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(54) **Title**: MEDICAL MONITORING DEVICE WITH FLEXIBLE CIRCUITRY

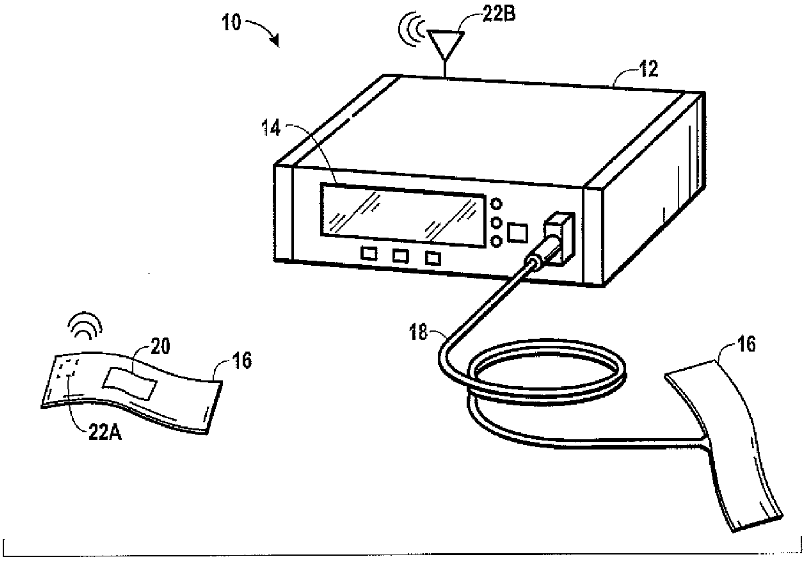

FIG. 1

(57) **Abstract**: Embodiments described herein may include systems and methods for monitoring physiological parameters of a patient. Specifically, embodiments disclose the use of a flexible circuitry in a medical sensor that is small and lightweight and easily bendable, such that it may be comfortably affixed to a patient while also providing added electronic functions, such as digital conversion and wireless capability.

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MEDICAL MONITORING DEVICE WITH FLEXIBLE CIRCUITRY

BACKGROUND

The present disclosure relates generally to medical devices and, more particularly, to medical monitoring devices.

This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present disclosure, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

In the field of medicine, doctors often desire to monitor certain physiological characteristics of their patients. Accordingly, a wide variety of devices have been developed for monitoring physiological characteristics. Such devices provide doctors and other healthcare personnel with the information they need to provide the best possible healthcare for their patients. As a result, such monitoring devices have become an indispensable part of modern medicine.

One technique for monitoring certain physiological characteristics of a patient is commonly referred to as pulse oximetry, and the devices built based upon pulse oximetry techniques are commonly referred to as pulse oximeters. Pulse oximetry may be used to measure various blood flow characteristics, such as the blood-oxygen saturation of hemoglobin in arterial blood, the volume of individual blood pulsations supplying the tissue, and/or the rate of blood pulsations corresponding to each heartbeat of a patient.

Pulse oximeters typically utilize a non-invasive sensor that is placed on or against a patient's tissue that is well perfused with blood, such as a patient's finger, toe, forehead or earlobe. The sensor is usually small, lightweight, and flexible so that it may be easily and comfortably held against the patient's tissue. The pulse oximeter sensor emits light and photoelectrically senses the absorption and/or scattering of the light after passage through the perfused tissue. The data collected by the sensor may then be used to calculate one or more of the above physiological characteristics based upon the absorption or scattering of the light. More specifically, the emitted light is typically selected to be of one or more wavelengths that are absorbed or scattered in an amount related to the presence of oxygenated versus de-oxygenated hemoglobin in the blood. The amount of light absorbed and/or scattered may then be used to estimate the amount of the oxygen in the tissue using various algorithms.

Due to the flexibility and small size of the pulse oximeter sensor, the amount of circuitry included in the sensor is usually rather limited. Accordingly, the sensor is usually coupled through a cable to a monitor that sends and receives electrical signals to the sensor and includes circuitry used for processing the received signals and performing other functions that are outside the limited capabilities of the sensor.

This conventional configuration, however, may have several disadvantages. For example, the cable may tend to pick up unwanted electrical noise, thereby reducing the signal-to-noise ratio of transmitted signal. For another example, the transmission of analog signals through the resistive cable may result in substantial power loss. For yet another example, the patient's comfort and mobility may be limited by the cable running between the sensor and the monitor. It may be desirable, therefore, to provide a medical sensor with improved processing functionality while maintaining the sensor's flexibility and comfort.

BRIEF DESCRIPTION OF THE DRAWINGS

Advantages of the disclosure may become apparent upon reading the following detailed description and upon reference to the drawings in which:

FIG. 1 is a perspective view of a medical monitoring system with flexible, bandage-style sensors in accordance with an embodiment;

FIG. 2 is a perspective view of a partially assembled flexible, bandage-style sensor in accordance with an embodiment in which the sensor includes a display and a wireless device;

FIGS. 3A and 3B are perspective views of the back side of the bandage-style sensor of FIG. 2 in accordance with an embodiment;

FIG. 4A is a perspective view of a flexible clip-style sensor, in accordance with an embodiment;

FIG. 4B is a cross-sectional view of the flexible clip-style sensor of FIG. 4A taken along line 4-4, in accordance with an embodiment; and

FIGS. 5-7 are block diagrams of the sensors of FIGS. 1-4 in accordance with various embodiments.

DETAILED DESCRIPTION

One or more embodiments will be described below. In an effort to provide a concise description of these embodiments, not all features of an actual implementation are described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

The present disclosure is directed to an improved medical sensor that includes flexible circuitry. For the purposes of the present specification, the term "flexible circuit" is intended to describe a deformable integrated circuit that may be flexed without damaging the circuit. By including flexible circuitry within the sensor, the processing capabilities of the sensor may be improved while maintaining the sensor's flexibility and comfort. The enhanced processing capabilities of the sensor may include amplification and filtering of signals received by the sensing components of the sensor and analog-to-digital conversion of the received signals. The digital signals may then be transmitted to the monitor with less power consumption and higher signal-to-noise ratio. Certain other embodiments may additionally include circuitry that enables the sensor to wirelessly transmit the digital signals to the monitor, thereby eliminating the communications cable. Further embodiments may include a sensor with circuitry that enables the sensor to calculate and/or display some physiological parameters.

Referring to the figures and turning initially to FIG. 1, a medical monitoring device is illustrated in accordance with an embodiment and is generally designated by the reference numeral **10**. The device **10** may include a monitor **12** which may house hardware and software configured to compute various physiological parameters. The monitor **12** may be configured to operate as a pulse oximeter or as a multi-parameter monitor, such as those available from Nellcor Puritan Bennett L.L.C. and/or Covidien.

The monitor **12** may include a display **14** to display the various physiological parameters. For example, the display **14** may display the pulse rate and the concentration of a blood analyte, such as, percent oxygen saturation of hemoglobin, for example. The display **14** may show the physiological parameters and calculated values in any appropriate manner. For example, the calculated values may be displayed numerically and/or as a waveform over time. Additionally, any notifications or alerts prompted by abnormal measurements, calculated values and/or other conditions may be displayed.

One or more flexible sensors 16, in accordance with various embodiments, may be communicatively coupled to the monitor 12. As shown in FIG. 1, the sensors 16 are flexible and, thus, may be attached to the tissue of a patient in a variety of ways. For example, the sensor 16 may be wrapped around a portion of a patient, such as a finger, toe, arm, leg, earlobe, etc. In other embodiments, the sensor may be held against the patients' forehead or torso, such that the sensor fits the contours of the tissue.

