

PATIENT MONITOR WITH MOBILE COMPUTING DEVICE CONNECTIVITY**BACKGROUND**Field of the Disclosure

The present disclosure relates in general to noninvasive patient monitoring systems, including oximeters and co-oximeters, and their accessories such as sensors or cables. In particular, this disclosure relates to patient monitors capable of connectivity to a mobile computing device.

Description of the Related Art

Oximetry utilizes a noninvasive optical sensor to measure physiological parameters of a patient. In general, the sensor has light emitting diodes (LEDs) that transmit optical radiation into a tissue site and a detector that responds to the intensity of the optical radiation after absorption (e.g., by transmission or transreflectance) by, for example, pulsatile arterial blood flowing within the tissue site. Based on this response, a processor determines measurements for oxygen saturation (SpO_2), pulse rate, plethysmograph waveforms, perfusion quality index (e.g., an index that quantifies perfusion), assessments of other blood constituents, parameters or analytes, including for example, a percent value for arterial carbon monoxide saturation (HbCO), a percent value for methemoglobin saturation (a brownish-red form of hemoglobin that cannot function as an oxygen carrier) (HbMet), total hemoglobin (HbT), fractional SpO_2 (SpaO_2) or the like. Additionally, caregivers often desire knowledge of HbO_2 , Hb , blood glucose (HbGu), water, the presence or absence of therapeutic drugs (aspirin, Dapson, nitrates, or the like) or abusive/recreational drugs (methamphetamine, alcohol, steroids, or the like), concentrations of carbon dioxide (CO_2), oxygen (O_2), oxygen concentration, pH levels, bilirubin, perfusion quality, albumin, cyanmethemoglobin, and sulfhemoglobin (HbSulf), signal quality or the like. It is noted that “oximetry” as used herein encompasses its broad ordinary meaning known to one of skill in the art, which includes at least those noninvasive procedures for measuring parameters of circulating blood through spectroscopy. Moreover, “plethysmograph” as used herein (commonly referred to as “photoplethysmograph”), encompasses its broad ordinary meaning

known to one of skill in the art, which includes at least data representative of a change in the absorption of particular wavelengths of light as a function of the changes in body tissue resulting from pulsing blood.

Oximeters capable of reading many of the foregoing parameters during noise due to patient movement, electromagnetic interference, and ambient light are available from Masimo Corporation (Masimo) of Irvine, California. Moreover, portable and other oximeters are disclosed in at least U.S. Pat. Nos. 6,770,028, 6,658,276, 6,157,850, 6,002,952, and 5,769,785, incorporated by reference herein, and others' patent publications such as those listed at <http://www.masimo.com/patents.htm>. Such noise filtering oximeters have gained rapid acceptance in a wide variety of medical applications, including surgical wards, intensive care and neonatal units, general wards, home care, physical training, and virtually all types of monitoring scenarios. Some blood parameter monitors including oximeters are the standard of care in certain critical environments like surgery and neonatal care.

Mobility and ease of use are key factors in the health care industry because they correlate to efficient, rapid patient care as well as enable patients to participate in their own care. Therefore, there is a need for physiological monitoring devices to be compatible with handheld monitors such as common mobile computing devices for ease of use and portability.

SUMMARY

Advantageously, in certain embodiments, a physiological monitoring system can be designed to include a sensor and cable assembly with a processing board or card, and the system may be connectable to a mobile computing device, such as a smartphone, such that display of the monitored physiological data may occur on the computing device. The board or card may communicate the data for display with the mobile computing device wirelessly or through a physical and electrical connection with the cable assembly. In some embodiments, the board or card may include one or more signal processors and associated memory, I/O, and the like to provide monitored physiological data to applications executing on traditional smartphone processing environments, such that board or card handles advanced signal processing and the smartphone displays parameter data. As a result, the physiological

monitoring system can be more portable than existing monitoring systems, thereby facilitating enhanced patient care for more patients. For example, such a system may be sent home with a patient to gather physiological measurement data outside the hospital setting.

