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(54) **PHYSIOLOGICAL MEASUREMENT COMMUNICATIONS ADAPTER**

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Publication Classification

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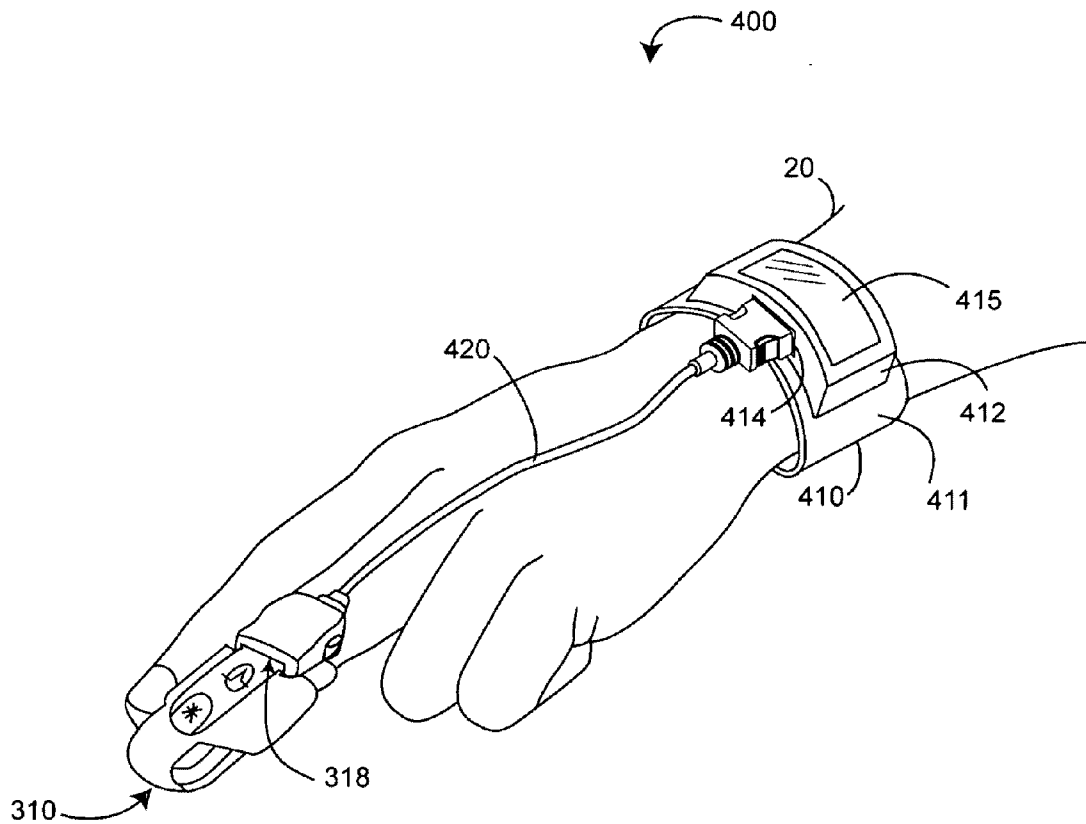
(22) Filed: **Jul. 31, 2015**

Related U.S. Application Data

(63) Continuation of application No. 14/217,788, filed on Mar. 18, 2014, now Pat. No. 9,113,832, which is a continuation of application No. 14/037,137, filed on Sep. 25, 2013, now Pat. No. 9,113,831, which is a continuation of application No. 12/955,826, filed on Nov. 29, 2010, now Pat. No. 8,548,548, which is a continuation of application No. 11/417,006, filed on May 3, 2006, now Pat. No. 7,844,315, which is a continuation of application No. 11/048,330, filed on Feb. 1, 2005, now Pat. No. 7,844,314, which is a continuation of application No. 10/377,933, filed on Feb. 28, 2003, now Pat. No. 6,850,788.

(57) **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.



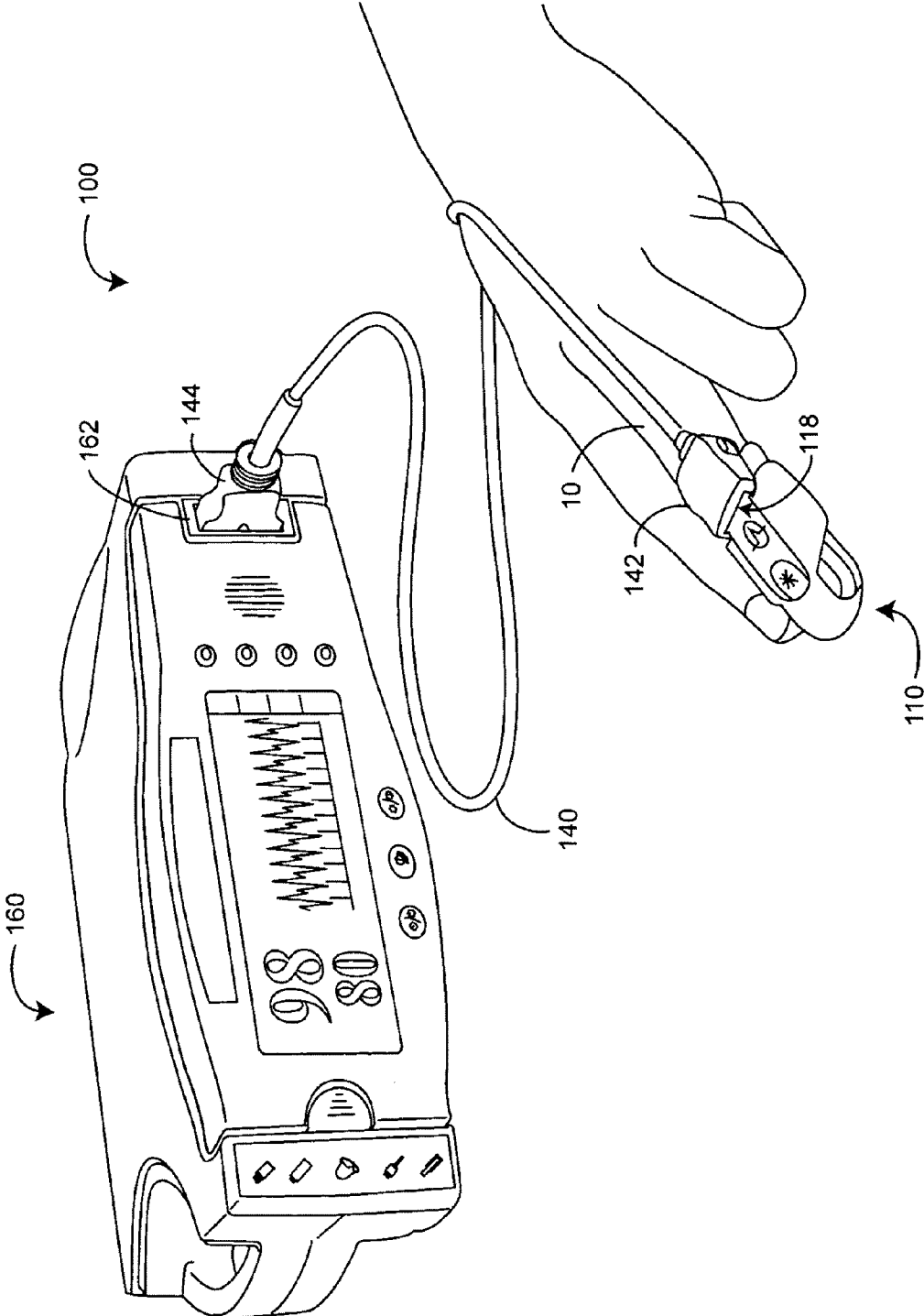


FIG. 1 (Prior Art)