In some embodiments, the sensor 16 may be communicatively coupled to the monitor 12 via a cable 18. In other embodiments, however, the sensor 16 may communicate with the monitor 12 wirelessly. In the latter case, both the monitor 12 and the sensor 16 may include wireless devices that allow the monitor and the sensor to communicate as will be explained below in reference to FIG. 6. By eliminating the cable 18, the patient is no longer tethered to the monitor 12 and may move more freely without the risk of inadvertently jerking or damaging the cable 18. In this way, the sensor 16 may be less susceptible to movement or accidental removal, and the risk of the sensor 16 or the monitor 12 is reduced.

The sensor 16 may also include a display 20 that provides information regarding the physiological parameters of the patient, such as blood oxygenation and heart rate. In some embodiments, the sensor 16 may receive the displayed physiological parameters from the monitor 12. As such, the sensor 16 may transmit the raw physiological data to the monitor 12, and the monitor 12 may then calculate physiological parameters based the physiological data and transmit the physiological parameters back to the sensor 16 for display. In other embodiments, the sensor 16 may include flexible circuitry configured to calculate the physiological parameters based on the data gathered by the sensor 16. In this way, the senor 16 may be a stand-alone unit, capable of providing physiological data without the use of the monitor 12. The sensor 16 may, therefore, be used in situations in which a monitor 12 may not be readily available or convenient, such as during an emergency, patient transportation, or other situations where the patient is away from a medical facility. By displaying physiological parameters directly on the sensor 16, a medical service provider may devote greater attention to the patient while obtaining important information regarding the patient's health.

Additional details of the sensor 16 are provided with reference to FIGS. 2-7. Specifically, FIGS. 2-4 illustrate various embodiments of sensor construction, while FIGS. 5-7 illustrate the electrical components that may be included in various embodiments. Turning first to FIG. 2, a perspective view of the sensor 16 is illustrated. As shown in FIG. 2, the circuitry of the sensor 16 may be housed within a flexible outer covering that may include a flexible top layer 23 and a flexible bottom layer 24. Both the top layer 23 and bottom layer 24 may include flexible polymers, such as silicon polymers, polyvinylchloride, and polyethylene. The polymers may be elastomeric to provide for flexibility of the sensor 16 such that it may conform to the tissue of a patient. In some embodiments, the top and bottom layers 23 and 24 may include cloth or a bandage material, such as gauze. The top layer 23 and bottom layer 24 may be held together by an adhesive. For convenience, FIG. 2 shows the top layer 23 as partially separated from the bottom layer 24 to provide a view of the internal circuitry within the sensor 16. In some embodiments, the top layer 23 may include a window 26 to enable viewing of a display 20. The window 26 may be an unfilled aperture within the top layer 23 or, alternatively, the window may include a clear polymer layer. In some embodiments, the top layer 23 and bottom layer 24 may also include complimentary fastening mechanisms 28, such as rows of buttons or strips of hhok and loop type fasteners, which allow the sensor 16 to be wrapped around an extremity of the patient and held in position.

As is also shown in FIG. 2, the sensor **16** may also include one or more flexible circuits **30** held between the top layer **23** and the bottom layer **24**. The flexible circuits **30** provide the added functionality of the sensor **16**, which will be described further below in relation to FIGS. 5-7. In embodiments with more than one flexible circuit **30**, the flexible circuits **30** may be physically and communicatively coupled to one another by a flexible circuit board **32**, such as a "flex" circuit board made from a flexible polymer substrate, such as polyimide. The flexible circuit board **32** may be communicatively coupled to electrical leads from the cable **18** at an electrical interface **34**. In this way, signals from the monitor **12** may be routed to or from the emitter **38**, detector **40**, and other circuit components.

The flexible circuits **30** may include flexible semiconductors fabricated on a flexible polymer substrate according to any of several flexible semiconductor fabrication techniques. In some embodiments, for example, the flexible circuits **30** may include thin film transistors (TFTs), such as low-temperature polysilicon TFTs deposited on a flexible polymer substrate. In some embodiments, the TFTs may be deposited on the flexible polymer substrate by a method of chemical vapor deposition (CVD) or physical vapor deposition (PVD), such as sputtering. Furthermore, in some embodiments, the flexible circuits **30** may be inkjet printed on the polymer substrate at low temperature using a low-temperature liquid silicon, such as polysilane or cyclopentasilane.

The flexible circuits **30** may include some or all of the circuit components of the sensor **16**, such as emitters, detectors, drivers, processors, batteries, etc, as will be described below. Among other things, the flexible circuits **30** may include the display **20** and the wireless device **22A**. The display **20** may be any thin flexible display, such as a flexible organic light-emitting diode OLED display or a flexible electrophoretic display, for example. The wireless device **22A** on the sensor **16** may include a flexible radio frequency antenna, such as a flexible microstrip antenna or flexible patch antenna, for example.

Sensors 16 in accordance with present embodiments may be either transmissive or reflective. In a transmissive sensor 16, emitted light signals pass completely through the patient's tissue before being received by the sensor 16. In a reflective sensor 16, the emitted light signals penetrate the patient's tissue only partially before being reflected back and received by the sensor 16. Embodiments of a transmissive sensor 16 and a reflective sensor 16 are illustrated in FIGS. 3A and 3B, respectively.

Turning first to FIG. 3A, a bottom layer **24** of a transmissive sensor **16** is illustrated in accordance with embodiments. The bottom layer **24** of the sensor **16** is held adjacent to the tissue of a patient so that the sensor **16** may detect physiological data of the patient through an emitter **38** and a detector **40**, both of which may be held in close proximity to the skin or tissue of the patient. The emitter **38** may include a red emitter and an infra-red emitter that are configured to transmit electromagnetic radiation through the tissue of a patient. In accordance with this embodiment, the red and infra-red emitters may include light emitting diodes (LEDs) that emit electromagnetic radiation in the respective region of the electromagnetic spectrum. The radiation emitted by the emitter **38** into the patient's tissue is detected by the detector **40** after the radiation has passed through or reflected from blood perfused tissue of the patient **42**, and the detector **40** generates an electrical signal correlative to the amount of radiation detected.

To facilitate the transmission of light through the patient's tissue, the bottom layer 24 of the sensor 16 may include transparent windows 36 that expose the emitter 38 and detector 40 and allow light to pass through the tissue of a patient from the emitter 38 to the detector 40. The windows 36 may be unfilled apertures within the bottom layer 24 or, alternatively, the windows 36 may include a clear polymer layer. The bottom layer 24 may also include one or more adhesive layers 44 for attaching the sensor 16 to the skin of the patient and securing the emitter 38 and the detector 40. Furthermore, the adhesive layers 44 may surround both the emitter 38 and the detector 40 to prevent the emitter 38 and the detector 40 from moving relative to the skin of the patient.

The emitter **38** may include any kind of light emitting diodes (LED) suitable for pulse oximetry, while the detector may include any suitable kind of photodiode. In some embodiments, the emitter **38** and the detector **40** may be flexible and may be formed directly on the flexible circuits **30** of the sensor **16**. For example, the emitter **38** may include one or more organic light emitting diodes (OLEDs) formed on the plastic substrate of the flexible circuits **30**. Additionally, the detector **40** may also include an organic diode configured to operate as a light-detecting photodiode. The emitter **38** and the detector **40** may be disposed on opposite sides of the tissue so that the detector **40** may detect light transmitted through the tissue by the emitter **38**.

