

(12) **Patent Application Publication**
Al-Ali

(10) **Pub. No.: US 2017/0224233 A1**
(43) **Pub. Date: Aug. 10, 2017**

(60) Provisional application No. 60/367,428, filed on Mar. 25, 2002.

Publication Classification

(51) **Int. Cl.**

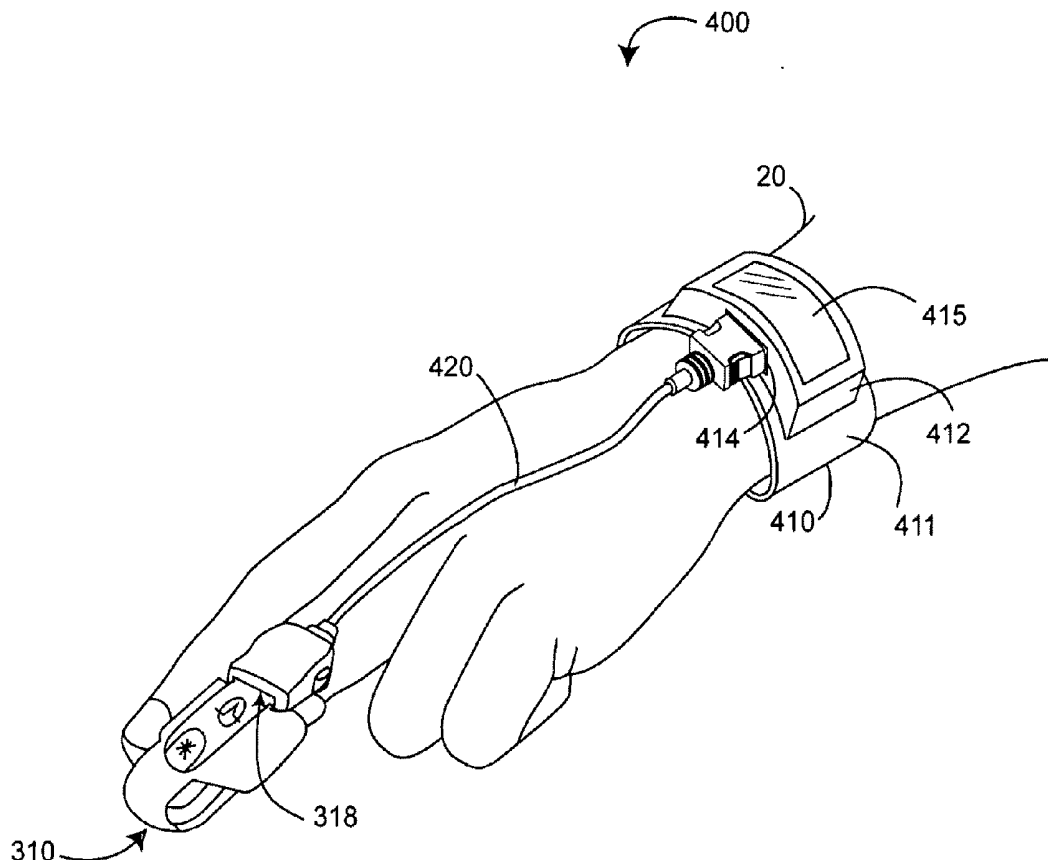
<i>A61B 5/0205</i>	(2006.01)
<i>A61B 5/1455</i>	(2006.01)
<i>A61B 5/0404</i>	(2006.01)
<i>A61B 5/00</i>	(2006.01)
<i>A61B 5/021</i>	(2006.01)

(52) **U.S. Cl.**
CPC *A61B 5/0205* (2013.01); *A61B 5/0024*
(2013.01); *A61B 5/021* (2013.01); *A61B*
5/0404 (2013.01); *A61B 5/14552* (2013.01);
A61B 5/6824 (2013.01); *A61B 5/6826*
(2013.01); *A61B 5/6831* (2013.01); *A61B*
2562/222 (2013.01); *A61B 2562/227* (2013.01)

(57) **ABSTRACT**

ABSTRACT

A sensor interface is configured to receive a sensor signal. A transmitter generates a transmit signal. A receiver receives the signal corresponding to the transmit signal. Further, a monitor interface is configured to communicate a waveform to the monitor so that measurements derived by the monitor from the waveform are generally equivalent to measurements derivable from the sensor signal.



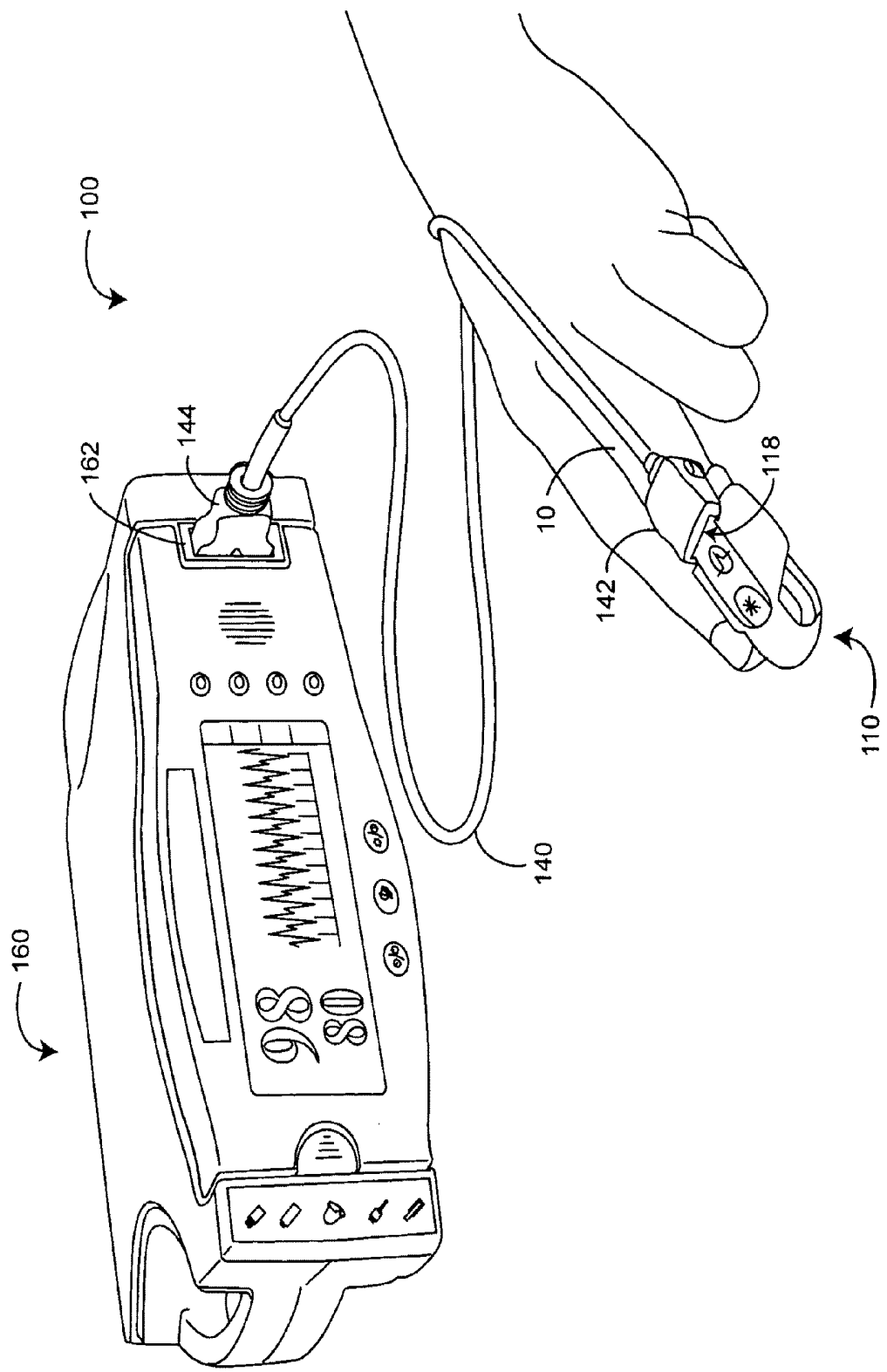


FIG. 1 (Prior Art)

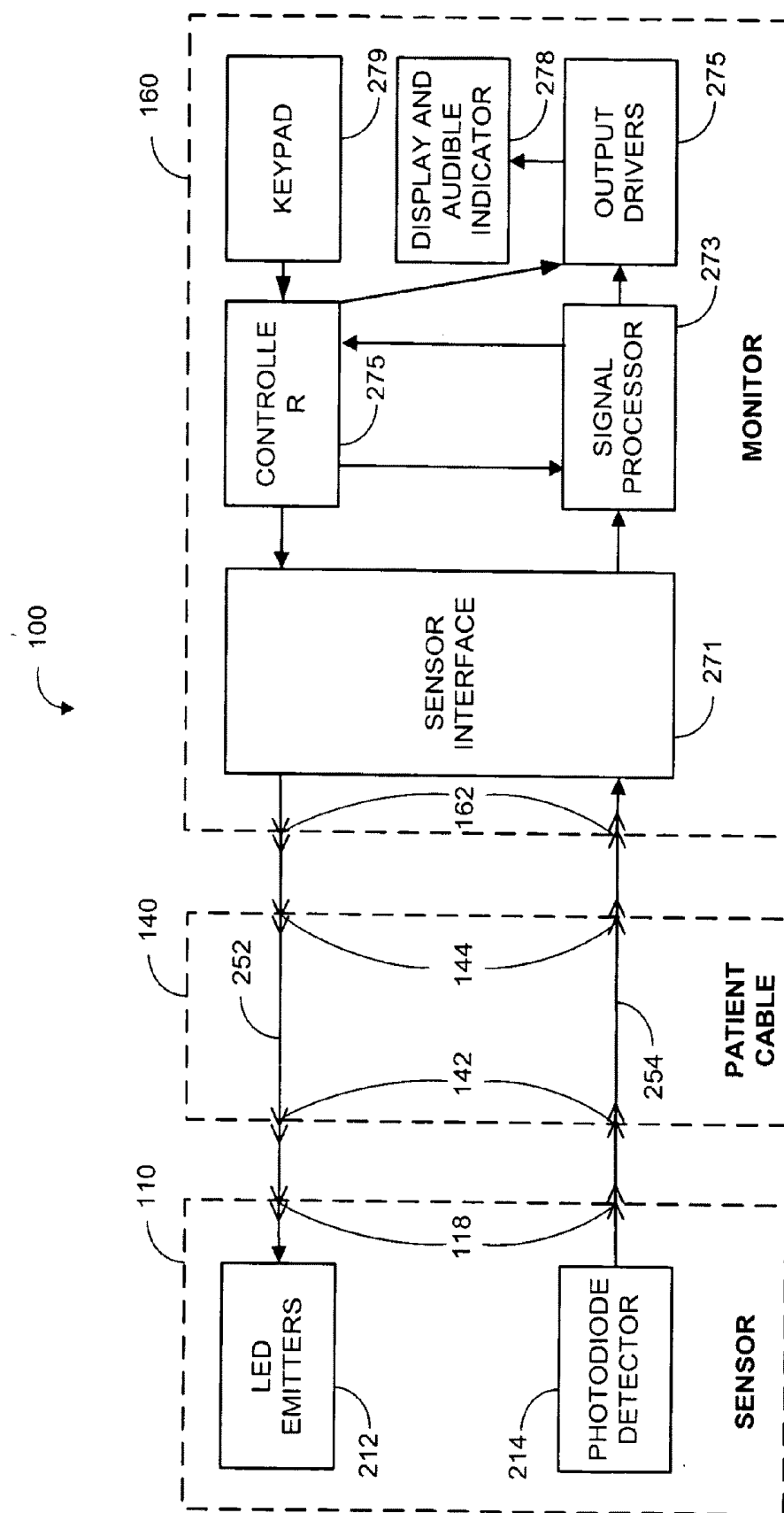


FIG. 2 (Prior Art)