Physiological monitoring systems such as are described herein advantageously enable oximeter use outside of the traditional hospital setting. This is beneficial for more comprehensive patient care. For instance, prior to a surgical procedure during which a patient will be sedated, such as by general anesthesia, a physician may be concerned about the patient's proclivity toward apnea. A portable oximetry sensor compatible with the patient's smartphone may be sent home with the patient prior to the procedure, and the sensor may be worn overnight. Data collected from the sensor may be passed to the smartphone and made available to the doctor, such as by uploading to the internet or being downloadable from the device, to identify a risk of hypoxemia. This example illustrates one of the many benefits of a portable oximetry system compatible with a common mobile computing device.

For purposes of summarizing the disclosure, certain aspects, advantages and novel features of the inventions have been described herein. It is to be understood that not necessarily all such advantages can be achieved in accordance with any particular embodiment of the inventions disclosed herein. Thus, the inventions disclosed herein can be embodied or carried out in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other advantages as can be taught or suggested herein.

BRIEF DESCRIPTION OF THE DRAWINGS

Throughout the drawings, reference numbers can be re-used to indicate correspondence between referenced elements. The drawings are provided to illustrate embodiments of the inventions described herein and not to limit the scope thereof.

FIG. 1 illustrates an embodiment of a physiological monitoring system.

FIG. 2 illustrates another embodiment of a physiological monitoring system.

FIG. 3 illustrates an embodiment of a software application for display and management of physiological monitoring data.

DETAILED DESCRIPTION

I. Example Physiological Monitoring System

Figures 1 and 2 illustrate embodiments of a physiological monitoring system 100. The physiological monitoring system 100 shown in **Figure 1** comprises a sensor 110, first cable 120, processing module 130, second cable 140, connection port 150, and a mobile computing device, illustrated here as smartphone 160. Although specific reference may be made to smartphones in this disclosure, persons skilled in the art will understand that a mobile computing device compatible with the physiological sensor system may be one of a wide range of mobile devices such as a laptop, tablet computer, netbook, PDA, media player, mobile game console, or other microprocessor based device configured to interface with a physiological sensor. Some embodiments of the mobile computing device may be used with the system for display of data as well as storage of data. Cables used with the device can be flex cables or other cables, including cables having triboelectric properties.

In various embodiments, the sensor 110 provides data in the form of an output signal indicative of an amount of attenuation of predetermined wavelengths (ranges of wavelengths) of light by body tissues, such as, for example, a digit, portions of the nose or ear, a foot, or the like. The predetermined wavelengths often correspond to specific physiological data desired, including for example, blood oxygen information such as SpO₂, blood glucose, total hemoglobin, methemoglobin, carboxyhemoglobin, bulk tissue property measurements, water content, pH, blood pressure, respiration related information, cardiac information, indications of perfusion, or the like.

The sensor data may be corrupted by noise due to patient movement, electromagnetic interference, or ambient light. Therefore, the sensor data is transmitted from sensor 110 along the first cable 120 to the processing module 130, which may apply noise filtering and signal processing techniques described below to provide output data for display on the smartphone 160. Such complex processing techniques may exceed the processing capabilities of the smartphone 160, and therefore the processing module 130 handles signal processing and transmits the processed sensor parameter data as output measurement data.

Smartphone 160 may be coupled to the processing module 130 by a second cable 140 and connection port 150.

Smartphone 160 may include a display screen such as an LED or LCD screen, and may include touch sensitive technologies in combination with the display screen. Smartphone 160 may include software configured to display some or all of the output measurement data on the display screen. The data display may comprise numerical or graphical representations of blood oxygen saturation, heart rate, and/or a plethysmographic waveform, and some embodiments may simultaneously display numerical and graphical data representations.