Turing now to FIG. 3B, a bottom layer **24** of a reflective sensor **16** is illustrated in accordance with embodiments. In this embodiment, as in FIG. 3A, the bottom layer **24** may also include one or more adhesive layers **44** that surround both the emitter **38** and the detector **40** and secure the emitter **38** and the detector **40** to the skin of the patient. In this embodiment, however, the sensor **16** may operate by reflecting light from the tissue of the patient, rather than transmitting light through the tissue. Accordingly, the emitter **38** and the detector **40** may be positioned close to one another to reduce the transmission path between the emitter **38** and the detector **40**. In this embodiment, the sensor **16** may be disposed adjacent to any part of a patient's body that is conducive to measuring physiological parameters, such as the forehead, for example. Again, the flexibility of the flexible circuits **30** enables the sensor **16** to easily bend to fit the contour of the tissue to which it is attached.

Embodiments of the present invention may also include a clip-style sensor 16 configured to grasp the tissue of a patient. Turning to FIGS. 4A and 4B, an embodiment of a clip-style sensor **16** is illustrated, in accordance with embodiments. Turning first to FIG. 4A, the sensor **16** may include a sensor body **46** with an upper clip portion **48** and a lower clip portion **50** coupled together by a hinge **52** that allows the upper clip portion **48** and a lower clip portion **50** to flex outward to receive a body part of the patient, such as a patient's finger. As shown in FIG. 4A, the sensor body **46** may be a single, continuous structure that includes a semi-rigid polymer injection molded around the flexible circuitry **30** and other circuit components of the sensor **16**. In this embodiment, the hinge **52** may be a living hinge formed by a thinning of the semi-rigid polymer, and the flexible circuits **30** may pass through the hinge **52**. Further, the resiliency of the hinge **52** may provide a compressive force that holds the upper clip portion **48** and the lower clip portion **50** in place against the patient's tissue. In alternative embodiments, the upper clip portion **48** and the lower clip portion **50** of the sensor body **46** may be separate pieces coupled together by the hinge **52**, which may be spring loaded to provide the compressive force for holding the upper clip portion **48** and the lower clip portion **50** against the patient's tissue.

Together, the upper clip portion **48** and the lower clip portion **50** may be configured to flex outward about the hinge **52** to allow the finger of a patient to be inserted into the sensor **16** for testing. Furthermore, the sensor body **46** may also include grips **54** to facilitate the flexing of the sensor body **48** and the placement of the sensor **16** around the patient's finger. As will be shown, both the upper clip portion **48** and the lower clip portion **50** may house a variety of flexible electronic circuits and devices for measuring biological parameters.

FIG. 4B shows a side cross-sectional view of the clip-style embodiment of sensor assembly **16**. As shown in FIG. 4B, the sensor **16** includes a emitter **38** and a detector **40** embedded in the sensor **16** on opposite sides of the sensor **16**. In this embodiment, light signals may be emitted by emitter **38** into the bottom of patient's finger, transmitted through the patient's finger tissue, and received by detector **40**. The detector **38** and the emitter **40** may each include or be adjacent to a transparent window which allows light to be transmitted from the emitter **40** to the detector **38**, through the patient's finger tissue.

As in the sensor **16** described in relation to FIGS. 1-3, the sensor **16** may include a flexible circuit **30**. The flexible circuit **30** may include electrical leads located on a surface of the flexible circuit **30** at an electrical interface **56**. The flexible circuit leads may be electrically coupled at the electrical interface **56** to electrical leads from the cable **18** so that signals may be routed to or from the emitter **38**, detector **40**, and other circuit components.

In other embodiments, the clip-style sensor **16** may also include a wireless device so that signals may be routed to or from the emitter **38**, detector **40**, and other circuit components wirelessly, and the cable **18** may not be present. In some embodiments, the flexible circuit **30** may be one continuous flexible circuit **30** that extends from the electrical interface **56** through both the upper clip portion **48** and the lower clip portion **50**, bending approximately 180 degrees at the joint **30**. Moreover, as shown in FIG. 4B, the flexible circuit **30** may be folded on itself one or more times to increase the amount of circuitry that may be included in the sensor **16**. In some embodiments, the flexible circuit **30** may include a thin insulative sheet (not shown) to prevent electrical shorting between the folded layers. In other embodiments, electrical insulation may be provided by a thin insulative sheet imposed between the folded layers. By including the flexible circuit **30** in the clip-style sensor **16**, a relatively large amount of circuitry may be included within the sensor **16**, thus enhancing the capabilities of the sensor as described below while maintaining the flexibility, small size, and comfort of the sensor **16**.

Various other physical embodiments of the sensor **16** with flexible circuitry **30** may be possible. In fact, many techniques may be used for holding the sensor **16** against the skin of a patient, and the examples recited above should not be considered an exhaustive list of possible embodiments.

Turning now to FIGS. 5-7, the electrical features of various embodiments of the sensor **16** are described. Embodiments of the sensor **16** may include various levels of additional functionality, some of which will be described below. For example, FIG. 5 describes a sensor **16** electrically coupled by a cable to a monitor **12**, wherein the sensor **16** includes, among other things, circuitry for amplification, filtering, and digital conversion of the signals received by the detector **40**. For another example, FIG. 6 describes a sensor **16** with circuitry that enables the sensor to communicate with the monitor **12** wirelessly. For yet another example, FIG. 7 describes a sensor **16** with a display **20** and circuitry for calculating and displaying some physiological parameters. It will be understood that an actual implementation described herein may include more or fewer components as needed for a specific application.

Turning first to FIG. 5, a block diagram of the monitoring device **10** with the sensor **16** is illustrated in accordance with an embodiment. As shown in FIG. 5, the monitor **12** may include one or more processors **62**. The processor **62** may be configured to calculate physiological parameters using various algorithms programmed into the monitor **12** and based on signals received from the sensor **16**. For example, the processor **62** may compute a percent oxygen saturation of hemoglobin and/or a pulse rate, among other useful physiological parameters.

The processor **62** may be connected to other component parts of the monitor **12**, such as one or more read only memories (ROM) **64**, one or more random access memories (RAM) **66**, the display **20**, and control inputs **70**. The ROM **64** and the RAM **66** may be used in conjunction, or independently, to store the algorithms used by the processor **62** in computing physiological parameters. The ROM **64** and the RAM **66** may also be used in conjunction, or independently, to store signals received from the sensor **16** for use in the calculation of the aforementioned algorithms. The control inputs **70** may be provided to allow a user to interface with the monitor **12** and may include soft keys, dedicated function keys, a keyboard, and/or keypad type interfaces for providing parameters, data, and/or instructions to the monitor **12**.

As described above in relation to FIGS. 3-4, the sensor **16** may include an emitter **38** and a detector **40**. Additionally, the sensor **16** of FIG. 5 may also perform many of the functions traditionally performed by the monitor **12**. For example, the sensor **16** may include a light drive **72** that provides signals to a red emitter **38A** and an infra-red emitter **38B** that cause the emitters **38A** and **38B** to produce the emitted light signals. The light drive **72** may be driven by an analog signal from the monitor **12**, which controls the timing and intensity of the light signals emitted by the emitters **38A** and **38B**. The analog signal from the monitor **12** may then trigger the light drive **72** to generate an excitation signal that is transmitted to the emitters **38A** and **38B**. In accordance with an embodiment, the light drive **72** may be a simplified light drive circuit discussed in detail in U.S. Patent Application No. 12/343,799, entitled "LED Drive Circuit and Method for Using Same," by Ethan Peterson, which was filed December 24, 2008, and is incorporated herein by reference in its entirety for all purposes. The simplified light drive **72** described therein may include fewer circuit components as compared to light drive circuits typically found on pulse oximetry monitors.