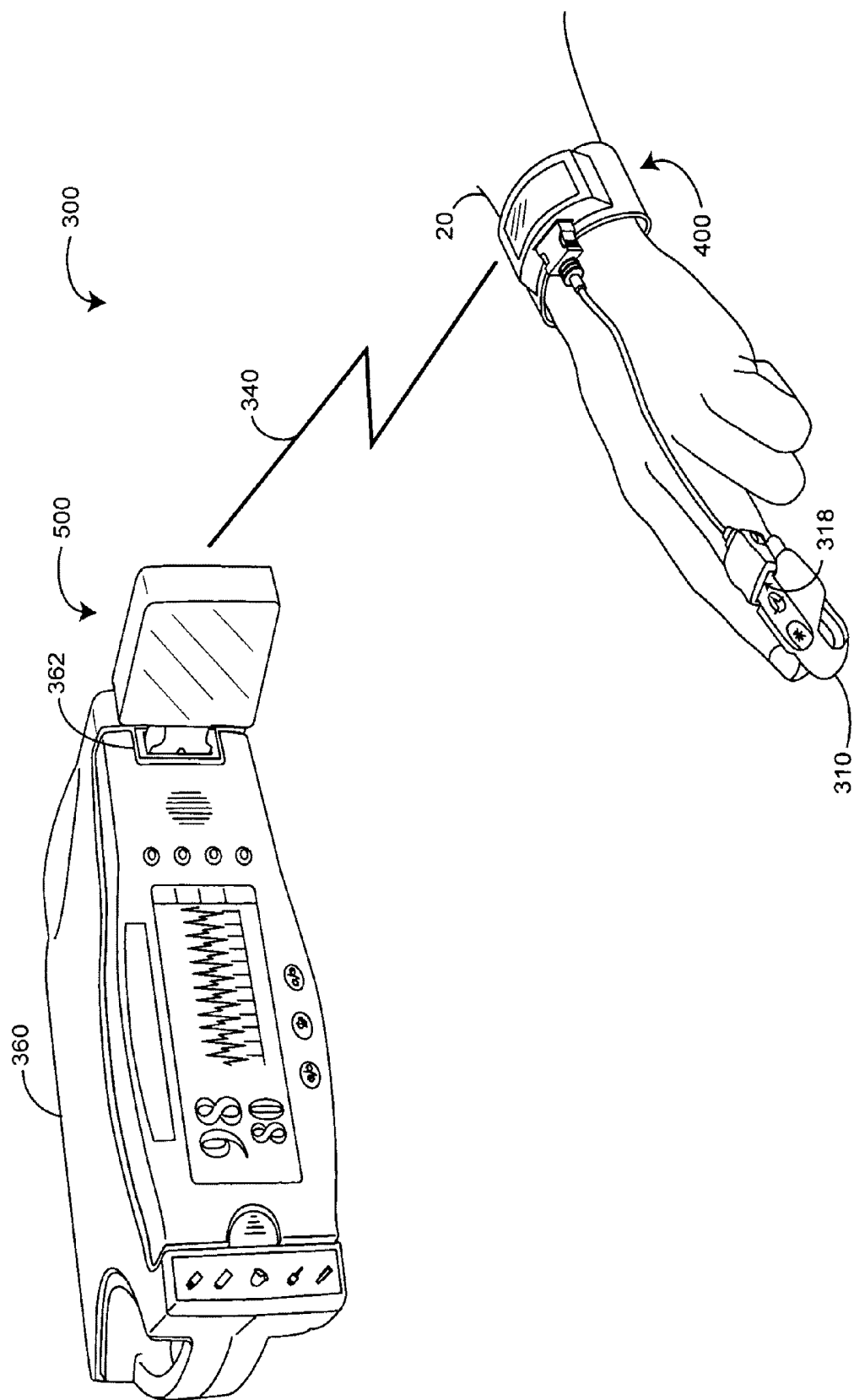


FIG. 3

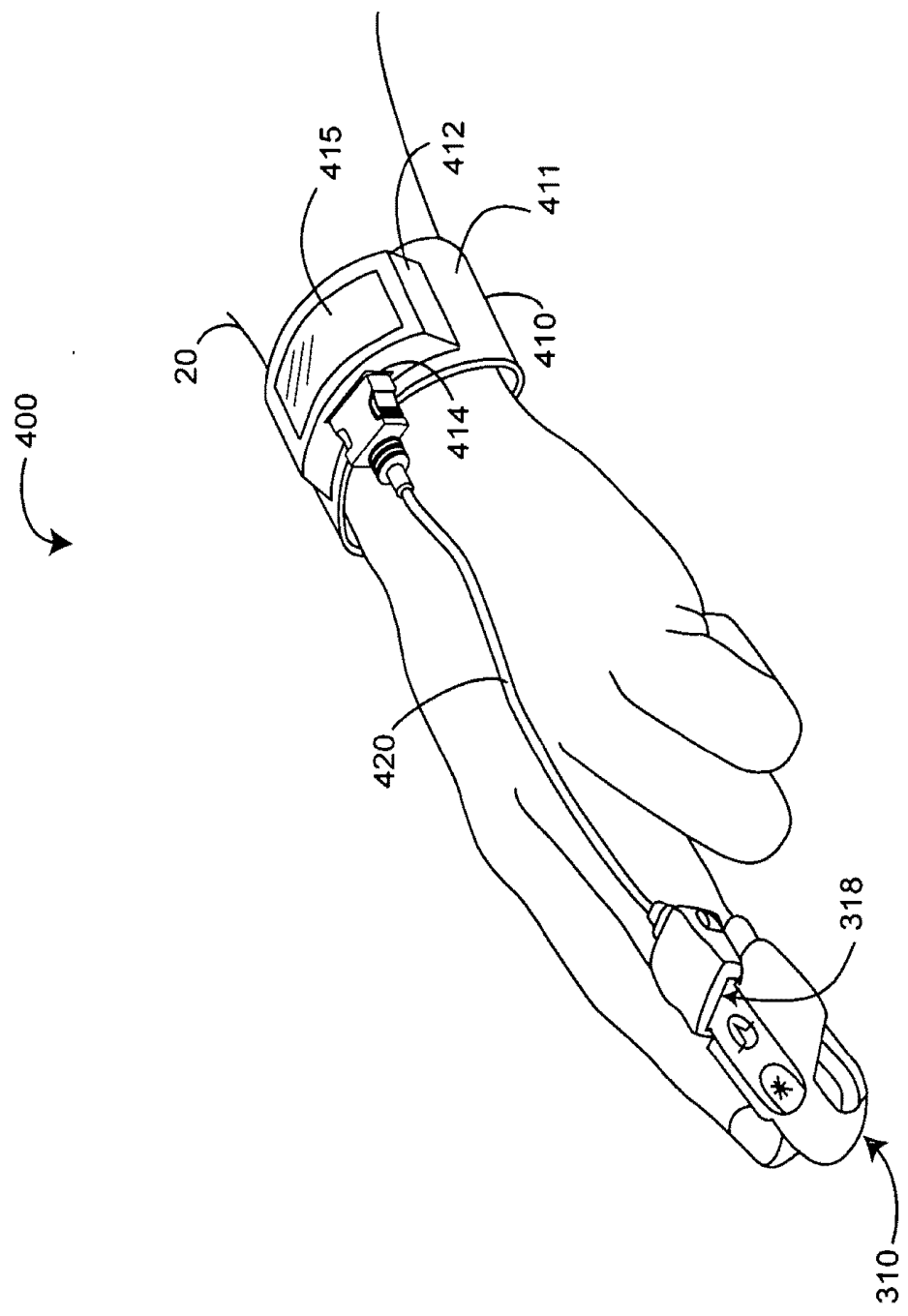


FIG. 4A

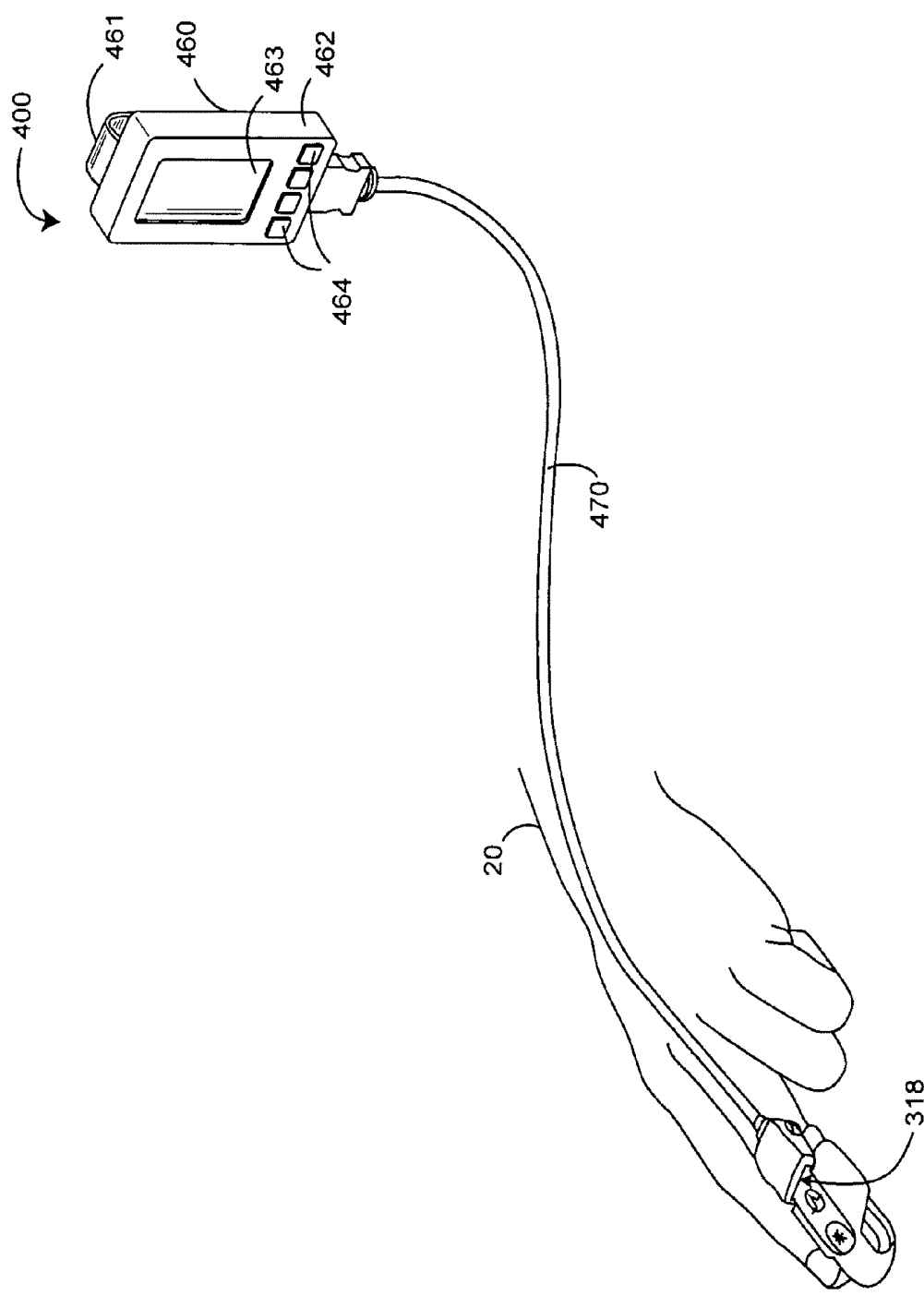


FIG. 4B

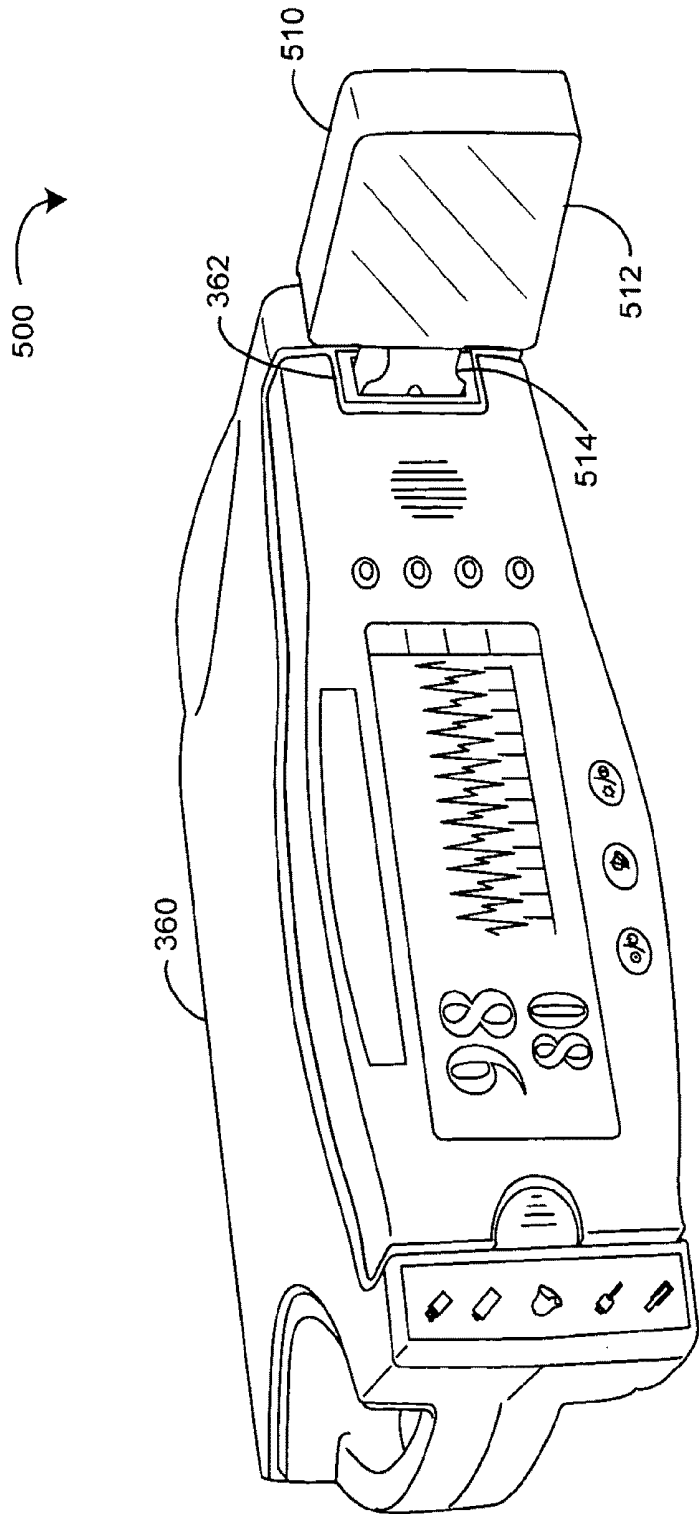


FIG. 5A

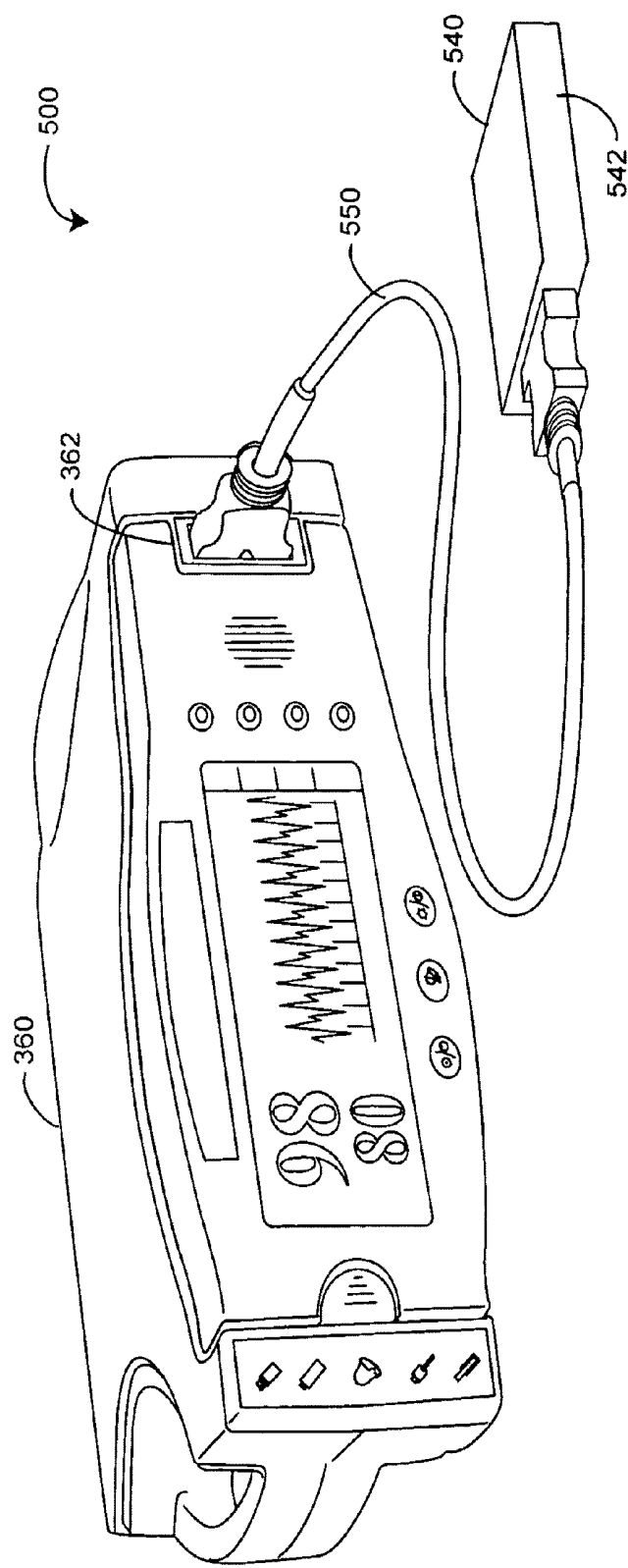


FIG. 5B

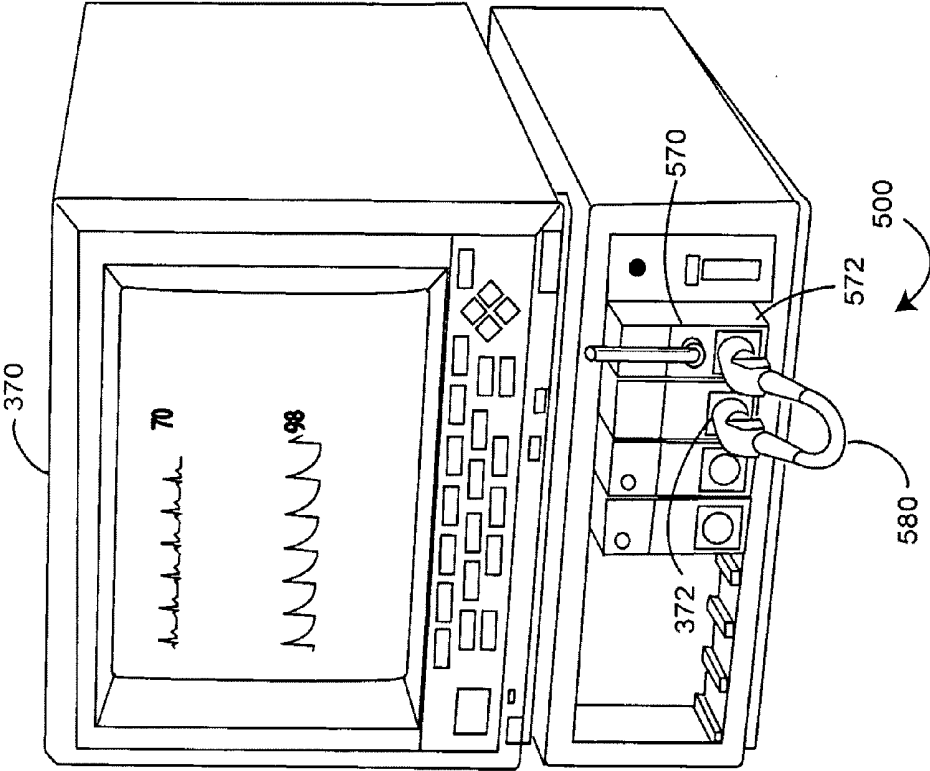


FIG. 5C

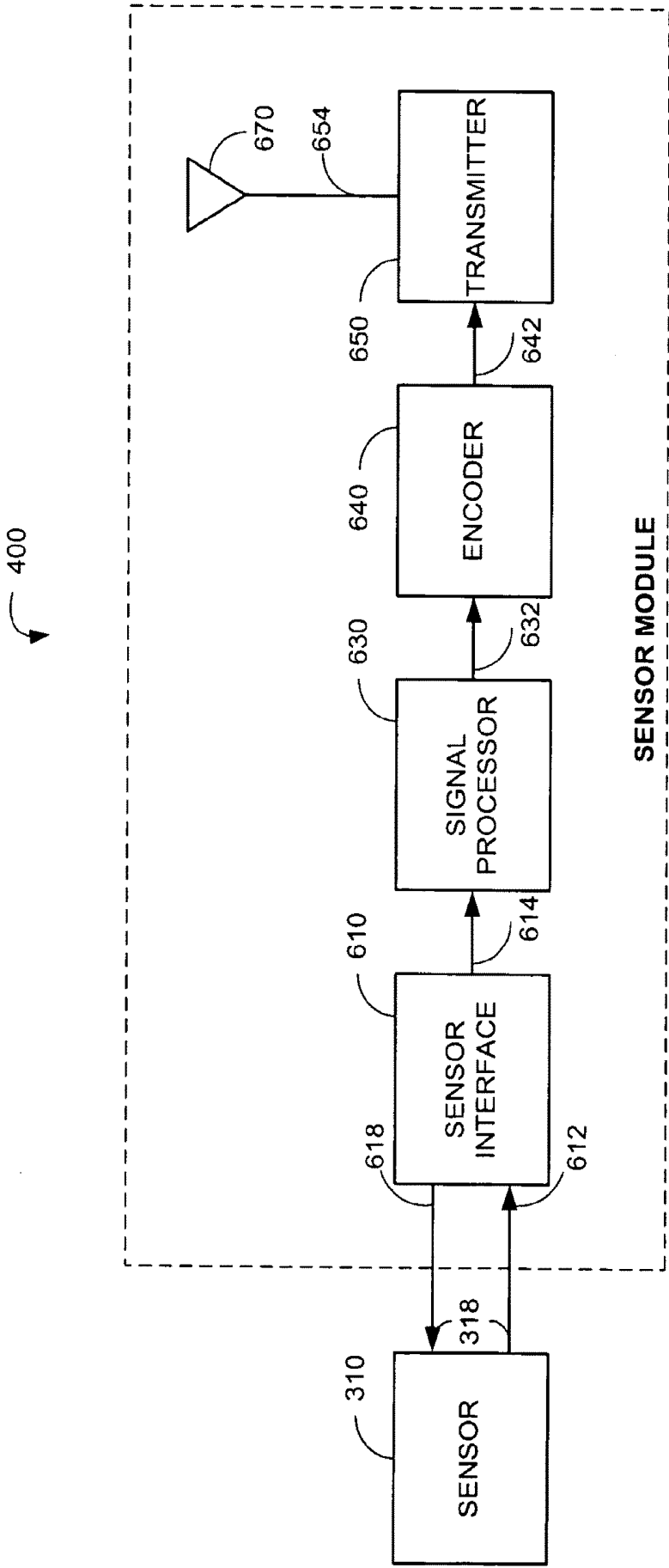


FIG. 6

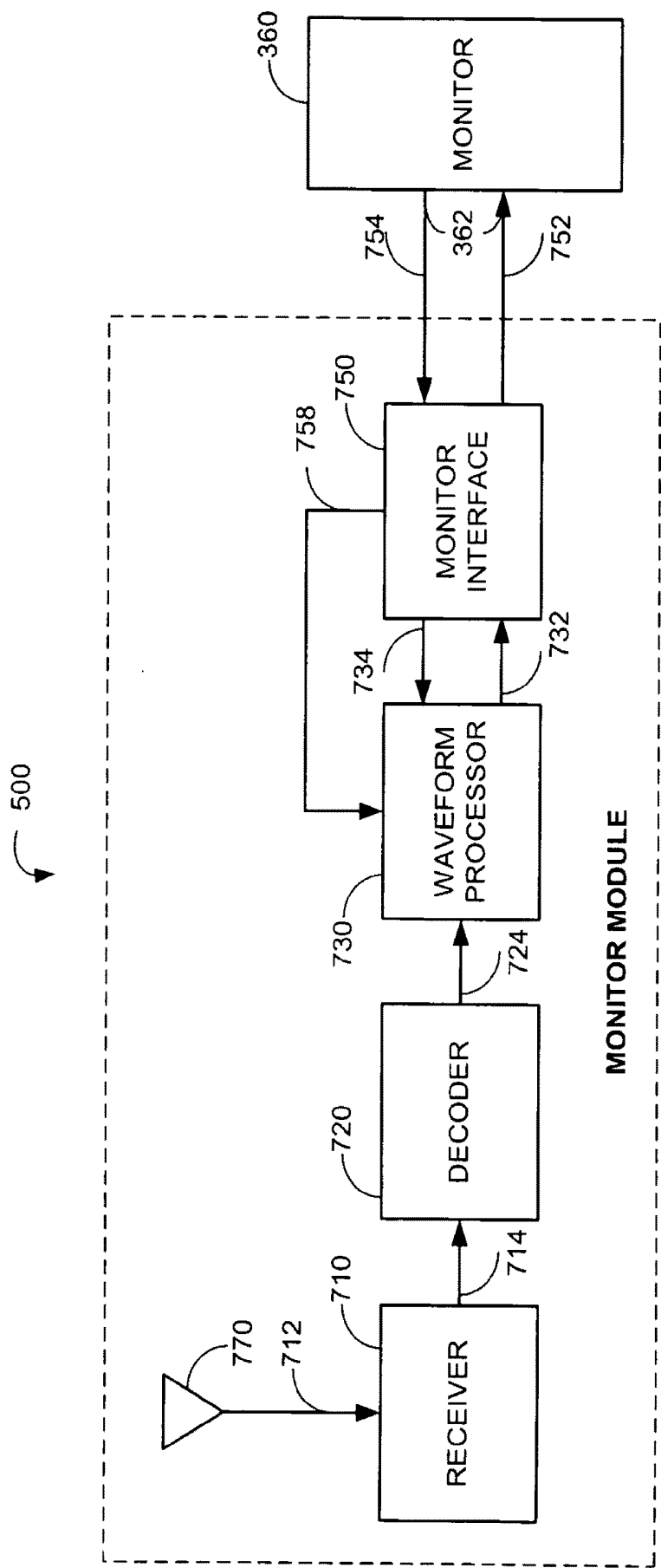


FIG. 7

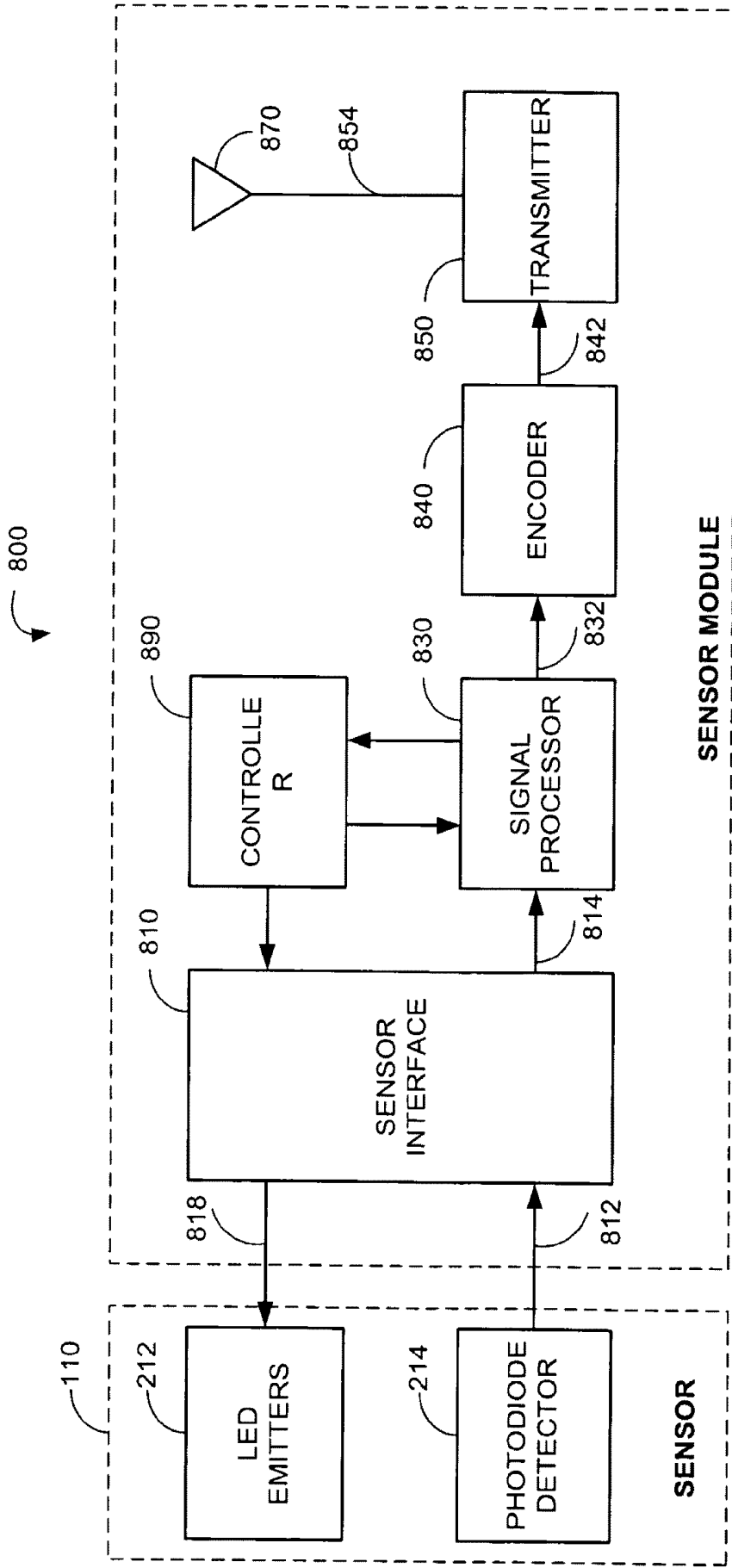


FIG. 8

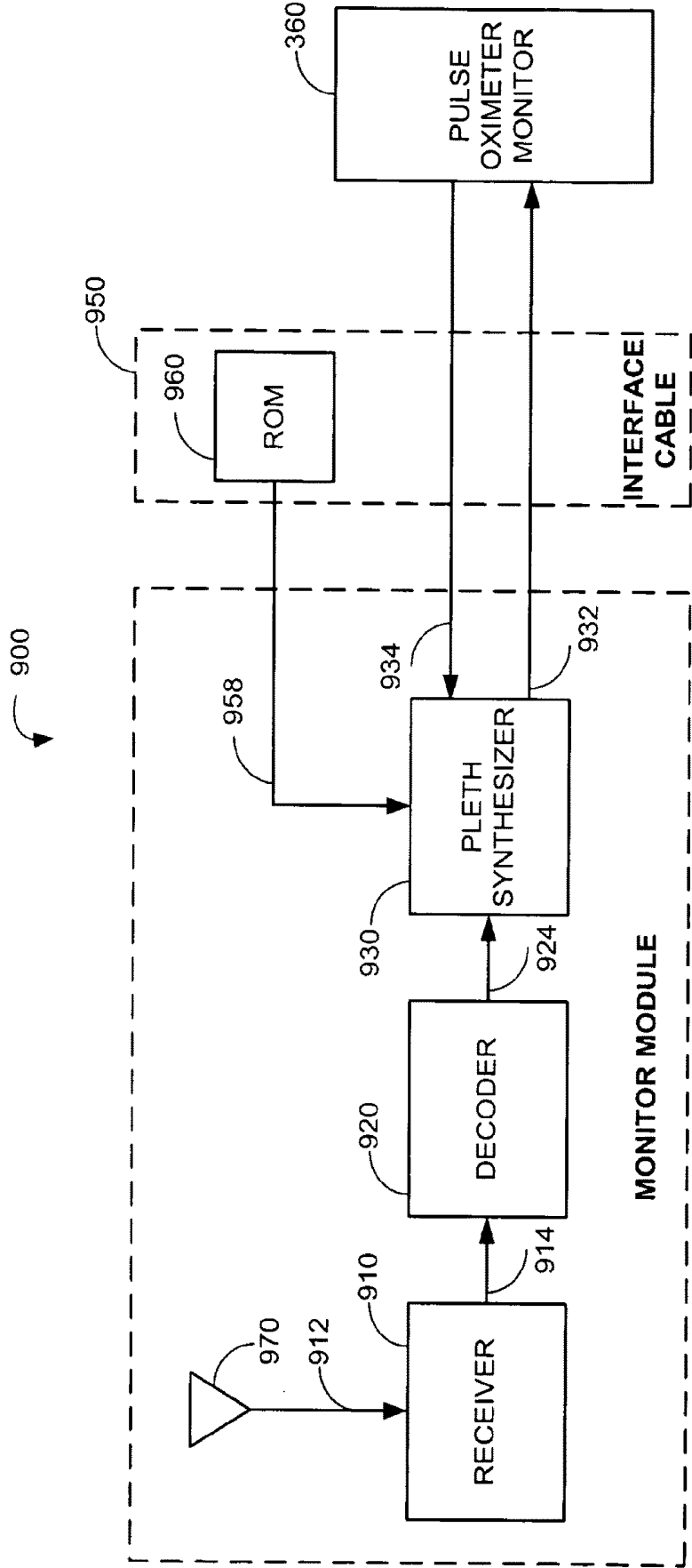


FIG. 9

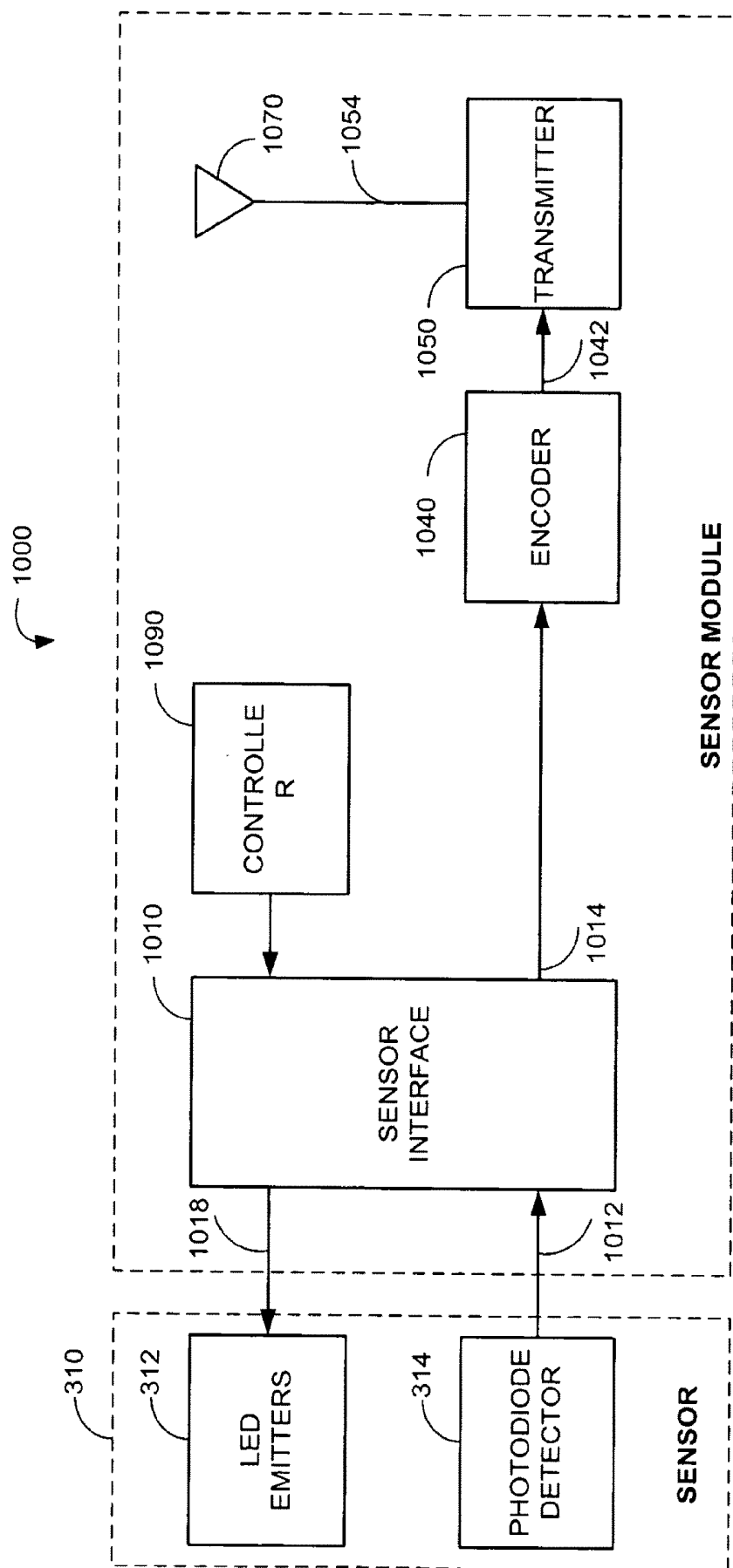


FIG. 10

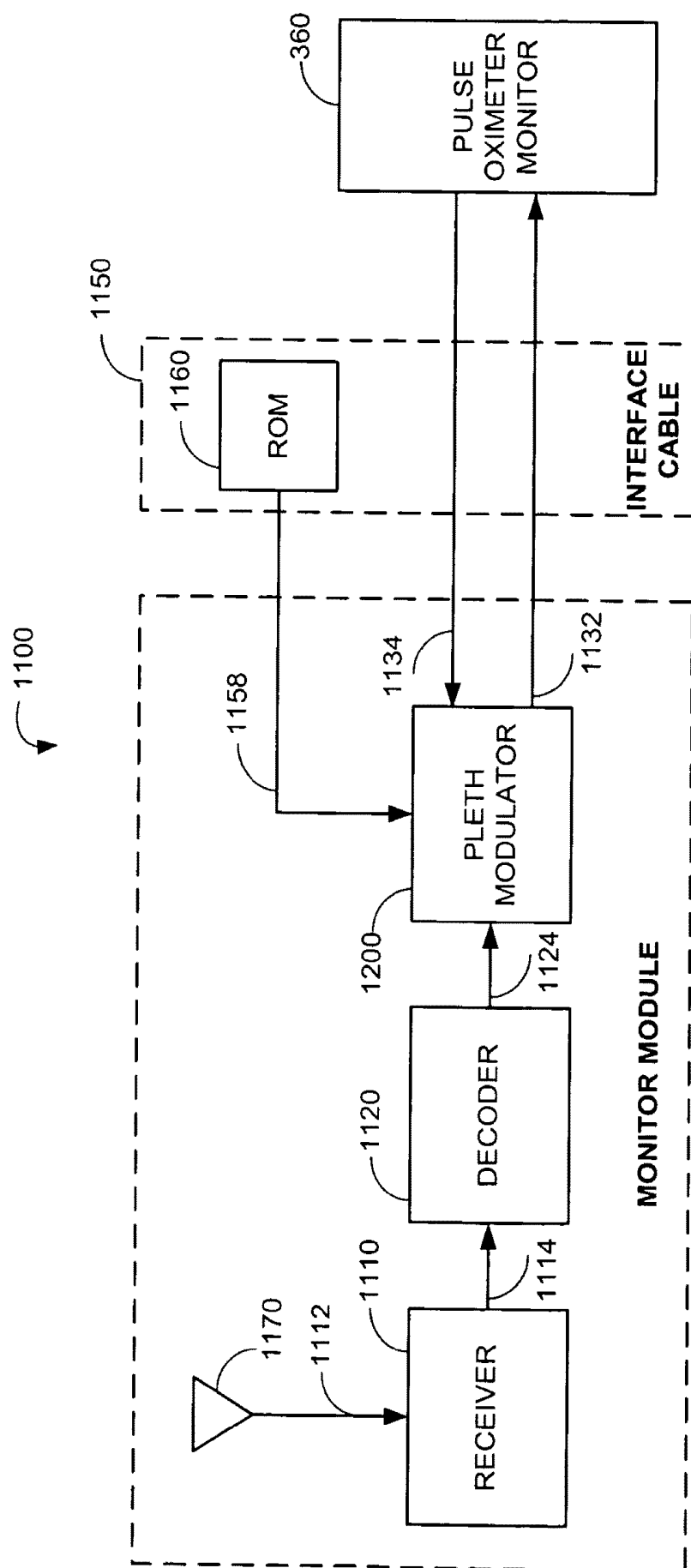


FIG. 11

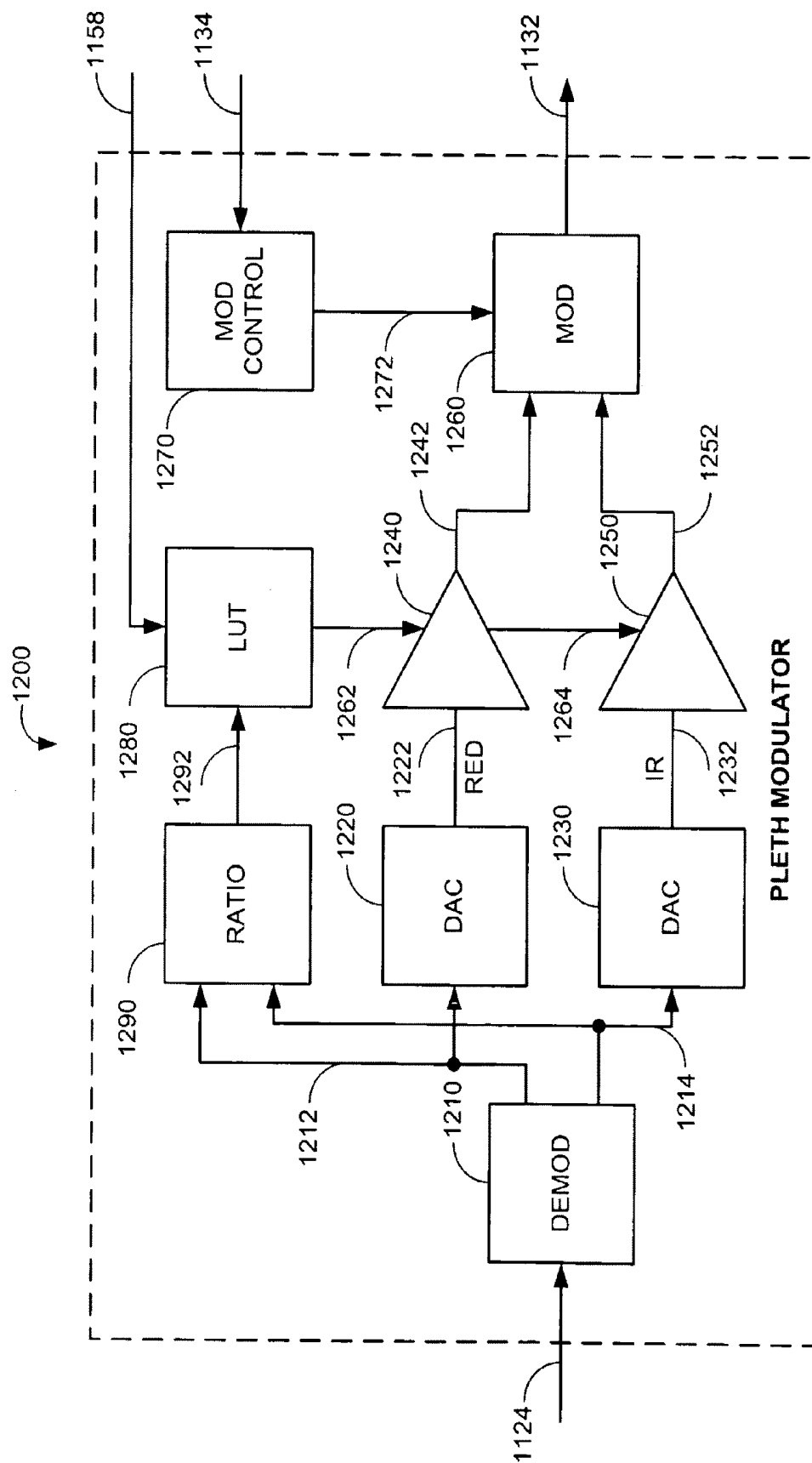


FIG. 12

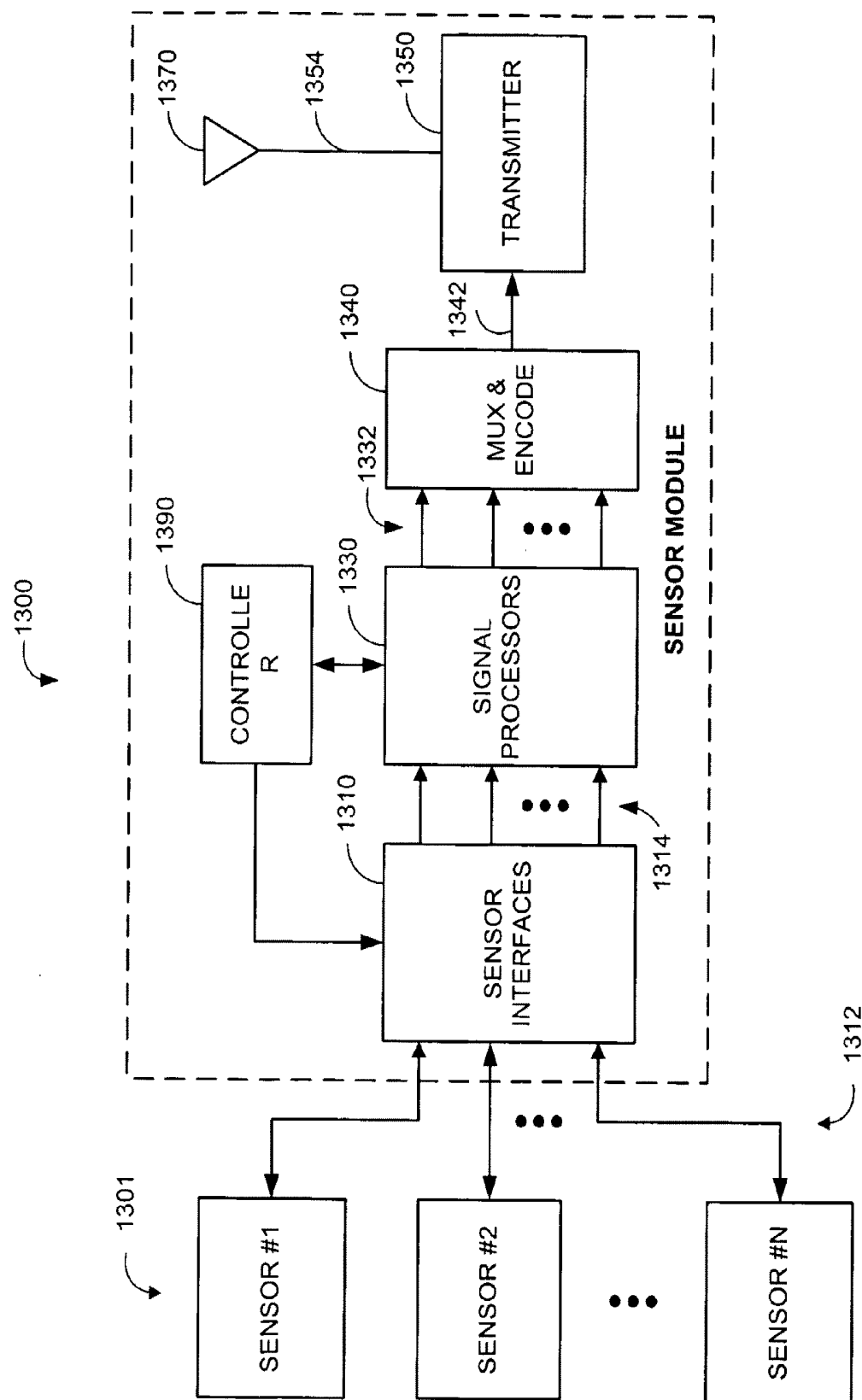


FIG. 13

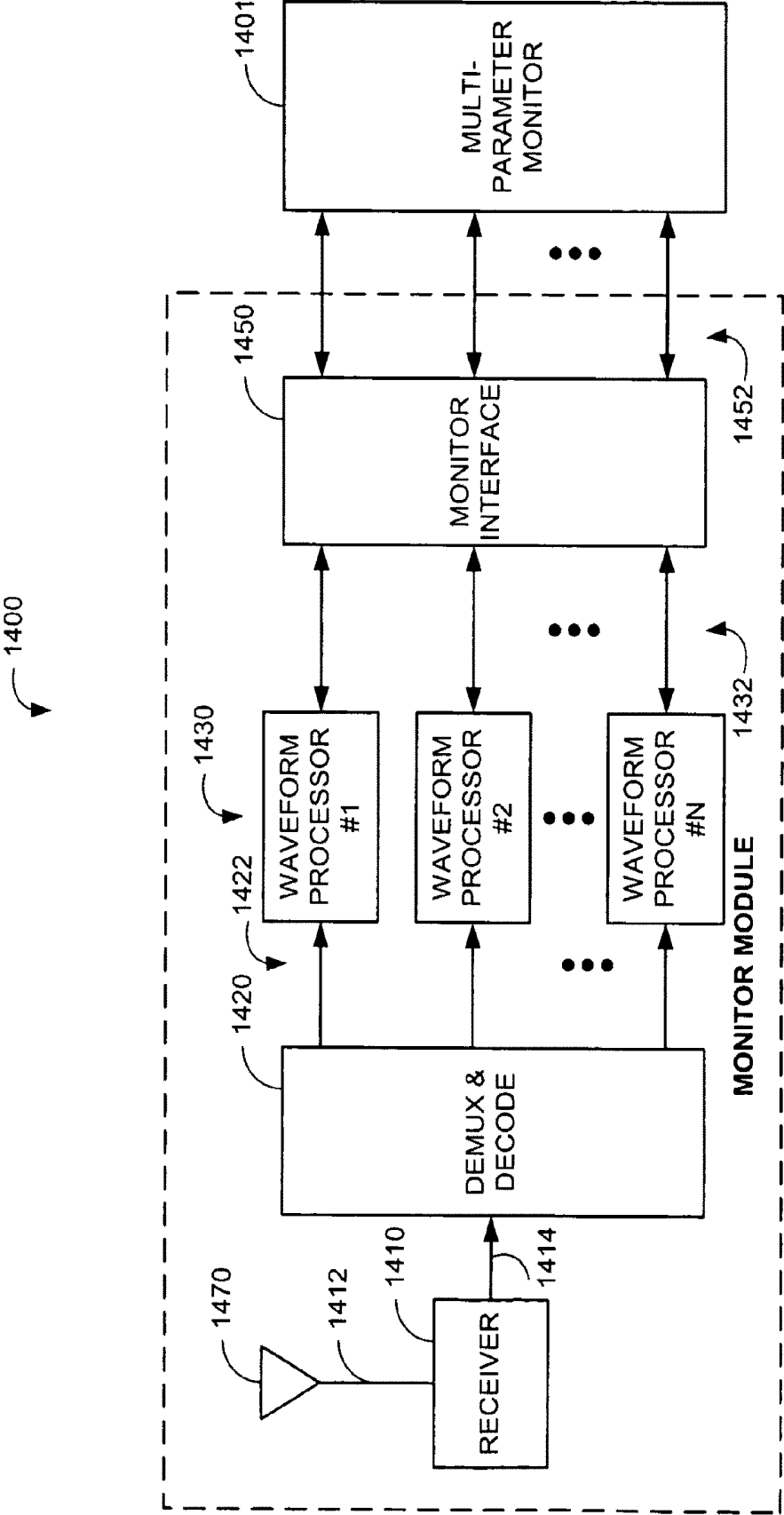


FIG. 14

BODY WORN MOBILE MEDICAL PATIENT MONITOR

REFERENCE TO RELATED APPLICATION

[0001] The present application is a continuation of U.S. patent application Ser. No. 15/448,989, filed on Mar. 3, 2017, entitled “Physiological Measurement Communications Adapter,” which is a continuation of U.S. patent application Ser. No. 14/815,232, filed on Jul. 31, 2015, entitled “Physiological Measurement Communications Adapter,” which is a continuation of U.S. patent application Ser. No. 14/217,788, filed on Mar. 18, 2014, entitled “Wrist-Mounted Physiological Measurement Device,” now U.S. Pat. No. 9,113,832, which is a continuation of U.S. patent application Ser. No. 14/037,137, filed on Sep. 25, 2013, entitled “Physiological Measurement Communications Adapter,” now U.S. Pat. No. 9,113,831, which is a continuation of U.S. patent application Ser. No. 12/955,826, filed on Nov. 29, 2010, entitled “Physiological Measurement Communications Adapter,” now U.S. Pat. No. 8,548,548, which is a continuation of U.S. patent application Ser. No. 11/417,006, filed on May 3, 2006, entitled “Physiological Measurement Communications