The smartphone 160 may include software such as an application configured to manage output measurement data from the processing module 130. The application functionality can include trend analysis, current measurement information, alarms associated with above/below threshold readings, reminders to take measurement data at certain times or cycles, display customization, iconic data such as hearts beating, color coordination, bar graphs, gas bars, charts, graphs, or the like, all usable by a caregiver or smartphone user to enable helpful and directed medical monitoring of specified physiological parameters.

In some embodiments, software capable of analyzing the output measurement data received from the processing module 130 and making the data available in an appropriate manner health management is installed on the smartphone 160. In some embodiments, the smartphone 160 comprises software which allows a user to view the data in a multitude of ways. For example, in some embodiments a user may be able to view the raw data received from the sensor 110. In other embodiments, a user may be able to select from a plurality of graphical representations of the data (e.g., bar graphs, charts, etc). In other embodiments, the user may be able to manipulate the data to visualize trends in the data. The smartphone 160 may also be able to alert the user to an abnormal data reading. For example, an abnormally low or high blood oxygen saturation reading may cause the smartphone 160 to buzz, vibrate or otherwise notify the user of an abnormal reading.

The smartphone 160 may have the capability of sending physiological data to a computer (e.g., a home computer) on which the user manages his health data. The data can also be sent to a physician or pharmacist for their expertise and feedback. The smartphone

160 and the computing device to which data is being sent may be connected directly or via a network such as a LAN, WAN or the Internet. The connection may be wired or wireless. Other connection configurations are also possible.

The system 100 as illustrated in **Figure 2** shows an exploded view of the processing module 130 and the connection port 150 to reveal the components thereof.

Coupled to cable 120 is an information element 133. The information element 133 could be provided through an active circuit such as a transistor network, memory chip, EEPROM (*electronically erasable programmable read-only memory*), EPROM (*erasable programmable read-only memory*), or other identification device, such as multi-contact single wire memory devices or other devices, such as those commercially available from Dallas Semiconductor or the like.

The processing module 130 comprises a lower shell 131, an enclosure with bend relief 132, processing board 134, and an upper shell 135. The enclosure 132, upper shell 135, and lower shell 131 surround the processing board 134 to protect the sensitive circuitry of the board 134 from damage. In such an embodiment, processing board 134 is the portion of the module 130 that communicates with the first cable 120 and sensor 110, as well as with the second cable 140 and mobile computing device. In an embodiment, the board 134 may access information stored on the information element 133 of the first cable 120.

Preferable, the processing board is comprises one of many OEM boards commercially available from Masimo which process incoming intensity signals responsive to an amount of attenuation of light in pulsing patient blood and which determine output measurements for a wide variety of physiological parameters from the processing. The processing board 134 may comprise the MS-2040 OEM board available from Masimo, which can measure Masimo optical SET measurements such as oxygen saturation (SpO2), pulse rate, perfusion index (PI), signal quality (SIQ), optionally pleth variability index (PVI), and the like. The physiological monitoring system 100 can also include, in addition to or instead of the MS-2040 OEM board, other processing boards available from Masimo. For example, the physiological monitoring system 100 can include the MX-5 board available from Masimo, which has variable power consumption based on which parameters are being acquired and displayed. The MX-5 board can measure the Masimo SET parameters described above plus

optional rainbow® parameters including: hemoglobin (SpHb), oxygen content (SpOC), carboxyhemoglobin (SpCO), methemoglobin (SpMet), and acoustic respiration rate (RRa) (among possibly others). The addition of the acoustic respiration rate can result in the display of the physiological monitoring system 100 outputting a second waveform (e.g., an acoustic respiration waveform).

The board 134 may comprise a signal processing system. Embodiments of the signal processing system may employ a noise filtering system may to filter the data obtained during pulse oximetry measurements using red and infrared light, as such data is often contaminated due to motion. Identification and removal of these motion artifacts is often a prerequisite to any signal processing used to obtain blood oxygen saturation, pulse rate, or other physiological data. The signal processing system may provide the desired parameters as outputs for a display. Outputs for display are, for example, blood oxygen saturation, heart rate, and a clean plethysmographic waveform. Complex operations such as noise filtering and signal processing require significant computational overhead.