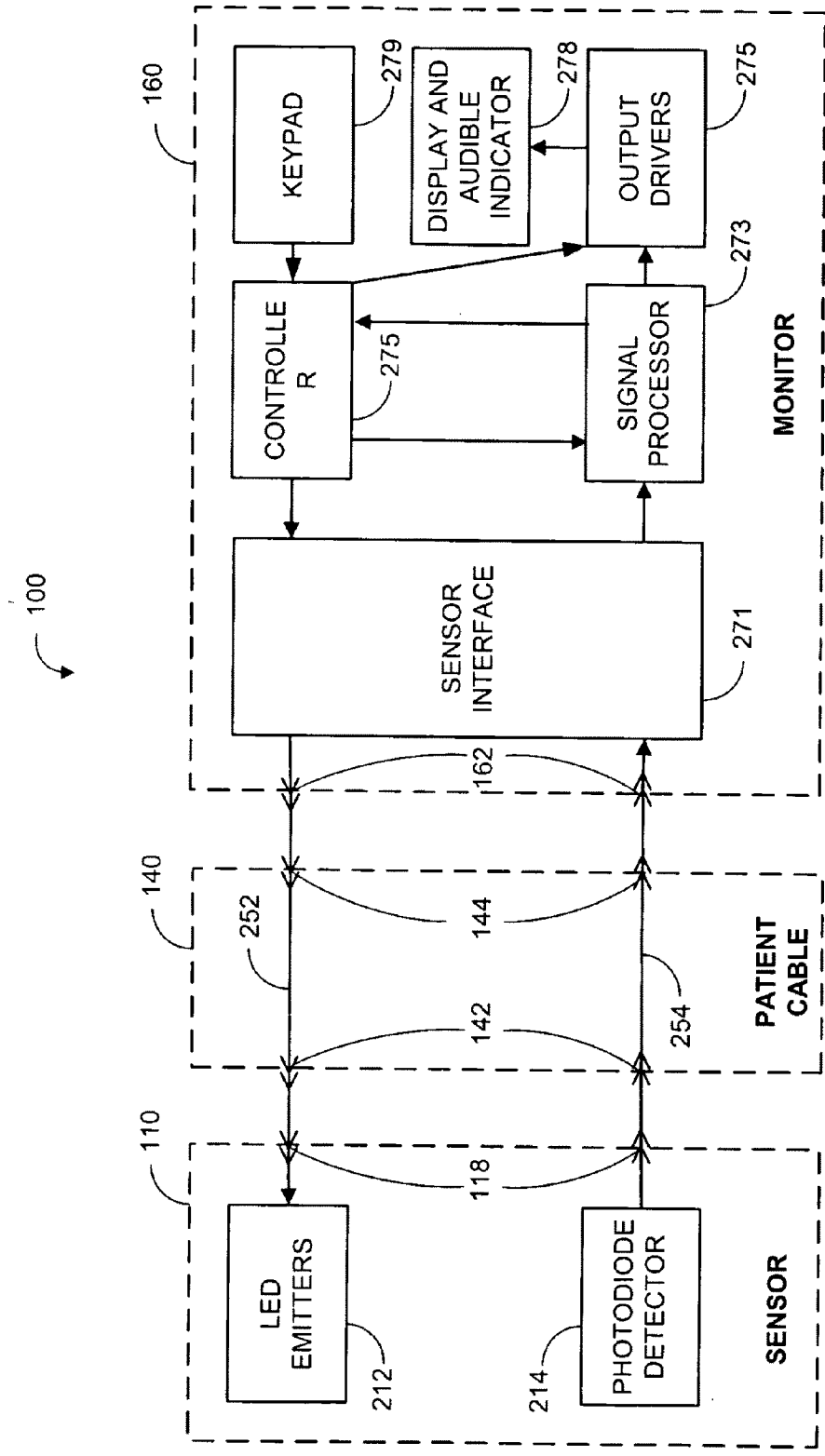


FIG. 2 (Prior Art)