Adapter,” now U.S. Pat. No. 7,844,315, which claims priority benefit under 35 U.S.C. §120 to, and is a continuation of, U.S. patent application Ser. No. 11/048,330, filed Feb. 1, 2005, entitled “Physiological Measurement Communications Adapter,” now U.S. Pat. No. 7,844,314, which is a continuation of U.S. patent application Ser. No. 10/377,933, entitled “Physiological Measurement Communications Adapter,” now U.S. Pat. No. 6,850,788, which claims priority benefit under 35 U.S.C. §119(e) from U.S. Provisional Application No. 60/367,428, filed Mar. 25, 2002, entitled “Physiological Measurement Communications Adapter.” The present application also incorporates the foregoing utility disclosures herein by reference.

BACKGROUND OF THE INVENTION

[0002] Patient vital sign monitoring may include measurements of blood oxygen, blood pressure, respiratory gas, and EKG among other parameters. Each of these physiological parameters typically requires a sensor in contact with a patient and a cable connecting the sensor to a monitoring device. For example, FIGS. 1-2 illustrate a conventional pulse oximetry system **100** used for the measurement of blood oxygen. As shown in FIG. 1, a pulse oximetry system has a sensor **110**, a patient cable **140** and a monitor **160**. The sensor **110** is typically attached to a finger **10** as shown. The sensor **110** has a plug **118** that inserts into a patient cable socket **142**. The monitor **160** has a socket **162** that accepts a patient cable plug **144**. The patient cable **140** transmits an LED drive signal **252** (FIG. 2) from the monitor **160** to the sensor **110** and a resulting detector signal **254** (FIG. 2) from the sensor **110** to the monitor **160**. The monitor **160** processes the detector signal **254** (FIG. 2) to provide, typically, a numerical readout of the patient's oxygen saturation, a numerical readout of pulse rate, and an audible indicator or “beep” that occurs in response to each arterial pulse.