The connection port 150 comprises shell 151, bend relief 152, connector 153, and cap 154. Bend relief 152 is an important feature of a medical cable assembly for both the electrical and mechanical integrity and performance of the second cable 140. The connection port 150 is typically rigid, and the bend relief 152 provides a transition from the stiffness of the connection port 150 to the flexibility of the second cable 140. Preferably, bend relief 152 will prevent mechanical force applied to the exterior of the cable from being transferred to the electrical terminations within the connector, which could lead to failure.

Shell 151 generally encloses connector 153 and may be matable with cap 154 to provide added protection for the connector 153. Connector 153 may be shaped to physically and electrically connect with a specific device. Connection port 150 may be one of many different types of ports. For example, connection port 150 may be a device-specific port such as an iPhone port or another smartphone port, a USB port, an Ethernet port for connection to a wired network, a serial port (e.g., RS232), a video out port which allows projection of the device screen on a larger display, combinations of the same, or the like. Further, the connection port 150 may be equipped with one or more wireless interfaces (such as WiFi, Bluetooth, Zigbee, or the like).

Figure 3 illustrates an embodiment of an application for display and management of physiological monitoring data. Some embodiments of the software application may be used with the smartphone 160 of Figures 1 and 2. Smartphone 160 comprises a display 310, which may be used to generate a user interface for the software application. The application may include a plurality of display portions in which a plurality of physiological parameters may be displayed, such as SpO2 display 320, heart rate display 330, perfusion index display 350, or plethysmographic waveform display 350. The configuration of these various display portions is meant for illustrative purposes, and one skilled in the art would appreciate that the parameter displays could be rearranged relative to one another, displayed alone, or the user interface could be modified to include other parameter display portions. Further, although some of the parameter display portions employ numerical representations of the physiological data, some embodiments may employ graphical representations, for example a beating heart may indicate heart rate.

The user interface may also include an options display portion 360 which allows the user to interact with his physiological monitoring data in a variety of ways. For example, the user may choose to view trends in the data or to change the manner in which the data is represented such as by viewing a histogram or other graph. The user may be also able to view the history of his physiological measurement data. A settings option may be displayed which would allow the user to modify other aspects of the program, and may also enable the user to set alarms or reminders to take future measurements.

In certain embodiments, the application may be downloadable from a computer network at a cost, by subscription, pay-per-use, or the like. Other embodiments may advantageously incorporated caregiver-specific applications which include reminders for timed measurements or protocols. For example, a caregiver for a pre-surgical patient may desire measurement data for a certain minimum time per minimum period (20 min per every hour) or the like to have sufficient data to make diagnosis or decisions for treatment. A caregiver-specific application may be advantageously programmed to accomplish such a protocol. Moreover, signal quality or confidence indicators such as perfusion index ("PI") or signal IQ ("SIQ") may be used to ensure data meets certain minimum confidence and/or signal-to-noise limitations. Thus, the application may implement the protocol and extend or

add measurement intervals to ensure minimum signal quality standards are met. Other caregiver-specific applications may provide animated or textual instructions, links to online information regarding certain monitoring situations, ailments, or other useful patient research.

In an embodiment, data acquired through the application may be uploaded to caregiver or device provider systems to increase the population data and used to improve signal processing. In a preferred embodiment, issues of privacy and compliance with governmental regulations are strictly enforced through the application logic. In some embodiments, non-identifying demographic information may advantageously be associated with such data. Moreover, password and/or additional authentication requirements may be required to access stored data in the application, such as, for example, fingerprint technologies, facial recognition technologies employing the smartphone's camera, voice recognition technologies employing the smartphone's audio transducer, or the like may further assist in meeting privacy concerns.