For another example of added sensor **16** functionality, the sensor **16** may also include circuitry for converting the analog signal received from the detector **40** into a digital signal. Specifically, the sensor **16** may include an amplifier **74** that amplifies the electrical signal generated by the detector **40** and a filter **76** that reduces unwanted signals located outside the frequencies of interest. The amplified and filtered signal may then be provided to an analog-to-digital converter (ADC **78**) that converts the analog signal into a digital format. The digital signal may then be provided to the monitor **12** for further processing, such as for the calculation of various physiological parameters. By transmitting a digital signal from the sensor **16** to the monitor **12** rather than an analog signal, the electrical interference introduced by the cable **18** may be reduced.

Turning now to FIG. 6, a block diagram of another embodiment of the monitoring device **12** with the sensor **16** is illustrated. As shown in FIG. 6, the sensor **16** may include the emitter **38** and the detector **40**, as well the additional circuitry such as the light drive **72**, the amplifier **74**, the filter **76**, and the ADC **78**, as discussed above in relation to FIG. 5. In this embodiment, however, the sensor **16** and the monitor **12** both include wireless devices **22A** and **22B** that enable the sensor **16** and the monitor **12** to communicate wirelessly. In this way, the communications cable **18** may be eliminated. The wireless device **22A** on the sensor **16** may also include driver circuitry (not shown) that receives the digital signal from the ADC **78** and generates an excitation signal for driving an antenna (not shown). In an embodiment, the sensor **16** may transmit data via a wireless communication protocol such as, but not limited to, WiFi, Bluetooth or ZigBee.

In some embodiments, the monitor **12** may communicate with several sensors **16** at the same time. In such embodiments, the operator of the monitor **12** may choose to view physiological data from one or more sensors **16** at any time. To correlate a sensor **16** with a particular patient **42**, each sensor **16** may provide a unique identifier that allows the health care provider to match sensor **16** readings with the patient **42** wearing the sensor **16**. In various embodiments, for example, each sensor **16** may be tuned to a slightly different broadcast frequency, or each sensor **16** may periodically broadcast an identification sequence.

As is also shown in FIG. 6, the sensor **16** may also include a display **20** that may display various information about the sensor **16** and/or the patient **42**. In embodiments, the display **20** may include a numerical display. As such, the display **20** may receive incoming data and convert the data into a format suitable for driving the display **20**. Furthermore, the display **20** may be configured to cycle through a set of display data, either on a timed basis or responsive to an input of the user.

In some embodiments, the display **20** may be configured to display data corresponding to the sensor **16**, such as, for example, battery life and/or whether the sensor **16** is transmitting a wireless signal. Moreover, the display **20** may also be configured to display any useful data corresponding to a physiological parameter of a patient **42**, such as, for example, a pulse rate and/or a blood-oxygen saturation level. In the embodiment shown in FIG. 6, the sensor **16** may not have processor circuitry suitable for generating the displayed physiological data. Therefore, the sensor **16** may receive physiological data through the wireless link provided by the wires devices **22A** and **22B**. As such, physiological data may be calculated by the processor **62** of the monitor **12** based on the digital signals received from the ADC **78** of the sensor **16**, as discussed above. The physiological data may then be transmitted back to the sensor **16** via the wireless device **22B**. The wireless device **22A** may then route the physiological data to the display **20**. The same physiological data may also be displayed on the display **14** of the monitor **12**. Including a display **20** on the sensor **16** provides several advantages. For example, by displaying information regarding the battery life of the sensor **16**, a caregiver may be alerted to replace or recharge the sensor **16**. For another example, displaying information regarding the health of the patient in direct proximity to the patient, may enable the caregiver to devote greater attention to the patient while still monitoring physiological data provided by the sensor **16**.

As is also shown in FIG. 6, the sensor **16** may include a power source **82**, such as a battery for example. The power source **82** may serve to power several of the electrical components of the sensor **16** such as the light drive **72**, the amplifier **74**, the ADC 78, the wireless device **22A**, and the display **20**. The power source **82** may include any small, lightweight battery such as a "coin cell" or "button cell." In some embodiments, the power source **82** may include lithium ion batteries, such as nanowire batteries, i.e., high performance lithium ion batteries made from silicon nanowires. Furthermore, in some embodiments, the power source **82** may include one or more flexible thin-film batteries, which may be included in or coupled to the flexible circuitry **30**. Furthermore, in some embodiments, the power source **82** may be rechargeable.

In some embodiments, the sensor **16** may be activated by coupling the power source **82** to the sensor circuitry **16**. For example, an electrically insulative film (not shown) may be inserted between the power source **82** and an electrical contact coupling the power source **82** to the sensor circuitry, thus blocking the flow of current from the power source. In this way, removal of the electrically insulative film may activate the sensor **16**.

Turning now to FIG. 7, a block diagram of another embodiment of a sensor **16** is illustrated. As discussed above, some or all of the circuit components shown in FIG. 7 may be included on one or more flexible circuits **30**. As shown in FIG. 7, the sensor **16** may include several additional circuit components traditionally included in the monitor **12**. For example, in addition to the signal processing and display capabilities discussed above, the sensor **16** may also include a processor **62**. The processor **62** may be communicatively coupled to the light drive **72** for controlling the timing and intensity of the emitters **38A** and **38B**. Additionally, the processor **62** may be communicatively coupled to the ADC **78** for receiving the digital signal output of the ADC **78** and calculating physiological parameters based on the received digital signals. In some embodiments, the processor **62** may be a synchronous, i.e. clocked, circuit. In other embodiments, however, the processor **62** may be asynchronous, this reducing the power usage of the processor **62** and reducing the heat generated by the processor **62**.

Other components of the sensor **16** may also be coupled to the processor **62**, such as the display **20** and the wireless device **22**. The display **20** may be a simplified display as discussed above in relation to FIG. 6. The wireless device **22A** may allow the sensor **16** to transmit data wirelessly to a remote monitor **12**. For example, the wireless device **22A** may enable the sensor **16** to transmit digital signals received from the ADC **78** to the remote monitor, as discussed above in relation to FIG. 6. Additionally, the wireless device **22A** may also enable the sensor **16** to transmit physiological parameters calculated by the sensor **16** to the remote monitor **12**. The remote monitor **12** may use the data received from the sensor **16** to execute more advanced features that may not be included in the sensor **16**. For example, the remote monitor **12** may calculate additional physiological data that may require more robust algorithms. For another example, the remote monitor **12** may store physiological data gathered over time by the sensor **16** in a long term memory. In this way, information pertaining to physiological trends over time may be stored and displayed by the monitor **12**.

Furthermore, the processor(s) **62** may also be coupled to a memory such as read-only memory (ROM) **64** and/or a random access memory (RAM) **66**. In certain embodiments, the ROM **64** may be used to store one or more pulse oximetry algorithms, which may be simplified pulse oximetry algorithms such that the computer code associated with those algorithms may be reduced and the circuit footprint of the ROM **64** on the flexible circuitry **30** may also be reduced. In other embodiments, the calculation algorithms may be hardwired into the processor **62**, and the ROM **64** may be eliminated, thereby further reducing the circuit footprint of the sensor **16** circuitry on the flexible circuit **30**. For example, the processor **62** may be an application specific integrated circuit (ASIC) or a programmable logic device (PLD). The RAM **66** may store intermediate values that are generated in the process of calculating patient parameters as well as certain software routines used in the operation of the sensor **16**, such as measurement algorithms, light drive algorithms, and patient parameter calculation algorithms, for example.