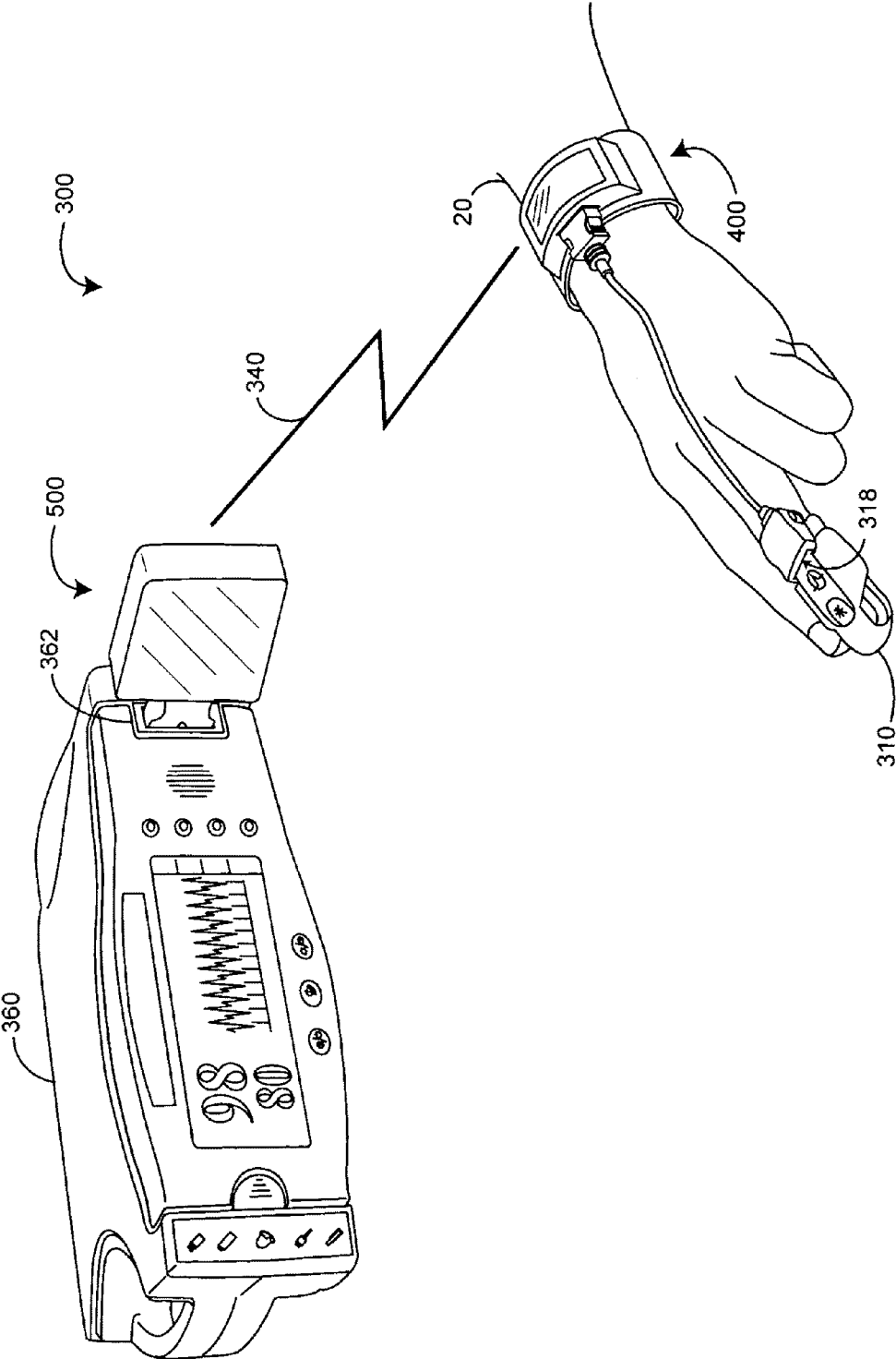


FIG. 3

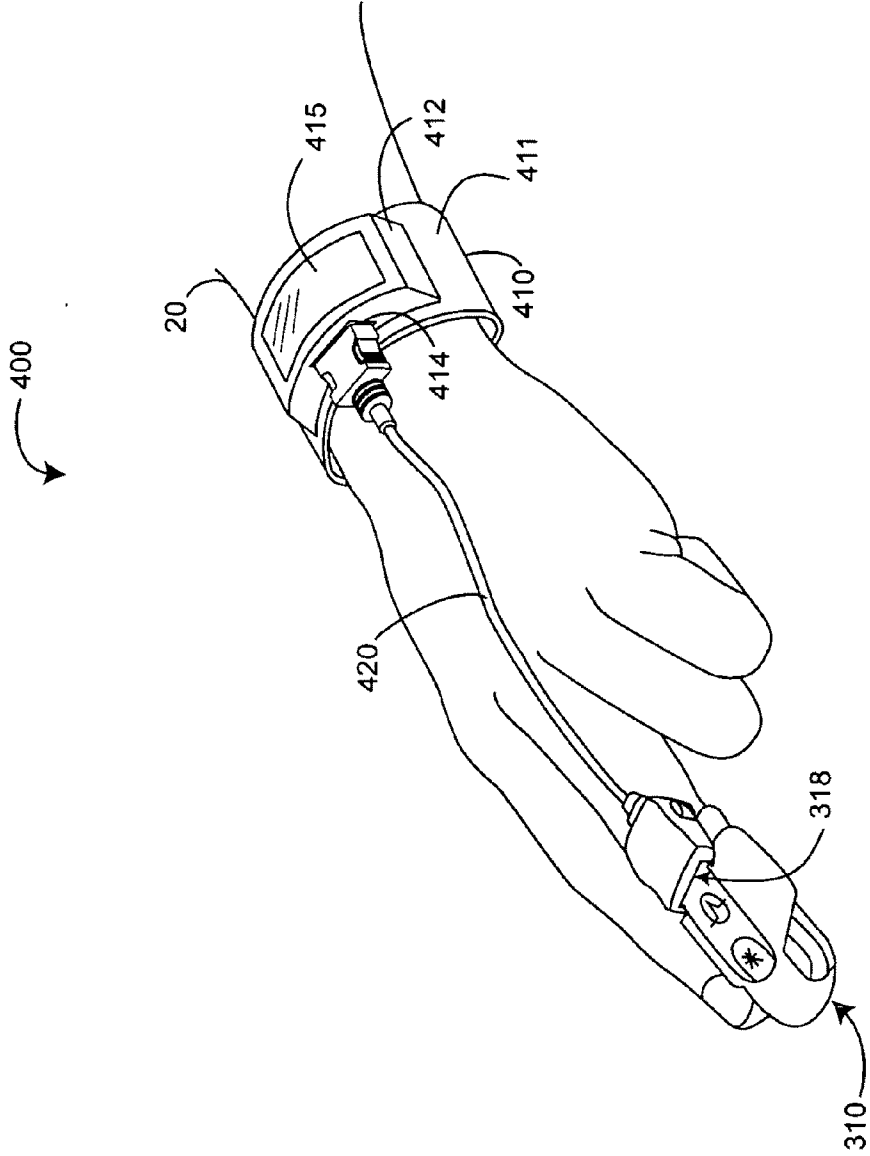


FIG. 4A

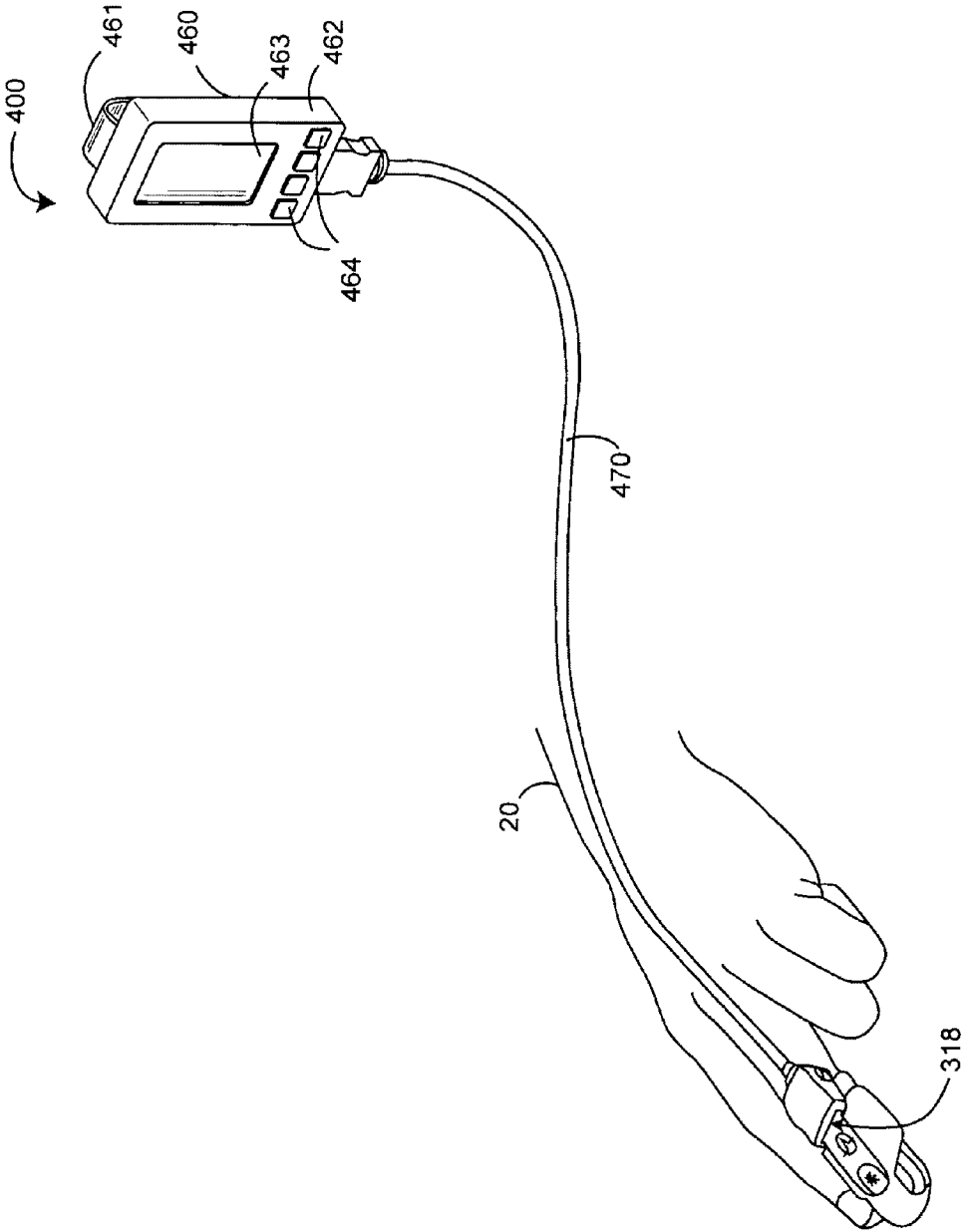


FIG. 4B

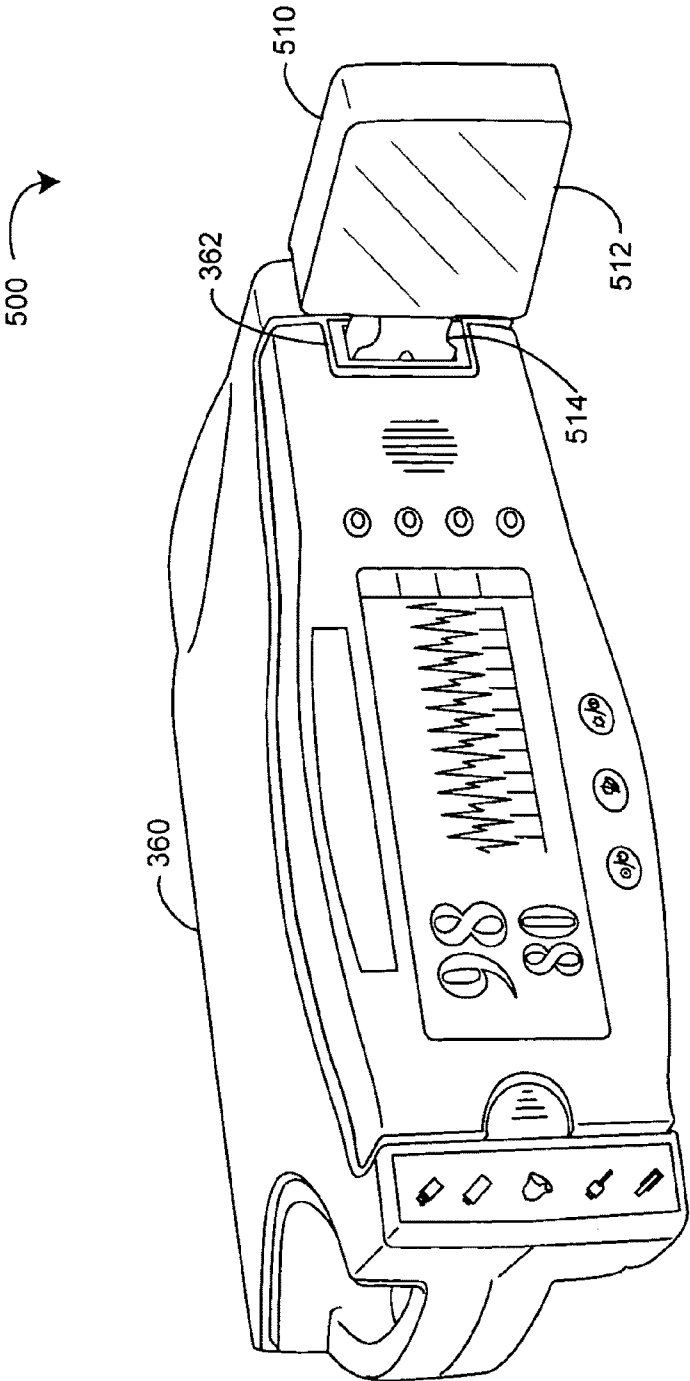


FIG. 5A

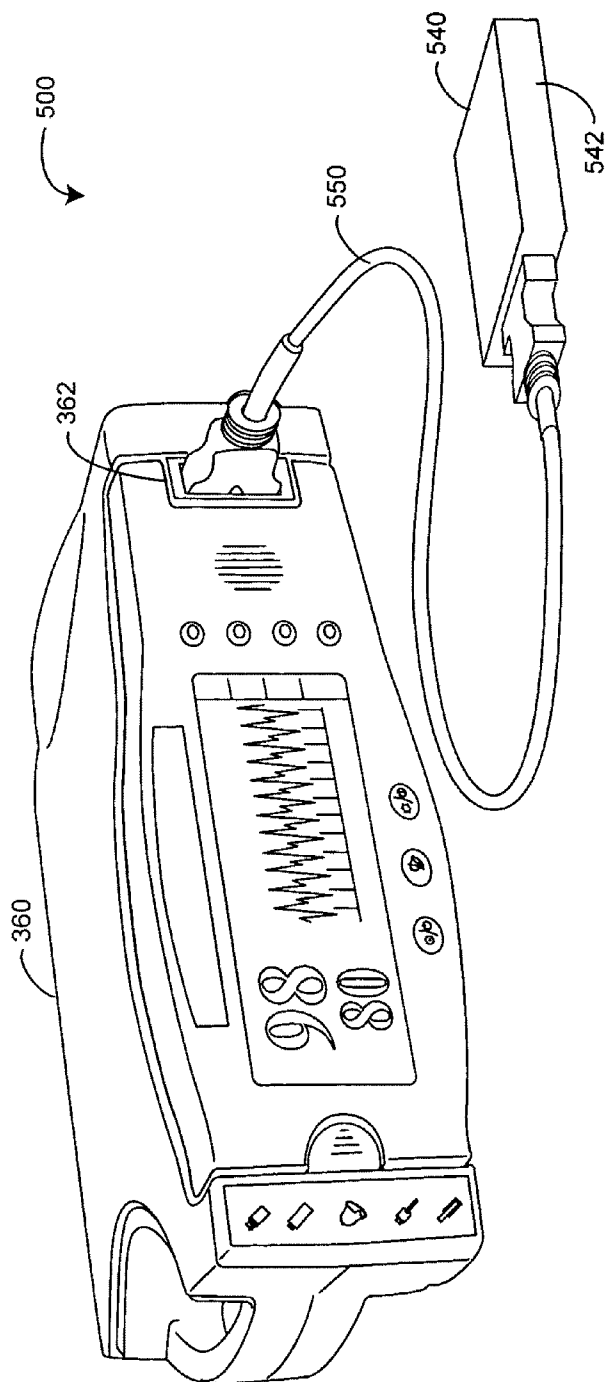


FIG. 5B

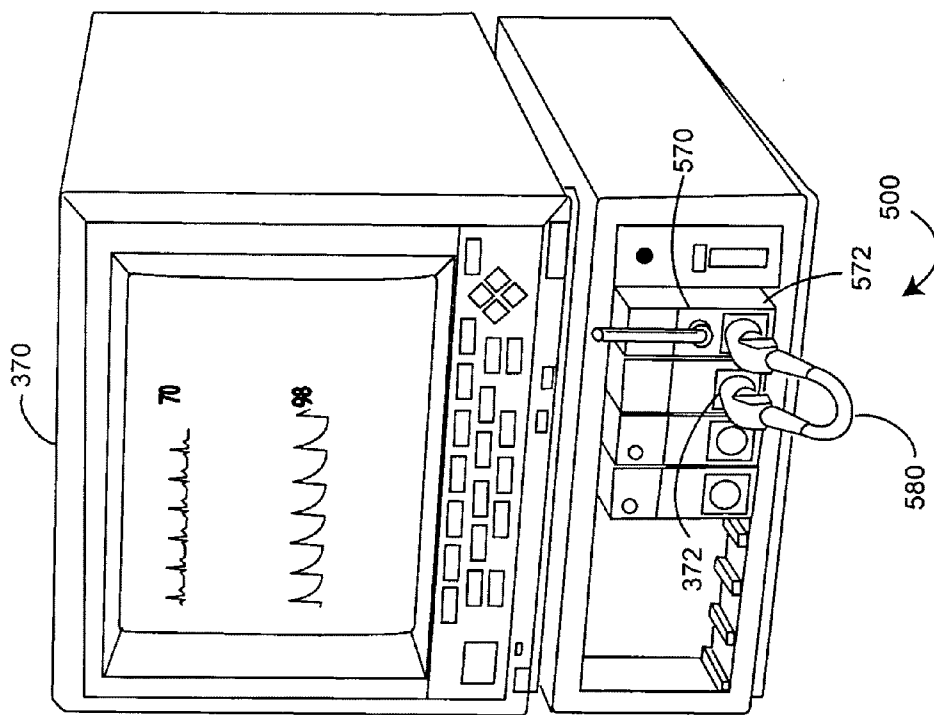


FIG. 5C

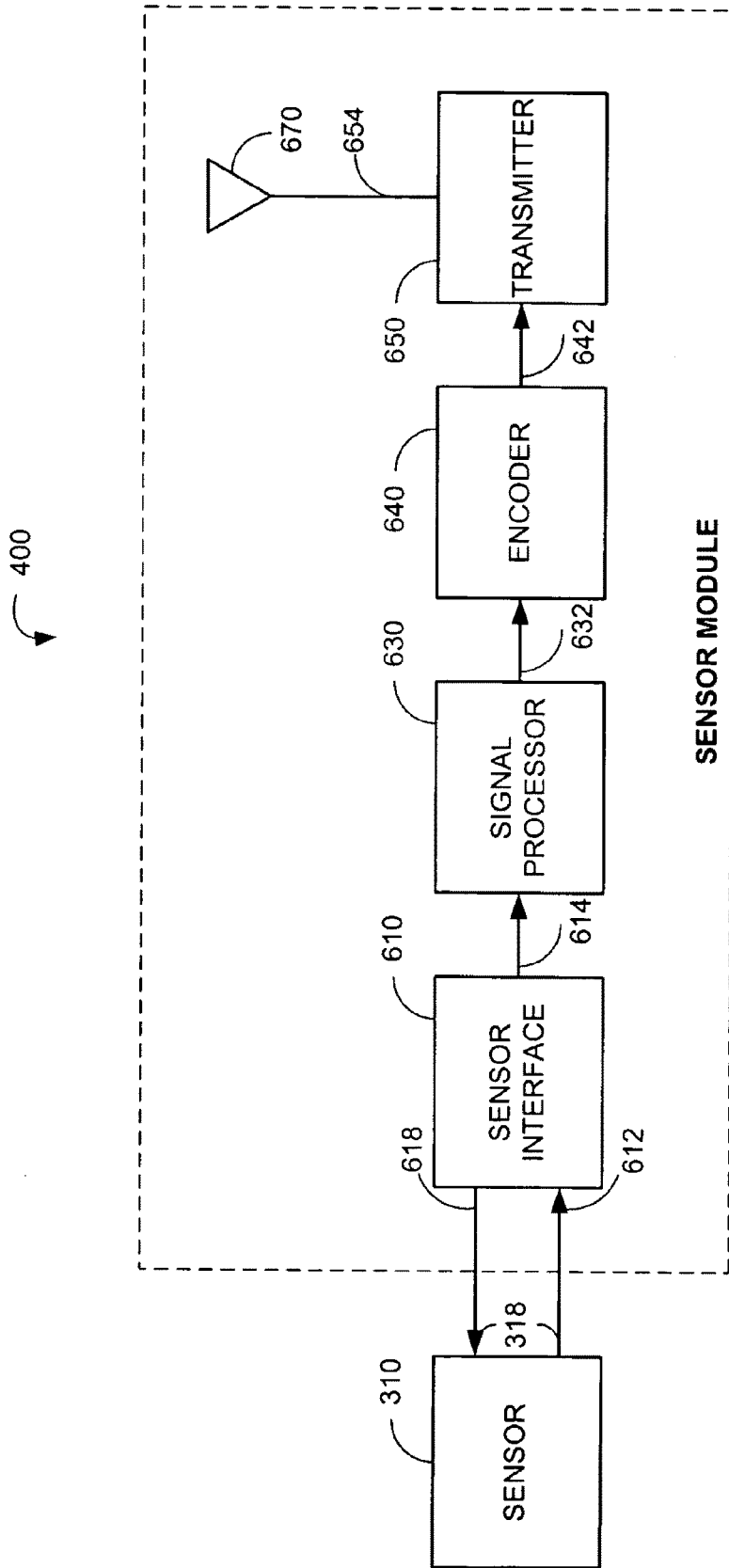


FIG. 6

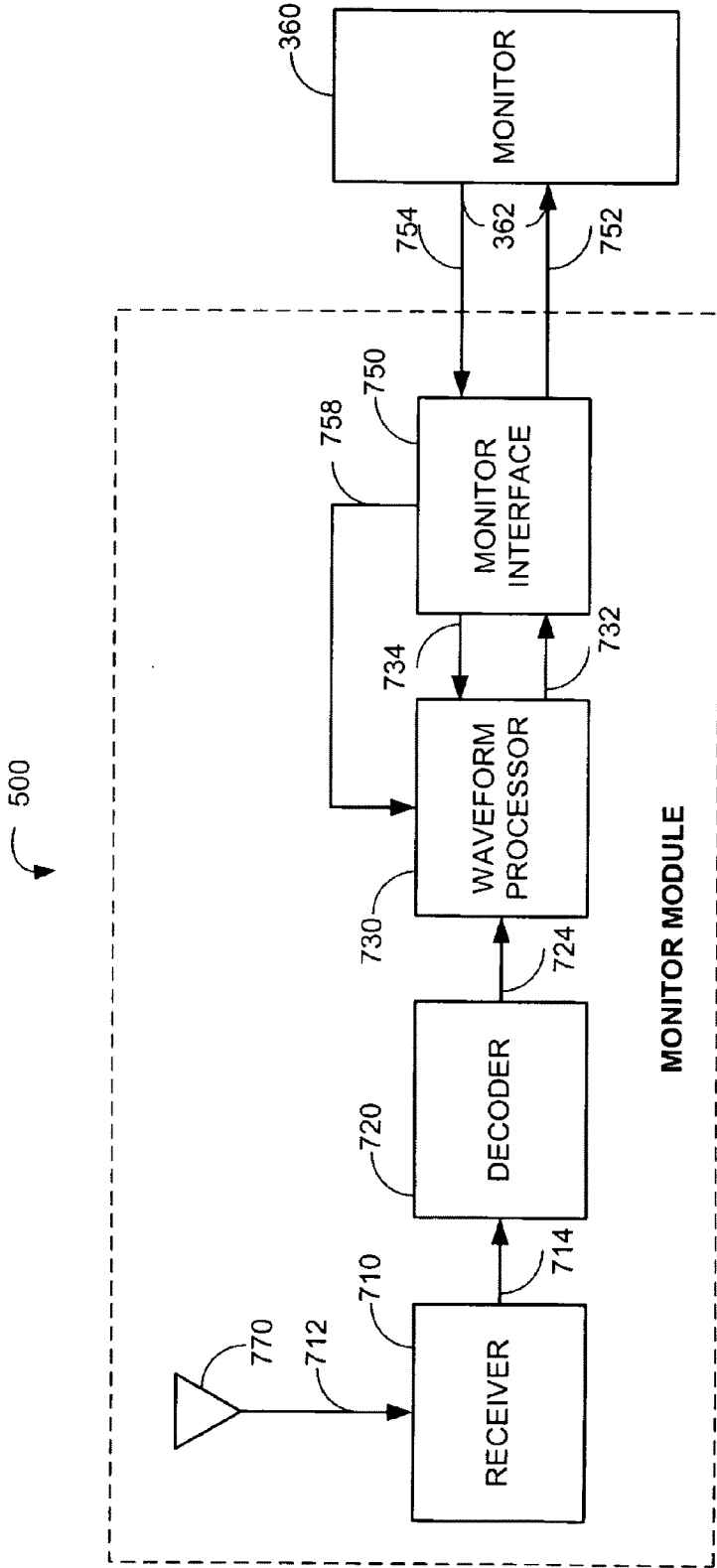


FIG. 7

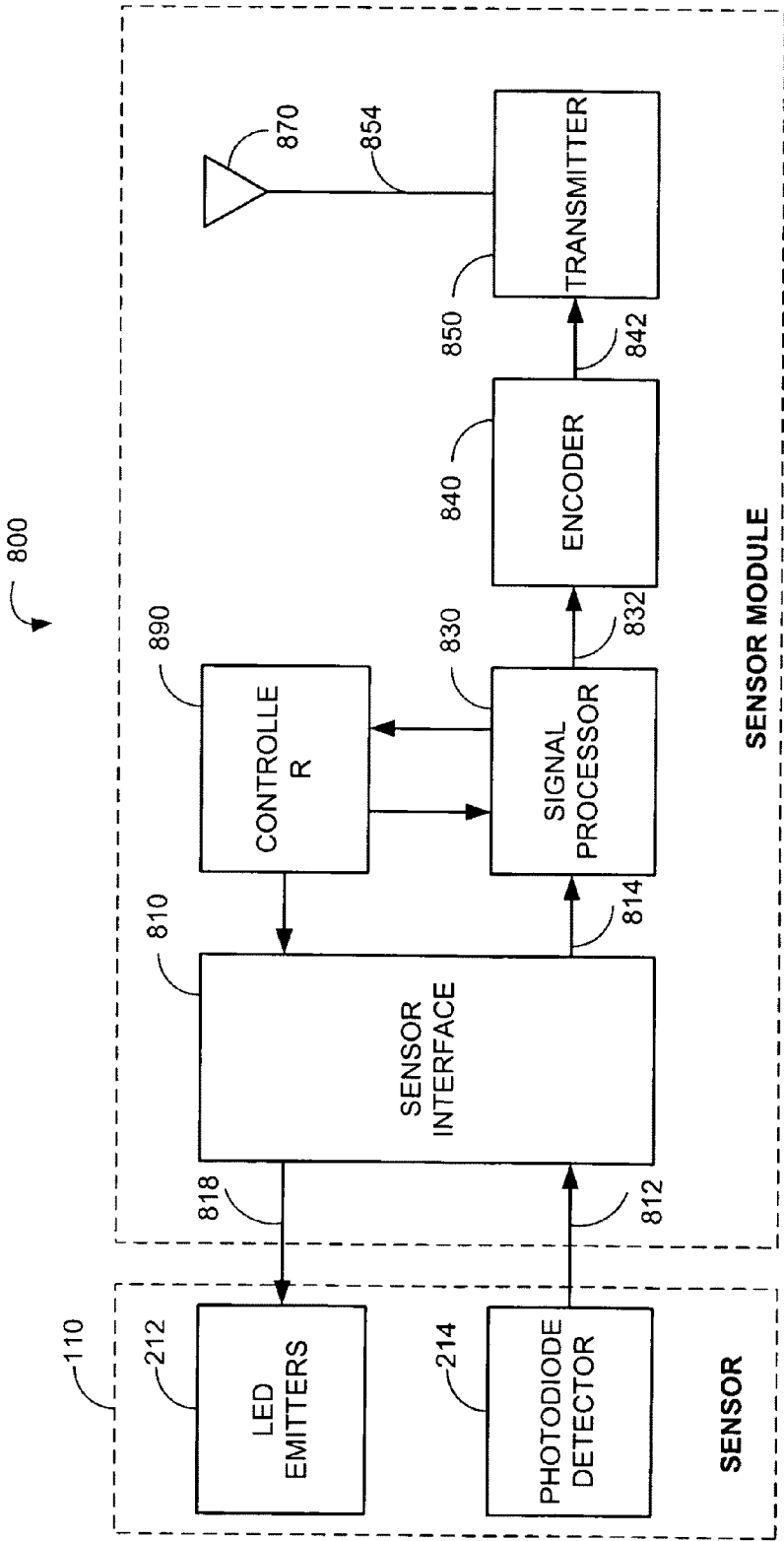


FIG. 8

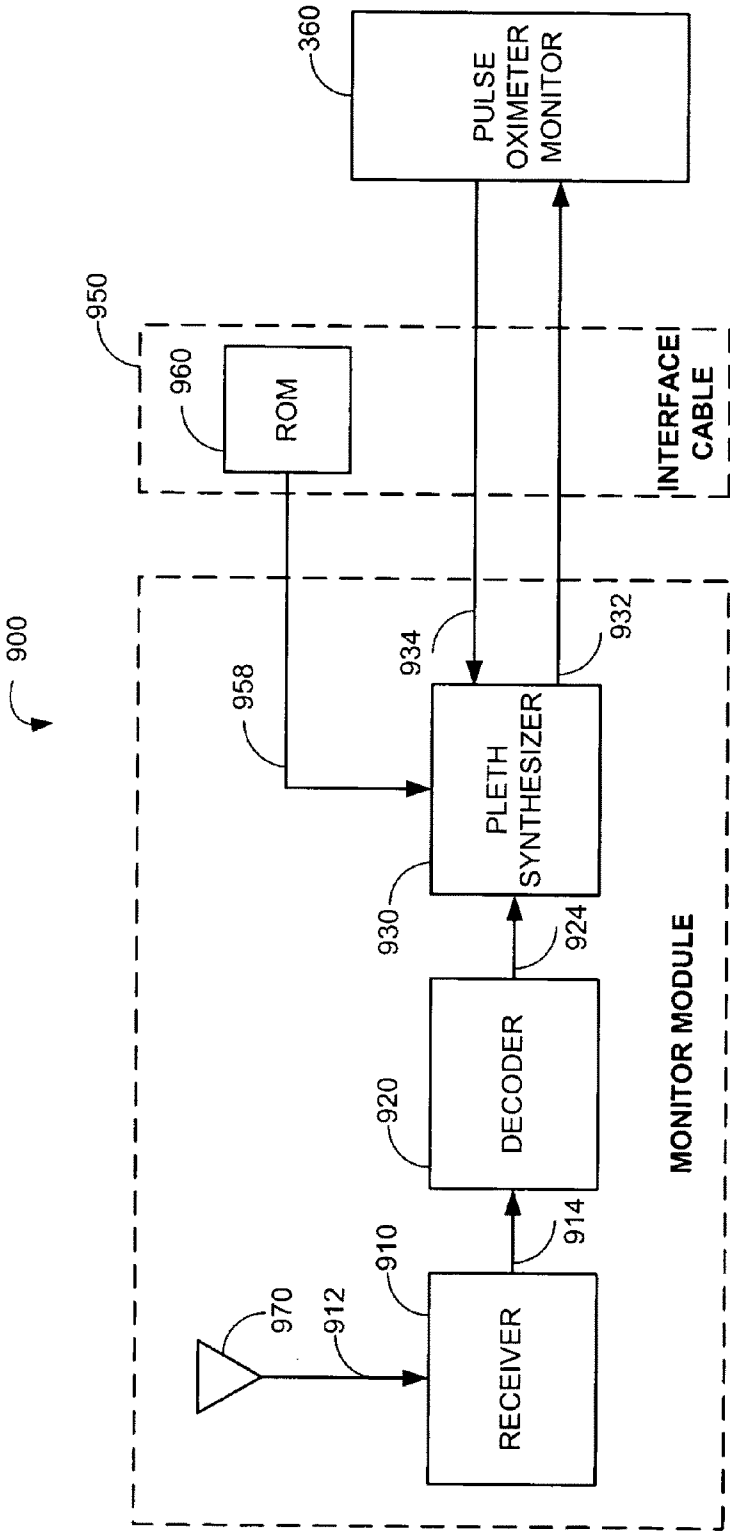


FIG. 9

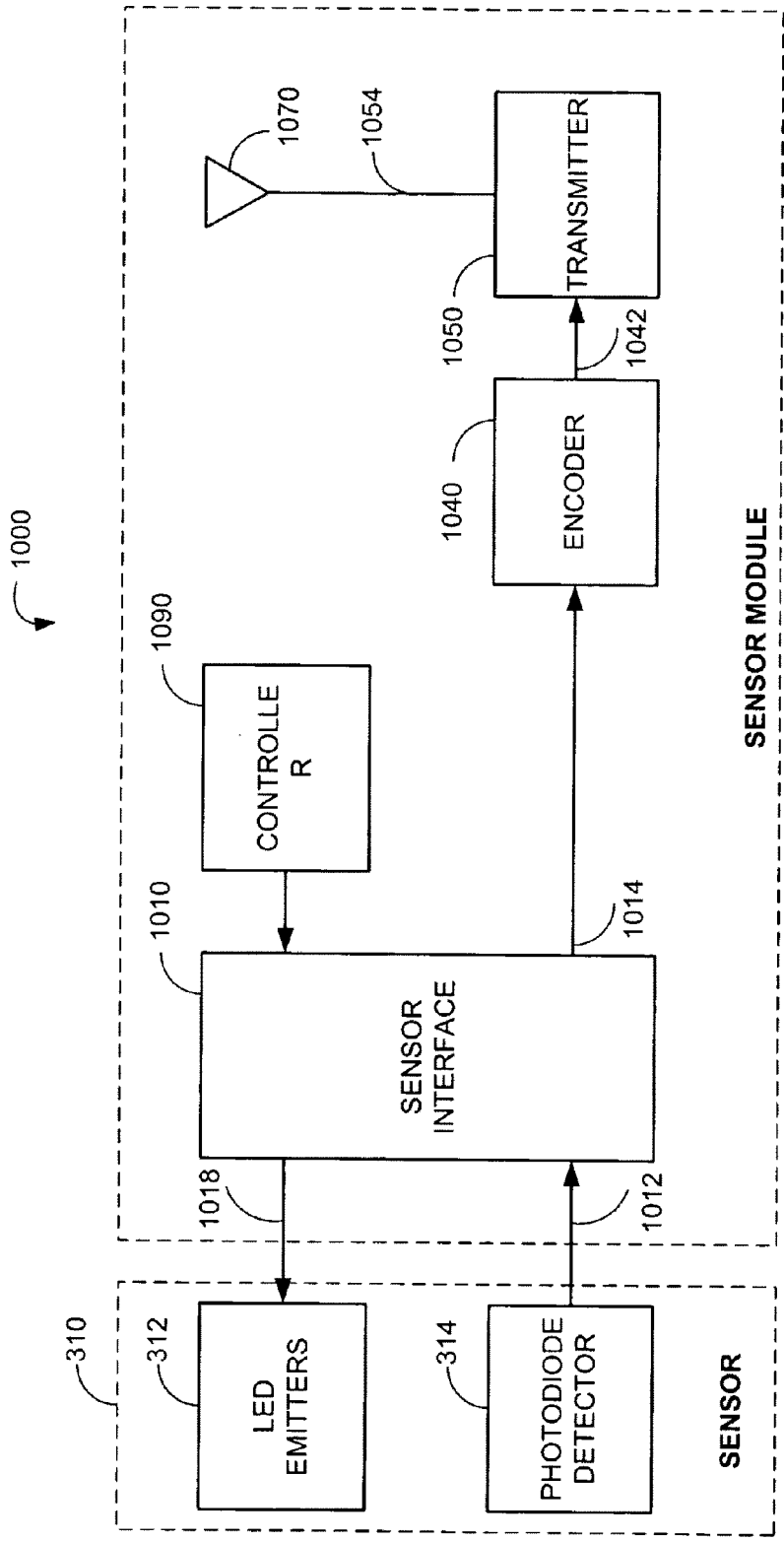


FIG. 10

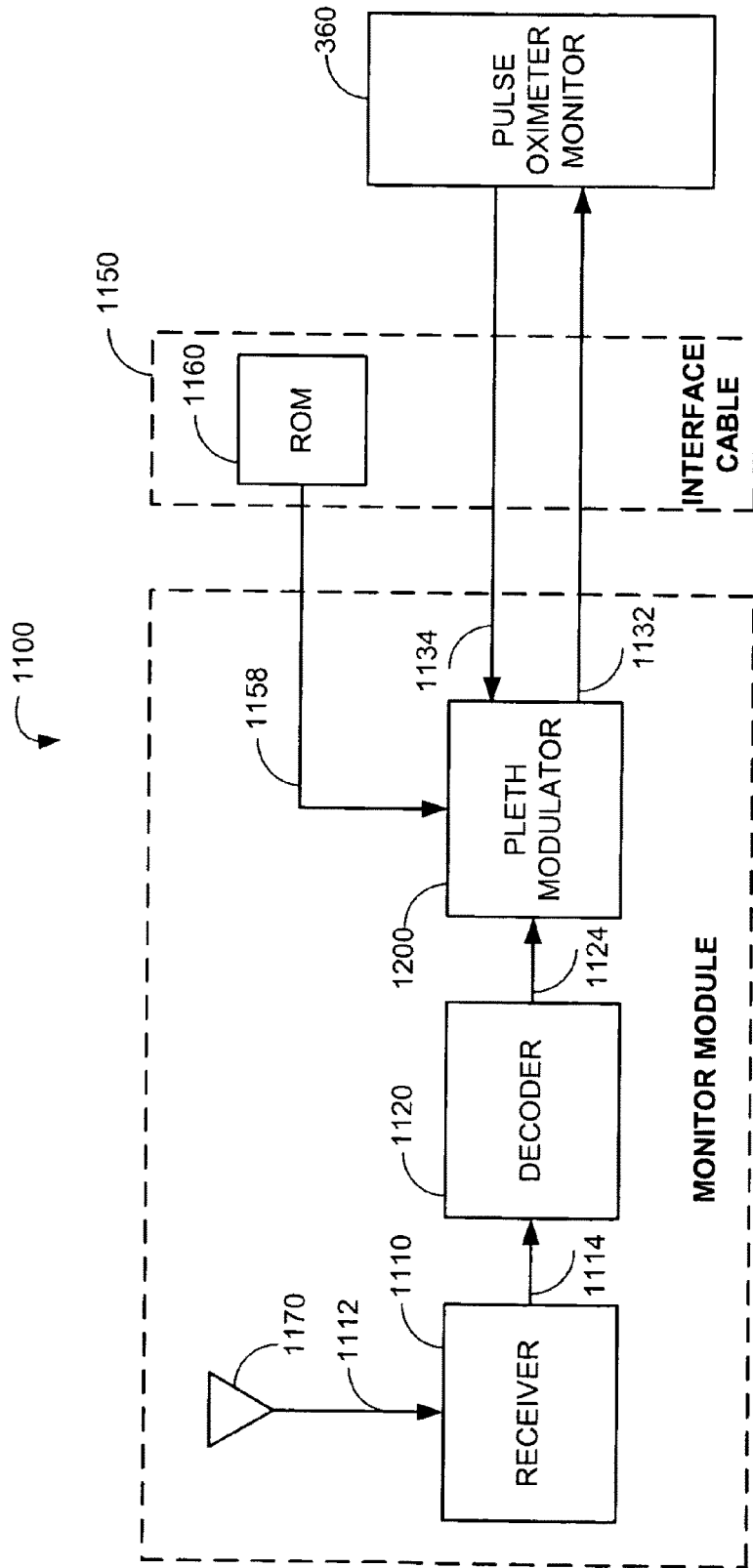


FIG. 11

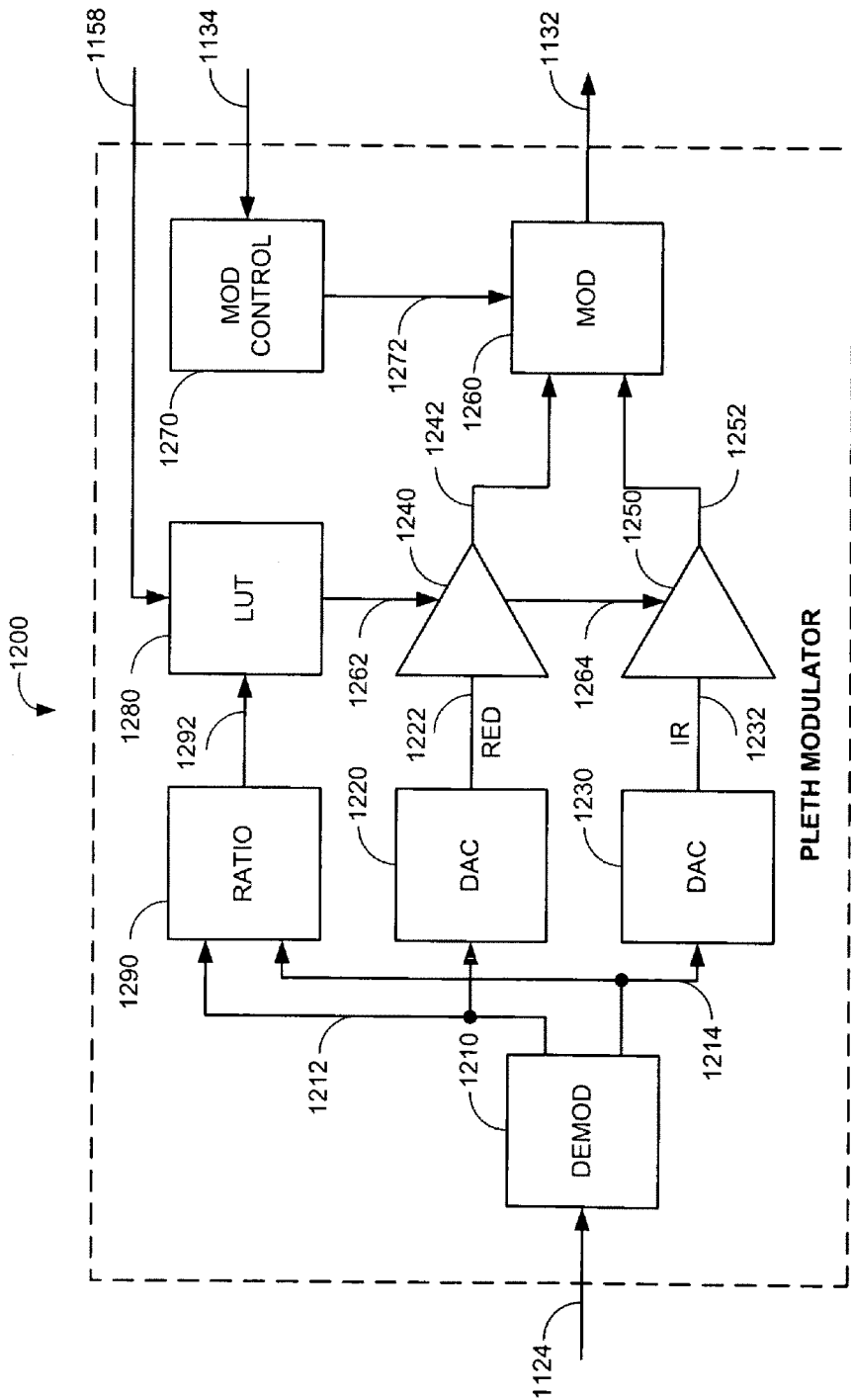


FIG. 12

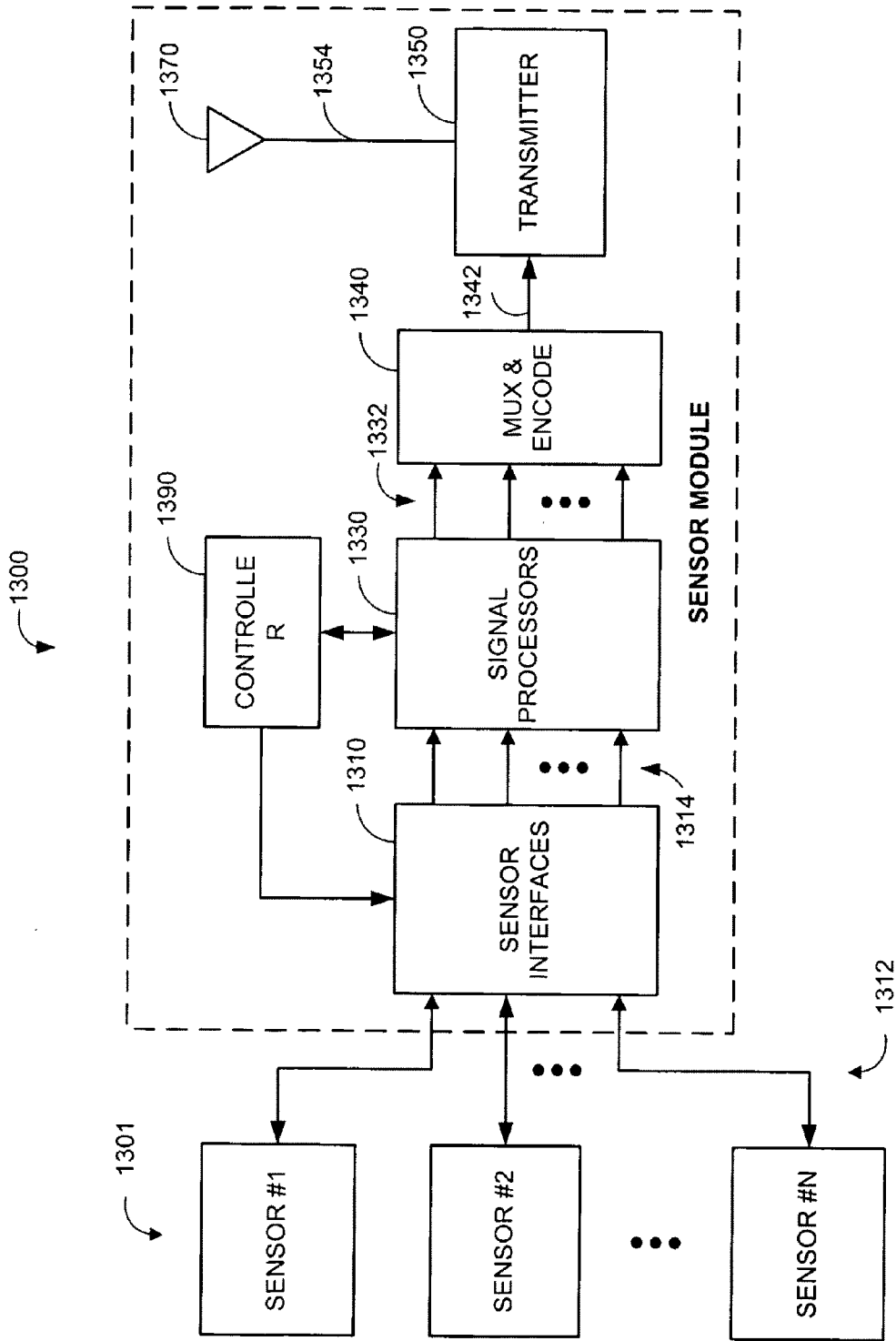


FIG. 13

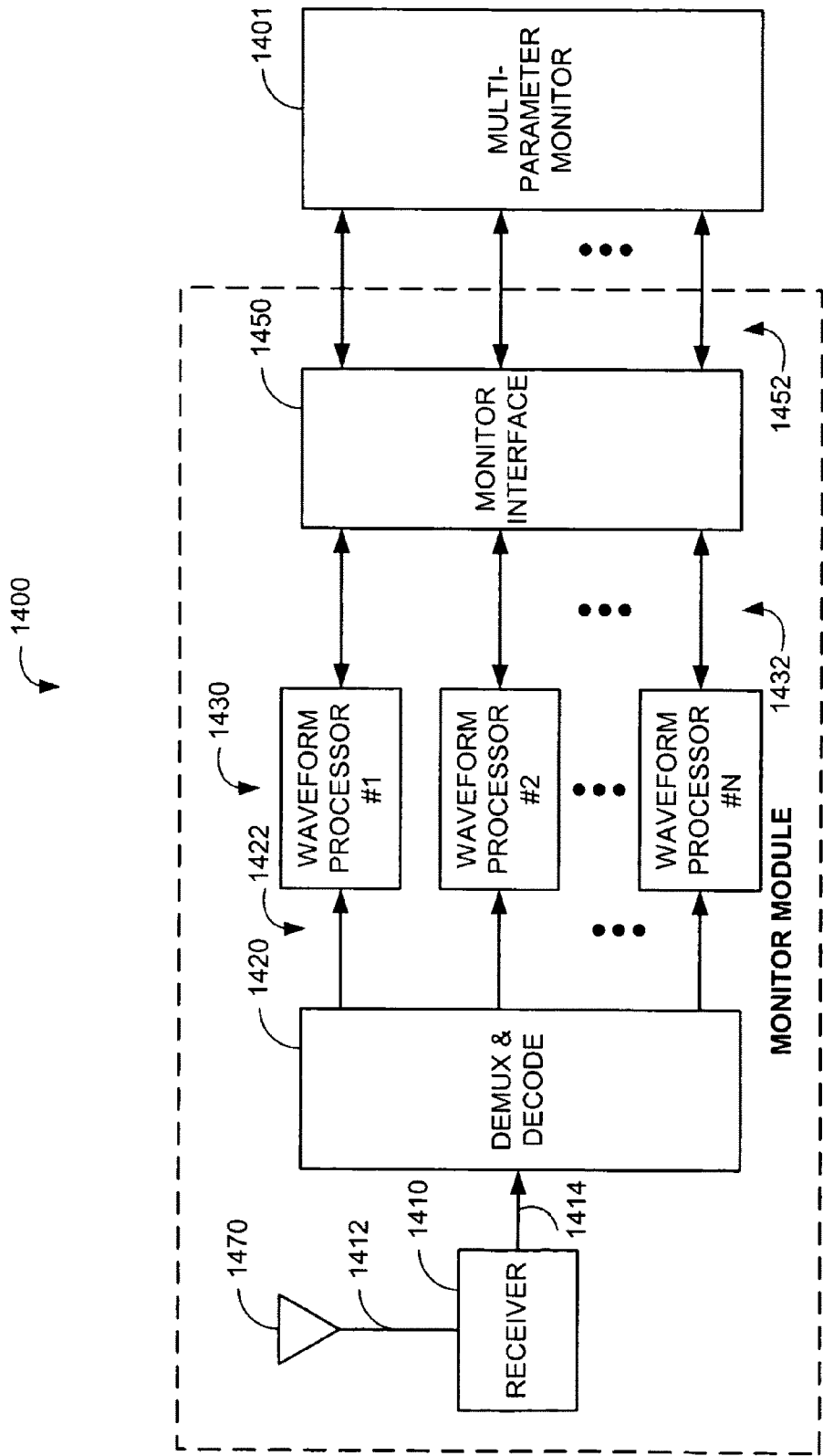


FIG. 14

PHYSIOLOGICAL MEASUREMENT COMMUNICATIONS ADAPTER

REFERENCE TO RELATED APPLICATION

[0001] The present application is a continuation of U.S. patent application Ser. No. 14/217,788, filed on Mar. 18, 2014, entitled “Wrist-Mounted Physiological Measurement Device,” which is a continuation of U.S. patent application Ser. No. 14/037,137, filed on Sep. 25, 2013, entitled “Physiological Measurement Communications Adapter,” 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 differential 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 predetermined 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 wave-

form. 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 receive 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

Overview

[0025] 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.

[0026] 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.

[0027] 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.

[0028] 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

[0029] 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.

[0030] 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