II. Terminology

Many other variations than those described herein will be apparent from this disclosure. For example, depending on the embodiment, certain acts, events, or functions of any of the algorithms described herein can be performed in a different sequence, can be added, merged, or left out all together (e.g., not all described acts or events are necessary for the practice of the algorithms). Moreover, in certain embodiments, acts or events can be performed concurrently, e.g., through multi-threaded processing, interrupt processing, or multiple processors or processor cores or on other parallel architectures, rather than sequentially. In addition, different tasks or processes can be performed by different machines and/or computing systems that can function together.

The various illustrative logical blocks, modules, and algorithm steps described in connection with the embodiments disclosed herein can be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the

particular application and design constraints imposed on the overall system. The described functionality can be implemented in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the disclosure.

The various illustrative logical blocks and modules described in connection with the embodiments disclosed herein can be implemented or performed by a machine, such as a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor can be a microprocessor, but in the alternative, the processor can be a controller, microcontroller, or state machine, combinations of the same, or the like. A processor can also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. Although described herein primarily with respect to digital technology, a processor may also include primarily analog components. For example, any of the signal processing algorithms described herein may be implemented in analog circuitry. A computing environment can include any type of computer system, including, but not limited to, a computer system based on a microprocessor, a mainframe computer, a digital signal processor, a portable computing device, a personal organizer, a device controller, and a computational engine within an appliance, to name a few.

The steps of a method, process, or algorithm described in connection with the embodiments disclosed herein can be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module can reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of non-transitory computer-readable storage medium, media, or physical computer storage known in the art. An exemplary storage medium can be coupled to the processor such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium can be integral to the processor. The processor and the storage medium can

reside in an ASIC. The ASIC can reside in a user terminal. In the alternative, the processor and the storage medium can reside as discrete components in a user terminal.

Conditional language used herein, such as, among others, "can," "might," "may," "e.g.," and the like, unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include, while other embodiments do not include, certain features, elements and/or states. Thus, such conditional language is not generally intended to imply that features, elements and/or states are in any way required for one or more embodiments or that one or more embodiments necessarily include logic for deciding, with or without author input or prompting, whether these features, elements and/or states are included or are to be performed in any particular embodiment. The terms "comprising," "including," "having," and the like are synonymous and are used inclusively, in an open-ended fashion, and do not exclude additional elements, features, acts, operations, and so forth. Also, the term "or" is used in its inclusive sense (and not in its exclusive sense) so that when used, for example, to connect a list of elements, the term "or" means one, some, or all of the elements in the list.

While the above detailed description has shown, described, and pointed out novel features as applied to various embodiments, it will be understood that various omissions, substitutions, and changes in the form and details of the devices or algorithms illustrated can be made without departing from the spirit of the disclosure. As will be recognized, certain embodiments of the inventions described herein can be embodied within a form that does not provide all of the features and benefits set forth herein, as some features can be used or practiced separately from others.

WHAT IS CLAIMED IS:

1. A physiological monitoring system comprising:
 - a sensor configured to monitor one or more physiological parameters of a patient;
 - a mobile computing device comprising a display; and
 - a processing board configured to establish an electrical signal connection between the sensor and the mobile computing device, wherein the processing board receives data representing the monitored one or more physiological parameters and performs signal processing to provide the desired parameters as outputs for the display.

ABSTRACT

Systems and method for monitoring patient physiological data are presented herein. In one embodiment, a physiological sensor and a mobile computing device may be connected via a cable or cables, and a processing board may be connected between the sensor and the mobile computing device to conduct advanced signal processing on the data received from the sensor before the data is transmitted for display on the mobile computing device.