From the embodiments describe above, it will be appreciated that several advantages may be achieved by including flexible circuitry within a medical sensor **16**. The use flexible circuitry enables the addition of several electronic components that would traditionally be included in a monitor coupled to a sensor rather than the sensor itself. For example, the use of flexible semiconductor circuitry may enable the sensor to amplify and filter analog signals generated by the detector **40** and convert the analog signals into a digital signal that may then be transmitted to the monitor **12** with less electromagnetic interference and higher signal-to-noise ratio. Additionally, the use of flexible semiconductor circuitry may enable the sensor **16** to communicate wirelessly with the monitor **12**, thus increasing the mobility and comfort of the patient. Furthermore, the use of flexible semiconductor circuitry may enable the sensor **16** to calculate and/or display physiological data detected by the sensor. Moreover, all of the benefits described above may be achieved while maintaining the comfort and flexibility of the sensor **16.**

CLAIMS

What is claimed is:

1. A sensor capable of placement adjacent to tissue to be tested, comprising:

a light emitter and a light detector capable of acquiring physiological data from a patient;

a flexible circuit comprising an analog-to-digital converter capable of being coupled to an output of the light detector and capable of outputting a digital signal based at least in part upon the physiological data from the patient; and

a flexible outer covering capable of being positioned generally adjacent the tissue of a patient, and capable of housing the flexible circuit.

2. The sensor of claim 1, wherein the flexible circuit comprises thin film transistors disposed on a flexible polymer substrate.

3. The sensor of claim 1, wherein the flexible circuit comprises low-temperature polycrystalline silicon.

4. The sensor of claim 1, wherein the flexible outer covering is capable of being wrapped generally around a body part of a patient.

5. The sensor of claim 1, wherein the flexible outer covering comprises a clip capable of generally attaching to an extremity of the patient.

6. The sensor of claim 1, wherein the light emitter comprises a generally flexible, organic light emitting diode.

7. The sensor of claim 1, wherein the flexible circuit comprises a wireless device coupled to an output of the digital-to-analog converter, and capable of wirelessly transmiting the digital signal to a monitor.

8. The sensor of claim 1, wherein the flexible circuit comprises an amplifier coupled to an output of the detector, and a filter coupled to an output of the amplifier, wherein an output of the filter is coupled to an input of the digital-to-analog converter.

9. The sensor of claim 1, wherein the flexible circuit comprises a drive circuit coupled to an input of the emitter and configured to provide an electrical signal to the emitter that causes the emitter to emit a signal into a tissue of the patient.

10. The sensor of claim 1, wherein the flexible circuit comprises a display capable of displaying an output based at least in part upon the physiological data, and/or a state of the sensor.

11. The sensor of claim 1, wherein the flexible circuit comprises a processor cvapable of recieveing the digital signal. and further capable of generating an output based at least in part upon the physiological data.

12. A monitoring system, comprising:

a sensor, comprising:

a light emitter and a light detector, capable of acquiring physiological data from a patient;

a flexible circuit comprising an analog-to-digital converter coupled to an output of the light detector and capable of outputting a digital signal based at least in part upon the physiological data from the patient; and

a monitor communicatively coupled to the sensor, and capable of receiving the digital signal, and further capable of generating an output based at least in part upon the physiological data.

13. The monitoring system of claim 12, wherein the output corresponding to the physiological data is capable of being transmitted from the monitor to the sensor; and wherein the sensor comprises a display configured to display the output.

14. The monitoring system of claim 12, wherein the flexible circuit of the sensor comprises a flexible wireless transmitter capable of transmittin the digital signal to the monitor.

15. The monitoring system of claim 12, wherein the flexible circuit of the sensor comprises a thin film transistor comprising generally low-temperature, polycrystalline silicon disposed on a flexible polymer substrate.

16. A method of generating physiological data, comprising:

driving circuit configured to drive a light emitting diode generally disposed in a sensor and configured to emit a light signal into a tissue;

receiving a modified light signal generally via a light detector disposed in the sensor, the modified light signal corresponding to the light signal after it has passed through the tissue;

generating a digital signal in part using an analog-to-digital converter generally disposed in the sensor, the digital signal based at least in part upon the modified signal; and

generating a physiological parameter at least in part upon the digital signal;

wherein the driving circuit, the light emitting diode, the light detector, and/or the analog-to-digital converter comprises a flexible circuit.

17. The method of claim 16, wherein generating a physiological parameter comprises sending the digital signal to a flexible processor disposed generally on the sensor.

18. The method of claim 16, comprising wirelessly transmitting the digital signal via a flexible wireless transmitter to a monitor, display, and/or other device.

19. The method of claim 18, comprising wirelessly transmitting the physiological parameter from the monitor, display, and/or other device to the sensor and displaying the physiological parameter on a flexible display disposed generally on an outer surface of the sensor.

20. The method of claim 16, wherein driving the light emitting diodes comprises sequentially activating a red light emitting diode and an infrared light emitting diode using a flexible light drive disposed in the sensor.