[0031] 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.

[0032] 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.

[0033] 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.

[0034] 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

[0035] 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.

[0036] As shown in FIG. 6, the sensor interface 610 conditions and digitizes the sensor signal 612 to generate the con-

ditioned 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**.

[0037] 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.

[0038] 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.

[0039] 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.

[0040] 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 constructed 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**.

[0041] 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

[0042] 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

[0043] 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.

[0044] 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.

[0045] 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 **810** 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).

[0046] 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 SpO₂ 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.

[0047] 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.

[0048] 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

[0049] 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.

[0050] 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.

[0051] 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).

[0052] 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.

[0053] 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).

[0054] 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 performed within a monitor module may reduce sensor module size and power consumption at a cost of increase transmission bandwidth.

[0055] 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 embodi-

ment, 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

[0056] 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.

[0057] 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.

[0058] 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 fre-

quency 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).

[0059] 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.

[0060] 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 pulse oximetry device comprising:

a housing including at least a signal processor and a transmitter;

a display positioned on the housing and in communication with the signal processor;

a strap configured to securely mount the housing on an appendage of a user;

a pulse oximetry sensor in communication with the signal processor and configured to be mounted to a finger of the user, wherein the pulse oximetry sensor includes at least: a light emitter configured to emit light into a tissue site of the finger of the user; and

a light detector configured output a signal responsive to at least a portion of the emitted light after attenuation by tissue of the tissue site; and

a cable configured to enable communication between the signal processor and the pulse oximetry sensor, wherein the cable is coupled to both the housing and the pulse oximetry sensor,

wherein the signal processor is configured to:

receive the signal from the pulse oximetry sensor; derive, from the signal, measurements of oxygen saturation and pulse rate; and

display, on the display, the measurements, and

wherein the transmitter is configured to:

receive the signal from the pulse oximetry sensor; and transmit a transmit signal responsive to the signal to a receiver configured to adapt the transmit signal to a monitor-compatible signal based on characterization information specific to a monitor device, the monitor-compatible signal usable by the monitor device to