[0003] As shown in FIG. 2, the sensor **110** has both red and infrared LED emitters **212** and a photodiode detector **214**. The monitor **160** has a sensor interface **271**, a signal processor **273**, a controller **275**, output drivers **276**, a display and audible indicator **278**, and a keypad **279**. The monitor **160** determines oxygen saturation by computing the differ-

ential absorption by arterial blood of the two wavelengths emitted by the sensor emitters **212**, as is well-known in the art. The sensor interface **271** provides LED drive current **252** which alternately activates the red and IR LED emitters **212**. The photodiode detector **214** generates a signal **254** corresponding to the red and infrared light energy attenuated from transmission through the patient finger **10** (FIG. 1). The sensor interface **271** also has input circuitry for amplification, filtering and digitization of the detector signal **254**. The signal processor **273** calculates a ratio of detected red and infrared intensities, and an arterial oxygen saturation value is empirically determined based on that ratio. The controller **275** provides hardware and software interfaces for managing the display and audible indicator **278** and keypad **279**. The display and audible indicator **278** shows the computed oxygen status, as described above, and provides the pulse beep as well as alarms indicating oxygen desaturation events. The keypad **279** provides a user interface for setting alarm thresholds, alarm enablement, and display options, to name a few.

SUMMARY OF THE INVENTION