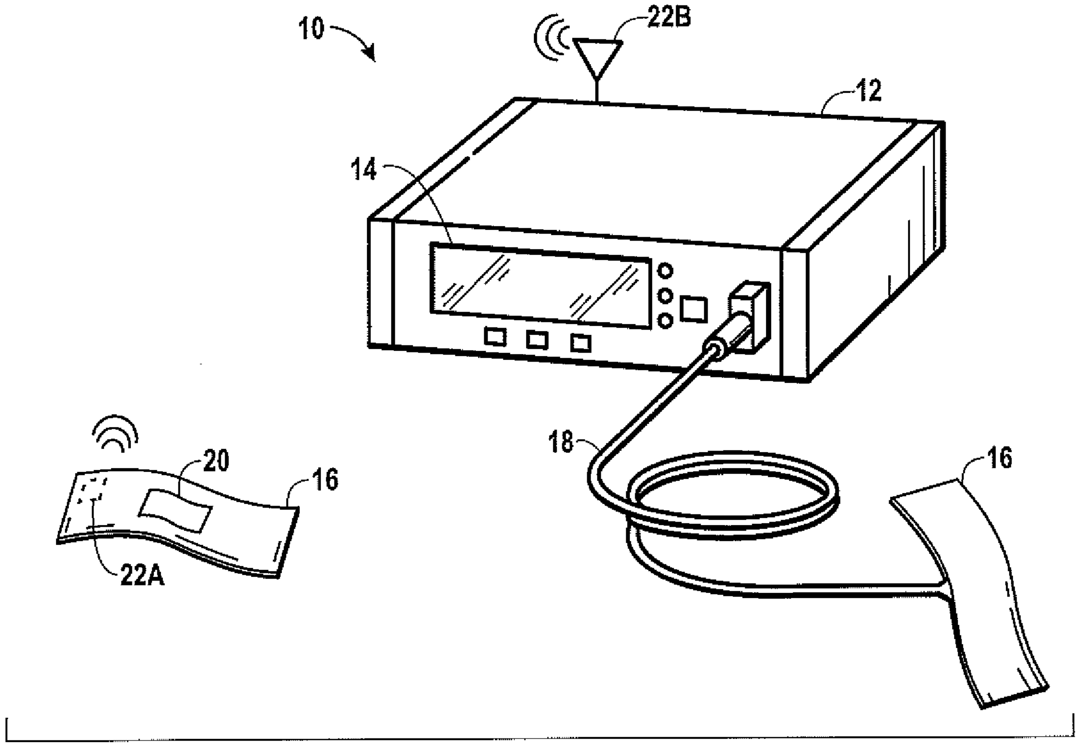


FIG. 1

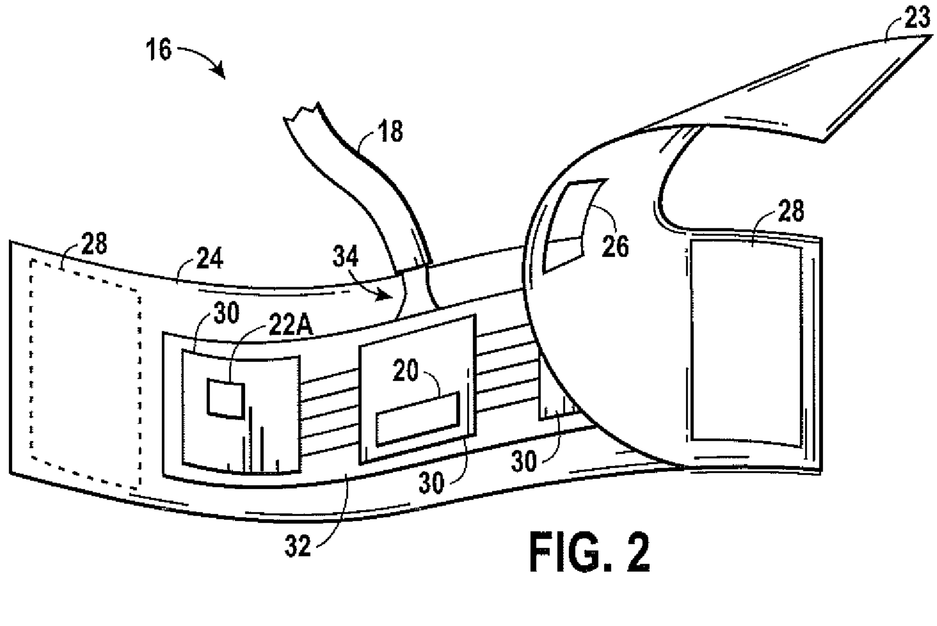


FIG. 2

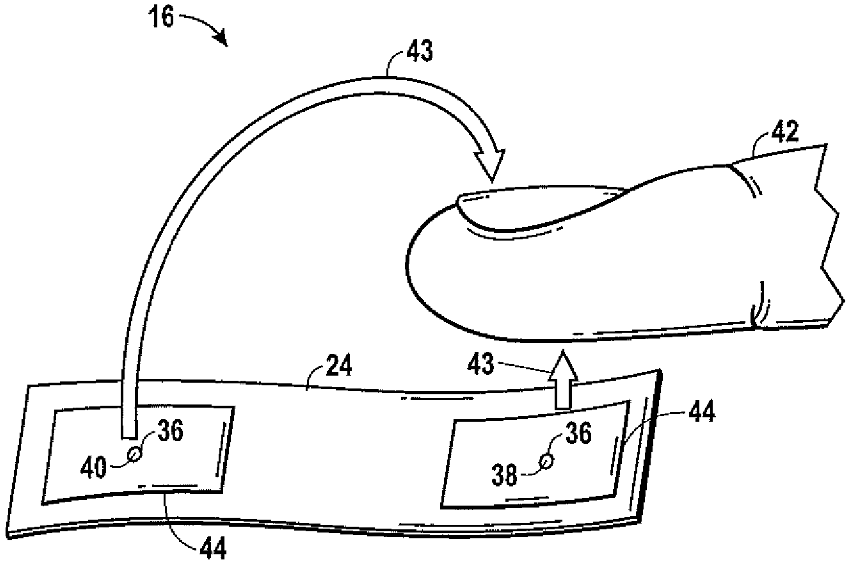


FIG. 3A

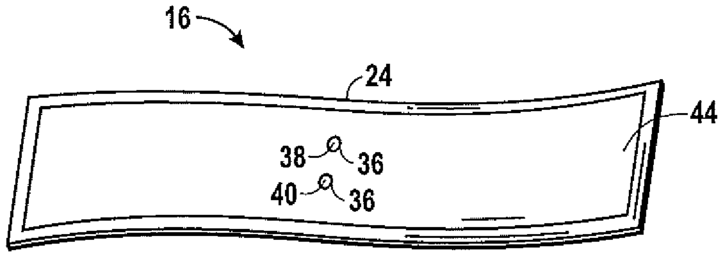


FIG. 3B

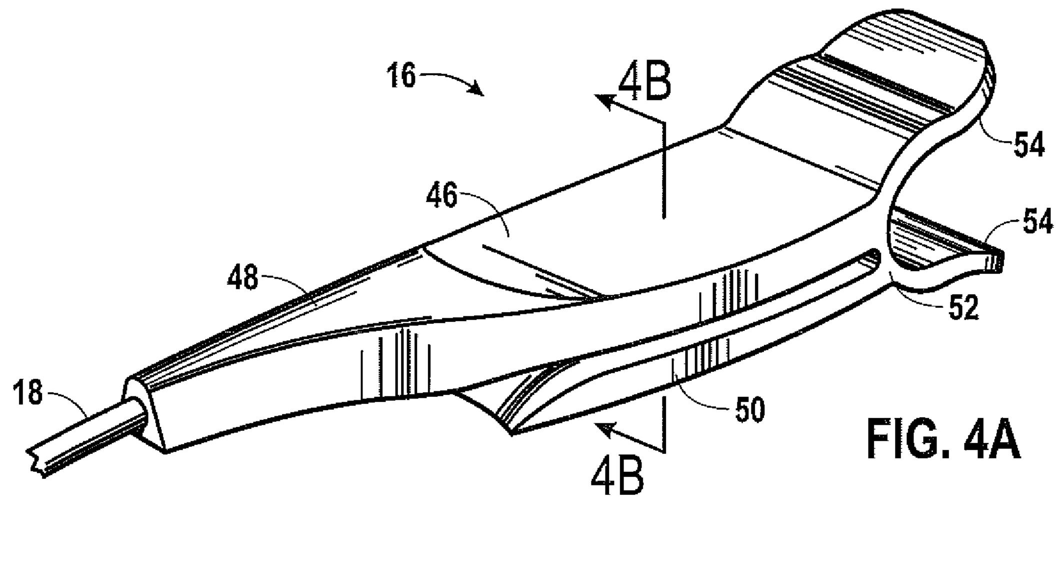


FIG. 4A

3/6

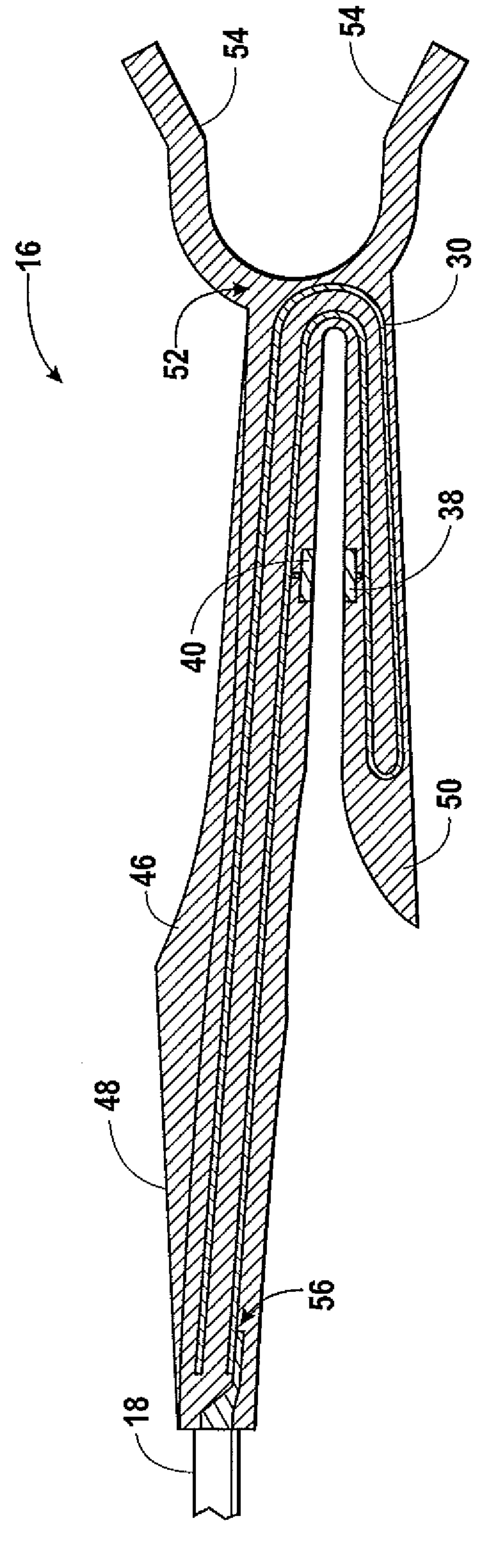