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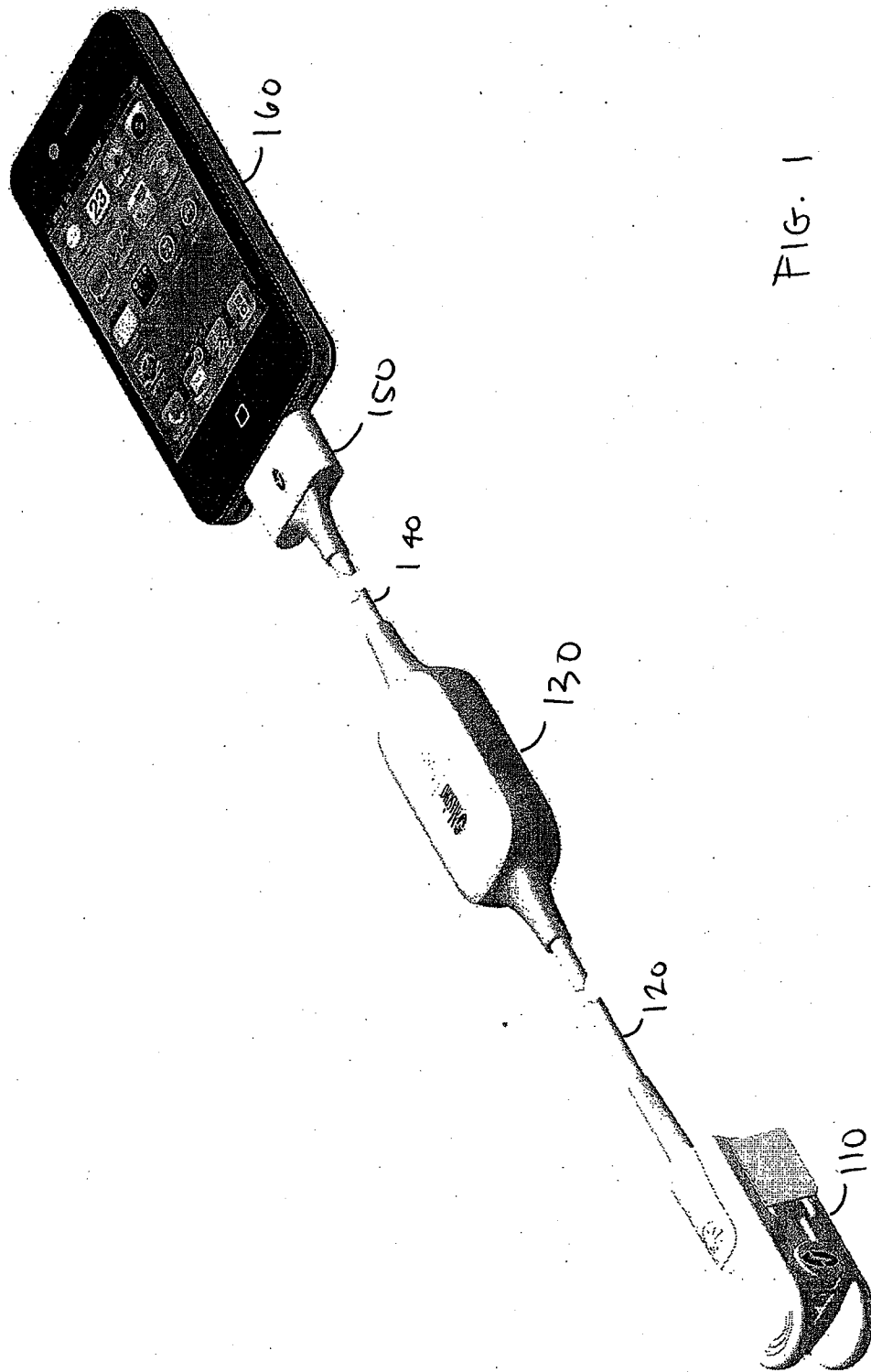