[0004] Conventional physiological measurement systems are limited by the patient cable connection between sensor and monitor. A patient must be located in the immediate vicinity of the monitor. Also, patient relocation requires either disconnection of monitoring equipment and a corresponding loss of measurements or an awkward simultaneous movement of patient equipment and cables. Various devices have been proposed or implemented to provide wireless communication links between sensors and monitors, freeing patients from the patient cable tether. These devices, however, are incapable of working with the large installed base of existing monitors and sensors, requiring caregivers and medical institutions to suffer expensive wireless upgrades. It is desirable, therefore, to provide a communications adapter that is plug-compatible both with existing sensors and monitors and that implements a wireless link replacement for the patient cable.

[0005] An aspect of a physiological measurement communications adapter comprises a sensor interface configured to receive a sensor signal. A transmitter modulates a first baseband signal responsive to the sensor signal so as to generate a transmit signal. A receiver demodulates a receive signal corresponding to the transmit signal so as to generate a second baseband signal corresponding to the first baseband signal. Further, a monitor interface is configured to communicate a waveform responsive to the second baseband signal to a sensor port of a monitor. The waveform is adapted to the monitor so that measurements derived by the monitor from the waveform are generally equivalent to measurements derivable from the sensor signal. The communications adapter may further comprise a signal processor having an input in communications with the sensor interface, where the signal processor is operable to derive a parameter responsive to the sensor signal and where the first baseband signal is responsive to the parameter. The parameter may correspond to at least one of a measured oxygen saturation and a pulse rate.