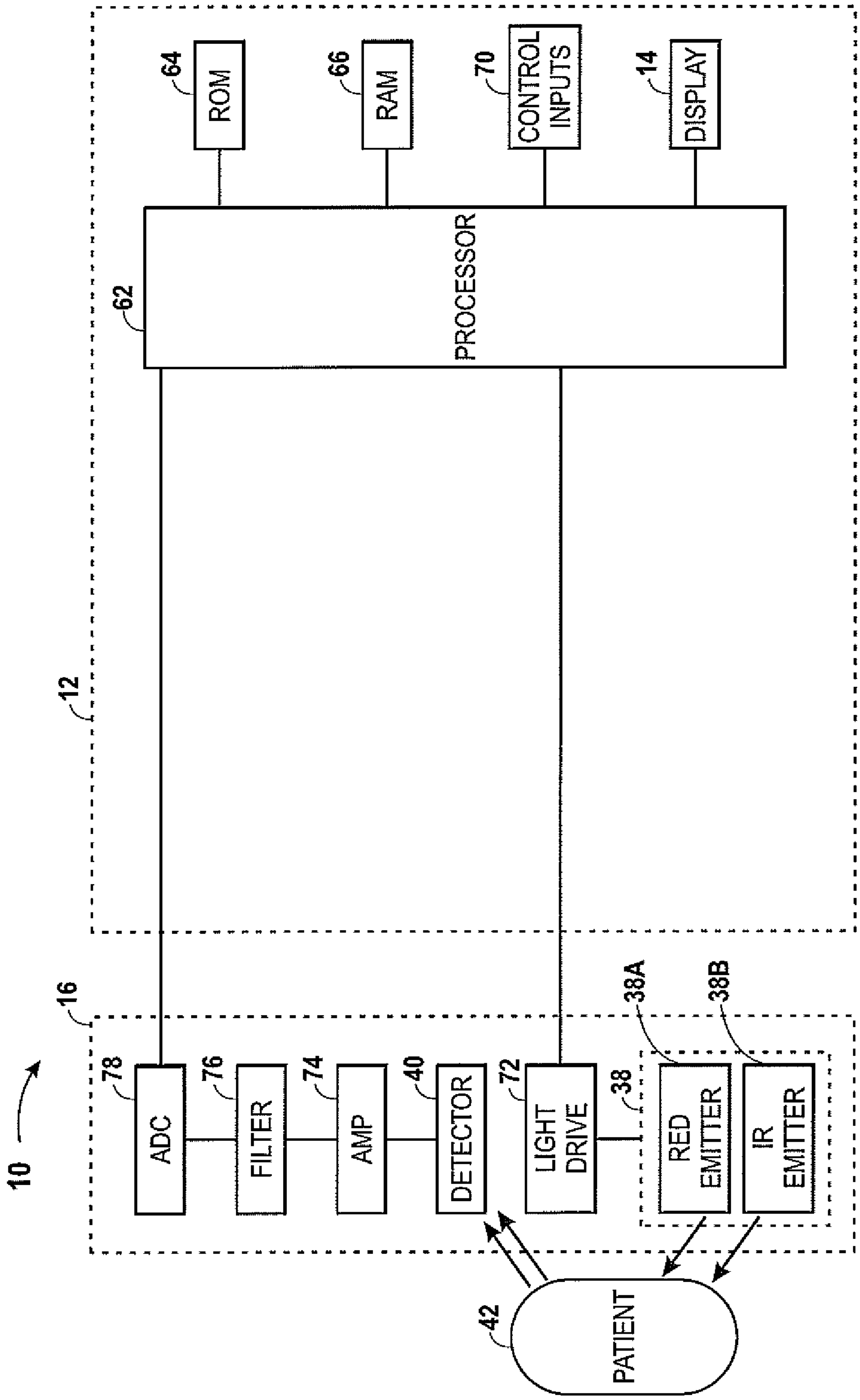


FIG. 4B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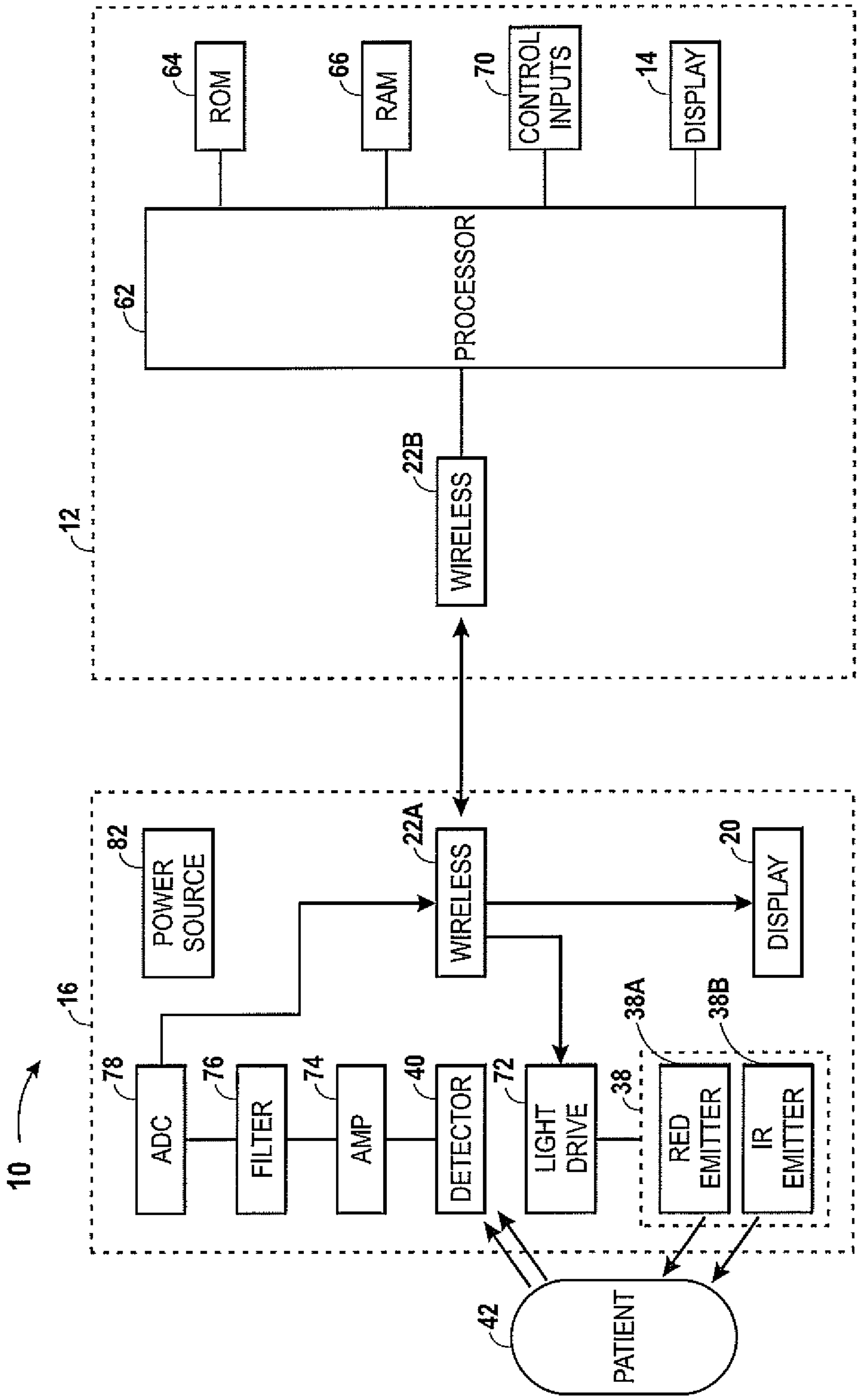
12
16
ROM
64
RAM
66
CONTROL INPUTS
70
DISPLAY
14
PROCESSOR
62
ADC
78
FILTER
76
AMP
74
DETECTOR
40
LIGHT DRIVE
72
38
RED EMITTER
38A
IR EMITTER
38B
PATIENT
42