provide physiological parameter measurements consistent with the signal received from the pulse oximetry sensor.

3. The pulse oximetry device of claim 2, wherein transmit signal is transmitted wirelessly.

4. The pulse oximetry device of claim 2, wherein the display is positioned on an outward facing portion of the housing such that the measurements displayed on the display are viewable by the user.

5. The pulse oximetry device of claim 2 further comprising: one or more input mechanisms useable by the user to affect at least one of an operational mode or characteristics of the pulse oximetry device.

6. The pulse oximetry device of claim 5, wherein the one or more input mechanisms comprise keys.

7. The pulse oximetry device of claim 6, wherein the display wraps at least partially around the appendage of the user.

8. The pulse oximetry device of claim 2, wherein the pulse oximetry sensor is disposable.

9. A method of monitoring oxygen saturation and pulse rate of a user comprising:

providing a pulse oximetry device according to claim 2; mounting the pulse oximetry device on an appendage of the user; and

activating the pulse oximetry device such that measurements of oxygen saturation and/or pulse rate are provided by the pulse oximetry device and displayed a display of the pulse oximetry device.

10. A pulse oximetry device comprising:

a housing including at least a signal processor;

a display positioned on the housing and in communication with the signal processor;

a strap usable to mount the housing on an appendage of a user;

a pulse oximetry sensor in communication with the signal processor and configured to be mounted to a tissue site of the user, wherein the pulse oximetry sensor includes at least:

