface comprises at least one of: a BLUETOOTH Low Energy (BLE) interface, a radio frequency identification (RFID) interface, or a near-field communication (NFC) interface.

18. The method of claim **17**, wherein the at least one physiological parameter comprises at least one of: a heart rate, a blood pressure, or a blood oxygenation level.

19. The method of claim **17**, wherein the at least one sensor further comprises an accelerometer, wherein at least a portion of the information indicative of at least one physiological parameter is detected by the accelerometer.

20. The method of claim **17**, wherein the at least one sensor further comprises a temperature sensor, wherein at least a portion of the information indicative of at least one physiological parameter is detected by the temperature sensor.

* * * * *

专利名称(译)	生理参数的无创连续监测		
公开(公告)号	US20170027515A1	公开(公告)日	2017-02-02
申请号	US14/813713	申请日	2015-07-30
申请(专利权)人(译)	实实在在的生命科学LLC		
当前申请(专利权)人(译)	实实在在的生命科学LLC		
[标]发明人	WISER ROBERT FRANCIS		
发明人	WISER, ROBERT FRANCIS		
IPC分类号	A61B5/00 A61B5/145 A61B5/0205		
CPC分类号	A61B5/6833 A61B5/0059 A61B2562/0219 A61B5/14542 A61B5/02055 A61B5/0002 A61B5/0205 A61B5/021 A61B5/024 A61B5/0261 A61B5/14552 A61B5/7225 A61B2560/0412 A61B2562/0233 A61B2562/04		
外部链接	Espacenet USPTO		

摘要(译)

描述了涉及可安装在身体上的装置的系统和方法。所述可安装在身体上的装置包括第一光源和第二光源，其可分别发射具有至少第一和第二波长的光。该可安装于身体的装置包括至少一个传感器，其被配置为检测具有第一波长和第二波长的光。该可安装于身体的装置包括电池，通信接口和控制器。控制器包括存储器，处理器和具有一个或多个通道的Σ-Δ模数转换器（ADC）。控制器执行各种操作，诸如使得第一光源和第二光源发射光并且经由至少一个传感器接收指示至少一个生理参数的信息。控制器还可以经由Σ-ΔADC执行处理指示至少一个生理参数的信息，以便提供生理数据。