FIG. 5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PATIENT
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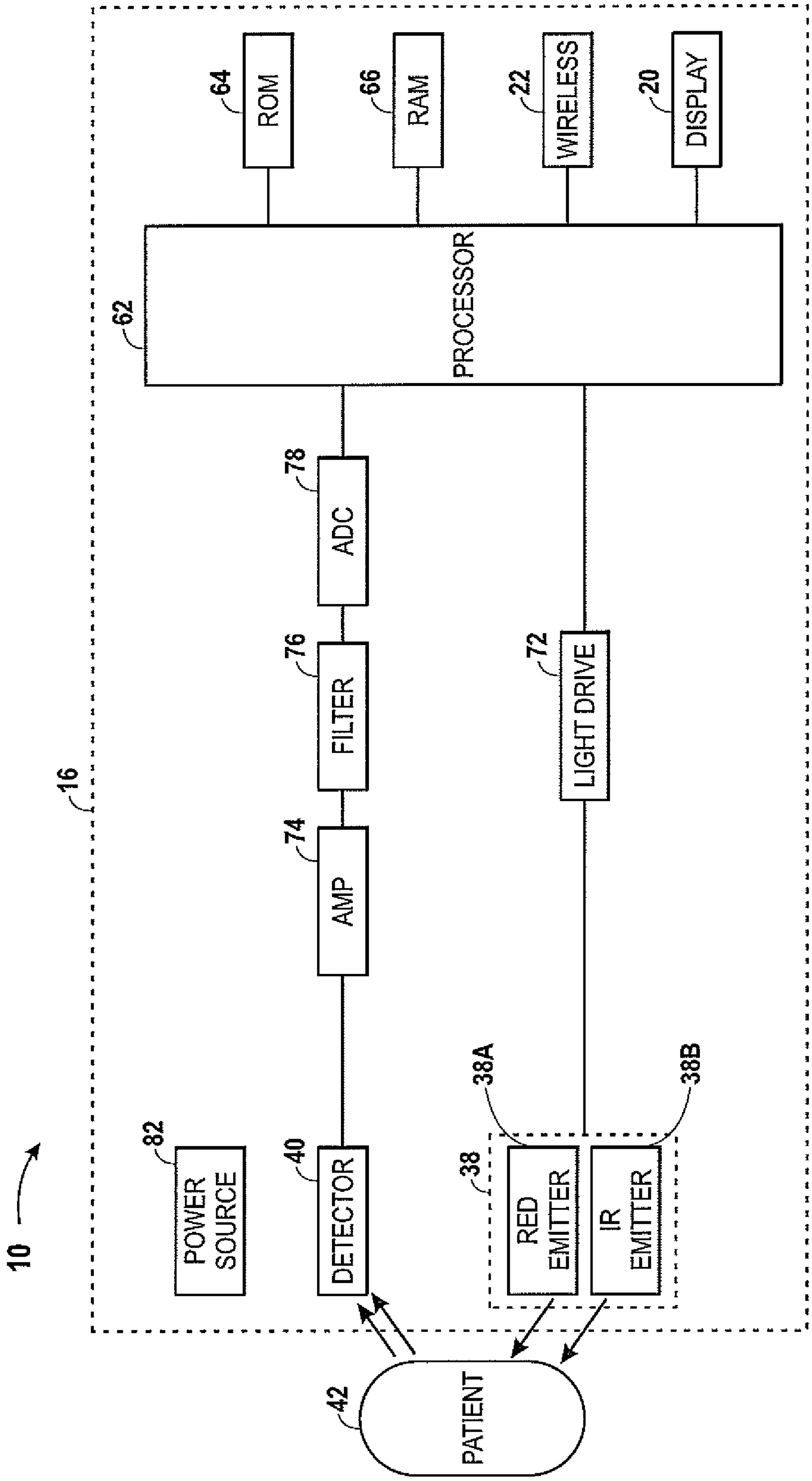
FIG. 6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RED EMITTER
IR EMITTER
PATIENT
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FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2010/025360

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B5/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B

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

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

EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2009/012380 A1 (GONOPOLSKIY OLEG [US] ET AL) 8 January 2009 (2009-01-08) the whole document -----	1-20
Y	US 2008/177163 A1 (WANG SHIH-PING [US] ET AL) 24 July 2008 (2008-07-24) paragraph [0003] - paragraph [0009] paragraph [0046] figure 10 -----	1-20
A	US 2008/312517 A1 (GENOE JAN [BE] ET AL) 18 December 2008 (2008-12-18) paragraph [0055] paragraph [0107] - paragraph [0108] paragraph [0056] ----- -/--	1-20

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 April 2010	07/05/2010

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Fax: (+31–70) 340–3016	Abraham, Volkhard

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2010/025360

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2005/228298 A1 (BANET MATTHEW J [US] ET AL) 13 October 2005 (2005-10-13) paragraph [0013] - paragraph [0016] paragraph [0046] - paragraph [0051] figures 10,11 -----	1-20
A	US 2006/282001 A1 (NOEL MICHEL [CA] ET AL) 14 December 2006 (2006-12-14) paragraph [0005] - paragraph [0014] figures 1-7 -----	1-20
X,P	WO 2009/124076 A1 (NELLCOR PURITAN BENNETT LLC [US]; PETERSEN ETHAN [US]; PEREZ MARK [US]) 8 October 2009 (2009-10-08) the whole document -----	1,2,4, 7-9,11, 12,14, 16-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2010/025360

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US 2008177163 A1	24-07-2008	NONE	
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		WO 2006111472 A2	26-10-2006
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		US 2005228301 A1	13-10-2005
US 2006282001 A1	14-12-2006	NONE	
WO 2009124076 A1	08-10-2009	NONE	

专利名称(译)	具有柔性电路的医疗监控设备		
公开(公告)号	EP2408348A1	公开(公告)日	2012-01-25
申请号	EP2010706103	申请日	2010-02-25
[标]申请(专利权)人(译)	内尔科尔普里坦贝内特公司		
申请(专利权)人(译)	NELLCOR PURITAN BENNETT LLC		
当前申请(专利权)人(译)	COVIDIEN LP		
[标]发明人	GILLAND BRUCE		
发明人	GILLAND, BRUCE		
IPC分类号	A61B5/00		
CPC分类号	A61B5/14552 A61B5/0002		
优先权	12/404887 2009-03-16 US		
外部链接	Espacenet		

摘要(译)

本文描述的实施例可以包括用于监测患者的生理参数的系统和方法。具体地，实施例公开了在医疗传感器中使用柔性电路，其小而轻且易于弯曲，使得其可以舒适地固定到患者身上，同时还提供附加的电子功能，例如数字转换和无线能力。