[0006] One embodiment may further comprise a waveform generator that synthesizes the waveform from a pre-determined shape. The waveform generator synthesizes the waveform at a frequency adjusted to be generally equivalent to the pulse rate. The waveform may have a first amplitude

and a second amplitude, and the waveform generator may be configured to adjusted the amplitudes so that measurements derived by the monitor are generally equivalent to a measured oxygen saturation.

[0007] In another embodiment, the sensor interface is operable on the sensor signal to provide a plethysmograph signal output, where the first baseband signal is responsive to the plethysmograph signal. This embodiment may further comprise a waveform modulator that modifies a decoded signal responsive to the second baseband signal to provide the waveform. The waveform modulator may comprise a demodulator that separates a first signal and a second signal from the decoded signal, an amplifier that adjusts amplitudes of the first and second signals to generate a first adjusted signal and a second adjusted signal, and a modulator that combines the first and second adjusted signals into the waveform. The amplitudes of the first and second signals may be responsive to predetermined calibration data for the sensor and the monitor.

[0008] An aspect of a physiological measurement communications adapter method comprises the steps of inputting a sensor signal at a patient location, communicating patient data derived from the sensor signal between the patient location and a monitor location, constructing a waveform at the monitor location responsive to the sensor signal, and providing the waveform to a monitor via a sensor port. The waveform is constructed so that the monitor calculates a parameter generally equivalent to a measurement derivable from the sensor signal.

[0009] In one embodiment, the communicating step may comprise the substeps of deriving a conditioned signal from the sensor signal, calculating a parameter signal from the conditioned signal, and transmitting the parameter signal from the patient location to the monitor location. The constructing step may comprise the substep of synthesizing the waveform from the parameter signal. In an alternative embodiment, the communicating step may comprise the substeps of deriving a conditioned signal from said sensor signal and transmitting the conditioned signal from the patient location to the monitor location. The constructing step may comprise the substeps of demodulating the conditioned signal and re-modulating the conditioned signal to generate the waveform. The providing step may comprise the substeps of inputting a monitor signal from an LED drive output of the sensor port, modulating the waveform in response to the monitor signal, and outputting the waveform on a detector input of the sensor port.

[0010] Another aspect of a physiological measurement communications adapter comprises a sensor interface means for inputting a sensor signal and outputting a conditioned signal, a transmitter means for sending data responsive to the sensor signal, and a receiver means for receiving the data. The communications adapter further comprises a waveform processor means for constructing a waveform from the data so that measurements derived by a monitor from the waveform are generally equivalent to measurements derivable from the sensor signal, and a monitor interface means for communicating the waveform to a sensor port of the monitor. The communications adapter may further comprise a signal processor means for deriving a parameter signal from the conditioned signal, where the data comprises the parameter signal. The waveform processor means may comprise a means for synthesizing the waveform from the parameter signal. The data may comprise the conditioned signal, and

the waveform processor means may comprise a means for modulating the conditioned signal in response to the monitor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is an illustration of a prior art pulse oximetry system;

[0012] FIG. 2 is a functional block diagram of a prior art pulse oximetry system;

[0013] FIG. 3 is an illustration of a physiological measurement communications adapter;

[0014] FIGS. 4A-B are illustrations of communications adapter sensor modules;

[0015] FIGS. 5A-C are illustrations of communications adapter monitor modules;

[0016] FIG. 6 is a functional block diagram of a communications adapter sensor module;

[0017] FIG. 7 is a functional block diagram of a communications adapter monitor module;

[0018] FIG. 8 is a functional block diagram of a sensor module configured to transmit measured pulse oximeter parameters;

[0019] FIG. 9 is a functional block diagram of a monitor module configured to received measured pulse oximeter parameters;

[0020] FIG. 10 is a functional block diagram of a sensor module configured to transmit a plethysmograph;

[0021] FIG. 11 is a functional block diagram of a monitor module configured to receive a plethysmograph;

[0022] FIG. 12 is a functional block diagram of a waveform modulator;

[0023] FIG. 13 is a functional block diagram of a sensor module configured for multiple sensors; and

[0024] FIG. 14 is a functional block diagram of a monitor module configured for multiple sensors.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0025] Overview

[0026] FIG. 3 illustrates one embodiment of a communications adapter. FIGS. 4-5 illustrate physical configurations for a communications adapter. In particular, FIGS. 4A-B illustrate sensor module configurations and FIGS. 5A-C illustrate monitor module configurations. FIGS. 6-14 illustrate communications adapter functions. In particular, FIGS. 6-7 illustrate general functions for a sensor module and a monitor module, respectively. FIGS. 8-9 functionally illustrate a communications adapter where derived pulse oximetry parameters, such as saturation and pulse rate are transmitted between a sensor module and a monitor module. Also, FIGS. 10-12 functionally illustrate a communications adapter where a plethysmograph is transmitted between a sensor module and a monitor module. FIGS. 13-14 functionally illustrate a multiple-parameter communications adapter.

[0027] FIG. 3 illustrates a communications adapter 300 having a sensor module 400 and a monitor module 500. The communications adapter 300 communicates patient data derived from a sensor 310 between the sensor module 400, which is located proximate a patient 20 and the monitor module 500, which is located proximate a monitor 360. A wireless link 340 is provided between the sensor module 400 and the monitor module 500, replacing the conventional

patient cable, such as a pulse oximetry patient cable 140 (FIG. 1). Advantageously, the sensor module 400 is plug-compatible with a conventional sensor 310. In particular, the sensor connector 318 connects to the sensor module 400 in a similar manner as to a patient cable. Further, the sensor module 400 outputs a drive signal to the sensor 310 and inputs a sensor signal from the sensor 310 in an equivalent manner as a conventional monitor 360. The sensor module 400 may be battery powered or externally powered. External power may be for recharging internal batteries or for powering the sensor module during operation or both.

[0028] As shown in FIG. 3, the monitor module 500 is advantageously plug-compatible with a conventional monitor 360. In particular, the monitor's sensor port 362 connects to the monitor module 500 in a similar manner as to a patient cable, such as a pulse oximetry patient cable 140 (FIG. 1). Further, the monitor module 500 inputs a drive signal from the monitor 360 and outputs a corresponding sensor signal to the monitor 360 in an equivalent manner as a conventional sensor 310. As such, the combination sensor module 400 and monitor module 500 provide a plug-compatible wireless replacement for a patient cable, adapting an existing wired physiological measurement system into a wireless physiological measurement system. The monitor module 500 may be battery powered, powered from the monitor, such as by tapping current from a monitor's LED drive, or externally powered from an independent AC or DC power source.

[0029] Although a communications adapter 300 is described herein with respect to a pulse oximetry sensor and monitor, one of ordinary skill in the art will recognize that a communications adapter may provide a plug-compatible wireless replace for a patient cable that connects any physiological sensor and corresponding monitor. For example, a communications adapter 300 may be applied to a biopotential sensor, a non-invasive blood pressure (NIBP) sensor, a respiratory rate sensor, a glucose sensor and the corresponding monitors, to name a few.

Sensor Module Physical Configurations

[0030] FIGS. 4A-B illustrate physical embodiments of a sensor module 400. FIG. 4A illustrates a wrist-mounted module 410 having a wrist strap 411, a case 412 and an auxiliary cable 420. The case 412 contains the sensor module electronics, which are functionally described with respect to FIG. 6, below. The case 412 is mounted to the wrist strap 411, which attaches the wrist-mounted module 410 to a patient 20. The auxiliary cable 420 mates to a sensor connector 318 and a module connector 414, providing a wired link between a conventional sensor 310 and the wrist-mounted module 410. Alternatively, the auxiliary cable 420 is directly wired to the sensor module 400. The wrist-mounted module 410 may have a display 415 that shows sensor measurements, module status and other visual indicators, such as monitor status. The wrist-mounted module 410 may also have keys (not shown) or other input mechanisms to control its operational mode and characteristics. In an alternative embodiment, the sensor 310 may have a tail (not shown) that connects directly to the wrist-mounted module 410, eliminating the auxiliary cable 420.

[0031] FIG. 4B illustrates a clip-on module 460 having a clip 461, a case 462 and an auxiliary cable 470. The clip 461 attaches the clip-on module 460 to patient clothing or objects near a patient 20, such as a bed frame. The auxiliary cable 470 mates to the sensor connector 318 and functions

as for the auxiliary cable 420 (FIG. 4A) of the wrist-mounted module 410 (FIG. 4A), described above. The clip-on module 460 may have a display 463 and keys 464 as for the wrist-mounted module 410 (FIG. 4A). Either the wrist-mounted module 410 or the clip-on module 460 may have other input or output ports (not shown) that download software, configure the module, or provide a wired connection to other measurement instruments or computing devices, to name a few examples.

Monitor Module Physical Configurations

[0032] FIGS. 5A-C illustrate physical embodiments of a monitor module 500. FIG. 5A illustrates a direct-connect module 510 having a case 512 and an integrated monitor connector 514. The case 512 contains the monitor module electronics, which are functionally described with respect to FIG. 7, below. The monitor connector 514 mimics that of the monitor end of a patient cable, such as a pulse oximetry patient cable 140 (FIG. 1), and electrically and mechanically connects the monitor module 510 to the monitor 360 via the monitor's sensor port 362.

[0033] FIG. 5B illustrates a cable-connect module 540 having a case 542 and an auxiliary cable 550. The case 542 functions as for the direct-connect module 510 (FIG. 5A), described above. Instead of directly plugging into the monitor 360, the cable-connect module 540 utilizes the auxiliary cable 550, which mimics the monitor end of a patient cable, such as a pulse oximetry patient cable 140 (FIG. 1), and electrically connects the cable-connect module 540 to the monitor sensor port 362.

[0034] FIG. 5C illustrates a plug-in module 570 having a plug-in case 572 and an auxiliary cable 580. The plug-in case 572 is mechanically compatible with the plug-in chassis of a multiparameter monitor 370 and may or may not electrically connect to the chassis backplane. The auxiliary cable 580 mimics a patient cable and electrically connects the plug-in module 570 to the sensor port 372 of another plug-in device. A direct-connect module 510 (FIG. 5A) or a cable-connect module 540 (FIG. 5B) may also be used with a multiparameter monitor 370.

[0035] In a multiparameter embodiment, such as described with respect to FIGS. 13-14, below, a monitor module 500 may connect to multiple plug-in devices of a multiparameter monitor 370. For example, a cable-connect module 540 (FIG. 5B) may have multiple auxiliary cables 550 (FIG. 5B) that connect to multiple plug-in devices installed within a multiparameter monitor chassis. Similarly, a plug-in module 570 may have one or more auxiliary cables 580 with multiple connectors for attaching to the sensor ports 372 of multiple plug-in devices.

Communications Adapter Functions

[0036] FIGS. 6-7 illustrate functional embodiments of a communications adapter. FIG. 6 illustrates a sensor module 400 having a sensor interface 610, a signal processor 630, an encoder 640, a transmitter 650 and a transmitting antenna 670. A physiological sensor 310 provides an input sensor signal 612 at the sensor connector 318. Depending on the sensor 310, the sensor module 400 may provide one or more drive signals 618 to the sensor 310. The sensor interface 610 inputs the sensor signal 612 and outputs a conditioned signal 614. The conditioned signal 614 may be coupled to the transmitter 650 or further processed by a signal processor

630. If the sensor module configuration utilizes a signal processor **630**, it derives a parameter signal **632** responsive to the sensor signal **612**, which is then coupled to the transmitter **650**. Regardless, the transmitter **650** inputs a baseband signal **642** that is responsive to the sensor signal **612**. The transmitter **650** modulates the baseband signal **642** with a carrier to generate a transmit signal **654**. The transmit signal **654** may be derived by various amplitude, frequency or phase modulation schemes, as is well known in the art. The transmit signal **654** is coupled to the transmit antenna **670**, which provides wireless communications to a corresponding receive antenna **770** (FIG. 7), as described below.

[0037] As shown in FIG. 6, the sensor interface **610** conditions and digitizes the sensor signal **612** to generate the conditioned signal **614**. Sensor signal conditioning may be performed in the analog domain or digital domain or both and may include amplification and filtering in the analog domain and filtering, buffering and data rate modification in the digital domain, to name a few. The resulting conditioned signal **614** is responsive to the sensor signal **612** and may be used to calculate or derive a parameter signal **632**.

[0038] Further shown in FIG. 6, the signal processor **630** performs signal processing on the conditioned signal **614** to generate the parameter signal **632**. The signal processing may include buffering, digital filtering, smoothing, averaging, adaptive filtering and frequency transforms to name a few. The resulting parameter signal **632** may be a measurement calculated or derived from the conditioned signal, such as oxygen saturation, pulse rate, blood glucose, blood pressure and EKG to name a few. Also, the parameter signal **632** may be an intermediate result from which the above-stated measurements may be calculated or derived.

[0039] As described above, the sensor interface **610** performs mixed analog and digital pre-processing of an analog sensor signal and provides a digital output signal to the signal processor **630**. The signal processor **630** then performs digital post-processing of the front-end processor output. In alternative embodiments, the input sensor signal **612** and the output conditioned signal **614** may be either analog or digital, the front-end processing may be purely analog or purely digital, and the back-end processing may be purely analog or mixed analog or digital.

[0040] In addition, FIG. 6 shows an encoder **640**, which translates a digital word or serial bit stream, for example, into the baseband signal **642**, as is well-known in the art. The baseband signal **642** comprises the symbol stream that drives the transmit signal **654** modulation, and may be a single signal or multiple related signal components, such as in-phase and quadrature signals. The encoder **640** may include data compression and redundancy, also well-known in the art.