FIG. 1

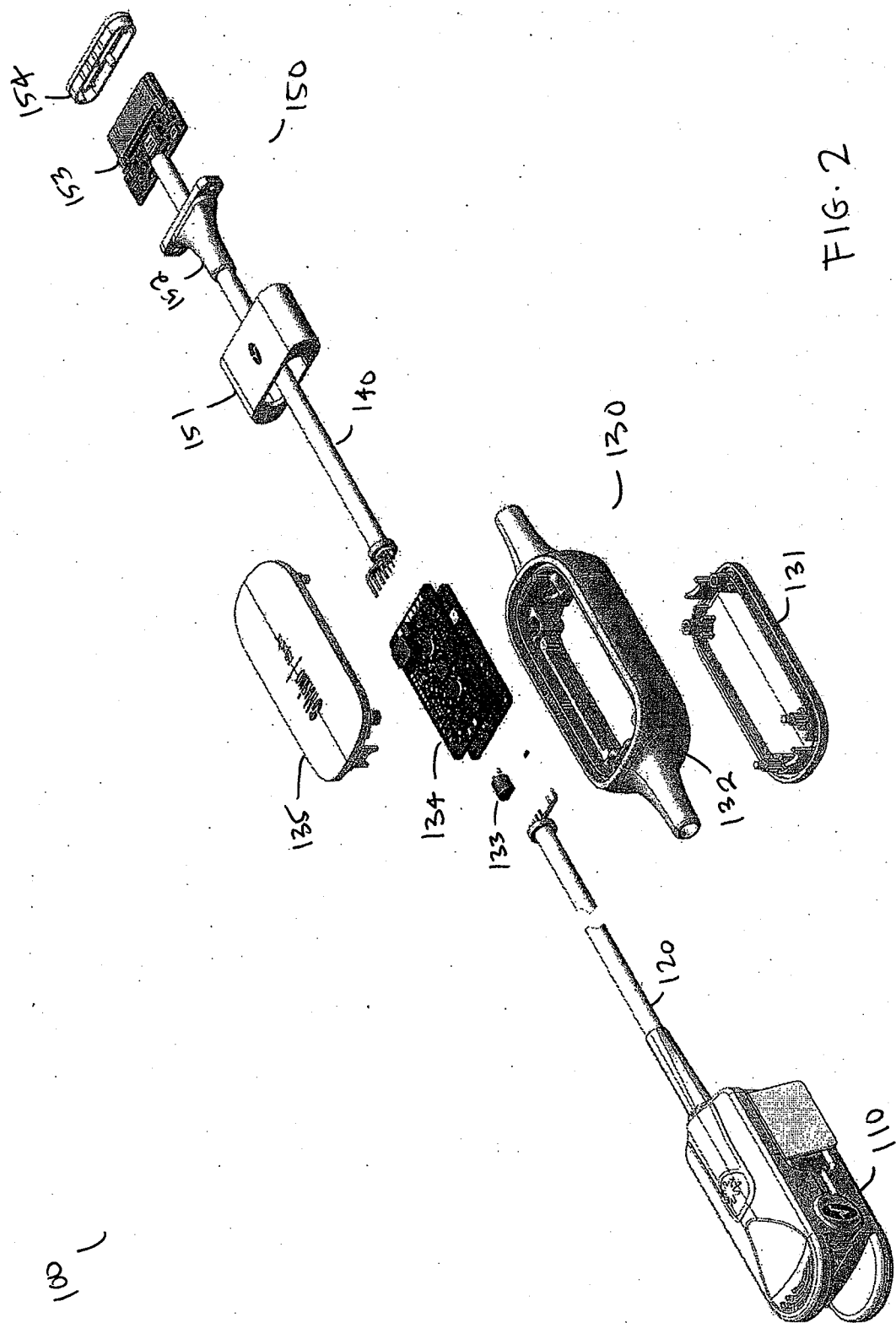


FIG. 2

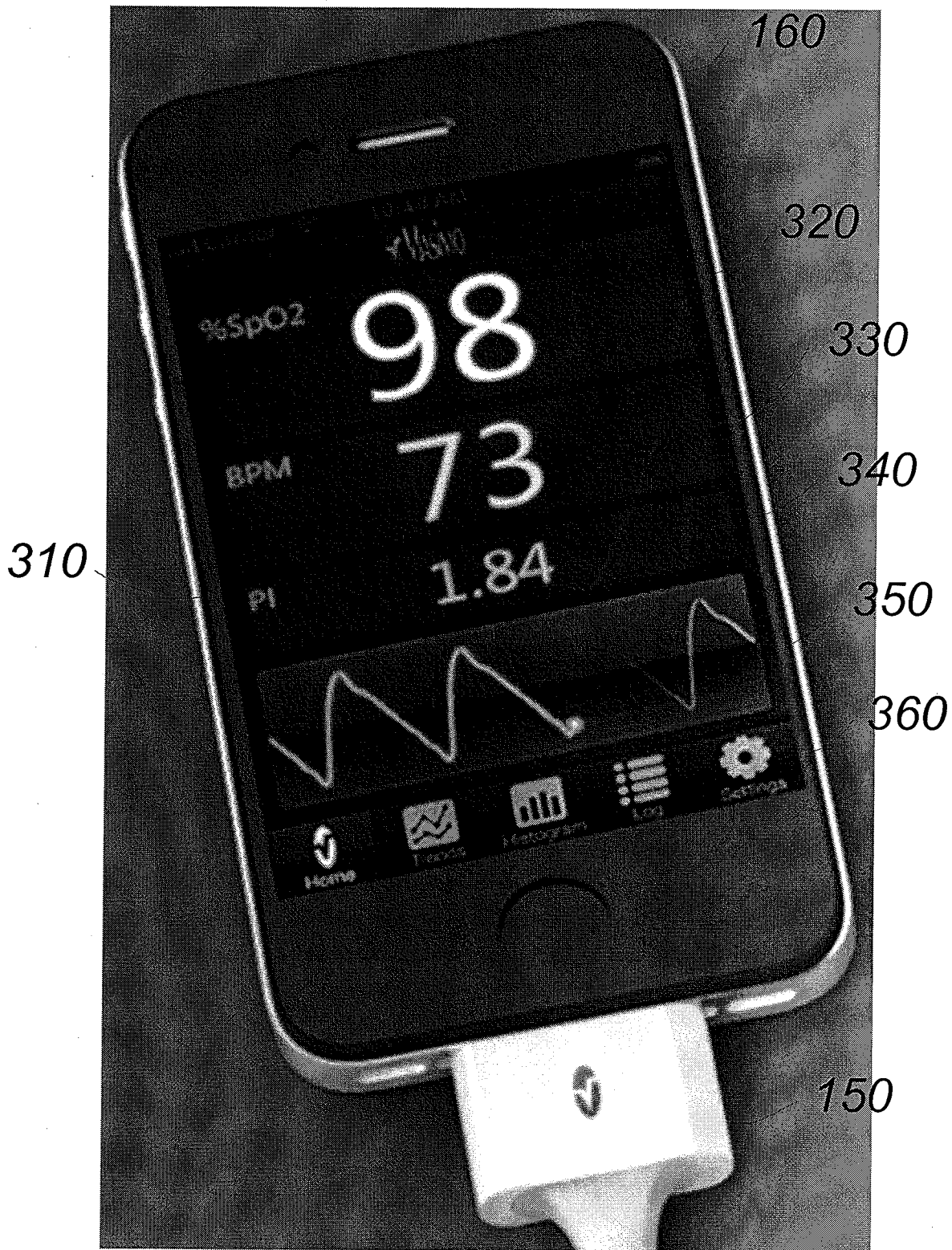


FIG. 3

Electronic Acknowledgement Receipt	
EFS ID:	13800449
Application Number:	61703729
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Title of Invention:	PATIENT MONITOR WITH MOBILE COMPUTING DEVICE CONNECTIVITY
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Payment Type	Credit Card
Payment was successfully received in RAM	\$ 250
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1		SPECIFICATION.pdf	679042	yes	13
			869bc044a362b94aa0d5cdce81aec47dbc3b059d		
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Specification		1	11	
	Claims		12	12	
	Abstract		13	13	
Warnings:					
Information:					
2	Drawings-only black and white line drawings	FIGURES.pdf	545906	no	3
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3	Provisional Cover Sheet (SB16)	Provisional_ADS_MASIMO925PR.pdf	2071714	no	3
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