a light emitter configured to emit light into the tissue site of the user; and

a light detector configured output a signal responsive to at least a portion of the emitted light after attenuation by tissue of the tissue site; and

a cable configured to enable communication between the signal processor and the pulse oximetry sensor, wherein the cable is coupled to both the housing and the pulse oximetry sensor,

wherein the signal processor is configured to:

receive the signal from the pulse oximetry sensor;

derive, from the signal, measurements of oxygen saturation and pulse rate; and

display, on the display, the measurements.

11. The pulse oximetry device of claim 10 further comprising:

one or more input keys useable by the user to affect at least one of an operational mode or characteristics of the pulse oximetry device.

12. The pulse oximetry device of claim 11, wherein the display is positioned on an outward facing portion of the housing such that the measurements displayed on the display are viewable by the user.

13. The pulse oximetry device of claim 12, wherein the display wraps at least partially around the appendage of the user.

14. The pulse oximetry device of claim **10** further comprising:

a sensor interface configured to receive the signal from the pulse oximetry sensor and condition the signal such that the conditioned signal is responsive to the signal, wherein the measurements are derived from the conditioned signal.

15. The pulse oximetry device of claim **14**, wherein conditioning the signal includes at least one of buffering, digital filtering, smoothing, averaging, adaptive filtering, frequency transforming, or modifying data rates.

16. A pulse oximetry device comprising:

a housing including at least a signal processor and a transmitter;

a strap usable to mount the housing on an appendage of a user;