[0041] FIG. 7 illustrates a monitor module **500** having a receive antenna **770**, a receiver **710**, a decoder **720**, a waveform processor **730** and a monitor interface **750**. A receive signal **712** is coupled from the receive antenna **770**, which provides wireless communications to a corresponding transmit antenna **670** (FIG. 6), as described above. The receiver **710** inputs the receive signal **712**, which corresponds to the transmit signal **654** (FIG. 6). The receiver **710** demodulates the receive signal to generate a baseband signal **714**. The decoder **720** translates the symbols of the demodulated baseband signal **714** into a decoded signal **724**, such as a digital word stream or bit stream. The waveform processor **730** inputs the decoded signal **724** and generates a con-

structed signal **732**. The monitor interface **750** is configured to communicate the constructed signal **732** to a sensor port **362** of a monitor **360**. The monitor **360** may output a sensor drive signal **754**, which the monitor interface **750** inputs to the waveform processor **730** as a monitor drive signal **734**. The waveform processor **730** may utilize the monitor drive signal **734** to generate the constructed signal **732**. The monitor interface **750** may also provide characterization information **758** to the waveform processor **730**, relating to the monitor **360**, the sensor **310** or both, that the waveform processor **730** utilizes to generate the constructed signal **732**.

[0042] The constructed signal **732** is adapted to the monitor **360** so that measurements derived by the monitor **360** from the constructed signal **732** are generally equivalent to measurements derivable from the sensor signal **612** (FIG. 6). Note that the sensor **310** (FIG. 6) may or may not be directly compatible with the monitor **360**. If the sensor **310** (FIG. 6) is compatible with the monitor **360**, the constructed signal **732** is generated so that measurements derived by the monitor **360** from the constructed signal **732** are generally equivalent (within clinical significance) with those derivable directly from the sensor signal **612** (FIG. 6). If the sensor **310** (FIG. 6) is not compatible with the monitor **360**, the constructed signal **732** is generated so that measurements derived by the monitor **360** from the constructed signal **732** are generally equivalent to those derivable directly from the sensor signal **612** (FIG. 6) using a compatible monitor.

Wireless Pulse Oximetry

[0043] FIGS. 8-11 illustrate pulse oximeter embodiments of a communications adapter. FIGS. 8-9 illustrate a sensor module and a monitor module, respectively, configured to communicate measured pulse oximeter parameters. FIG. 10-11 illustrate a sensor module and a monitor module, respectively, configured to communicate a plethysmograph signal.

Parameter Transmission

[0044] FIG. 8 illustrates a pulse oximetry sensor module **800** having a sensor interface **810**, signal processor **830**, encoder **840**, transmitter **850**, transmitting antenna **870** and controller **890**. The sensor interface **810**, signal processor **830** and controller **890** function as described with respect to FIG. 2, above. The sensor interface **810** communicates with a standard pulse oximetry sensor **310**, providing an LED drive signal **818** to the LED emitters **312** and receiving a sensor signal **812** from the detector **314** in response. The sensor interface **810** provides front-end processing of the sensor signal **812**, also described above, providing a plethysmograph signal **814** to the signal processor **830**. The signal processor **830** then derives a parameter signal **832** that comprises a real time measurement of oxygen saturation and pulse rate. The parameter signal **832** may include other parameters, such as measurements of perfusion index and signal quality. In one embodiment, the signal processor is an MS-5 or MS-7 board available from Masimo Corporation, Irvine, Calif.

[0045] As shown in FIG. 8, the encoder **840**, the transmitter **850** and the transmitting antenna **870** function as described with respect to FIG. 6, above. For example, the parameter signal **832** may be a digital word stream that is serialized into a bit stream and encoded into a baseband signal **842**. The baseband signal **842** may be, for example,

two bit symbols that drive a quadrature phase shift keyed (QPSK) modulator in the transmitter 850. Other encodings and modulations are also applicable, as described above. The transmitter 850 inputs the baseband signal 842 and generates a transmit signal 854 that is a modulated carrier having a frequency suitable for short-range transmission, such as within a hospital room, doctor's office, emergency vehicle or critical care ward, to name a few. The transmit signal 854 is coupled to the transmit antenna 870, which provides wireless communications to a corresponding receive antenna 970 (FIG. 9), as described below.

[0046] FIG. 9 illustrates a monitor module 900 having a receive antenna 970, a receiver 910, a decoder 920, a waveform generator 930 and an interface cable 950. The receive antenna 970, receiver 910 and decoder 920 function as described with respect to FIG. 7, above. In particular, the receive signal 912 is coupled from the receive antenna 970, which provides wireless communications to a corresponding transmit antenna 870 (FIG. 8). The receiver 910 inputs the receive signal 912, which corresponds to the transmit signal 854 (FIG. 8). The receiver 910 demodulates the receive signal 912 to generate a baseband signal 914. Not accounting for transmission errors, the baseband signal 914 corresponds to the sensor module baseband signal 842 (FIG. 8), for example a symbol stream of two bits each. The decoder 920 assembles the baseband signal 914 into a parameter signal 924, which, for example, may be a sequence of digital words corresponding to oxygen saturation and pulse rate. Again, not accounting for transmission errors, the monitor module parameter signal 924 corresponds to the sensor module parameter signal 832 (FIG. 8), derived by the signal processor 830 (FIG. 8).

[0047] Also shown in FIG. 9, the waveform generator 930 is a particular embodiment of the waveform processor 730 (FIG. 7) described above. The waveform generator 930 generates a synthesized waveform 932 that the pulse oximeter monitor 360 can process to calculate SpO_2 and pulse rate values or exception messages. In the present embodiment, the waveform generator output does not reflect a physiological waveform. In particular, the synthesized waveform is not physiological data from the sensor module 800, but is a waveform synthesized from predetermined stored waveform data to cause the monitor 360 to calculate oxygen saturation and pulse rate equivalent to or generally equivalent (within clinical significance) to that calculated by the signal processor 830 (FIG. 8). The actual intensity signal from the patient received by the detector 314 (FIG. 8) is not provided to the monitor 360 in the present embodiment. Indeed, the waveform provided to the monitor 360 will usually not resemble a plethysmographic waveform or other physiological data from the patient to whom the sensor module 800 (FIG. 8) is attached.

[0048] The synthesized waveform 932 is modulated according to the drive signal input 934. That is, the pulse oximeter monitor 360 expects to receive a red and IR modulated intensity signal originating from a detector, as described with respect to FIGS. 1-2, above. The waveform generator 930 generates the synthesized waveform 932 with a predetermined shape, such as a triangular or sawtooth waveform stored in waveform generator memory or derived by a waveform generator algorithm. The waveform is modulated synchronously with the drive input 934 with first and second amplitudes that are processed in the monitor 360 as red and IR portions of a sensor signal. The frequency and the

first and second amplitudes are adjusted so that pulse rate and oxygen saturation measurements derived by the pulse oximeter monitor 360 are generally equivalent to the parameter measurements derived by the signal processor 830 (FIG. 8), as described above. One embodiment of a waveform generator 930 is described in U.S. Patent Application No. 60/117,097 entitled "Universal/Upgrading Pulse Oximeter," assigned to Masimo Corporation, Irvine, Calif. and incorporated by reference herein. Although the waveform generator 930 is described above as synthesizing a waveform that does not resemble a physiological signal, one of ordinary skill will recognize that another embodiment of the waveform generator 930 could incorporate, for example, a plethysmograph simulator or other physiological signal simulator.

[0049] Further shown in FIG. 9, the interface cable 950 functions in a manner similar to the monitor interface 750 (FIG. 7) described above. The interface cable 950 is configured to communicate the synthesized waveform 932 to the monitor 360 sensor port and to communicate the sensor drive signal 934 to the waveform generator 930. The interface cable 950 may include a ROM 960 that contains monitor and sensor characterization data. The ROM 960 is read by the waveform generator 930 so that the synthesized waveform 932 is adapted to a particular monitor 360. For example, the ROM 960 may contain calibration data of red/IR versus oxygen saturation, waveform amplitude and waveform shape information. An interface cable is described in U.S. Patent Application No. 60/117,092, referenced above. Monitor-specific SatShare™ brand interface cables are available from Masimo Corporation, Irvine, Calif. In an alternative embodiment, such as a direct connect monitor module as illustrated in FIG. 5A, an interface cable 950 is not used and the ROM 960 may be incorporated within the monitor module 900 itself.

Plethysmograph Transmission

[0050] FIG. 10 illustrates another pulse oximetry sensor module 1000 having a sensor interface 1010, encoder 1040, transmitter 1050, transmitting antenna 1070 and controller 1090, which have the corresponding functions as those described with respect to FIG. 8, above. The encoder 1040, however, inputs a plethysmograph signal 1014 rather than oxygen saturation and pulse rate measurements 832 (FIG. 8). Thus, the sensor module 1000 according to this embodiment encodes and transmits a plethysmograph signal 1014 to a corresponding monitor module 1100 (FIG. 11) in contrast to derived physiological parameters, such as oxygen saturation and pulse rate. The plethysmograph signal 1014 is illustrated in FIG. 10 as being a direct output from the sensor interface 1010. In another embodiment, the sensor module 1000 incorporates a decimation processor, not shown, after the sensor interface 1010 so as to provide a plethysmograph signal 1014 having a reduced sample rate.

[0051] FIG. 11 illustrates another pulse oximetry monitor module 1100 having a receive antenna 1170, a receiver 1110, a decoder 1120 and an interface cable 1150, which have the corresponding functions as those described with respect to FIG. 9, above. This monitor module embodiment 1100, however, has a waveform modulator 1200 rather than a waveform generator 930 (FIG. 9), as described above. The waveform modulator 1200 inputs a plethysmograph signal from the decoder 1120 rather than oxygen saturation and pulse rate measurements, as described with respect to FIG.

9, above. Further, the waveform modulator 1200 provides an modulated waveform 1132 to the pulse oximeter monitor 360 rather than a synthesized waveform, as described with respect to FIG. 9. The modulated waveform 1132 is a plethysmographic waveform modulated according to the monitor drive signal input 1134. That is, the waveform modulator 1200 does not synthesize a waveform, but rather modifies the received plethysmograph signal 1124 to cause the monitor 360 to calculate oxygen saturation and pulse rate generally equivalent (within clinical significance) to that derivable by a compatible, calibrated pulse oximeter directly from the sensor signal 1012 (FIG. 10). The waveform modulator 1200 is described in further detail with respect to FIG. 12, below.

[0052] FIG. 12 shows a waveform modulator 1200 having a demodulator 1210, a red digital-to-analog converter (DAC) 1220, an IR DAC 1230, a red amplifier 1240, an IR amplifier 1250, a modulator 1260, a modulator control 1270, a look-up table (LUT) 1280 and a ratio calculator 1290. The waveform modulator 1200 demodulates red and IR plethysmographs ("pleths") from the decoder output 1124 into a separate red pleth 1222 and IR pleth 1232. The waveform modulator 1200 also adjusts the amplitudes of the pleths 1222, 1232 according to stored calibration curves for the sensor 310 (FIG. 10) and the monitor 360 (FIG. 11). Further, the waveform modulator 1200 re-modulates the adjusted red pleth 1242 and adjusted IR pleth 1252, generating a modulated waveform 1132 to the monitor 360 (FIG. 11).

[0053] As shown in FIG. 12, the demodulator 1210 performs the demodulation function described above, generating digital red and IR pleth signals 1212, 1214. The DACs 1220, 1230 convert the digital pleth signals 1212, 1214 to corresponding analog pleth signals 1222, 1232. The amplifiers 1240, 1250 have variable gain control inputs 1262, 1264 and perform the amplitude adjustment function described above, generating adjusted red and IR pleth signals 1242, 1252. The modulator 1260 performs the re-modulation function described above, combining the adjusted red and IR pleth signals 1242, 1252 according to a control signal 1272. The modulator control 1270 generates the control signal 1272 synchronously with the LED drive signal(s) 1134 from the monitor 360.

[0054] Also shown in FIG. 12, the ratio calculator 1290 derives a red/IR ratio from the demodulator outputs 1212, 1214. The LUT 1280 stores empirical calibration data for the sensor 310 (FIG. 10). The LUT 1280 also downloads monitor-specific calibration data from the ROM 1160 (FIG. 11) via the ROM output 1158. From this calibration data, the LUT 1280 determines a desired red/IR ratio for the modulated waveform 1132 and generates red and IR gain outputs 1262, 1264 to the corresponding amplifiers 1240, 1250, accordingly. A desired red/IR ratio is one that allows the monitor 360 (FIG. 11) to derive oxygen saturation measurements from the modulated waveform 1132 that are generally equivalent to that derivable directly from the sensor signal 1012 (FIG. 10).

[0055] One of ordinary skill in the art will recognize that some of the signal processing functions described with respect to FIGS. 8-11 may be performed either within a sensor module or within a monitor module. Signal processing functions performed within a sensor module may advantageously reduce the transmission bandwidth to a monitor module at a cost of increased sensor module size and power consumption. Likewise, signal processing functions per-

formed within a monitor module may reduce sensor module size and power consumption at a cost of increase transmission bandwidth.

[0056] For example, a monitor module embodiment 900 (FIG. 9) described above receives measured pulse oximeter parameters, such as oxygen saturation and pulse rate, and generates a corresponding synthesized waveform. In that embodiment, the oxygen saturation and pulse rate computations are performed within a sensor module 800 (FIG. 8). Another monitor module embodiment 1100 (FIG. 11), also described above, receives a plethysmograph waveform and generates a remodulated waveform. In that embodiment, minimal signal processing is performed within a sensor module 1000 (FIG. 10). In yet another embodiment, not shown, a sensor module transmits a plethysmograph waveform or a decimated plethysmograph waveform having a reduced sample rate. A corresponding monitor module has a signal processor, such as described with respect to FIG. 8, in addition to a waveform generator, as described with respect to FIG. 9. The signal processor computes pulse oximeter parameters and the waveform generator generates a corresponding synthesized waveform, as described above. In this embodiment, minimal signal processing is performed within the sensor module, and the monitor module functions are performed on the pulse oximeter parameters computed within the monitor module.

Wireless Multiple Parameter Measurements

[0057] FIGS. 13-14 illustrate a multiple parameter communications adapter. FIG. 13 illustrates a multiple parameter sensor module 1300 having sensor interfaces 1310, one or more signal processors 1330, a multiplexer and encoder 1340, a transmitter 1350, a transmitting antenna 1370 and a controller 1390. One or more physiological sensors 1301 provide input sensor signals 1312 to the sensor module 1300. Depending on the particular sensors 1301, the sensor module 1300 may provide one or more drive signals 1312 to the sensors 1301 as determined by the controller 1390. The sensor interfaces 1310 input the sensor signals 1312 and output one or more conditioned signals 1314. The conditioned signals 1314 may be coupled to the transmitter 1350 or further processed by the signal processors 1330. If the sensor module configuration utilizes signal processors 1330, it derives multiple parameter signals 1332 responsive to the sensor signals 1312, which are then coupled to the transmitter 1350. Regardless, the transmitter 1350 inputs a baseband signal 1342 that is responsive to the sensor signals 1312. The transmitter 1350 modulates the baseband signal 1342 with a carrier to generate a transmit signal 1354, which is coupled to the transmit antenna 1370 and communicated to a corresponding receive antenna 1470 (FIG. 14), as described with respect to FIG. 6, above. Alternatively, there may be multiple baseband signals 1342, and the transmitter 1350 may transmit on multiple frequency channels, where each channel conveys data responsive to one or more of the sensor signals 1314.

[0058] As shown in FIG. 13, the sensor interface 1310 conditions and digitizes the sensor signals 1312 as described for a single sensor with respect to FIG. 6, above. The resulting conditioned signals 1314 are responsive to the sensor signals 1312. The signal processors 1330 perform signal processing on the conditioned signals 1314 to derive parameter signals 1332, as described for a single conditioned signal with respect to FIG. 6, above. The parameter

signals 1332 may be physiological measurements such as oxygen saturation, pulse rate, blood glucose, blood pressure, EKG, respiration rate and body temperature to name a few, or may be intermediate results from which the above-stated measurements may be calculated or derived. The multiplexer and encoder 1340 combines multiple digital word or serial bit streams into a single digital word or bit stream. The multiplexer and encoder also encodes the digital word or bit stream to generate the baseband signal 1342, as described with respect to FIG. 6, above.

[0059] FIG. 14 illustrates a multiple parameter monitor module 1400 having a receive antenna 1470, a receiver 1410, a demultiplexer and decoder 1420, one or more waveform processors 1430 and a monitor interface 1450. The receiver 1410 inputs and demodulates the receive signal 1412 corresponding to the transmit signal 1354 (FIG. 13) to generate a baseband signal 1414 as described with respect to FIG. 7, above. The demultiplexer and decoder 1420 separates the symbol streams corresponding to the multiple conditioned signals 1314 (FIG. 13) and/or parameter signals 1332 (FIG. 13) and translates these symbol streams into multiple decoded signals 1422, as described for a single symbol stream with respect to FIG. 7, above. Alternatively, multiple frequency channels are received to generate multiple baseband signals, each of which are decoded to yield multiple decoded signals 1422. The waveform processors 1430 input the decoded signals 1422 and generate multiple constructed signals 1432, as described for a single decoded signal with respect to FIGS. 7-12, above. The monitor interface 1450 is configured to communicate the constructed signals 1432 to the sensor ports of a multiple parameter monitor 1401 or multiple single parameter monitors, in a manner similar to that for a single constructed signal, as described with respect to FIGS. 7-12, above. In particular, the constructed signals 1432 are adapted to the monitor 1401 so that measurements derived by the monitor 1401 from the constructed signals 1432 are generally equivalent to measurements derivable directly from the sensor signals 1312 (FIG. 13).

[0060] A physiological measurement communications adapter is described above with respect to wireless communications and, in particular, radio frequency communications. A sensor module and monitor module, however, may also communicate via wired communications, such as telephone, Internet or fiberoptic cable to name a few. Further, wireless communications can also utilize light frequencies, such as IR or laser to name a few.

[0061] A physiological measurement communications adapter has been disclosed in detail in connection with various embodiments. These embodiments are disclosed by way of examples only. One of ordinary skill in the art will appreciate many variations and modifications of a physiological measurement communications adapter within the scope of the claims that follow.

1. (canceled)

2. A body worn mobile medical monitoring device configured to minimize cable wiring from a sensor by placement of one or more sensor communication ports, the mobile medical monitoring device comprising:

- a housing configured to be secured on a lower arm of a patient being monitored via a strap extending around the lower arm of the patient;
- a display positioned on a face of the housing, opposite the strap, so as to be visible to a user;

a first sensor communication port positioned on a side of the housing and configured to face a hand of the lower arm of the patient when the mobile medical monitoring device is mounted to the lower arm of the patient, wherein:

the first sensor communication port is configured to provide wired communication with a pulse oximetry sensor attached to a digit of the hand of the patient, and

the first sensor communication port is positioned on the side of the housing such that a path from the first sensor communication port on the side of the housing to the digit of the patient is shorter than any other path from any other side of the housing to the digit of the patient.

3. The mobile medical monitoring device of claim 2, wherein the wired communication with the pulse oximetry sensor is provided via a tail extending from the pulse oximetry sensor.

4. The mobile medical monitoring device of claim 3, wherein the tail comprises a cable that is configured to be removably attachable to the first sensor communication port.

5. The mobile medical monitoring device of claim 4, wherein a length of the cable corresponds to the path from the sensor communication port on the side of the housing to the digit of the patient.

6. The mobile medical monitoring device of claim 4, wherein the cable is appropriately sized based on the path from the sensor communication port on the side of the housing to the digit of the patient.

7. The mobile medical monitoring device of claim 4, wherein the path from the sensor communication port on the side of the housing to the digit of the patient runs at least partly along a backside of the hand of the patient.

8. The mobile medical monitoring device of claim 2, wherein the face of the housing comprises a single user interface.

9. The mobile medical monitoring device of claim 8, wherein the single user interface comprises the display.

10. The mobile medical monitoring device of claim 9, wherein:

the housing comprises a back side that is opposite the face of the housing,

the strap is mountable to the back side of the housing, and the face of the housing is raised from the strap and the lower arm of the patient to enable positioning of the first sensor communication port on the side of the housing between the lower arm of the patient and the face of the housing.

11. The mobile medical monitoring device of claim 10, wherein:

the front side of the housing comprises a bezel and the display, and

a top of the first sensor communication port is located below the face of the housing.

12. The mobile medical monitoring device of claim 11, wherein the display is positioned centrally on the face of the housing.

13. The mobile medical monitoring device of claim 12, wherein the display positioned on the face of the housing is sized such that the display covers most of a length of a shortest dimension of the face of the housing, and wherein the mobile medical monitoring device further comprises:

second and third sensor communication ports positioned on the housing and configured to provide wired communication with one or more additional physiological sensors.

14. (canceled)

15. A body worn, battery-powered medical monitoring device configured to provide on-patient and remote monitoring of patient physiological parameters, the medical monitoring device comprising:

- a battery configured to provide power to the medical monitoring device such that the medical monitoring device may operate without a wired power connection;
- a case configured to house the battery;
- a strap configured to attach the case to an arm of a patient and be mountable to the case;
- a first communications port positioned on a side of the case configured to be nearest to a hand of the arm of the patient when the case is mounted to the arm of the patient, the first communications port configured to removably couple with a cable of a finger- or thumb-type pulse oximetry sensor and positioned on the case to provide a path from the first communications port to a digit of the hand of the patient that avoids tangling of the cable;
- a second communications port configured to provide communications with a second physiological sensor arrangement;
- a third communications port configured to provide communications with a third physiological sensor arrangement;
- a display configured to provide real time measurements of patient physiological parameters based at least in part on data obtained from at least the pulse oximetry sensor via the first communications port; and
- a transmitter configured to wirelessly transmit information indicative of real time measurements of patient physiological parameters based at least in part on data obtained from the pulse oximetry sensor via the first communications port.

16. The medical monitoring device of claim **15**, wherein the path from the first communications port to a digit of the hand is shorter than any path from any communications port located on any other side of the case to the digit of the hand.

17. The medical monitoring device of claim **15** further comprising:

- one or more hardware processors configured to:
 - process the data obtained from the pulse oximetry sensor; and
 - determine, based at least in part on the data, the real time measurements of patient physiological parameters.

18. The medical monitoring device of claim **17**, wherein: the one or more hardware processors are further configured to:

- receive additional data from at least the second physiological sensor arrangement and the third physiological sensor arrangement;
- determine, based at least in part on the additional data, real time measurements of additional patient physiological parameters; and
- cause to be displayed, on the display, the real time measurements of additional patient physiological parameters; and

the transmitter is further configured to:

- wirelessly transmit information indicative of real time measurements of additional patient physiological parameters based at least in part on the additional data.

19. The medical monitoring device of claim **18**, wherein the display is positioned on a front, user-facing side of the case to enable a user to view the real time measurements of patient physiological parameters and the real time measurements of additional patient physiological parameters.

20. The medical monitoring device of claim **19**, wherein the second physiological sensor arrangement comprises an EKG sensor arrangement and the third physiological sensor arrangement comprises a blood pressure sensor arrangement.

21. The medical monitoring device of claim **20**, wherein: the first, second, and third communication ports are communicatively coupled to respective first, second, and third sensor interfaces; and

the first, second, and third sensor interfaces are uniquely configured to receive signals from the respective pulse oximetry sensor, EKG sensor arrangement, and blood pressure sensor arrangement.

22. An body worn portable patient monitoring device configured to provide on-patient and remote monitoring of patient physiological parameters, the portable patient monitoring device comprising:

- a pulse oximetry sensor configured to be wrapped around a digit of a patient, the pulse oximetry sensor including at least:
 - a light emitter configured to emit light into a tissue site of the digit of the patient;
 - a light detector configured output a first signal responsive to at least a portion of the emitted light after attenuation by tissue of the tissue site; and
 - a cable extending from the pulse oximetry sensor and configured to electrically convey the first signal;
- a blood pressure sensor configured to output a second signal responsive to at least a blood pressure parameter of the patient;
- an additional sensor arrangement configured to output a third signal responsive to at least one additional physiological parameter of the patient other than blood pressure or oxygen saturation, the at least one additional physiological parameter including at least one of: temperature or respiration rate;
- a housing configured to be secured to a lower arm of the patient, the housing having a size and shape configured to be secured to the lower arm of the patient;
- a strap mountable to the back side of the housing, the strap configured to secure the housing to the lower arm of the patient;
- a display positioned on a front side of the housing that is opposite a back side of the housing, the display configured to show a status of the portable patient monitoring device and one or more parameter measurements so as to be viewable by a user, wherein the display is positioned centrally on the front side of the display and is sized such that the display spans most of a length of a shortest dimension of the front side of the housing, and wherein the front side of the housing comprises a single user interface and a bezel;
- one or more user input mechanisms configured to control an operational mode of the portable patient monitoring device in response to inputs from a user;

a first sensor port positioned on a first side of the housing, wherein:

- the first side of the housing is configured to face toward a hand having the digit of the patient under measurement when the housing is secured to the lower arm of the patient,
- the first sensor port is configured to removably physically couple with the pulse oximetry sensor via the cable and to electrically receive the first signal from the pulse oximetry sensor,
- the cable is configured to run from the first sensor port, at least part way along a path down the arm of the patient, and to the digit of the patient to which the pulse oximetry sensor is configured to be wrapped around,
- the front side of the housing is raised from the strap and the lower arm of the patient to enable positioning of the first sensor port on the first side of the housing between the lower arm of the patient and the front side of the housing, and
- a top of the first sensor port is located below the front of the housing;

a second sensor port positioned on the housing and configured to provide electrical communication with the blood pressure sensor arrangement and to electrically receive second signal from the blood pressure sensor arrangement;

a third sensor port positioned on the housing and configured to provide electrical communication with the additional sensor arrangement and to electrically receive the third signal from the additional sensor arrangement;

a rechargeable battery positioned within the housing and configured to power the portable patient monitoring

device such that the portable patient monitoring device is portable and wearable by the patient;

one or more signal processing arrangements positioned within the housing and configured to:

- receive the first signal from the pulse oximetry sensor via one or more sensor interfaces;
- process the first signal from the pulse oximetry sensor to determine measurements of oxygen saturation and pulse rate;
- receive the second signal from the blood pressure sensor arrangement via the one or more sensor interfaces, the second signal responsive to at least a blood pressure parameter of the patient;
- receive the third signal from the additional sensor arrangement via the one or more sensor interfaces, the third signal responsive to the at least one additional physiological parameter of the patient including at least one of: temperature or respiration rate; and
- cause the measurements of oxygen saturation, pulse rate, blood pressure, and the at least one additional physiological parameter to all be displayed on the display of the portable patient monitoring device; and

a transmitter positioned within the housing and configured to:

- wirelessly transmit a transmit signal including the information indicating the measurements of oxygen saturation, pulse rate, blood pressure, and the at least one additional physiological parameter to a separate computing device configured to display, on a remote display, the measurements of oxygen saturation, pulse rate, blood pressure, and the at least one additional physiological parameter.

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专利名称(译)	BODY WORN移动医疗患者监测		
公开(公告)号	US20170224233A1	公开(公告)日	2017-08-10
申请号	US15/499619	申请日	2017-04-27
[标]申请(专利权)人(译)	梅西莫股份有限公司		
申请(专利权)人(译)	Masimo公司		
当前申请(专利权)人(译)	Masimo公司		
[标]发明人	AL ALI AMMAR		
发明人	AL-ALI, AMMAR		
IPC分类号	A61B5/0205 A61B5/1455 A61B5/0404 A61B5/00 A61B5/021 A61B5/024		
CPC分类号	A61B5/0024 A61B5/021 A61B5/0404 A61B5/14552 A61B5/0205 A61B5/6826 A61B5/6831 A61B2562/222 A61B2562/227 A61B5/6824		
优先权	60/367428 2002-03-25 US		
其他公开文献	US9788735		
外部链接	Espacenet USPTO		

摘要(译)

传感器接口配置为接收传感器信号。发射器产生发射信号。接收器接收对应于发送信号的信号。此外，监视器接口被配置为将波形传送到监视器，使得由监视器从波形导出的测量值通常等于可从传感器信号导出的测量值。