a pulse oximetry sensor in communication with the signal processor and configured to be mounted to a tissue site of the user, wherein the pulse oximetry sensor includes at least:

a light emitter configured to emit light into a tissue site of the user; and

a light detector configured output a signal responsive to at least a portion of the emitted light after attenuation by tissue of the tissue site; and

a cable configured to enable communication between the signal processor and the pulse oximetry sensor, wherein the cable is coupled to both the housing and the pulse oximetry sensor,

wherein the signal processor is configured to:

receive the signal from the pulse oximetry sensor; and
derive, from the signal, measurements of oxygen saturation and pulse rate,

wherein the transmitter is configured to:

receive the signal from the pulse oximetry sensor; and
transmit a transmit signal responsive to the signal to a receiver configured to adapt the transmit signal to a monitor-compatible signal based on characterization information specific to a monitor device, the monitor-compatible signal usable by the monitor device to provide physiological parameter measurements consistent with the signal received from the pulse oximetry sensor.

17. The pulse oximetry device of claim **16**, wherein transmit signal is transmitted wirelessly.

18. The pulse oximetry device of claim **16**, wherein the cable extends from the tissue site of the user to the housing.

19. The pulse oximetry device of claim **18**, wherein the tissue site comprises a finger of the user.

20. The pulse oximetry device of claim **19**, wherein the appendage of the user comprises an arm of the user.

21. The pulse oximetry device of claim **16**, wherein the signal processor is further configured to derive, from the signal, real time measurements of perfusion index and signal quality.

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